Wind European Industrial Initiative Team
2010 – 2012 Implementation Plan

Produced by the TPWind Secretariat

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Introduction and background

The Wind Energy Roadmap was published by the European Commission (EC) on October 7th, 2009, in the framework of its Communication on Investing in the Development of Low Carbon Technologies. Following its publication, the roadmap was officially presented and discussed at the Strategic Energy Technology Plan (SET-Plan) workshop, held in Stockholm on October 21st and 22nd, 2009, and organized by the European Commission and the Swedish Energy Agency.

The roadmap is set to become one of the most important instruments for the development of wind power in the 2010 – 2020 period and will play a key role in fighting climate change and in helping EU Member States to meet the 2020 targets identified by the new RES Directive (approved in December 2008), by achieving the following goals:

- A wind energy penetration level of 20% in 2020;
- Onshore wind power fully competitive in 2020;
- 250.000 new skilled jobs created in the EU by the wind energy sector in the 2010 – 2020 period.

The roadmap, which has a total budget of € 6 bn (private and public resources), is a long term programme for increasing and coordinating the funding of wind energy R&D, so as to ensure its quick development and deployment in the EU. It focuses on the following key areas:

- New turbines and components;
- Offshore technology;
- Grid Integration;
- Resource assessment and spatial planning.

The implementation will require a yearly investment of public and private resources of approximately € 600 m, up from € 383 m in 2007. The Wind Energy Roadmap will be launched at the Madrid SET-Plan conference on June 3rd and 4th, 2010. It originates from the European Wind Initiative (EWI), one of the industrial initiatives proposed by the European Commission in its SET-Plan, published in November 2007.

The EWI was developed by the European Wind Energy Technology Platform (TPWind) in cooperation with the European Commission and EU Member States and was therefore the result of a shared and concerted process. It was finalized in the summer of 2009 and submitted to the EC, which published it as the Wind Energy Roadmap (COM(2009) 519).

As requested by the SET-Plan High Level Steering Group, TPWind has developed its Implementation Plan for the first three years (i.e. 2010 – 2012). As stated by the SET-Plan secretariat document from Dec. 14th, 2009, the implementation plan should cover the first 3-year period <u>and will be revised every year, thus becoming rolling out programmes</u>. The following elements should be included:

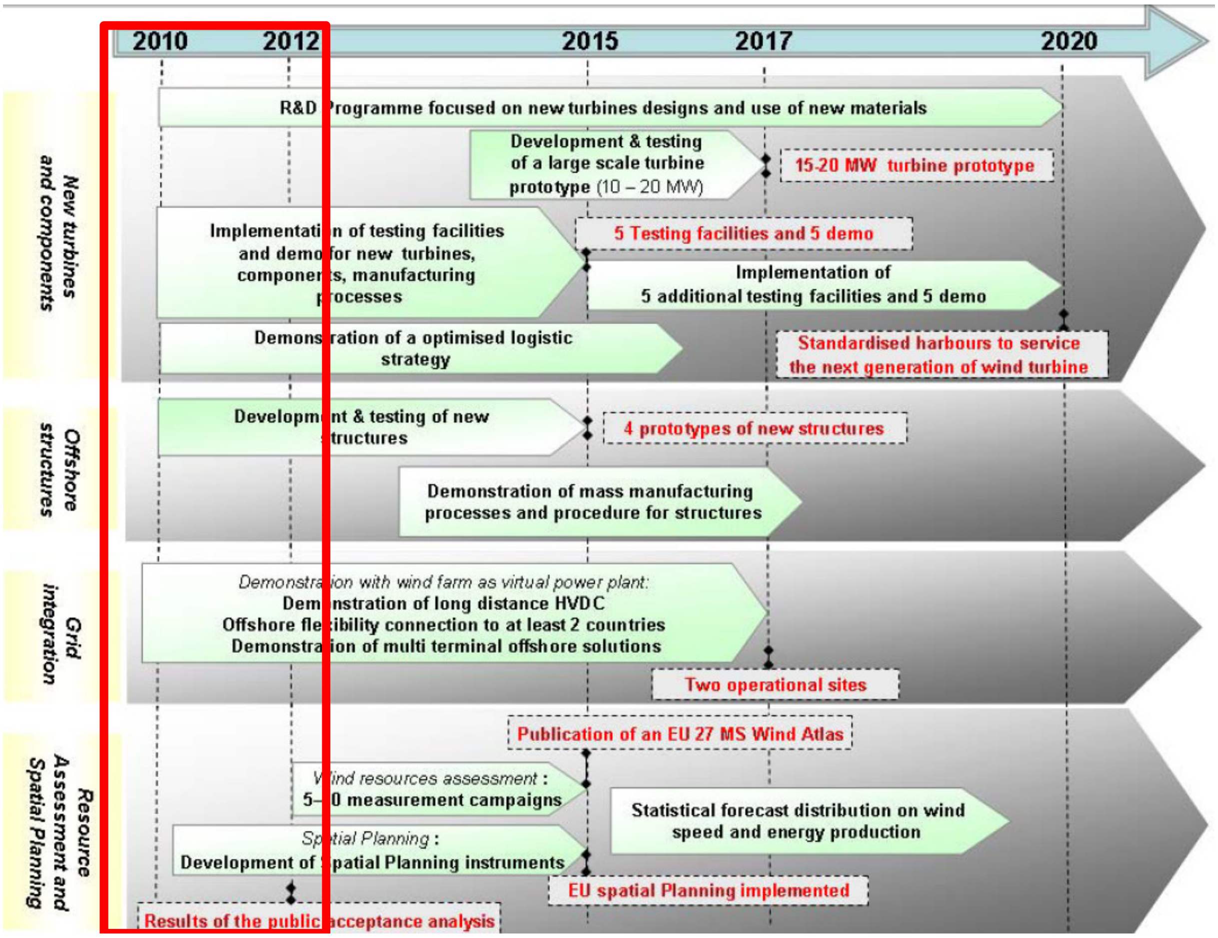
- Taking into account the present technology, and projects financed by the EU and Member States, identifying the priority actions to move towards the objective / milestone
- Estimate the budgets, the European added-value of the actions and the risk involved by the different actions
- Identify the existing available public and private financial sources
- Identify the needed actors and potential countries to finance the actions
- Define Key Performance Indicators

- Estimate the contribution of the identified priority actions towards the 2020 objectives/milestones
- Identify possible links with joined programmes of the EERA

This document therefore outlines the actions that should be launched in the first phase of the roadmap. Further to that, it provides an indication of relevant key performance indicators (KPIs), an analysis of the EU added value of each project as well as an indication of relevant budgets and available funding schemes (EU or national), as requested by the European Commission and the Joint Research Centre.

Wind Energy Roadmap priorities for the 2010 – 2012 period

The roadmap priorities for 2010 - 2012 period are highlighted in the following diagram, which was published by the EC in its Communication on Investing in the Development of Low Carbon Technologies:



Source: European Commission, "A Technology Roadmap" - SEC(2009) 1295

On the 2010-2012 period, the launch of the Wind Energy Roadmap focuses on the first steps towards the technology objectives and milestones stated by the European Communication on Investing in the Development of Low Carbon Technologies. In the following, the actions, key performance indicators, and relation to existing programmes are described, for each sub-chapter:

- New turbines and components,
- Offshore substructures,

- Grid integration,
- Resource assessment and spatial planning.

1. New turbines and components

The objectives described by the European Commission's Wind Energy Roadmap are the following:

- To develop large scale turbines in the range of 10 - 20 MW especially for offshore applications;
- To improve the reliability of the wind turbine components through the use of new materials, advanced rotor designs, control and monitoring systems;
- To further automate and optimize manufacturing processes such as blade manufacturing through cross industrial cooperation with automotive, maritime and civil aerospace;
- To develop innovative logistics including transport and erection techniques, in particular in remote, weather hostile sites.

These objectives are supported by the following Actions (Figure 1):

- R&D programme focused on new turbine designs, materials and components addressing on- and offshore applications coupled with a demonstration programme dedicated to the development and testing of a large scale turbine prototype (10-20MW);
- A network of 5-10 European testing facilities to test and assess efficiency and reliability of wind turbine systems;
- An EU cross-industrial cooperation and demonstration programme drawing upon the know-how from other industrial sectors (e.g. offshore exploration) for mass production of wind systems focused on increased component and system reliability, advanced manufacturing techniques and offshore turbines. A set of 5 – 10 demonstration projects testing the production of the next generation of turbines and components will be carried out.

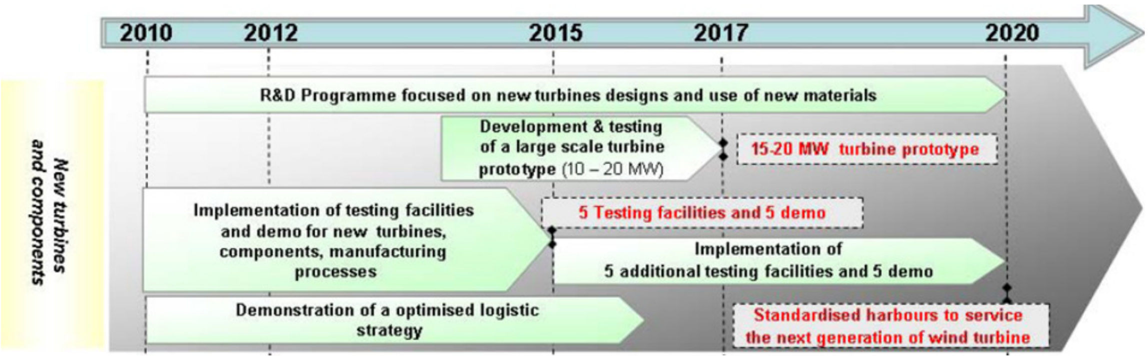


Figure 1: Wind Technology Roadmap, New turbines and components section. Source: European Commission, 2009. Communication on Investing in the Development of Low Carbon Technologies.

R&D programme focused on new turbine designs, materials and component, activities starting on period 2010-2012

The R&D programme has to start early, in order to deliver timely results and products able to penetrate the market in the second half of the decade. For the first period, 2010-2012, the launch of the European Wind Initiative should focus on starting as early as possible the large-scale R&D programme, with a focus on large-systems, in particular for offshore wind developments *(activity 1.1.1)*. This first activity is a stepwise approach, firstly agreeing on large concepts to be explored, and progressively up scaling the designs (8-10 MW, 12MW, and 15+MW). The innovation is transferred to the market through calls financed under the *New Entrants Reserve* (see next page). This will set the ground for the next phase of this roadmap component, consisting in the development and testing of a large-scale prototype (start 2014, prototype in 2017).

In this area, activity 1.1.1 largely builds on the results of the *UpWind* project, and the FP7 call ENERGY.2010.2.3-1 *"Cross-sectoral approach to the development of very large offshore wind turbines"*. *UpWind* demonstrated the feasibility of new rotors for very large wind turbines and components concepts for large-scale designs. The FP7 call ENERGY.2010.2.3-1 will develop and test sub-components for 10 MW+ scale turbines, to facilitate the market integration of such products in the medium term. The proposed *activity 1.1.1* is focused on the next phase, namely the next generation of wind turbines, in the 10 to 20 MW range.

As a support to the large R&D programme, having a focus on medium-term issues, *activity 1.1.2* focuses on improving the reliability of existing large wind turbines designs in the 4-10 MW range, which are likely to constitute the mainstream offshore market up to 2020, increasing the efficiency of the large offshore wind farms deployed in medium-depth waters, and reduce fatigue loads due to wake effects inside those farms. This activity focuses on monitoring and handling wake effects in large wind farm arrays, and assessing / improving the reliability of current large wind turbine designs. This activity will support the deployment of the upcoming Member State's National action plans[1].

In addition, the New Entrance Reserve proposes to finance the market deployment of on-shore wind turbines optimised for complex terrains (e.g. forested terrains, mountainous areas), and on-shore wind turbines optimised for cold climates. For this purpose, the necessary research and demonstration activities should start in 2010 (*activity 1.1.3 on complex terrains, and 1.1.4 on extreme climates)*, in order to supply the necessary products for a minimum of one large-scale demonstration per topic for the second NER call in 2013.

As illustrated in Annex III *"Synergies with the European Energy Research Alliance"*, this sub-programme is implemented through a strong partnership between the industry and the EERA, through the EERA programme in the field of Aerodynamics, Offshore wind farms and Wind conditions.

Network of 5-10 European testing facilities, activities starting on period 2010-2012

The upscaling of designs increases the financial impact of technical failures, and thus the financial risks. Handling this risk implies dedicated testing facilities to be operational on short notice. As stated by the wind energy roadmap, 5 testing facilities for large-scale concepts should be available in 2015 for complete systems and various extreme climate types. This is implemented through a first investigation phase on period 2010-2012 *(activities 1.2.1, 1.2.2, 1.2.3).*

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[1] The recent FP7-funded project NIMO (€ 3.4 m) relates to *activity 1.1.2* (reliability, maintenance, condition monitoring).

As illustrated in Annex III *"Synergies with the European Energy Research Alliance"*, this sub-programme is implemented through a strong partnership between the industry and the EERA, through the EERA programme in the field of Research facilities.

An EU cross-industrial cooperation and demonstration programme, activities starting on period 2010-2012

For this first period, the large-scale EU cross-industrial programme starts with an action on the large-scale manufacturing and logistics processes for large wind turbine components *(activity 1.3.1)*. This activity will prepare for the large-scale diffusion of large products, in the 5-10 MW range up to 2015, and for larger products towards the end of the decade. This section should be updated and complemented for the next annual programme review.

Relation between the proposed activities and current Programmes

Relation with the European Economic Recovery Plan

The European Economic Plan for Recovery (EEPR) can be considered as a first phase the sub-programme *New turbines and components*, *activity 1.3.1* with a focus on the mass-manufacturing of existing large-scale wind turbine designs:

- Nordsee Ost : 48 6MW turbines (RePower) on jacket foundations ; EEPR (€ 55 m) co-finances the supply of the turbines.
- Borkum West, 1st phase: 40 5 MW turbines (Multibrid) on tripod foundations ; EEPR (€ 50 m) co-finances the turbines and tripods.

In addition, the EEPR supports the Aberdeen wind deployment centre, for the development of a facility for testing of multi-MW turbines with innovative structures and substructures and optimisation of manufacturing capacities of offshore wind energy production equipment. This project is directly relevant to *activity 1.1.3*.

Relation with the New Entrance Reserve funding scheme:

The NER scheme put aside 300 million carbon allowances (€6 – 9 bn), which are likely to be allocated on the period 2011 – 2015 for financing carbon capture and storage and renewable energy projects. Two calls are foreseen, the first one early 2010 and the second one in 2013. It should be noted that the NER does not finance pilot projects, but is a complementary funding in order to cover the additional risk of accelerating the market penetration of advanced concepts. Some of the foreseen concepts do not exist yet, and one objective of the Wind Energy Roadmap is to create the necessary products and processes for developing such technologies. From the annex of the draft document, currently under negotiation, eligibility criteria are drafted:

- Off-shore wind (minimum turbines size 6 MW) with nominal capacity of 40 MW;
- Off-shore wind (minimum turbines size 8 MW) with nominal capacity of 40 MW;
- Off-shore wind (minimum turbines size 10 MW) with nominal capacity of 40 MW;
- Floating off-shore wind systems with nominal capacity 25 MW;
- On-shore wind turbines optimised for complex terrains (e.g. forested terrains, mountainous areas): with nominal capacity 25 MW ;
- On-shore wind turbines optimised for cold climates with nominal capacity 25 MW.

The NER financing scheme should be synchronized with the implementation of the Wind Energy Roadmap. 6 MW turbines are currently under demonstration, whereas 8 and 10 MW technologies are not yet available on the market. Therefore, the 2010 call should focus on *activity 1.1.2 "Improved reliability of large turbines, and wind farms"*. The next calls should support the market penetration of the innovative components and designs developed in each step of activity *1.1.1 "Large-scale turbines and innovative designs".*

Sub-programme 1: R&D programme focused on new turbine designs, materials and components

Number	Description	Budget (2010-2012)
1.1.1	Large scale turbines and innovative design for reliable turbines rated 10 – 20 MW • Advanced aerodynamic modeling, design and testing, including flow devices for distributed aerodynamic control of very large rotor blades and aero tools for turbines on floating structures.	€ 33 m
	• Characterization and development of materials and components for wind turbines, including upscaling effects.	€ 58 m
	• Detail development and integration of drive trains – mechanical transmission, generator and power electronics – both theoretical and sub-system validation.	€ 139 m
	• Sensing, algorithms and actuation in control strategies and systems	€ 10 m
1.1.2	Improved reliability of large turbines, and wind farms • Analysis of flow in and around large wind farms an through control optimization of power performance and minimizing dynamic loading.	€ 33 m
	• Increased reliability of current large offshore designs: smarter O&M with preventive maintenance and condition monitoring; optimizing life-cycle cost.	€ 30 m *(follow-up demonstration to be financed through the New Entrance Reserve)*
1.1.3	Turbine optimisation and demonstration for complex terrain	€ 10 m *(follow-up demonstration to be financed through the New Entrance Reserve)*
1.1.4	Turbine optimisation and demonstration for extreme climates	€ 10 m *(follow-up demonstration to be financed through the New Entrance Reserve)*
TOTAL		€ 323 m

<u>Sub-programme 2:</u> A network of 5-10 European testing facilities

Number	Description	Budget (2010 – 2012)
1.2.1	Definition of methods and standards for testing large wind turbine components. In close cooperation with the EERA.	€ 10 m
1.2.2	Five new and improved system-lab testing facilities for 10 – 20 MW turbines. In close cooperation with the EERA.	€ 150 m
1.2.3	Two additional field testing facilities for 10 – 20 MW aimed at increasing reliability. In close cooperation with the EERA. This activity includes the identification of offshore test sites required by *activity 2.1.1*. Aberdeen offshore test centre included, funded by the EEPR.	€ 150 m
TOTAL		€ 310 m EEPR incl.

Sub-programme 3: An EU cross-industrial cooperation and demonstration programme drawing upon the know-how from other industrial sectors for mass production of wind systems

Number	Description	Budget (2010 – 2012)
1.3.1	Development of five large scale manufacturing and logistics processes, both size and numbers for in and out-of-factory and site erection. The EEPR provides € 92 m, through the financing of demonstrators.	€ 250 m
TOTAL		€ 250 m incl. EEPR

2. Offshore technology

The objectives described by the European Commission's Wind Energy Roadmap are the following:

Focus on structures for large-scale turbines and deep waters (>30m):

- To develop new stackable, replicable and standardized substructures for large scale offshore turbines such as: tripods, quadropods, jackets and gravity-based structures;
- To develop floating structures with platforms, floating tripods, or single anchored turbine.

These objectives are supported by the following Actions (Figure 2):

- A development and demonstration programme for new structures distant from shore aiming at lower visual impact and at different water depths (>30m). At least 4 structure concepts should be developed and tested under different conditions.
- A demonstration programme on advanced mass-manufacturing processes of offshore structures.

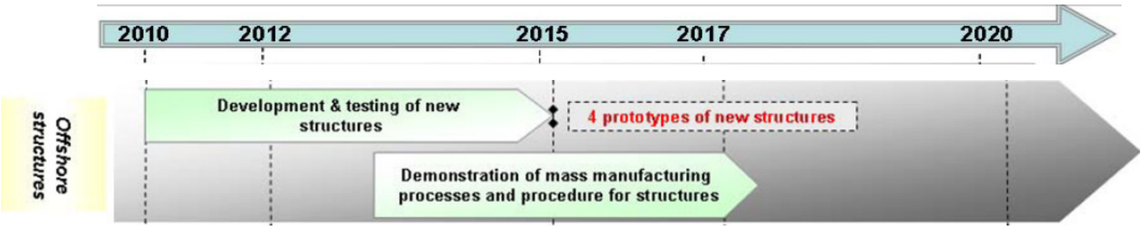

Figure 2: Wind Technology Roadmap, offshore structures section. Source: European Commission, 2009. Communication Investing in the Development of Low Carbon Technologies.

On the 2010-2012 period, focus is given to the large scale deployment of the offshore wind technology in high water depths:

- Development and testing of innovative support structures,
- Automation of substructures manufacturing,
- Technology transfer from the Oil & Gas sector.

Development and testing of new structures, activities starting on 2010-2012:

As stated by the Wind Energy Roadmap (Figure 3), the aim of this sub-programme is to test and demonstrate 4 innovative prototypes of substructures, including floating concepts on the 2015-2018 period.

On period 2010-2012, the industry activities focus on identifying the sites and substructure types to be demonstrated in the next phase *(activity 2.1.1)*. This priority is strongly related to activity 1.2.3 *"field testing facilities"*, under sub-programme 2 of the *New turbine and components* priority.

As illustrated in Annex III *"Synergies with the European Energy Research Alliance"*, this sub-programme is implemented through a strong partnership between the industry and the EERA, through the EERA programme in the field of Offshore wind. As a first investigation phase, the EERA programme proposes a specific activity on *Generic novel turbine and sub-structure concepts for deep sea*, to assess various possible novel designs of turbine and sub-structure for deep sea, bottom-fixed and floating, and giving step-changes in technology for reducing cost of energy from offshore wind farms.

Regarding deep-offshore structures (floating), the recent FP7 call *ENERGY.2009.2.9.1: Deep off-shore multi-purpose renewable energy conversion platforms for wind/ocean energy conversion*, should provide materials for further developing these future concepts. The FP7 grant is € 20 – 30 m.

In addition, deep off-shore floating structures hosting multi-MW wind energy converters should be demonstrated. The demonstration should address integrated (turbine and substructure) concepts including large cost-efficient floating structures, multi-MW wind energy converters and related equipment designed for wind farms management and for compliance with easy connectivity to the offshore grid. An FP7 could be formulated in that sense in 2010.

As presented in the next sub-programme, building and manufacturing will take place on period 2012-2015. On period 2015-2018, a demonstration and evaluation programme will be carried on, followed by a redesign phase, with focus on mass-manufacturing of substructures for large-scale turbines developed by the *New turbine and components* priority.

Automation of substructures manufacturing, activities starting on 2010-2012

A first phase to be launched on period 2010-2012 is an industry-wide study on mass-manufacturing of substructures *(activity 2.2.1)*, in order to supply the upcoming large-scale development of offshore wind in deeper waters. Since most of the offshore developments were based on monopiles foundations, the industrial capacity is not available to supply the necessary amount of substructures. Moreover, the unit cost (€/kg) of substructures needs to get closer to the cost of tower structures and serial production is needed.

In this regard the European Recovery Plan can be considered as a part or this sub-programme, supporting the mass-manufacturing of <u>existing</u> substructures designs:

- Bard I : 80 5MW turbines (Bard Engineering) on tripile foundations ; EEPR (53 M EUR) co-finances the serial manufacturing of the foundations.
- Global Tech I : 80 5MW turbines (Multibrid) on gravity foundations ; EEPR (58 M EUR) co-finances the serial manufacturing of the foundations.
- Borkum West, 1st phase : 40 5 MW turbines (Multibrid) on tripod foundations ; EEPR (42 M EUR) co-finances the turbines and tripods.

Following this initial phase (2010-2012), the manufacturing of the concepts demonstrated in the sub-programme *Development and testing of new structures* will be studied (2012-2015), with the aim to manufacture substructures suitable for the large-scale concept (10 MW+) developed by the *New turbine and components* priority (2015 onwards), which focuses on the development of future large designs requiring large-scale dedicated sub-structures, mass-manufactured.

Technology transfer from the Oil & Gas sector, activities starting on 2010-2012

This sub-programme builds on the action mentioned by the *New turbine and components* priority: *"An EU cross-industrial cooperation and demonstration programme drawing upon the know-how from other industrial sectors (e.g. offshore exploration) for mass production of wind systems focused on increased component and system reliability, advanced manufacturing techniques and offshore turbines. A set of 5 – 10 demonstration projects testing the production of the next generation of turbines and components will be carried out."*

Cross industrial cooperation is required not only on manufacturing, but also operations. A critical point for the offshore wind operators is to be able to operate under various national jusrisdictions. This point is particularly critical for transnational offshore wind projects such as Krieger's Flak. On period 2010-2012, a specific activity in this field focuses on technology transfer from the oil & gas, and maritime sectors on standards for safety operations, and standardization of sub contracting processes *(activity 2.3.1)*.

Sub-programme 1: Development and testing of new structures

Number	Description	Budget (2010 – 2012)
2.1.1	• Site identification for demonstration of large-scale substructures for medium and high depths. This activity is carried on in parallel to activity 1.2.3 under sub-programme 2 of the *New turbine and components* priority. • Development of deep-offshore concepts. Builds on 2009 FP7 call, and EERA activity for new offshore concepts.	Budget included in 1.2.3 FP7 current budget is € 20 – 30 m for a total project budget up to € 60 m
TOTAL		€ 60 m incl. FP7

Sub-programme 2: Automation of substructures manufacturing

Number	Description	Budget (2010 – 2012)
2.2.1	Industry-wide initiative on mass-manufacturing of substructures to supply the upcoming large European markets. Public-private partnerships built with the European Investment Bank under the Risk Sharing Finance Facility scheme. EEPR provides € 153 m through grants.	€ 250 m
TOTAL		€ 250 m incl. EEPR

Sub-programme 3: Technology transfer from the oil&gas sector

Number	Description	Budget (2010 – 2012)
2.3.1	• Standards for safety and operation, including standard safety factors • Standardisation of subcontracting, in partnership with the oil&gas and maritime sectors	€ 5 m
TOTAL		€ 5 m

3. Grid integration

The objectives described by the European Commission's Wind Energy Roadmap are the following:

Grid integration techniques for large-scale penetration of variable electricity supply:

- To demonstrate the feasibility of balancing power systems with high share of wind power using large-scale systems with High Voltage Alternative Current (HVAC) or High Voltage Direct Current (HVDC) interconnections.
- To investigate wind farms management as "virtual power plants".

This objective is supported by the following Actions (Figure 3):

- Grid integration techniques for large-scale penetration of variable electricity supply. A programme focused on wind farm management as "virtual power plants" to demonstrate at the industrial scale:
    - Offshore wind farms interconnected to at least two countries and combined with the use of different interconnection techniques.
    - Long distance High Voltage Direct Current
    - Controllable multi-terminal offshore solutions with multiple converters and cable suppliers.

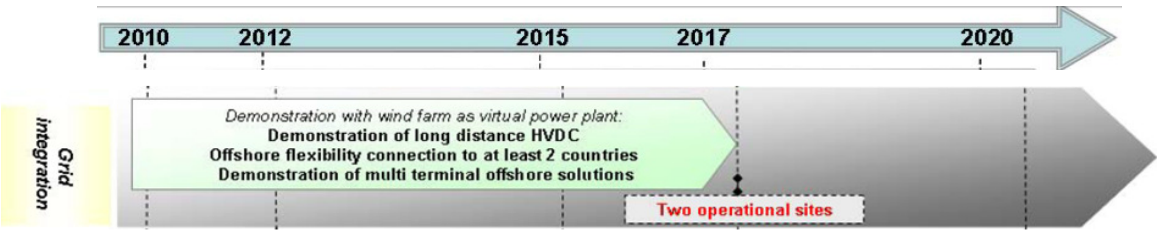

Figure 3: Wind Technology Roadmap, grid integration section. Source: European Commission, 2009. Communication on Investing in the Development of Low Carbon Technologies.

The focus of the grid integration area is therefore to provide the necessary basis for the transformation of the present European power systems with substantial amounts of mainly onshore wind energy into the future pan-European power system with massive amounts of onshore and offshore wind energy, and other renewable sources. The roadmap towards a successful transformation of the power system includes R&D and demonstrations within the following sub programmes:

- Grid connection and power transmission
- Secure and stable system dynamics
- Balancing and market operation

On period 2010-2012, a set of key activities are launched under these sub-programmes, to ensure the compatibility of HVDC VSC technologies on the market, the development of Virtual Power Plant providing equivalent services to the conventional power plants, and creating the tools and market conditions for a integration of large amounts of variable electricity supply.

There are already two major initiatives on the road towards the future pan-European power system:

- The FP7 project TWENTIES will demonstrate how new solutions can be used to support wind power integration, basically within all 3 sub areas above.
- The European Energy Program for Recovery (EEPR) will support offshore grid development, i.e. projects in the "grid connection and power transmission" sub area.

These activities are included into the following roadmap implementation plan.

Grid connection and power transmission, activities starting on period 2010-2012:

This sub-programme relates to the first objective of the Wind Energy Roadmap *"To demonstrate the feasibility of balancing power systems with high share of wind power using large-scale systems with High Voltage Alternative Current (HVAC) or High Voltage Direct Current (HVDC) interconnections."*

One expected result from the EEPR initiative is an extension of the planned Kriegers Flak projects from individual national grid connections to a combined solution including interconnections between the countries. Kriegers Flak is included in the current activity proposal *(activity 3.1.1)*, as it is related to the following actions of the Wind Energy Roadmap:

- Offshore wind farms interconnected to at least two countries and combined with the use of different interconnection techniques.
- Long distance High Voltage Direct Current

The main expected results from the TWENTIES project on power transmission is investigations and demonstrations of options for more flexible HVAC transmission grids. TWENTIES also deals with HVDC grids, with focus on demonstration of critical building blocks for dynamic security and protection.

On period 2010-2012, the European Wind Initiative focuses on a critical aspect for the development of large meshed DC grids, especially offshore and with the North Sea as the most challenging case. In this area, it is required to improve and verify the technology for this application at large scale. A special source of concern is compatibility of DC network components from different suppliers, which will hinder the stepwise modular development of the future European electricity system. This activity has to start on short notice, to ensure free and fair competition between suppliers before the large scale DC grid development is launched *(activity 3.1.2)*.

In this area, the EEPR project HVDC Hub (€ 74 m) (Shetland – Scotland) contributes to *activity 3.1.2*, since it demonstrates a multiple connection platform using HVDC VSC technology. This project, though does not primarily address the compatibility between components of different suppliers. The Cobra Cable (HVDC connection between Netherlands and Denmark) also contributes to this activity as it includes a study on how this cable can accommodate the future connection of wind farms that will be installed in the area of the planned cable route.

This activity is also related to the 2nd cluster of the proposed ENTSO-E R&D plan[2], *"Power technology for a more flexible, observable and controllable pan-European transmission grid"* and supports project abstract 6.4 *"Demonstrations of power technology for novel network architecture".*

Secure and stable system dynamics, activities starting on period 2010-2012:

This sub-programme focuses on the development and demonstration of the Virtual Power Plant concept, as stated by the Wind Energy Roadmap.

The aim is to ensure a secure and stable operation of the future power system with very large scale wind power. In existing power systems, the dynamic security and stability is mainly

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[2] ENTSO-E, 2010. Final R&D plan *"European grid towards 2020 challenges and beyond" (March 23rd, 2010). Available at: http://www.entsoe.eu/index.php?id=219*

ensured by conventional power plants, i.e. thermal and hydro plants with directly connected synchronous generators. To operate the future system in an optimal way, the renewable generation will have to provide the necessary services to ensure a secure and stable dynamic operation of the system *(activity 3.2.1).*

It can be considered as a follow-up of WindGrid, FENIX and PEGASE, and is complementary to TWENTIES. TWENTIES is limited to demonstrating existing technologies and to provide secondary frequency control and voltage control, whereas this sub-programme focuses on the concept of virtual wind power plant with future technologies, including the delivery of ancillary services of offshore wind farm clusters to the HVDC network.

This activity is related to the 3rd cluster of the proposed ENTSO-E R&D plan, *Network management and control* and supports project abstract 6.5 *"Demonstrations for renewables integration"*, and 6.13 *"Tools for the integration of active demand in the electrical system operations".*

As illustrated in Annex III *"Synergies with the European Energy Research Alliance"*, this sub-programme is supported by the EERA activities in the field of Grid integration.

Balancing and market operation, activities starting on period 2010-2012:

This sub-programme shall show feasibility of balancing power systems with high penetration of wind, supplementing the support from interconnections with the support from advanced wind power plant capabilities (frequency & voltage control), large-scale storage systems (e.g. hydropower, pump storage) and new flexible options such as electric vehicles, heat pumps, demand side response and more flexible thermal generation *(activity 3.3.1).*

Foreseen changes in the electrical systems are supported by various automation and commercial measures, e.g. adequate system coordination methods, and international intraday markets based using data from prediction systems. The impact of wind on other actors of the electricity market and on electricity prices should be assessed *(activity 3.3.2)*.

Activity 3.3.1 and 3.3.2 are related to the second and fourth cluster of the proposed ENTSO-E R&D plan: "*Power technology for a more flexible, observable and controllable pan-European transmission grid"* and *"Market rules"*, and support project abstract 6.10 *"Advanced tools for pan-European balancing markets"* and project abstract 6.12 *"Tools for renewable Market integration"*.

As illustrated in Annex III *"Synergies with the European Energy Research Alliance"*, this sub-programme is implemented through a strong partnership between the industry and the EERA, through the EERA programme in the field of Grid integration.

Interaction with the Electricity Grid Industrial Initiative

The implementation of the grid strand of the Wind Energy Industrial Initiative has to be coordinated with that of the Electricity Grid Initiative, in order to avoid duplication of efforts and fragmentation of R&D activities.

Following meetings held with the European Commission and Grid Initiative representatives, the wind energy industry and R&D community, represented by TPWind, developed a proposal on the distribution of grid tasks between the Wind and Grid Initiatives, which is outlined in this document.

For this reason, grid tasks described in the tables below (and identified by TPWind) are tentatively allocated to the Wind or Grid Initiative on the basis of their nature. The basic rationale behind the suggested sharing of tasks is that wind specific activities should remain within the Wind Initiative, also in view of their strategic importance.

Further to that, the Wind Initiative should be considered as an instrument supporting wind power generators and traders, while the Grid Initiative should focus on grid management. This has also been reflected in the proposed distribution of grid activities.

Finally, the design and planning of sustainable energy supply structures would require a joint implementation.

Regardless however of the proposed distribution of tasks, the vast majority of grid activities outlined in the two Initiatives will require close cooperation between wind and grid operators at implementation level.

IMPORTANT DISCLAIMER: **A final agreement on the distribution of grid tasks between the Wind and Grid Initiatives is still pending. For the same reason, a split of budget allocations between the two Initiatives for the implementation of grid related activities is also currently missing (only the total budget of each activity is available).**

Sub programme 1: Grid connection and power transmission

Number	Description	Suggested distribution of activities between the Wind and Grid Initiatives and comments	Total Budget (2010 – 2012) – to be split between the Wind and Grid Initiatives
3.1.1	Combined solutions for wind farm grid connection and interconnection of at least two countries. Different grid interconnection techniques (DC or AC) (demonstration of Kriegers Flak DC solution, covered by the EEPR)	**Wind** The sub-programme should be renamed "Grid connection of wind plants". The aim is to develop and demonstrate coordinated solutions for design, control and protection of wind farms and offshore interconnectors. This activity should therefore be led by the Wind Initiative. It is important to distinguish two principal areas of work in this activity: • Grid connection technologies (HVDC and HVAC) for offshore wind farms; • Solutions for Grid Connection of offshore wind farms to two (or more) Countries.	€ 150 m (EEPR)
		Grid In order to complement this activity, the Grid Initiative could propose an additional one dealing with the coordination of Load Frequency Control (LFC) in interconnected power system areas and the control of DC voltage.	

<table>
<tr><td rowspan="2">3.1.2</td><td rowspan="2">Controllable HVDC multi-terminal offshore and onshore solutions.
Development of requirement to grid connection of wind power plants to multi terminal HVDC grids.
Development of standards and requirements, which ensure compatibility between components from system security in normal and fault operation, and ensure compatibility between components from different (competing) suppliers.
Onshore and offshore demonstration of compatibility between components from different suppliers.
Budget from EEPR brings € 74 m under this priority.</td><td>Wind

The sub-programme should be renamed “Grid connection of wind plants”.
This activity should be split into two sections: one led by the Wind Initiative and one by the Grid Initiative.
The part led by the Wind Initiative should deal with the two following areas of work:
Requirements for grid connection of wind plants to the meshed HVDC grid (R&D);
Compatibility of DC grid components from different suppliers for large wind farm integration (R&D and demo).</td><td rowspan="2">€ 190 m</td></tr>
<tr><td>Grid

The part led by the Grid Initiative could focus on secure design and operation of multi-terminal HVDC networks.
Large scale HVDC networks will only be built if faults on the grid can be isolated and if the remaining grid can continue operation as it is the case with AC grids. For this purpose, the HVDC technology needs further development of DC breakers as well as protection coordination.
Further to that, the Grid Initiative could look at onshore HVDC highways for the so-called super grids.</td></tr>
<tr><td colspan="3">TOTAL</td><td>€ 340 m incl. EEPR</td></tr>
</table>

<u>Sub-programme 2</u>: Secure and stable system dynamics

3.2.1	Wind Power Plants requirements and solutions to wind farms supporting the system dynamics. Activities (R&D and Demonstration) to enable wind farms and wind farm clusters (large VPP's) to provide services and to offer characteristics similar to conventional power plants. • Validation of standard generic wind farm models as a basis for harmonisation of grid codes, and demonstration of the benefits of generic models and harmonisation, standardisation and certification of grid code capability. • Aggregation of wind farms with flexible generation and loads (covered by the TWENTIES project – Danish demonstrator) • Contribution of wind energy to the system demonstrating the possibility of aggregated wind farms to provide system services, with existing wind power technologies (covered by TWENTIES – Spanish demonstrator) • Investigation and definition of **future** need for system services for AC as well as DC connected wind power plants, and Wind power plant delivery of ancillary services to a DC	**Wind** The sub-programme should be renamed "Wind turbines capabilities for system support". To enable a high penetration of wind energy in the system, wind farms clusters or virtual power plants (VPP) should be operated as far as possible as conventional power plants (e.g. with limited ramp rates and with the provision of frequency response, supporting the system dynamics). These services can be dealt with by wind operators only.	€ 30 m

	network. • Integrated design of wind power plant grid integration with respect to system support and with optimal performance focused on systems with very large wind power penetration. • Integrated design and control of new concepts for large wind farms and virtual wind power plants, operated in a meshed DC offshore grid in the north sea • Development and demonstration of test procedures to validate the system support of the wind power plants.	**Grid** The specific task of this activity dealing with the needs and options for system services (AC/DC, HV/MV grids) could be dealt with by the Grid Initiative.	
TOTAL			€ 30 m

Sub-programme 3: Balancing and market operation

3.3.1	Balancing technologies for large scale wind power penetration: • Power priming, increasing flexibility of conventional power plants, storage, demand side options. The project should focus on technologies with large scale potential. (covered by TWENTIES) • New tools for probabilistic planning and operation of the system, enabling to design and simulate system long term operation (to be covered by ENTSO-E R&D programme)	**Wind** This activity should be split into two sections: one led by the Wind Initiative and one by the Grid Initiative. The Wind EII should deal with the section focusing on wind power plant capabilities (frequency and voltage control), in order to enable a proper balancing of power systems with high penetration levels of wind energy. **Grid** The Grid EII should focus on the other components (e.g. large-scale storage systems, increased flexibility of conventional power plants and demand side response). All these options have to be developed and demonstrated by all relevant parties (traders, regulators, as well as wind, grid and storage operators).	€ 30 m

3.3.2	Market integration: • Deployment of European wide electricity markets to increase flexibility and smooth out variability of wind power. Improving the local balancing area operation with coordinated TSO actions and congestion management (to be covered by ENTSO-E R&D programme). • European wide short- and mid-term wind power forecasting tools to enable and to foster full market integration. • The impact of wind on other actors of the electricity market and on electricity prices, with high penetration of wind power.	**Wind** Forecast techniques are very important to ensure a proper balancing of the system. European wide trading and balancing, as well as the support of grid operations, increases the importance of forecasting outputs from wind farms. This activity should be split into two sections: one led by the Wind Initiative and one by the Grid Initiative. The Wind EII should keep dealing with European wide short- and mid-term wind power forecasting tools to enable and to foster full market integration. **Grid** The Grid EII should focus on: • Deployment of European wide electricity markets to increase flexibility and smooth out variability of wind power. Improving the local balancing area operation with coordinated TSO actions and congestion management; • The impact of wind on other actors of the electricity market and on electricity prices, with high penetration of wind power.	€ 10 m
TOTAL			€ 40 m

Potentially missing grid activities in the Wind and Grid Initiatives

Following a review of the grid activities included in the Wind and Grid Initiative, TPWind identified a list of relevant tasks that could added to them.
These activities are outlined below: their inclusion in the Initiatives and their implementation will depend on future talks with the European Commission, EII representatives and, if the case, Member States.

Activity name and number	Suggested position	Comments
Connection to the grid and design of the connection	Wind	This component is currently missing in the Wind EII and could be added to it.
Architecture of offshore grids	Grid	The architecture of offshore grids should be properly addressed since it is more complex than just the connection of wind power plants (for the moment the design of offshore wind farms grid connections is taken into account only by the Wind EII). This item, currently missing from the Grid EII, is particularly important because the development of offshore grids is essential to the expansion of the offshore wind energy sector.
Energy storage	Grid	This component, currently missing in the Grid EII, could be dropped if Grid Initiative representatives believe that it is already properly addressed in their Implementation Plan.
Design of future flexible power systems – capacity and ramping adequacy	Grid	This component is currently missing in the Grid EII and could be added to it.

4. Resource Assessment, spatial planning and social acceptance

The objectives described by the European Commission's Wind Energy Roadmap are the following:

- To assess and map wind resources across Europe and to reduce forecasting uncertainties of wind energy production;
- To develop spatial planning methodologies and tools taking into account environmental and social aspects;
- To address and analyze social acceptance of wind energy projects including promotion of best practices.

This objective is supported by the following Actions (Figure 4):

- Resource assessment and spatial planning to support wind energy deployment. A R&D programme for forecasting distribution of wind speeds and energy production that includes: Wind measurement campaigns; Database on wind data, environmental and other constrains; Spatial planning tools and methodologies for improved designs and production.

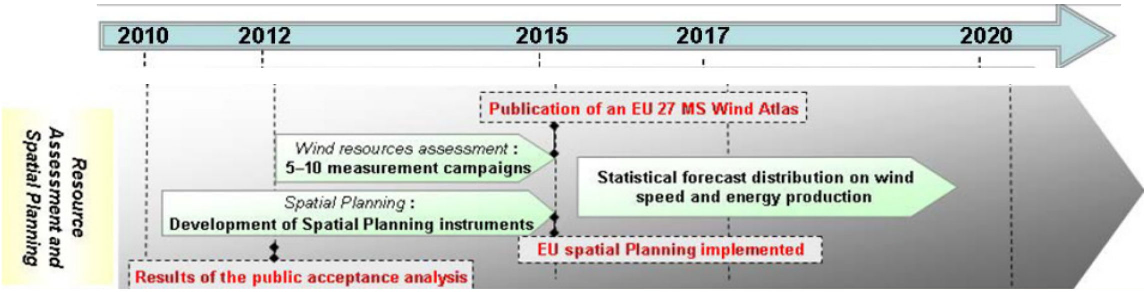

Figure 4: Wind Technology Roadmap, grid integration section. Source: European Commission, 2009. Communication on Investing in the Development of Low Carbon Technologies.

Wind resource assessment, activities starting on period 2010-2012

Several large-scale measurement campaigns will be launched in complex terrain, at forested and near shore / offshore sites across Europe. The campaigns will be based on high-quality measurements of wind speed, direction and turbulence at different heights, including three-dimensional turbulence measurements, and remote sensing techniques. The resulting database will be made available to the research and industrial community. This work will lead to improved design for large scale wind turbines, as described in activity 1.1.1 *"Large scale turbines and innovative design for reliable turbines rated 10 – 20 MW"*, under sub-programme 1 of the *New turbine and components* priority. On the 2015-2017 period, it will lead to an updated high resolution EU-27 wind atlas.

On period 2010-2012, priority is put on identifying the sites and measurement techniques enabling to launch such a large-scale measurement campaign *(activity 4.1.1)*. This experiment will build on improving existing measurement stations, but also on newly developed facilities.

As illustrated in Annex III *"Synergies with the European Energy Research Alliance"*, this sub-programme is implemented through a strong partnership between the industry and the EERA, through the EERA programme in the field of Research facilities, and will be lead by EERA in strong collaboration with the industry. Synergies could also be foreseen with the European Spatial Agency, as a provider of satellite data for on- and offshore wind applications.

Under *activity 4.1.1*, a second activity to be coordinated by EERA, with strong industrial support, sets the research basis for the European Handbook for Integrated Spatial Planning of Renewable Energy resources: Part I Wind Energy resources. Activities for this research theme are strongly connected to the EU wind energy technology Roadmap's milestone on establishing " Tools for spatial planning and a new European Wind Resource Atlas covering all 27 member countries". The first action is to produce a "White Book" on the need and the process towards the Handbook. It is foreseen that this will include consultancies with the Commission and research groups from other sustainable energy sectors. A challenge here will be to set up the research strategy enabling an end product which is of use for research, public and industry and in the follow up of the RES Directive. A scientific demanding activity will be to develop the model-chain from global to micro-scale especially tailored for calculating wind resources.

Development of spatial planning instruments, activities starting on period 2010-2012

Integrated long-term planning for wind energy onshore and offshore is required. Building new transmission lines is a lengthy process, hindering rapid RES deployment. For wind energy, this challenge should be addressed by pursuing integrated long-term planning of future developments. Knowing in advance how much, where and when wind power will be developed in a country ensures that the grid can be modernized in time for increasing wind penetrations. In addition, it enables to accurately plan the supply chain investments, as demonstrated by the UK Round 3 process and the German planning process.

A cooperation programme including Member States, TSOs and the EC is required to develop the methodologies and instruments enabling on and offshore spatial planning for future wind power developments and transnational electricity interconnections, taking into account environmental aspects and other uses of the on- and offshore areas.

On period 2010-2012, a coordination process should be initiated at European level for the offshore sector *(activity 4.2.1)*, both for Northern and Southern Europe, integrating the results of several EU-funded projects as WindSpeed, OffshoreGrid, WindBarriers, and the newly accepted Seanergy project. Major stakeholders such as the Pentalateral forum, government representatives, and ENTSO-E will be involved[3]. The objective of this process is to agree on spatial planning objectives, methodologies and tools, taking into account existing spatial planning processes lead by governments and TSOs. This phase will be followed by the development of jointly agreed spatial planning instruments for maritime energy activities and grid developments.

Onshore, a gap exists between countries with a high penetration level of wind energy in the electricity system, and countries with a high wind potential and a low penetration level. In 2010, the EU countries will submit their National Action Plans to the European Commission. The smooth implementation of the proposed objectives over the next ten years would benefit from a transfer of spatial planning methodologies, tools and policies for wind energy and grid development. Such transfer can be initiated by voluntary Member States, through a thematic network.

Public acceptance analysis, activities starting on period 2010-2012

Social acceptance is a broad topic, related to environmental impacts, spatial planning (distance, visibility, noise, shadow flicker – included in *activity 4.2.1*), but also economic value to the local communities. On period 2010-2012, strong links will be created with the IEA Wind Task 28 on social acceptance, dealing with the environmental issues. A specific complementary activity *(activity 4.3.1)* is required on assessing the societal economic value of wind energy, including industrial transformation strategies, regional benefits, technology exports, employment, land value, and the impact on the electricity market prices, with projections to the 2020 and 2030 timeframes.

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[3] This activity is related to the 1st cluster of the proposed ENTSO-E R&D plan.

Sub-programme 1: Wind resource assessment

Number	Description	Budget (2010 – 2012)
4.1.1	• Generation of a series of unique data sets to evaluate and develop new models for wind energy related physics (public database) – phase 1 – programme definition, site identification for new measurement stations, networking and upgrade of existing facilities. • White paper on the European Handbook for Integrated Spatial Planning of Renewable Energy resources: Part I Wind Energy resources. (EU Roadmap activity) **Activity coordinated by EERA.** Potential synergies with the European Space Agency programmes.	€ 25 m
TOTAL		€ 25 m

Sub-programme 2: Development of spatial planning instruments

Number	Description	Budget (2010 – 2012)
4.2.1	• Coordination process for onshore and offshore spatial planning in the framework of an integrated maritime policy. • Wind energy cooperation between Member States on onshore spatial planning in the framework of the NAPs implementation.	€ 10 m
TOTAL		€ 10 m

Sub-programme 3: Public acceptance analysis

Number	Description	Budget (2010 – 2012)
4.3.1	European wind study on the social economic value of wind energy in the EU	€ 2 m
TOTAL		€ 2 m

Overarching Key Performance Indicators (KPIs)

Introduction

Overarching KPIs will measure the overall impact of the Wind Energy Roadmap. They will therefore be used by the SETIS to monitor its implementation together with technical KPIs (see Annex III of this document), which will focus on specific activities.

The Wind Energy Roadmap will use the Levelised Cost of Electricity (LCOE) as its overarching KPIs. There will therefore be one KPI for onshore and one for offshore, since the cost structure of these two sectors is different.
2020 targets for both onshore and offshore are already identified in this section of the Implementation Plan, together with relevant assumptions.
The ultimate success of the Roadmap will therefore depend on the achievements of these targets.

The methodology

The Levelised Cost of Electricity (LCOE) is widely used to compare the generation technologies. The definition given in the literature treats the fuel costs in the same way as the operation and maintenance costs and does not take into account the additional cost of carbon emissions. In our analysis the formula had to be expanded, separating the fuel costs from the operation and maintenance costs and adding the carbon costs. The main reason for that is that in our analysis the fuel and carbon costs carry a risk associated with their volatility and therefore have to be accounted separately. In our analysis, the LCOE is thus defined as:

$$LCOE[€/_{MWh}] = \frac{LI[€/_{y}] + DO\&M[€/_{y}] + DC_f[€/_{y}] + DC_{CO2}[€/_{y}]}{E[^{MWh}/_{y}]} \qquad (1)$$

Where

- *LI[€/y]* : levelised investment
- *DO&M [€/y]*: annual discounted operation and maintenance cost
- DC_f *[€/y]* : annual discounted fuel cost
- DC_{CO2} *[€/y]* : annual discounted carbon emission cost and
- *E [MWh/y]* : annual energy production

The cost components are defined in the following sections 1.1 to 1.3.

Technology costs

The levelised investment and the operation and maintenance costs define the technology costs for each different power plant examined.

A. Levelised investment: it is defined as the annual breakdown of the total capital cost (formula 2):

$$LI = C * P * CRF \qquad (2)$$

Where:

- *LI [€/y] :* levelised investment
- *C [€/kW]:* the capital cost
- *P [kW]:* installed capacity of the examined power plant

- *CRF [%]:* capital recovery factor. The CRF is used to convert the present value of the cost components into equal annual payments over a specified time using a specified discount rate. It is defined by formula (3) as:

$$CRF = \frac{d}{(1-(1+d)^{-N})} \quad (3)$$

Where

- *N [y]:* technical lifetime of the examined technology. It represents the expected years of operation of each different power plant.
- *d [%]:*real discount rate, used to discount the future cost streams in their present value. In the first part of the analysis the same value is used to discount all the different cost components without distinguishing whether some of them are riskier than others. It is defined by formula (4) as:

$$d = \frac{d_n - i}{1 - i} \quad (4)$$

Where

- *i [%]:* inflation rate. It reflects the inflation variation. The inflation is an indication of how much is the increase in the value of goods within the economy. The assumption regarding the inflation is based on Eurostat's figures [19].
- *d_n [%]:* the nominal discount rate, not taking into account the inflation.

B. Annual discounted operation and maintenance cost:
   DO&M [€/y]: represents the levelised cost component associated with the operation and maintenance costs. It is defined by formula (5) as:

$$DO\&M = \Sigma O\&M * CRF \quad (5)$$

Where:

- *CRF [%]* : capital recovery factor (formula 3)
- *ΣO&M[€]:*sum of the present values of total O&M. It is calculated following the concept of discounting the future expenditures and then summing them up in order to transfer them in the present and levelise them. Formula (6) is used:

$$\Sigma O\&M = O\&M * \sum_N \frac{1}{(1+d)^N} \quad (6)$$

Where

- *N [y]:* technical lifetime of the examined technology
- *d [%]:*real discount rate
- *O&M [€/y]:* total operation and maintenance costs. They consist of a fixed [€/kW] and a variable [€/kWh] part. The fixed part includes mainly costs of land renting and various costs which depend on the size of the plant. The variable part includes the main operation and maintenance costs as well as insurance costs. In the case of wind energy the total annual O&M costs are the sum of the variable and the grid balancing costs. In the case of nuclear power, the insurance cost is identified as a separate cost and it is added on the variable and the fixed O&M costs.

Fuel costs

The part of the cost that is related to fuel is expressed through the annual discounted fuel cost DC_f [€/y] which is defined in formula (7):

$$DC_f = \Sigma AC_f * CRF \tag{7}$$

Where

- *CRF(%) :* capital recovery factor as defined previously (formula 3)
- *ΣAC_f [€] :* Sum of the present values of annual fuel costs . Assuming that the annual cost of fuel will remain constant throughout the lifetime of the project, the annual expenditure has to be discounted to the present value. It is calculated using formula (8):

$$\Sigma ACf = AC_f * \sum_N \frac{1}{(1+d_f)^N} \tag{8}$$

Where

- *N[y] :* technical lifetime of the examined technology
- *d_f [%]:* discount rate related to fuel cost . It is used to discount the future fuel cost to present values. In the first part of the analysis this discount rate does not take into account the risk of the volatility of fuel price, so it is assumed to be the same with the real discount rate *d*, used for discounting the capital and O&M costs.
- *AC_f [€/y]:* annual cost of fuel. For this value the assumptions regarding the price of fuel in €/kWh of the IEA are respected.

Carbon costs

The costs related to carbon emission are expressed through the annual discounted carbon cost *DC_{CO2} [€/y]* which is defined in formula (9):

$$DC_{CO2} = \Sigma AC_{CO2} * CRF \tag{9}$$

Where:

- *CRF [%]:*capital recovery factor (formula 3)
- *ΣAC_{CO2} [€]* : sum of the present values of annual carbon costs. Assuming that the carbon price will remain constant throughout the lifetime of the project, the future expenses have to be discounted to the present values. The sum of these present values gives the total cost related to carbon under these assumptions. The calculation is performed using formula (10):

$$\Sigma AC_{CO2} = AC_{CO2} * \sum_N \frac{1}{(1+d_{CO2})^N} \tag{10}$$

Where

- *N [y]:* technical lifetime of each technology examined
- *d_{CO2}[%]:* discount rate related to carbon cost. It will be used to discount the future cost of carbon emissions to the present. As for the discount rate for fuel, in the first part of the analysis the volatility of the carbon price is not taken into account and the discount rate is the same as the one for discounting the capital and O&M costs.
- *AC_{CO2} [€/y]:* annual expenditure related to carbon emissions for the fossil fuel power plants. It is calculated using formula (11):

$$AC_{CO2} = f_{CO2} * P_{CO2} \tag{11}$$

Where

- f_{CO2} *[ton/MWh] :* emission factor and gives the amount of CO_2 emitted per MWh of electricity generated,
- P_{CO2} *[€/ton]:* price of CO_2. It follows assumptions provided by the literature

Including the risk

As mentioned in the previous section when the LCOE is calculated for fossil fuel and nuclear generation, a risk has to be taken into account. This risk is associated with the volatility of fuel and carbon price. In our analysis we include this risk by using a differentiated discount rate when accounting for cost components which carry this risk: Fuel and Carbon Cost. Therefore the discount rate takes a different value for each technology when accounting for the fuel and carbon cost. This means that for each technology the discount rates used in formulas (8) and (10) are replaced with the according risk adjusted ones. The new differentiated discount rates are presented in the table with the assumptions.

Projecting the Levelised Cost Of Electricity

Each technology experiences the effects of learning. Generally this implies that the technological progress over the years is resulting in increasing the efficiency in constructing the same products. This leads to a decrease on the cost of producing the same output. Each time that the cumulative capacity of a product doubles, the cost of producing one respected unit is decreased by a percentage – the learning rate. In our analysis, the learning effect is applied to the main cost components assuming that the impact is the same for all the cost elements; capital and O&M costs.
The future cost will depend on the present cost as well as the present and future total installed capacity of each power technology. The formula applied to calculate the future cost is presented below (12):

$$C_{future} = C_{present}\left(\frac{P_{future}}{P_{present}}\right)^{\frac{\ln(1-LR)}{ln2}} \qquad (12)$$

Where:

- C_{future} *:* future value for a specific cost component
- $C_{present}$ *:* present value for the same cost component
- P_{future} [GW]: total installed capacity of the respective power plant
- $P_{present}$ [GW]: total installed capacity of the respective power plant
- *LR* [%]: represents the learning rate applied to each power technology

Starting Assumptions

The following tables present our assumptions on each technology.

Assumptions	GAS	COAL
Total Plant Capacity (MW)	1000	1000
Load Factor (%)	80%	80.00%
Nominal discount rate (%)	7.50%	7.50%
Inflation rate(%)	2%	2%
Discount rate used (%)	5.61%	5.61%
Lifetime (y)	30	40

Capital, Investment Cost (€/kW)	600	1600
Total Fixed Annual Cost (€/kW)	12	40
Total O&M Annual Cost (€/kWh)	0.0023	0.001
CO2 emissions factor	0.35	0.85

Table 1: Assumptions for Gas and Coal generation

NUCLEAR	Assumption
Total Plant Capacity (MW)	1000
Load Factor (%)	85%
Nominal discount rate (%)	7.5%
Inflation rate(%)	2%
Discount rate used (%)	5.61%
Lifetime (y)	40
Overnight cost (€/kW)	3,000.00
Total Capital Cost (€/kW)	6,000.00
Total Fixed Annual Cost (€/kW)	15.00
Total O&M Annual Cost (€/kWh)	0.02
Insurance Cost (€/kWh)	0.00019

Table 2: Assumptions for Nuclear Generation

WIND POWER	ONSHORE	OFFSHORE
Total Plant Capacity (MW)	40	40
Size of Wind Turbines(MW)	2	5
Inflation (%)	2%	2%
Nominal Discount rate (%)	7.5%	7.5%
Real Discount rate (%)	5.61%	5.61%
Capital, Investment Cost (€/kW)	1250	2500
O&M costs (including the fixed annual costs, €/kWh)	0.0145	0.019
Balancing Costs (€/kWh)	0.003	0.003
Capacity Factor	25.00%	35.00%

Table 3: Assumptions for Wind Energy

	GAS			COAL		
	2010	2020	2030	2010	2020	2030
Fuel cost(€/kWh)	0.0246	0.0288	0.0339	0.0843	0.0728	0.0765
Carbon Cost (€/tCO2)	20	30	40	20	30	40
Capacity installed (GW)	185.60	208.00	242.00	202.60	182.00	158.00
Learning Rate(%)	5.00%	5.00%	5.00%	6.00%	6.00%	6.00%

	NUCLEAR		
	2010	**2020**	**2030**
Fuel cost(€/kWh)	0.0050	0.0050	0.0050
Carbon Cost (€/tCO2)	20	30	40
Capacity installed (GW)	127.00	108.00	103.00
Learning Rate(%)	3.00%	3.00%	3.00%

Table 4: Assumptions for Projecting the LCOE of Gas, Coal and Nuclear Generation

	WIND ONSHORE			WIND OFFSHORE		
	2009	2020	2030	2009	2020	2030
Capacity installed (GW)	74.00	190.00	250.00	1.47	40.00	150.00
Learning Rate (%)		10%	10%		5%	7%

Table 5: Assumptions for Projecting the LCOE of Wind Energy

Risk Assumptions				
Cost Component	**GAS**	**COAL**	**URANIUM**	**CARBON**
Risk – adjusted discount rate	2.90%	1.90%	3.40%	1.90%

Table 6: Risk Assumptions

Variables to consider

Variables to consider when projecting wind energy LCOE are the following:

Investment (L.I.)	Manufacturing costs (€/m²)
	Transport, installation, commissioning (€/m²)
	(Reservation for) decommissioning (€/m²)
Manufacturing costs	Size of rotor swept area
	Load reduction
	Materials
	Advanced components
	Design integration
	Grid connection
	Wind farm lay out
	Electrical rating, control, capacity factor
Energy production (E)	System efficiency
	Availability (= f(reliability, accessibility)) (% of time)
	V *(average)* cubed
Operation & Maintenance	Preventive O&M (condition monitoring, flight leader monitoring, condition dependant maintenance)
	Corrective maintenance
	Access (vessels)
	Facilities (Harbour – at sea)

Annex I: Financing

Risk analysis

The following table provide an overview of the European added-value, the level of risk (in a scale from 1, low, to 3, high) and the ideal sources of funding of each roadmap project included in this Implementation Plan (others will be added in the future to develop a post 2012 scenario). In principle, projects with a high EU added value or risk should be funded by European instruments (FP7 or EIB); the others can be supported by Member States:

Roadmap strand	Project number	Project label	Foreseen budget	Start date	End date	European added-value	Level of risk	Ideal funding source / instrument
Roadmap 1: New turbines and components	1.1.1	Large scale turbines and innovative design for reliable turbines rated 10 – 20 M	€ 240 m	2010	2015	+++	+++	Grant (FP7), complemented by national budgets. Market penetration supported by NER first and second calls
	1.1.2	Improved reliability of large wind turbines and wind farms	€ 63 m	2010	2012	+++	++	Grant (FP7), NER first call
	1.1.3	Turbine optimisation and demonstration for complex terrain	€ 10 m	2010	2012	+++	+++	Grant (FP7), demonstration under NER second call
	1.1.4	Turbine optimisation and demonstration for extreme climates	€ 10 m	2010	2012	+++	+++	Grant (FP7), demonstration under NER second call
	1.2.1	Definition of methods and standards for testing large wind turbine components	€ 10 m	2010	2012	+++	++	Grant (FP7)

Roadmap strand	Project number	Project label	Foreseen budget	Start date	End date	European added-value	Level of risk	Ideal funding source / instrument
	1.2.2	Improvement of size and capabilities of system-lab testing facilities for 10 – 20 MW turbines	€ 150 m	2010	2012	++	++	Member States or equity (EIB)
	1.2.3	Field testing facilities for 10 – 20 MW aimed at increasing reliability	€ 150 m	2010	2012	++	++	Member States or equity (EIB), incl. EEPR project Aberdeen included (est. € 50 m)
	1.3.1	Large scale manufacturing and logistics, both size and numbers for in and out-of-factory and site erection	€ 250 m	2010	2012	++	++	Member States and equity (EIB). EEPR accounts for € 92 m.
Roadmap 2: Offshore technology	2.1.1	Deep offshore, and site identification for demonstration of large-scale substructures	€ 60 m	2010	2012	+++	+	Deep offshore budget financed by current FP7 project. Site identification budget included in 1.2.3
	2.2.1	Industry-wide initiative on mass-manufacturing of substructures	€ 250 m	2010	2012	++	++	Member States and equity / loan (EIB). EEPR provides € 153 m through grants.
	2.3.1	Standards	€ 5 m	2010	2012	+++	+	Grant (IEE) / Industry
Roadmap 3: Grid integration	3.1.1	Combined solutions for wind farm grid connection and interconnection of at least two countries	€ 150 m	2010	2012	+++	+++	EEPR project Kriegers Flak
	3.1.2	Controllable HVDC multi-terminal offshore and onshore solutions	€ 190 m	2011	2013	+++	+++	Grant (FP7) for research component, demonstration under NER. Budget from EEPR brings € 74 m under this

Roadmap strand	Project number	Project label	Foreseen budget	Start date	End date	European added-value	Level of risk	Ideal funding source / instrument
								priority.
	3.2.1	Wind Power Plants requirements and solutions to wind farms supporting the system dynamics	€ 30 m	2011	2013	+++	+++	Grant (FP7)
	3.3.1	Balancing technologies for large scale wind power penetration	€ 30 m	2012	2014	+++	+++	Grant (FP7)
	3.3.2	Market integration	€ 10 m	2012	2014	+++	++	Grant (FP7) complemented by TSOs through ENTSO-E R&D budget
Roadmap 4: Resource assessment and spatial planning	4.1.1	Data sets for new models for wind energy	€ 25 m	2010	2012	+++	+++	Research and definition through FP7, installations by Member States
	4.2.1	Coordination process for on and offshore spatial planning	€ 10 m	2010	2012	+++	+	Grant (IEE), Member States
	4.3.1	European wind study on the social economic value of wind energy in the EU	€ 2 m	2010	2012	+++	+++	Grant (IEE), Member States

Table 1: Budgets, Risk and European added-value per activity. These parameters provide guidelines for identifying the funding sources and instruments.

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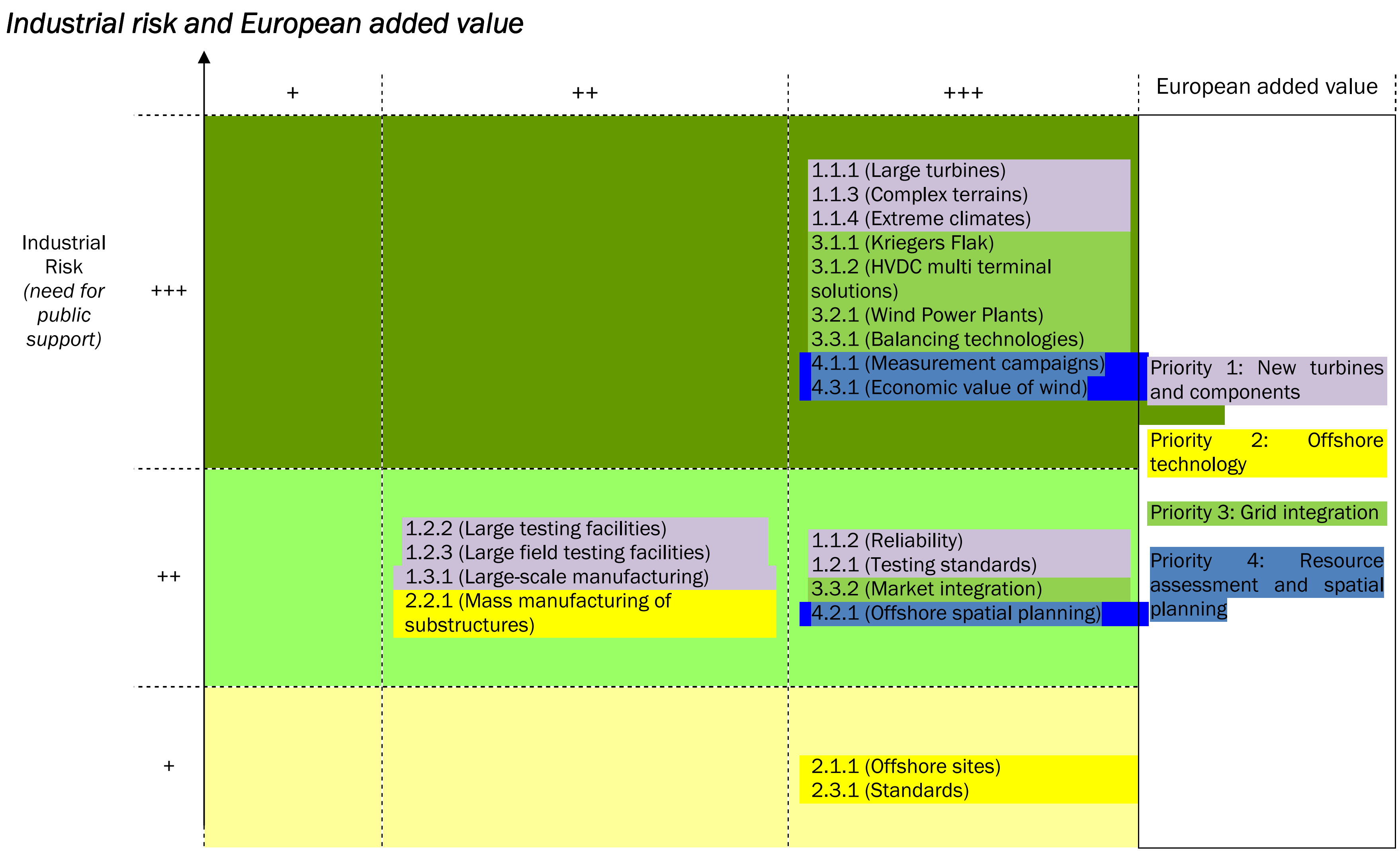

Figure 5: Based on Table 1 analysis. Roadmap components as a function of their European added-value and industrial risk (+ = low, ++ = medium, +++ = high).

Financing instruments

Preliminary research / Policy actions	Pre-competitive research	Demonstration / Test facilities	Market uptake / Innovation / Private infrastructures
1.1.1 (Large turbines) 4.1.1 (Measurement campaigns) 4.2.1 (Offshore spatial planning) 4.3.1 (Economic value of wind)	1.1.2 (Reliability) 1.1.3 (Complex terrains) 1.1.4 (Extreme climates) 1.2.1 (Testing standards) 3.2.1 (Wind Power Plants) 3.3.1 (Balancing technologies) 3.3.2 (Market integration)	1.2.2 (Large testing facilities) 1.2.3 (Large field testing facilities) 1.3.1 (Large-scale manufacturing) 2.1.1 (Offshore sites) 2.3.1 (Standards) 3.1.1 (Kriegers Flak) 3.1.2 (HVDC multi terminal solutions)	2.2.1 (Mass manufacturing of substructures)
EU Grants, Member States for relevant actions	EU Grants, Member States for relevant actions	EU Grants, Member States, equity (EIB)	Member States, Loans or equity (EIB)
Total public funding level 50%	Total public funding level 50%	Total public funding level 50%	Total public funding level 25%

Figure 6: Based on Table 1 analysis. Illustration of funding instruments and level of public support per activity.

Budget intensity and repartition on period 2010-2012

The following table provides a comparison between the total roadmap budget and the foreseen expenditure level on period 2010 – 2012 period. The average budget expenditure will be 24% of the total budget, for 20% of the period. This higher budget intensity is due to the EEPR, representing 36% of the budget spent.

If the EEPR is not taken into consideration, and therefore focusing on additional funds required, the budget intensity is 15%, lower than the expected 20%. This translates the fact that this first phase prepares the ground for large-scale demonstrators in the next phase.

Technology objectives	Total budget (M€)	Budget (M€) on period 2010-2012	Budget intensity
1. New turbines and components	2 500	760	30%
2. Offshore structure-related technologies	1 200	310	25%
3. Grid integration	2 100	334	16%
4. Resource assessment and spatial planning	200	36	18%
Total incl. EEPR	**6 000**	**1443**	**24%**
Total exl. EEPR	**6000**	**924 (EEPR 519)**	**15%**

Gantt chart on period 2010-2012

Action / Time	2010	2011	2012
1.1.1 Large scale turbines and innovative design for reliable turbines rated 10 – 20 MW	40	40	40 *(to end in 2015)*
1.1.2 Improved reliability of large wind farm clusters	21	21	21
1.1.3 Turbine optimisation and demonstration for complex terrain and extreme climates		5	5
1.2.1 Definition of methods and standards for testing large wind turbines components	10		
1.2.2 Improvement of size and capabilities of system-lab testing facilities (2 system-lab facilities by 2012)	50	50	50

1.2.3 Field testing facilities for 10 – 20 MW aimed at increasing reliability (2 field testing facilities by 2012)	50	50	50
1.3.1 Large scale manufacturing and logistics (2 facilities by 2012 – for 6MW turbines)	150	50	50
2.1.1 Site identification for demonstration of large-scale substructures (see activity 1.2.3)	*20*	*20*	*20*
2.2.1 Industry wide initiative on mass-manufacturing of substructures	150 (EEPR)	50	50
2.3.1 Technology transfer from oil & gas sector	1,67	1,67	1,66
3.1.1 Combined solutions for grid connection and interconnection	*150 (EEPR)*	*0*	*0*
3.1.2 HVDC multi-terminal offshore and onshore solutions	74 (EEPR)	40	40 *(to end in 2013)*
3.2.1 Wind power plants		10	10 *(to end in 2013)*
3.3.1 Balancing technologies for large scale wind power penetration			10 *(to end in 2014)*
3.3.2 Market integration			3,33 *(to end in 2014)*
4.1.1 Unique data sets to evaluate and develop new models for wind energy physics	8	8	8 *(phase II to start in 2012)*
4.2.1 Onshore and offshore spatial planning	10		
4.3.1 Study on social economic value of wind energy	1	1	
Cumulative budget	**215 + 519 EEPR**	**345**	**364**

Repartition of budget additional to EEPR on period 2010-2012

IMPORTANT DISCLAIMER: **The figures and scenarios provided in this section are based on the simulations and assumptions developed by the European Wind Energy Technology Platform (TPWind) and do not reflect the position of EU Institutions or Member States.**

Figure 7 presents the wind energy roadmap budgets at EU and National level, such as the industry contribution. In addition, the figures from the EEPR activities are included separately, together with the industry contribution to the EEPR activities (eligible costs)[4]. For a EEPR contribution of €519 m, the eligible project costs amounted approximately to €2.1 bn. Including the EEPR in our analysis, the private contribution to the wind energy roadmap implementation plan over the 2010-2012 period represents 74% of the total budget. The EU funds account for 8%, the national programmes for 4% and the EEPR for 14%.

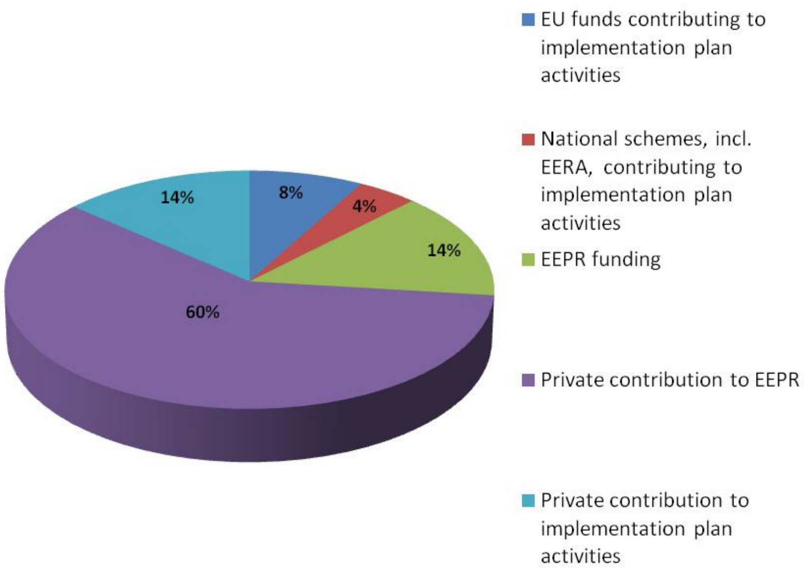

Figure 7: Illustration of the EEPR impact on the wind energy roadmap implementation plan. This figure includes, the EEPR funding, the eligible costs considered in EEPR funding, the additional EU funds requested by the implementation plan, and national funds.

Since the EEPR budgets are already allocated, the following section focuses on additional funding required by the wind energy roadmap implementation plan over the 2010-2012 period (Table 2). The following figures are based on the assumptions presented Table 1, Figure 5, and Figure 6. The industry involvement, and level of public financing at EU and MS level are illustrated by Figure 8. Excluding the EEPR, the industry contribution represents 45% of the 2010-2012 budget, EU funds represent 36% and Member States 19%, including the EERA budget. Figure 9 and **Error! Reference source not found.** illustrate the respective shares of EU funds, National funds and Industry participation for each roadmap component.

Roadmap strand	EU funds	National schemes, incl. EERA	Private contribution
Roadmap 1: New turbines and components	178.5	132.0	310.5

[4] From European commission document MEMO/09/543 of Dec. 9th 2009.

Roadmap 2: Offshore technology	44.6	12.1	105.3
Roadmap 3: Grid integration	56.7	0.0	56.7
Roadmap 4: Resource assessment and spatial planning	9.3	9.3	12.3
Total	289	153.4	484.7

Table 2: Funding repartition at EU, National levels, and Industry contribution, based on assumptions presented by Table 1, Figure 5, and Figure 6.

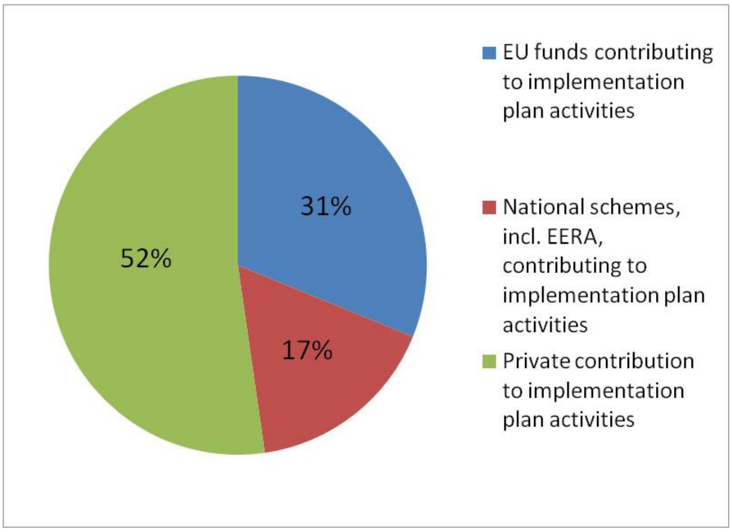

Figure 8: Funding repartition at EU, National level, and Industry contribution, based on assumptions presented by Table 1, Figure 5, and Figure 6.

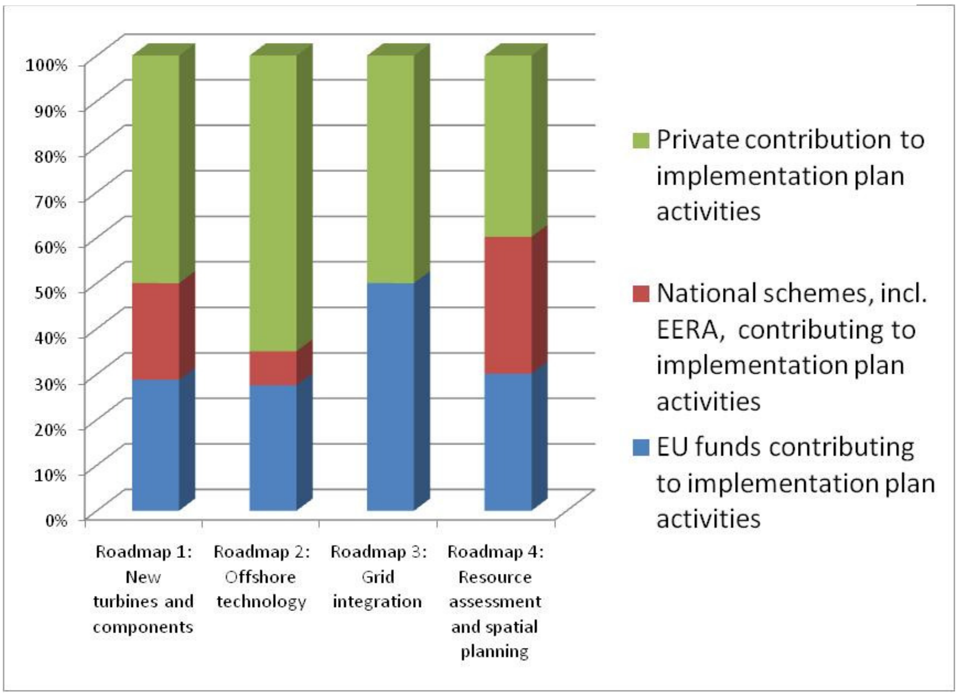

Figure 9: Funding repartition for each roadmap component at EU, National level, and Industry contribution, based on assumptions presented by Table 1, Figure 5, and Figure 6.

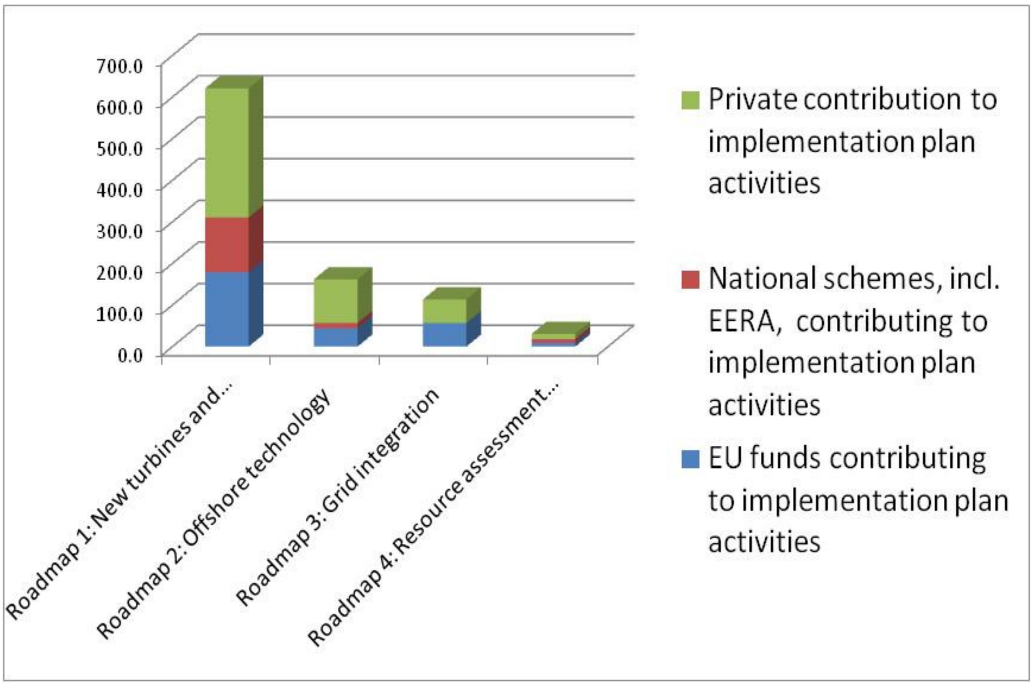

Figure 10: Funding repartition at EU, National level, and Industry contribution, based on assumptions presented by Table 1, Figure 5, and Figure 6

Finally, it should be noticed that the EEPR is not the only EU funding scheme / project already contributing to the implementation of the Roadmap. Other actions should be mentioned (see table below) and will be taken into consideration when allocating public funds in the coming years:

Action / Time (2010 – 2012)	Project / Programme	Call
1.1.1 Large scale turbines and innovative design for reliable turbines rated 10 – 20 MW	UPWIND (FP6) – ONLY FEASIBILITY	Topic FP7 ENERGY.2010.2.3-1: Cross-sectoral approach to the development of very large offshore wind turbines
1.1.2 Improved reliability of large wind farm clusters		
1.1.3 Turbine optimisation and demonstration for complex terrain and extreme climates	Partially covered by National Programme (SE)	
1.2.1 Definition of methods and standards for testing large wind turbines components	Partially covered by National Programmes (ES, UK, DE)	
1.2.2 Improvement of size and capabilities of system-lab testing facilities (2 system-lab facilities by 2012)		
1.2.3 Field testing facilities for 10 – 20 MW aimed at increasing reliability (2 field testing facilities by 2012)	Partially covered by National Programme (DK)	
1.3.1 Large scale manufacturing and logistics (2		

facilities by 2012 – for 6MW turbines)		
2.1.1 Site identification for demonstration of large-scale substructures (see activity 1.2.3)	Partially covered by National Programme (DE)	
2.2.1 Industry wide initiative on mass-manufacturing of substructures	Partially covered by EEPR (in 2010)	
2.3.1 Technology transfer from oil & gas sector		
3.1.1 Combined solutions for grid connection and interconnection	Partially covered by EEPR (in 2010)	
3.1.2 HVDC multi-terminal offshore and onshore solutions	Partially covered by EEPR (in 2010)	
3.2.1 Wind power plants	Partially covered by TWENTIES (FP7) – for demonstration of existing technologies – and National Programmes (DK, FI, SE, NO)	
3.3.1 Balancing technologies for large scale wind power penetration	Partially covered by TWENTIES (FP7) and National Programmes (DK and SE)	
3.3.2 Market integration	ENTSO-E R&D Programme	2010 Intelligent Energy Europe (IEE) call for proposals: ALTENER component; RES section
4.1.1 Unique data sets to evaluate and develop new models for wind energy physics		
4.2.1 Onshore and offshore spatial planning	Partially covered by the SEANERGY project (IEE) - offshore part	
4.3.1 Study on social economic value of wind energy		Current IEE call: ALTENER component; RES section

Annex II: Management structure

According to the EC Communication on Financing Low Carbon Technologies, Roadmaps will be implemented by strengthening and coordinating existing EU and national instruments. No new agencies or ad-hoc funding schemes are expected on period 2010-2012.

The managing structure developed by the European Commission and Council is the following:

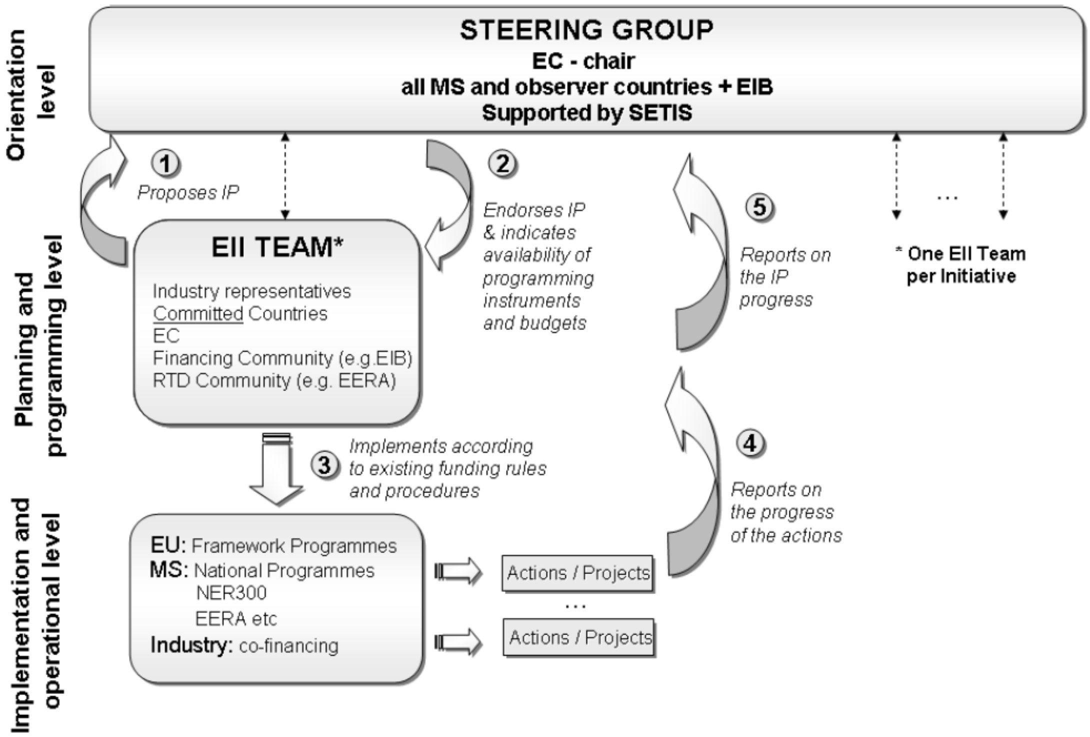

Figure 11: Governance structure for the rapid launch of the Wind Energy Roadmap.

The managing structure is based on the following principles:

- Light and non bureaucratic structure and governance;
- Open architecture;
- Shared objectives, planning, monitoring, reporting tools and implementation mechanisms;
- Partners engaged voluntarily (e.g. Member States);
- Preserved sovereignty over national research funds;
- Based on available instruments;
- Launch without delay (all EU Industrial Initiatives will be launched before the end of 2011).

As shown in the diagram above, the governance is based on three levels of intervention:

- Orientation level: SET-Plan Steering Group;

- Planning and Programming level – EII Team;
- Implementation and Operational level (i.e. execution of projects).

The governance will be therefore based on a common set of principles and practices shared by all Initiatives, which can nevertheless be adapted to the needs of each sector (which might emerge during the implementation phase).

The distribution of responsibilities between the three levels of intervention is outlined below.

Orientation level:

- Approve and ensure the global coherence of the Terms of Reference -regularly updated with SETIS support;
- Ensure the coherence and interaction between EII Teams;
- Assess and endorse the Implementation Plans (IP) proposed by EII Teams;
- Indicate availability of appropriate Programmes, instruments and budgets to contribute to the IP;
- Evaluate the overall progress of the Roadmap through the SETIS monitoring mechanisms;
- Provide an overall picture of the public contributions to the EII activities with the support of SETIS mapping activities;
- Report to the Commission and Council on the progresses of the EII.

Planning and Programming level:

- Develop the IP: actions (taking into account projects financed at Member States level), investment needs, Key Performance Indicators (KPIs) for monitoring the activities in cooperation with the SETIS;
- Address cross-cutting issues as necessary in collaboration with other EII Teams;
- Guide the implementation of the IP on the basis of the SET-Plan Steering Group orientations in terms of programmes and instruments;
- Monitor the technological progress of the IP through the dedicated KPIs;
- Report on the progress of the IP to the SET-Plan Steering Group.

Implementation and Operational level:

- Implement activities through projects;
- Ensure knowledge sharing and dissemination;
- Report on the progress of actions to the Planning & Programming level.

Next steps

The first meeting of the Wind EII Team (Planning and Programming level) was held in Brussels on May 19th, 2010. During the meeting, the 2010 – 2012 Implementation Plan was presented and discussed, together with its KPIs and the suggested distribution of grid tasks between the Wind and Grid Initiatives.

Following this meeting, the Wind EII Team will focus on the development of the 2011 Wind Energy Initiative Work Programme, which will guide its implementation in 2011 by defining which of its activities will be funded at EU and national level and how (i.e. by which funding instrument and with which budget).

Once completed, the 2011 Work Programme will be submitted to the SET-Plan High Level Steering Group for approval before being forward to EU and national authorities for implementation. TPWind, on behalf of the wind energy industry and R&D community, will develop the first draft of the 2011 Work Programme, which will be then discussed and finalized within the Wind EII Team.

Annex III: Technical Key Performance Indicators (KPIs)

IMPORTANT DISCLAIMER: **The following is a draft of the Roadmap's technical KPIs, which will be used to monitor the impact of each of its activities: the final version will have to be validated by the Wind EII Team.**

The measuring of KPIs will be carried out by the SETIS (Strategic Energy Technology Plan Information System) in cooperation with the Wind EII Team, so as to ensure a shared and transparent monitoring procedure that will involve EU Institutions, Member States and wind energy industry and R&D community representatives.
Technical KPIs will complement overarching KPIs, which will measure the overall impact of the Roadmap as already described in the text of the Implementation Plan:

Number	Description	KPI
1.1.1	Large scale turbines and innovative design for reliable turbines rated 10 – 20 MW • Advanced aerodynamic modeling, design and testing, including flow devices for distributed aerodynamic control of very large rotor blades and aero tools for turbines on floating structures. • Characterization and development of materials and components for wind turbines, including upscaling effects. • Detail development and integration of drive trains – mechanical transmission, generator and power electronics – both theoretical and sub-system validation. • Sensing, algorithms and actuation in control strategies and systems	Innovation for the very large concepts should be included by stage, and include upscaling. This programme should enable the demonstration of a 15-20 MW prototype on period 2017-2020, as stated by the Wind Energy Roadmap: • Develop and test a generator and drive train for turbine in the 10-20 MW range: 10 MW in 2012, 12 MW in 2016, over 15 MW in 2018; • Design and testing of very large blades including smart aerodynamic control over 80 m length. Goals: 80 m in 2014 (8-10 MW), 100 m in 2016 (12 MW), over 110 m in 2018 (15 MW+). Development and implementation of a smart control strategy minimizing the loads and improving the efficiency of a large offshore wind farm of 1 GW scale. The objective is to improve power output of the turbines in the centre of

1.1.2	Improved reliability of large turbines, and wind farms • Analysis of flow in and around large wind farms and through control optimization of power performance and minimizing dynamic loading. • Increased reliability of current large offshore designs: smarter O&M with preventive maintenance and condition monitoring; optimizing life-cycle cost.	the array by 5 to 10% Increased availability of current large offshore designs by 10%, measured in number of hours Designs and methodologies available in 2012, enabling to build two demonstrations funded by the *New Entrants Reserve* **Larger wind turbines with efficient design – (kg/kWh)** – Weight on top of mast per kWh produced over the wind turbine lifetime. It can be decomposed as: (kg/kW)*(kW/kWh), and is therefore an aggregate of two indicators: 1/ The weight / power ratio (kg/kW) is one of the limiting factors for large turbine developments. Technology improvements in materials (blades and drive train), drive trains design, and wind turbine design will improve the weight / power ratio. 2/The lifetime capacity factor (kW/kWh). For a given site, this factor relates to the wind turbine reliability and efficiency. **Reliable wind turbines and Maintenance procedures – (h/ nb_turbines)** – Number of maintenance and repair hours over the project lifetime per wind turbine. This parameter monitors the average wind turbine reliability and O&M practices at wind farm level. **System efficiency: Large efficient arrays of reliable turbines – Average wind farm power coefficient (Adimensional).** This indicator is based on the standard formula for instantaneous power: $P(V) = ½*\rho*\pi*R^2*V^3*C_p$, where ρ is the air density, R is the rotor diameter, V is the wind speed, and C_p is the power coefficient. For this indicator, we calculate a wind farm power coefficient: $C = P/(½*\rho*\pi*R^2*V^3)$, where: • P is the energy production over the project lifetime divided by

		the total number of hours over the lifetime. P is therefore the average wind farm power output. It is equal to the installed capacity*capacity factor. • $½*\rho*\pi*R^2*V^3$ is the maximum available power on the site, based on the site characteristics and rotor size, where ρ is the air density, R is the average wind turbine rotor diameter, V is the average wind speed on the site. When calculating C, we obtain the average wind farm power coefficient. This indicator is adimentional. It enables intercomparison of sites in similar conditions. It monitors the system efficiency, and therefore: the array efficiency, turbine efficiency, reliability, access and O&M practices.
1.1.3	Turbine optimisation and demonstration for complex terrain	The KPI should assess the efficiency of the optimised turbine for complex environments, compared to a reference turbine in standard conditions. We propose to use the wind turbine power coefficient formula: $C = P/(½*\rho*\pi*R^2*V^3)$, where ρ is the air density, R is the rotor diameter, V is the average wind speed, and P is the average wind turbine power output. P is calculated from the energy output over the project lifetime and the number of hours over the lifetime. The KPI is the ratio: C(complex) / C(reference). Technological developments should bring this ratio to 1. The standard turbine could be a 2 MW turbine in Denmark or North Germany. C(complex) can be used as a stand-alone indicator for comparing two demonstrations in similar conditions.
1.1.4	Turbine optimisation and demonstration for cold climates	
1.2.1	Definition of methods and standards for testing large wind turbine components. In close cooperation with the EERA.	Methods and standards for testing large components available in 2011
1.2.2	Five new and improved system-lab testing facilities for 10 – 20 MW turbines. In close cooperation with	Improved and additional system-lab testing facilities:

	the EERA.	• 2 additional drive-train testing facilities for 15 MW+ turbines in 2015 • 2 additional blade testing facilities for 15 MW+ turbines in 2015 • 1 dedicated wind tunnel for large-scale designs in 2015
1.2.3	Two additional field testing facilities for 10 – 20 MW aimed at increasing reliability. In close cooperation with the EERA. This activity includes the identification of offshore test sites required by *activity 2.1.*1. Aberdeen offshore test centre included, funded by the EEPR.	2 additional full-scale field testing facilities established in 2015, in addition to Aberdeen offshore wind farm. In 2012, sites are identified in agreement with national governments
1.3.1	Development of five large scale manufacturing and logistics processes, both size and numbers for in and out-of-factory and site erection.	The performance is assessed in MW produced per year for a wind turbine production facility, in square-meters per year for a blade manufacturing facility (total blade surface produced). 5 to 10 automated production facilities to mass manufacture wind turbines in the 10 to 20 MW range established: 6 MW facilities ready in 2012; 8-10 MW facilities ready in 2016; over 12 MW facilities ready in 2018
2.1.1	• Site identification for demonstration of large-scale substructures for medium and high depths. This activity is carried on in parallel to activity 1.2.3 under sub-programme 2 of the *New turbine and components* priority. • Development of deep-offshore concepts.	The efficiency of the deep offshore concepts depends on the amount of materials to be used per turbine (tons / MW). For medium depth, we propose a KPI in tons / MW.m. This ratio relates to the design efficiency for a given turbine capacity and water depth. The manufacturing of substructures can be monitored in meters of substructures in the water column produced per year (m/y). Design and demonstration of future substructure concepts, including floating, implemented through current FP7 programme, and EERA activity (plus KPI 1.2.3, which applies for site identification).

2.2.1	Industry-wide initiative on mass-manufacturing of substructures to supply the upcoming large European markets.	Development of the necessary manufacturing capacity to manufacture substructures suitable for water depths > 30 m, able to supply substructures for a project volume of 2 GW in 2012, 3.1 GW in 2015, and 6.9 GW in 2020
2.3.1	• Standards for safety and operation, including standard safety factors • Standardisation of subcontracting, in partnership with the oil&gas and maritime sectors	Safety factors agreed in 2012; Standards developed in 2012 and implemented in 2015; Standard contracts developed in 2012 and widely used in 2015.
3.1.1	Combined solutions for wind farm grid connection and interconnection of at least two countries. Different grid interconnection techniques (DC or AC) (demonstration of Kriegers Flak DC solution, covered by the EEPR)	The effectiveness of the interconnection capacity can be monitored in terms of power fluxes on the line (MWh / year). Since the interconnector is used both for wind farm connection and trade, the ratio between the wind farm power output and the total electricity volumes transiting through the interconnector provide an indication of the system effectiveness (Adimensional: MWh / MWh). HVDC multi terminal solutions implemented in Kriegers Flak
3.1.2	Controllable HVDC multi-terminal offshore and onshore solutions. • Development of requirement to grid connection of wind power plants to multi terminal HVDC grids. • Development of standards and requirements, which ensure compatibility between components from system security in normal and fault operation, and ensure compatibility between components from different (competing) suppliers. • Onshore and offshore demonstration of compatibility between	The growth in HVDC cable capacity can be monitored in MW. The collateral development of the HVDC market and its technology can be monitored through the length of installed cables and their capacity (km.MW). The development of HVDC cable for wind energy connection can be monitored in terms of distance of HVDC cables in Europe per installed (offshore) wind energy capacity (km/MW). Standards and requirements for multi terminal DC networks based on VSC technologies, including the interconnector voltage levels (HV) as well as the wind farm voltage levels (MV) defined in 2012

	components from different suppliers.	Demonstration of compatible HVDC VSC technologies ready to start in 2012
3.2.1	Wind Power Plants requirements and solutions to wind farms supporting the system dynamics. Activities (R&D and Demonstration) to enable wind farms and wind farm clusters (large VPP's) to provide services and to offer characteristics similar to conventional power plants. • Validation of standard generic wind farm models as a basis for harmonisation of grid codes, and demonstration of the benefits of generic models and harmonisation, standardisation and certification of grid code capability. • Aggregation of wind farms with flexible generation and loads (covered by the TWENTIES project – Danish demonstrator) • Contribution of wind energy to the system demonstrating the possibility of aggregated wind farms to provide system services, with existing wind power technologies (covered by TWENTIES – Spanish demonstrator) • Investigation and definition of **future** need for system services for AC as well as DC connected wind power plants, and Wind power plant delivery of ancillary services to a DC network. • Integrated design of wind power plant grid integration with respect to system support and with optimal performance focused on	The penetration of wind energy on a system can be monitored by the ratio between the annual wind production and the total annual consumption (adimensional: kWh / kWh). An interesting statistic shows the number of hours over a certain penetration level during the year. The ancillary services could be monitored by the number of times per year the wind farm had to respond to grid faults, maintain the right frequency level, or voltage level, and how many MWh were delivered in such conditions (MW/y). Development and demonstration of advanced technology and tools for system support by wind power plants enabling secure operation with a minimum of conventional generation online, equivalent to 50% wind penetration in 2013

	systems with very large wind power penetration. • Integrated design and control of new concepts for large wind farms and virtual wind power plants, operated in a meshed DC offshore grid in the north sea • Development and demonstration of test procedures to validate the system support of the wind power plants.	
3.3.1	Balancing technologies for large scale wind power penetration: • Power priming, increasing flexibility of conventional power plants, storage, demand side options. The project should focus on technologies with large scale potential. (covered by TWENTIES) • New tools for probabilistic planning and operation of the system, enabling to design and simulate system long term operation (to be covered by ENTSO-E R&D programme)	Balancing technology and tools for large scale power penetration identified and tested in 2012 (result to be achieved by the TWENTIES project). Validation of market integration methods, tools and network architecture scenarios enabling the integration of 20% of wind energy in 2020, 33% in 2030 and 50% in 2050
3.3.2	Market integration: • Deployment of European wide electricity markets to increase flexibility and smooth out variability of wind power. Improving the local balancing area operation with coordinated TSO actions and congestion management (to be covered by ENTSO-E R&D programme). • European wide short- and mid-term wind power forecasting tools to enable and to foster full market integration. • The impact of wind on other	The market integration can be monitored by the energy transiting on interconnectors (MWh), and the total interconnector capacity (MW). The impact on electricity prices in measured in euros / MWh of wind generation. The market evolution should see an evolution from the day-ahead markets towards the intraday and balancing markets (TWh). The performance of forecasting tools is assessed in terms of prediction error. The methodology was developed in the ANEMOS project for model benchmarking.

	actors of the electricity market and on electricity prices, with high penetration of wind power.	Validation of market integration methods, tools and network architecture scenarios enabling the integration of 20% of wind energy in 2020, 33% in 2030 and 50% in 2050
4.1.1	• Generation of a series of unique data sets to evaluate and develop new models for wind energy related physics (public database) – phase 1 – programme definition, site identification for new measurement stations, networking and upgrade of existing facilities. • White paper on the European Handbook for Integrated Spatial Planning of Renewable Energy resources: Part I Wind Energy resources. (EU Roadmap activity)	The KPI is related to the number of measurement points, and the database use can be monitored through a number of downloads, and a number of publications. Measurement sites and techniques identified in 2012, relevant sites upgraded, plus publication of White paper on the European Handbook for Integrated Spatial Planning of Renewable Energy resources (Part I Wind Energy resources published in 2010).
4.2.1	• Coordination process for onshore and offshore spatial planning in the framework of an integrated maritime policy. • Wind energy cooperation between Member States on onshore spatial planning in the framework of the NAPs implementation.	This activity can be monitored through the number of involved parties, the number of involved countries, and the number of created MSP schemes. Spatial planning processes: • Agreement on spatial planning methodologies and tools specifications in 2011 • Implementation of EU-27 onshore and offshore spatial planning in 2013
4.3.1	European wind study on the social economic value of wind energy in the EU	The socio economic value should be assessed in euros / MW. Societal economic benefits assessed in 2011

Annex IV: Synergies with the European Energy Research Alliance – Wind programme

The EERA joint programme was set in close cooperation with the European Wind energy Technology Platform. The EERA work programme strongly reflects the priorities of the European Wind Initiative, on basis of which the EC have prepared The Wind Energy Technology Roadmap. <u>However, the EERA joint programme is initiated by the research community and focuses on medium to long term research, thus supplementing the industry driven initiatives.</u>

The European Wind Initiative is industry driven. Some activities will be coordinated by EERA, with strong support of the private R&D. These specific activities are mentioned in the implementation plan, with their budget estimate, timeline and relevant KPIs.

With the research perspective the EERA joint programme on wind energy focuses on establishing the scientific basis and create new technological opportunities for implementing the strategic objectives of the European Industrial initiative on wind energy, being to improve the competitiveness of wind energy technologies, to enable the exploitation of the offshore resource and deep waters potential, and to facilitate grid integration of wind power. EERA may also provide a coordinated voice towards the European Commission and the member states on medium to long term research priorities and research that is needed in order to meet the industrial sector objectives.

Hence the programme aims at creating a balance between aligning the joint research with the needs of the industrial sector as formulated by the Technology Platform (TPWind) and in the EC Technology Roadmap for wind energy and providing an independent long term research strategy and programme. So far the process has derived advantage from strong synergies and extensive exchanges between EERA, the EAWE (The European Academy of Wind Energy) and TPWind. Hence it was decided by EERA to achieve as much synergy between the SRA work and the EERA Wind Energy Research programme.

A concrete example of this is the proposed priority of preparing the European Wind Energy and Integration Resource Atlas, which is listed in the SRA of TPWind and highlighted in the Technology Roadmap. This is an important activity for the future programme as EERA will be the appropriate body to carry out this large scale, medium to long term research activity included in the Technology Roadmap for wind energy. The Wind Atlas is a prominent example of the synergy between EERA, TPWind and the Technology Roadmap for wind energy.

<table>
<tr><th colspan="3">Summary of actions to be launched on period 2010-2012</th></tr>
<tr><th>Number</th><th>Description</th><th>Supported by EERA Wind activity</th></tr>
<tr><th colspan="3">New Turbines and Components</th></tr>
<tr><td>1.1.1</td><td>Large scale turbines and innovative design for reliable turbines rated 10 – 20 MW</td><td>Aerodynamics programme and Offshore Wind Farms programme – new models for aerodynamic interactions and identification of novel concepts for offshore wind turbines and substructures</td></tr>
<tr><td rowspan="2">1.1.2</td><td rowspan="2">Improved reliability of wind farm clusters
• Analysis of flow in and around large wind farms an through control optimization of power performance and minimizing dynamic loading.
• Smarter O&M with a.o. preventive maintenance and condition monitoring; optimizing life-cycle cost.</td><td>Aerodynamics programme – improved unsteady wake models</td></tr>
<tr><td>Offshore Wind Farms programme – numerical tools for predictive maintenance</td></tr>
<tr><td>1.1.3</td><td>Turbine optimisation and demonstration for complex terrain and extreme climates</td><td>Wind conditions programme – model improvements for siting large turbines, high heights, complex terrain, forested areas and extreme climates</td></tr>
<tr><td>1.2.1</td><td>Definition of methods and standards for testing large wind turbine components</td><td>Offshore Wind Farms programme – development of design tools for large offshore turbines and database for measurements and validation</td></tr>
<tr><td>1.2.2</td><td>Improvement of size and capabilities of system-lab testing facilities for 10 – 20 MW turbines</td><td rowspan="2">Research Facilities programme, clustering of existing research facilities, and identification of additional needs.</td></tr>
<tr><td>1.2.3</td><td>Field testing facilities for 10 – 20 MW aimed at increasing reliability. Aberdeen offshore test centre included, funded by the EEPR.</td></tr>
</table>

1.3.1	Large scale manufacturing and logistics, both size and numbers for in and out-of-factory and site erection	-
Offshore Technology		
2.1.1	Site identification for demonstration of large-scale substructures. This activity is carried on in parallel to activity 1.2.3 under	Offshore wind farms programme – Identification of novel concepts for offshore wind turbines and substructures
2.2.1	Industry-wide initiative on mass-manufacturing of substructures to supply the upcoming large European markets. Public-private partnerships built with the European Investment Bank under the Risk Sharing Finance Facility scheme.	-
2.3.1	• Standards for safety and operation, including standard safety factors • Standardisation of subcontracting, in partnership with the oil&gas and maritime sectors	-
Grid Integration		
3.1.1	Combined solutions for wind farm grid connection and interconnection of at least two countries. Different grid interconnection techniques (DC or AC) (demonstration of Kriegers Flak DC solution, covered by the EEPR)	-
3.1.2	Controllable HVDC multi-terminal offshore and onshore solutions.	-
3.2.1	Wind Power Plants requirements and solutions to wind farms supporting the system dynamics.	Grid integration programme – operate wind farms as conventional power plants
3.3.1	Balancing technologies for large scale wind power penetration	Grid integration programme – Grid planning and operation
3.3.2	Market integration	Grid interation programme – Wind energy and power management
Resource Assessment and Spatial Planning		
4.1.1	Generation of a series of unique data sets to	Research facilities

	evaluate and develop new models for wind energy related physics (public database). **Activity coordinated by EERA.**	programme – New Join Research Facilities
4.2.1	Coordination process for offshore spatial planning in the framework of an integrated maritime policy.	-
4.2.2	Wind energy cooperation between Member States on onshore spatial planning in the framework of the NAPs implementation.	-
4.3.1	European wind study on the social economic value of wind energy in the EU	-