UKERC

UKERC ENERGY RESEARCH ROADMAP SYNTHESIS : WIND ENERGY

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1. OVERVIEW

This document reviews and highlights the significant information presented in six wind energy (both onshore and offshore) roadmaps, including:

- Technology Roadmap-Wind Energy-International Energy Agency
- Technology Roadmap-China Wind Energy Development Roadmap-International Energy Agency
- Wind Energy Roadmap-Sustainable Energy Authority of Ireland
- The European Wind Initiative-The European Wind Energy Association
- 20% Wind Energy by 2030: Increasing Wind Energy's Contribution to US Electricity Supply-US Department of Energy
- ORECCA European Offshore Renewable Energy Roadmap-Offshore Renewable Energy Conversion Platform Coordination Action

This document provides the latest information on wind energy roadmaps. There has been several wind energy roadmaps published providing a national and global perspective to increasing wind energy deployment for both onshore and offshore wind. These documents will continue to be updated overtime as progress within the industry is made.

The roadmaps within this document provide an overview of the strategies taken from several countries, as well as examine the industry on a global scale. Whilst the scope and strategy of the roadmaps may differ, they share similar themes including technology development and innovation, need for better siting guidelines, policy framework and increased funding. Additionally, there is a focus on the identification of synergies between offshore wind and ocean energy.

The roadmaps reviewed within this document provide a high-level understanding of the current state of the wind energy sector, as well as challenges and opportunities for the successful acceleration of the industry.

2. TECHNOLOGY ROADMAP - WIND ENERGY

International Energy Agency

http://www.iea.org/publications/freepublications/publication/Wind_2013_Roadmap.pdf

The roadmap starts by providing the up-to-date statistics (at the time of writing) for the global wind energy industry. Since 2000, cumulative installed capacity grew by an average rate of 24% per year. In 2012, approximately 45GW of new wind power capacity was installed in more than 50 countries across the world, bringing the global onshore and offshore capacity at a total of 282GW. Furthermore, 2012 brought in $76.56 billion in new investment.

The roadmap then continues to highlight job growth, design changes and manufacturing, making a note that most of the wind turbine manufacturing companies are currently located in 6 countries: US, Denmark, Germany, Spain, India and China. Whilst majority of turbines are of the 3-blade design, there has been a focus on increasing the tower height, length of the blades and power capacity, increasing the rated capacity from 1.6MW in 2008 to 1.8MW in 2012.

The document moves forward stating that onshore wind energy is becoming more competitive in countries such as Brazil, Australia, Chile, Mexico, New Zealand, Turkey and South Africa, where the resource is good and the price for conventional generation is high. However, there is still a focused effort to reduce the levelised cost of energy, with reductions of 20-30% estimated by 2030.

The roadmap highlights the common barriers that many countries continue to face including:

- Permitting/authorisation delays
- High administrative costs
- Grid connection procedures
- Lengthy approval of EIAs
- Compliance with spatial planning
- Number of parties involved
- Absence of information on grid connection capacity
- Lack of planning for grid extension and reinforcements, insufficient grid capacity and land ownership
- Project financing for offshore wind projects

The roadmap offers a actions and timeframes for the development of wind technology. Each category outlines specific actions that should occur, all of timeframes ending between 2015 and 2050. These include actions which fall under the following three main categories:

- **Wind power technology:** focused on turbine technology and design with corresponding development of system design and tools, advanced components, O&M, reliability and testing;
- **Wind characteristics:** assessment of wind energy resource with resource estimates for siting, wind and external conditions for the turbine technology, and short-term forecasting methods;
- **Supply chains, manufacturing and installation issues.**

The roadmap also has a section which offers insight into the need for set policies, financing, public acceptance and international collaboration in order to create a successful industry. Strong market pull mechanisms are

needed to complement the technology push that will support higher shares of wind in electricity markets. In order to incentivise this investment, the government's role is to attract investment in clean energy technologies by facilitating a predictable and transparent policy framework, including integrating renewable energy policy into an overall energy strategy. The document presents action items to help attract investment to wind power, which include:

- Set short-term and long-term deployment targets
- Establish and implement incentives and support mechanisms in order to gain investor confidence; create a stable, predictable financing environment to lower costs for financing
- Internalise external costs of electricity production into market prices
- Encourage national and multilateral development banks to target clean energy deployment
- Further develop mechanisms to attract investment in wind deployment

This section also discusses the need for increased public engagement as a key element to further the development of the industry. If studies from other locations are unavailable, lack of information often leads decision makers to reject a wind proposal or take no action act all. In addition, the document also discusses the need streamline permitting practices in order to provide a more transparent permitting procedure, reducing project uncertainty, costs and timelines.

The roadmap concludes with providing an action plan and next steps which includes the main milestones, which include:

- Stimulate cost reductions to achieve cost competitiveness with new conventional power projection by 2020 for onshore and 2030 for offshore wind;
- Reduce uncertainty of resource assessment to 3% of projected output of wind power plants and increase technology reliability to 95% by 2020, also for offshore;
- By 2020, publish and encourage broad use of best practice guidelines for project development system integration and community integration;
- By 2020, include wind power in long-term regional planning with clear ways to address deployment barriers from transmission and safety distances to the built environment;
- By 2020, increase cost competitiveness by setting a price on emission through an emissions trading system, with carful design to ensure the emission price is meaningful and stable.

3. TECHNOLOGY ROADMAP - CHINA WIND ENERGY DEVELOPMENT ROADMAP 2050

International Energy Agency

http://www.oecd-ilibrary.org/energy/technology-roadmap-china-wind-energy-development-roadmap-2050_9789264166752-en

This roadmap is the result of a study which combines quantitative and qualitative approaches to analyse China's wind industry sector challenges and needs. The roadmap was created for government decision makers, research institutes, wind power enterprises and investor organisations as a means to monitor the progress of the objectives mentioned throughout the roadmap and to help encourage sustainable large-scale development of wind power in China.

The document starts by providing a brief history of the development of wind power within China which dates back to 1986 with initial demonstration development. The document then notes the speedy advancement in development between 2006 and 2010, when installed capacity increased from less than 10% in 2006 to 49% in 2010. In 2010, the total grid connected win power capacity reach 310 GW.

Looking forward, the next section presents the vision for wind power development and CO2 abatement in China highlighting the following targets/projections:

- By 2020, total installed capacity could be upwards of 200GW, and at the end of 2020, wind power will represent 11% of the total installed generation capacity and 5% of total electricity production.
- Between 2020 and 2030, land-based and offshore wind power will be developed with 20GW new capacity added annually, accounting for 30% of the total installed power capacity added in China. Projected that by 2030, cumulative installed capacity could be over 400GW.
- From 2030 and 2050, about 30GW of capacity will be added annually, accounting for about half of the newly installed capacity. By 2050, installed capacity could reach 1TW, with wind power meeting 17%% of the national electricity consumption. Additionally, offshore capacity is projected to reach 200GW.

The following section examines the investment and subsides in place for wind energy in China noting that since 2006, China has implemented region-specific feed-in tariffs for wind power. Further, subsidies of CNY .01/kWh to CNY .03/kWh will be awarded depending on distance between power transmission lines and wind farms will be awarded to help connect with farms to the power grid.

Next, the roadmap examines the CO2 abatement that as a result of increased wind energy. The roadmap suggests that wind power can replace 130mtce by 2020, 260mtce by 2030, and 660mtce by 2050. Additional reductions of CO2 are expected to amount to 300Mt by 2020, 600Mt by 2030 and 1500Mt by 2050.

The document also highlights the job opportunities associated with an expanding wind energy sector. It is estimated that 15 jobs are created for every megawatt of installed wind power, of which 13-14 are in the manufacturing sector and approximately 1.5 in the service sector. Numbers are expected to fall as efficiency increases.

The remainder of the roadmap provides recommendations for actions and milestones to be completed in the areas of:

- Wind technology development
- Wind turbines
- Wind farm development and construction
- Wind power integration
- Delivery and network integration
- Policy framework

The roadmap concludes by offering a series of recommendations to be implemented according to the type of organisation. Additionally, it stresses the importance of using the roadmap as a tool to ensure objectives are being met.

4. **WIND ENERGY ROADMAP**
   Sustainable Energy Authority of Ireland
   http://www.seai.ie/Publications/Energy_Modelling_Group/SEAI_2050_Energy_Roadmaps/Wind_Energy_Roadmap.pdf

This roadmap starts by providing the aim of the roadmap, which is to identify the actions that are required to accelerate the deployment of wind energy, both on and offshore, in Ireland so it becomes the largest source of energy. The roadmap was created with the intention that policymakers, industry and power system actors would use is as an aid in their efforts to successfully implement large amounts of wind energy in Ireland. It provides a variety of visual aids to show the potential of Irish wind.

The roadmap highlights the benefits of the economic and financial benefits that will result from increased wind deployment. The roadmap estimates that the combined onshore and offshore wind sector could create approximately 20,000 direct installation and O&M jobs by 2040. Additionally, the potential economic value of electricity generated by wind is estimated to reach almost €15 billion by 2050. It is expected that annual investment will hit a peak of between €6-12 billion by 2040, with a potential cumulative investment of €100-200 billion in 2050.

The roadmap continues, highlighting the contribution of the Irish wind industry. The roadmap estimates that Ireland can achieve deployment of between 11GW and 16GW of onshore wind and 30GW of offshore wind by 2050, with the potential to become an exporter of wind energy by 2030. Further, it is estimated by 2050, Irish wind could contribute 2.5% to EU Electricity Demand and just over 5% of EU wind energy generation could come from Ireland.

Finally, the roadmap presents the potential carbon abatement from use of wind energy. It is estimated that onshore and offshore wind could abate between 400 and 450Mt of CO2 by 2050.

5. **THE EUROPEAN WIND INITIATIVE**
   The European Wind Energy Association (EWEA)
   http://www.ewea.org/fileadmin/files/library/publications/reports/EWI_2013.pdf

In an effort to fight climate change, improve energy security, enhance Europe's competitiveness and maintain technological leadership, the European wind industry, European Commission and Member States created the European Wind Initiative (EWI) with the intent to meet the following objectives:

- Maintain Europe's technology leadership in on-shore and offshore wind power.
- Make onshore wind the most competitive energy source by 2020, with offshore following by 2030.
- Achieve a 20% of wind energy in EU total electricity consumption by 2020.
- Create 250,000 new skilled jobs in the EU by 2050.

In order to achieve these objectives the European Wind Initiative was created, which prioritises R&D in four main technology areas:

- New turbines and components
- Offshore technology
- Grid integration
- Resource assessment and spatial planning

These are elaborated further within the document, providing more specific actions within each technology area.

The EWI is the roadmap to reducing the cost of wind energy, which is presented in this document. The document presents the key research activities that are necessary to achieve cost reduction. These include but are not limited to the following:

- Increasing reliability, accessibility and efficiency of wind turbines;
- Improving the design and layout of wind farms;
- Demonstrating large wine turbine prototypes and large, interconnected offshore wind farms;
- Simplifying site assessment , gather data for improved designs on- and off-shore;
- Designing the economic and spatial planning instruments to deploy onshore and offshore win energy technologies.

The document continues, examining the financial resources necessary to implement the EWI. The implementation of the EWI requires an annual investment of public and private resources of approximately €600 million (totally €6 billion) between 2010 and 2020. Of the total €6 billion, it is estimated that 52% of the financing should come from industry whilst 31% should be contributed from EU funds and 17% from Member States.

The roadmap then presents the EWI requirement for 2013-2015 and beyond stressing that despite the variety of available EU programmes, wind energy R&D remains unfunded. There is a significant gap between the financial needs recognised by the EU Commission and the funds that have been allocated. The document then presents the recommendations provided by EWEA for the new EU financial framework 2014-2020 and the Strategic Energy Technology Plan (SET-Plan). The recommendations for the financial framework include:

- Fulfil the Europe 2020 vision of 3% of GDP allocated to research.
- Provide adequate support to renewable energy research, development and innovation matching the SET-plan objectives.
- Increase wind energy R&D funding and maintain Europe's global leadership in wind technology.
- Establish a dedicated budget line with €1.3 billion for the EWI under Horizon 2020 to provide financial and political security for investment in long-term projects.
- Finance projects with greater technological risk and secure that at least €1 billion of the Access to Risk Finance Facility is spent on SET-Plan project.

The recommendations for the implementation of the SET-Plan include:

- Ensure a robust EU political and financial framework for implementation of the SET-Plan as a key instrument for maintaining EU technology leadership and promoting renewable energies.
- Ensure effective coordination of EU and national wind energy R&D funds by simplifying current mechanisms or creating new ad-hoc ones.
- Follow the funding recommendations of the Wind EII Team on both an EU and national level.
- Allow for a bottom-up approach to wind R&D topics identification by publishing open calls for proposals to address the most compelling research needs and market gaps.
- Avoid the creation of new complex SET-Plan implementation mechanisms.

The next section of the roadmap provides the background of the SET-Plan and identifies two major timelines, for 2020 and 2050. The aim for 2020 is to accelerate the development and deployment of cost-effective low-carbon technologies such as wind power, whilst helping to reach the 20% greenhouse gas emissions target. The 2050 timeline aims to eliminate climate change to a global temperature rise of no more than 2°C, and lower the cost of renewable energy in an effort to place the EU at the forefront of the low carbon technology sector. The roadmap also acknowledges the need for the SET-Plan to align with the sector's objectives.

Finally, the document provides an overview of the European Wind Energy Technology Platform (TPWind), which brings together more thatn 150 wind energy researchers and experts. TPWind is critical for the SET-Plan as it took a crucial role in the development of the EWI.

6. 20% WIND ENERGY BY 2030: INCREASING WIND ENERGY'S CONTRIBUTION TO US ELECTRICITY SUPPLY

US Department of Energy

http://energy.gov/eere/wind/downloads/20-wind-energy-2030-increasing-wind-energys-contribution-us-electricity-supply

In order to address energy security and environmental issues, the nation needs to pursue a portfolio of energy options of which the 20% Wind Energy by 2030 is one potential scenario. The roadmap considers the challenges, estimates the impacts and discusses the specific needs and outcomes in the areas of technology, manufacturing and employment, transmission and grid integration, markets, siting strategies and potential environmental effects associated with the scenario.

The document starts by examining the current status of the US wind industry, which is growing rapidly due to production tax credits, rising concerns about climate change and renewable portfolio standards and goal in approximately 50% of the states. One of the main initiatives within the 20% scenario is to improve wind turbine performance. The three main categories under this initiative include:

- Avoid problems before installation
- Monitor performance
- Rapid deployment of problem resolution

Moving forward, the document provides a description of the 20% wind by 2030 scenario highlighting that a 20% wind scenario would require the US wind power capacity to grow from 11.6GW in 2006 to more than 300GW by 2030. Whilst a 'most likely' scenario is difficult to forecast, due to uncertainty, the 20% wind by 2030 scenario foregoes the uncertainties and contrasts the challenges and impacts of producing 20% of the nation's electricity from wind with a scenario in which no wind is added after 2006. The result in an estimate of the impacts associated with increased reliance on wind energy generation under the assumptions. The scenario is designed to consider incremental costs whilst recognising realistic constraints and considerations.

Moving forward, the roadmap examines the nation's wind resources. The US has more than 8000GW of available land-based wind resource that industry estimates can be captured economically. Additionally, studies suggest that 600GW of wind resources could be available for $60 to $100 per MWh, including the cost of connecting to the existing transmission system. Furthermore, data from NREL's WinDS model estimates the overall US generation capacity expansion that is required to meet projects electricity demand growth through 2030. Of the 293GW that would be added, approximately 50GW of this would be from offshore wind in the northeastern and southeastern seaboards.

The document also addresses the land requirements necessary for the increased deployment, stating that new land-based installations would require approximately 50,000 km^2. In parallel, the document also addresses the visual impacts and siting concerns of wind energy projects including habitat disturbance and wildlife collision, and addresses management practices for mitigation. Moving from this, the document touches on public perception and engagement and the associated challenges.

Finally, the last chapter of the report presents an overview of the US electricity markets and the impacts of the 20% wind scenario. This

section highlights that electricity in the US is supplied by more than 3000 utilities across the countries. Utilities and commissions work within a regulatory framework based on federal and state legislation, jurisdiction and specific regulations which vary throughout the country. Finally, the projected impacts of the scenario are provides. These impacts include:

- Environmental
- Water savings
- US energy security
- Energy consumers
- Local economics
- American workers

The document concludes by stressing that although there are significant costs, challenges and impacts associated with the 20% wind scenario, the positive impacts are significant and will outweigh a business-as-usual scenario.

7. 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 roadmap examines five key areas, which help to identify synergies in an effort to overcome barriers and accelerate deployment in a cost-effective and environmentally sustainable manner. The five key areas are:

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

The roadmap examines each of the key areas and focuses on the synergies in each area, which could lead to combined platforms and co-location.

The first section examines the resource, which highlights 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 off the coasts of Norway and the UK. This section also highlights that there is a European offshore wind target of 460GW and an international target of 1150GW by 2050.

Furthermore, the roadmap identified the importance of the resource water depths and distance from shore, noting that approximately 80% of the combined 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%

The next section examines financial support measures in place for offshore renewable energy. Currently, all countries, except Norway, have a Production Based Incentives(PBI) in place for offshore wind. This varies from .07 to .19€/kWh, highlighting that whilst Spain, Portugal and Denmark have attractive natural resources but have low PBIs than other countries with comparable resources. It also highlights that Norway, which has an attractive resource, has no PBI currently in place. The roadmap provides recommendations for developing a better balance

between market pull and technology push support mechanisms, and decreasing the cost of ocean energy.

The roadmap continues to discuss the challenges and opportunities associated with the technologies. The section identifies synergies and commonalities between offshore wind, wave and tidal energy sectors. These include:

- Foundations
- Array layout
- Mooring/fixed connection points
- Grid connection and integration
- Power take off
- O&M

The roadmap continues, focusing on the infrastructure needs of the offshore renewable energy industry. The section examines the synergies and strategies that are available when assessing the infrastructure needs of co-located technologies, and further highlights the need for the 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 are 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, electromagnetic field 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.