Strategic Research Agenda
Market Deployment Strategy

FROM 2008 TO 2030

2008 2030

European Wind Energy Technology Platform

Contents

Strategic Research Agenda

Market Deployment Strategy

FROM 2008 TO 2030

July 2008

European Wind Energy Technology Platform

Acknowledgments

The TPWind secretariat would like to thank all those who contributed to drafting and producing this report. In particular, we wish to gratefully acknowledge the TPWind Group chairpersons and vice-chairpersons, the TPWind Steering Committee members and the TPWind Executive Committee members.

Foreword

Wind energy is already a European success story, and this success is set to grow even further. Europe is the global leader in terms of wind energy technology and the foremost market for installations. In 2007, more net wind energy capacity was installed in the EU than any other form of power generating technology, and out of the 100 GW of worldwide capacity, 57 GW can be found in Europe.

Wind energy is helping the EU reach many of its energy, economic and environmental objectives. It improves competitiveness and security of energy supply, helps reduce greenhouse gas emissions, and provides a quick and efficient way towards the 20% binding targets for renewable energy production by 2020.

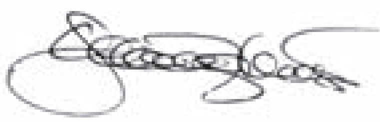
The European Wind Energy Technology Platform (TPWind) has a vision in which wind energy covers 12-14% of the EU's electricity consumption by 2020, with a total installed capacity of 180 GW. By 2030, it sees this increasing to cover 25% of electricity consumption, with 300 GW of installed capacity. Fulfilling this vision will be a major industrial and technological challenge.

To ensure that wind energy technology and the market develop efficiently, it is crucial that research resources across Europe are mobilised. This huge challenge will require investment to be coordinated at European and national level. It will also be necessary to coordinate public and industry resources.

To aid the coordination process, the members of TPWind have drawn up a common roadmap of the sector's research priorities. The roadmap is supported by a full action plan for Research, Development and Demonstration – the first ever strategic analysis of wind energy research carried out on such a scale – and a Market Deployment Strategy. I wish to thank and congratulate each TPWind member for the high-quality exchanges and hard work that have and continue to take place within TPWind.

The time has now come to begin implementing TPWind's vision, and the support of the European Commission and Member States will make all the difference. The Commission's Strategic Energy Technology Plan (SET-Plan) announces the upcoming European Wind Initiative (EWI), demonstrating the significant support that the European Union already gives to wind energy deployment.

Although the EWI covers only a small section of TPWind's priorities, it is an important first step on the long walk to the full realisation of the vision presented here. We are glad that, through this document, we can share part of the journey with you today.



Henning Kruse
TPWind Chairman

Executive Summary

In 2006, the European wind energy sector launched the European Wind Energy Technology Platform (TPWind). TPWind's tasks are to identify and prioritise areas for increased innovation, and new and existing research and development (R&D) tasks. Its primary objective is to reduce the social, environmental and technological costs of wind energy.

In 2030, wind energy will be a major modern energy source; reliable and cost-competitive in terms of cost per kWh. The market will be driven by concerns over:

- the impacts of climate change;
- oil and gas depletion;
- high costs and the unpredictable availability of fuel (security of supply); and
- CO_2 allowance prices and sustainability.

Developments will take place within the current context of decentralisation, decarbonisation and globalisation.

Wind energy is expected to develop in three phases:

- **Phase 1: Short term (2020)** – The market matures in western Europe and develops in central and eastern Europe. Competition from low labour cost countries increases further. Large-scale deployment of offshore wind energy begins. The installed capacity reaches 180 GW, including 40 GW offshore.

- **Phase 2: Medium term (2020-30)** – Wind energy continues to mature in all its applications, both onshore and offshore. The main developments are further cost reductions and high penetration technology. Deep offshore technology develops on an industrial scale. Exports from Europe grow. Installed capacity reaches 300 GW in 2030, when annual installations reach 20 GW, of which half is offshore and 7.5 GW is re-powering.

- **Phase 3: Long term (2030-50)** – The main European markets are in offshore and re-powering. Exports from Europe are strong.

The European industry will continue to lead the global market. Depending on future electricity demand, some 25% of EU electricity consumption, or a total of 300 GW, will be provided by wind, corresponding to annual CO_2 savings of nearly 600 Mt. This will be supported by an optimal industrial expansion in Europe. The European power markets will be much better integrated, with full separation in ownership of transmission and production activities, larger inter-connectors, an effective wholesale market and well-functioning balancing markets.

To make this vision a reality, four thematic areas have been identified: **wind conditions, wind turbine technology, wind energy integration** and **offshore deployment and operation**.

Wind conditions

TPWind proposes an ambitious long-term '3% vision'. Current techniques must be improved so that, given the geographic coordinates of any wind farm (flat terrain, complex terrain or offshore, in a region covered by extensive data sets or largely unknown) predictions **with an uncertainty of less than 3%** can be made concerning:

- the annual energy production ('resource');
- the wind conditions that will affect the design of the turbine ('design conditions'); and
- a short-term forecasting scheme for power production and wind conditions.

Wind power systems

The aim of the research prioritised by TPWind is to ensure that, by 2030, wind energy will be the most cost-efficient energy source on the market. This can only be achieved by developing technology that enables the European industry to deliver highly cost-efficient wind turbines.

Wind energy integration

TPWind focuses on the large-scale integration of wind power. The goal is to enable high penetration levels with low integration costs, while maintaining system reliability (security of electricity supply).

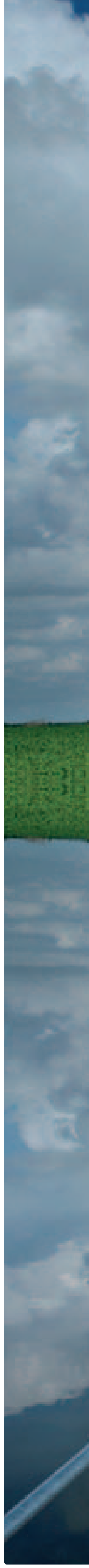


Photo: http://energypicturesonline.com

Offshore deployment and operations

The objective is to achieve the following:

- More than 10% of Europe's electricity demand to be covered by offshore wind
- Offshore generating costs that are competitive with other sources of electricity generation
- Commercially mature technology for sites with a water depth of up to 50 m, at any distance from shore
- Technology for sites in deeper water, proven through full-scale demonstration

In order to implement the TPWind 2030 vision and enable the large-scale deployment of wind energy, the support of a stable and well-defined market, policy and regulatory environment is essential. In the Market Deployment Strategy, the following areas are considered:

- Enabling market deployment
- Cost reduction
- Adapting policies
- Optimising administrative procedures
- Integrating wind into the natural environment
- Ensuring public support

In light of the recently changed energy, socio-political and environmental paradigm, there is a serious and urgent need to reprioritise the financing of Research, Development and Demonstration (RD&D) for energy.

Current instruments should be revised to take this new paradigm into account. Those that are compatible should be adapted and, where appropriate, new instruments should be developed.

The forthcoming European Wind Initiative, which is outlined in the Strategic Energy Technology Plan (SET-Plan), is a key opportunity to reinforce Europe's world leadership in RD&D financing and execution frameworks. TPWind's considerations are fully in line with the SET-Plan.

1. Introduction

1.1. The European Wind Energy Technology Platform (TPWind)

1.1.1. Technology Platforms

During the Barcelona European Council in 2002[1], the European Union (EU) set the goal of increasing the European research effort to 3% of the EU's GDP by 2010, with two-thirds coming from private investment and one-third from the public sector.

To reach this objective, the European Commission proposed six key instruments[2], one of which is the implementation of Technology Platforms. This instrument was designed to bring together companies, research institutions, the financial world and regulatory authorities at a European level to define a common research agenda. This research agenda aimed to mobilise a critical mass of both national and European public and private resources.

In this 'bottom up' approach, individual stakeholders set up a European Technology Platform, with the support and guidance of the European Commission as appropriate. European Technology Platforms are industry-led; they aim to achieve optimum research results and to reflect wider community interests. In order to achieve this goal, public authorities and other relevant stakeholders are involved.

European Technology Platforms follow a three-stage process:

STAGE 1: **Emergence and setting up:** At this stage, stakeholders are brought together. Industry plays an initiating role in this regard, with the aim of achieving a common vision for the way forward. The deliverable is a Strategic Vision Document communicating this common vision, which is endorsed by top executives from leading companies in the sector.

1 European Presidency, 2002. SN 100/1/02 REV1. *"Presidency Conclusions – Barcelona European Council 15 and 16 March 2002."*

2 European Commission, 2004. COM(2004) 353 final. *"Communication from the Commission – Science and technology, the key to Europe's future – Guidelines for future European Union policy to support research."*

Photo: Feindate

STAGE 2: **Definition of a Strategic Research Agenda (SRA):** The SRA is the key deliverable of a European Technology Platform. It sets out research and technological development priorities for the medium to long term, including measures for enhancing networking and clustering of the Research, Technology and Development (RTD) capacity and resources in Europe.

In parallel with the definition of an SRA, European Technology Platforms begin work on a Market Deployment Strategy (MDS). The MDS anticipates the key elements required in order to implement the SRA effectively. It aims to bridge the gap between the current state of development of a given technology and its deployment.

STAGE 3: **Implementation of the SRA:** During this phase, the SRA is implemented with the support of Community Research Programmes as appropriate. At the same time, the SRA makes an important contribution to the preparation of the Commission's proposals for future research programmes. The implementation of the SRA involves support from a range of sources, including the European Commission's Framework Programmes, other sources of European funding, national research programmes, industry funding and third-party private finance.

TPWind is at Stage 2 of this process. Its Strategic Vision Document[3] was drawn up by the Advisory Council and published in 2006. TPWind was officially launched in October 2006, in the presence of EU Energy Commissioner Andris Piebalgs.

3 http://www.windplatform.eu/fileadmin/ewetp_docs/Structure/061003Vision_final.pdf

Photo: Siemens

1.2. TPWind: objectives and structure

1.2.1. Objectives

TPWind's task is to identify and prioritise areas for increased innovation and new and existing research and development (R&D) tasks. Its primary objective is to make overall reductions in the social, environmental and technological costs of wind energy. This is reflected in TPWind's structure, where the issues raised by the Working Groups (see section 1.2.2, below) are focused on areas where technological improvement leads to significant cost reductions.

This helps to achieve the EU's renewable electricity production targets. The Platform develops coherent recommendations, with specific tasks, approaches, participants and the necessary infrastructure in the context of private R&D, and EU and Member State programmes, such as the EU's seventh Framework Programme (FP7).

1.2.2. Working Groups

Through its SRA, TPWind encourages Member States, EU institutions and the wind industry to intensify their research efforts in line with, or exceeding, the overall Lisbon objectives, while increasing its focus on the long-term view. TPWind will encourage long-term research findings to be considered when new wind energy prototypes are developed.

Through the Market Deployment Strategy, Member States, EU institutions and the wind industry are able to modify policy developments to the changing needs of the technology as it matures.

Accordingly, TPWind is structured as follows:

- Technology Research and Development Working Groups responsible for building the Strategic Research Agenda
- Policy/Market Development Working Groups responsible for building the Market Development Strategy

During the Platform Steering Committee's[4] second meeting, the final structure of TPWind was discussed and voted upon. The selected structure is summarised below, in Figure 1:

- Working Group 1: Wind Conditions
- Working Group 2: Wind Power Systems
- Working Group 3: Wind Energy Integration
- Working Group 4: Offshore Deployment and Operations
- Working Group 5: Wind Market and Economics
- Working Group 6: Wind Policy and Environment
- Finance Working Group: Assessing and procuring sufficient RD&D funds

1.2.3. Mirror Group

The Mirror Group is made up of the relevant ministries and energy agencies of Member States wishing to participate. The group is fundamental to the success of TPWind, since it provides the opportunity to:

- tailor national R&D activities to complement EU activities and vice versa; and
- develop synergies between different stakeholders.

4 The second TPWind Steering Committee meeting took place during the EWEC conference, in Milan, May 2007. See http://www.windplatform.eu/44.0.html.

1.2.4. Steering Committee

The Steering Committee is the decision-making body and executive arm of TPWind. Five Steering Committee members, elected for an 18-month period, form the Executive Committee, which is the primary link between the Steering Committee and the Secretariat.

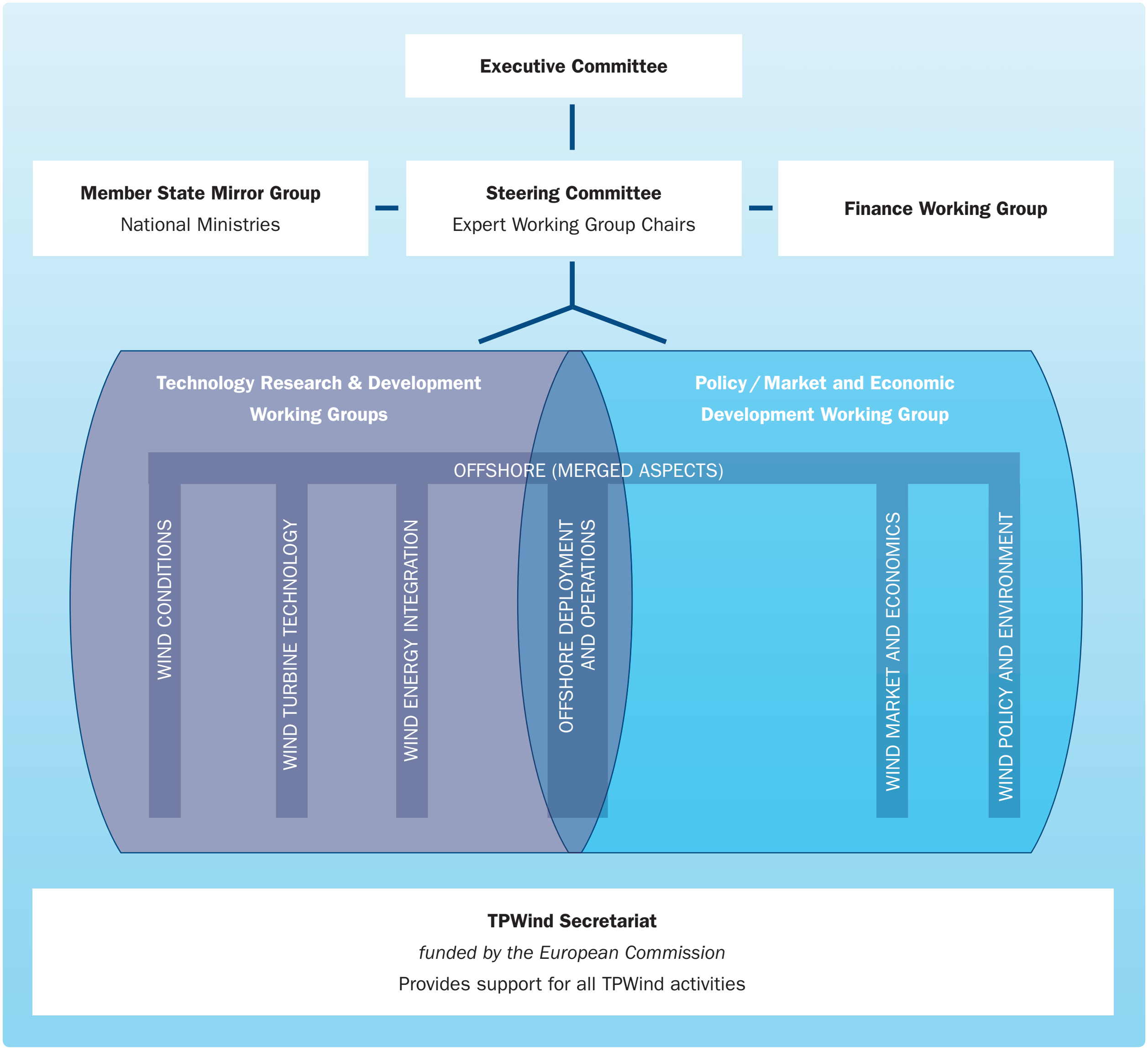
1.2.5. Secretariat

The Secretariat provides logistical, organisational and content-based support for TPWind's activities.

The Secretariat is made up of EWEA, Garrad Hassan and Risø/DTU and is under contract to the European Commission.

This document presents the main body of the Strategic Research Agenda. Additional background information and detailed research actions can be found on TPWind's website: http://www.windplatform.eu.

Figure 1: Structure of TPWind.



2. TPWind 2030 Vision

In 2030, wind energy will be a major global energy source. Markets will be driven by concerns over the impacts of:

- climate change;
- oil and gas depletion;
- the high cost and unpredictable availability of fuel (security of supply); and
- CO_2 allowance prices and sustainability.

The European wind industry will continue to lead the global market. Depending on future electricity demand, some 25% of EU electricity consumption, or a total of 300 GW, will be provided by wind, corresponding to nearly 600 million tonnes of CO_2 savings annually. Offshore wind will represent about 10% of the EU's electricity consumption and wind energy will be highly reliable and cost competitive.

By 2030:

- European power markets will be highly efficient and much better integrated, with full separation in ownership of transmission and production activities
- Wind power will no longer be a subsidised energy source. On the contrary, as a result of its volume and market value, it will reduce the variability of both the price and the cost of electricity
- The European wind sector will be a global centre of excellence, driving innovation and creating large numbers of attractive jobs
- The public will strongly support wind energy developments
- Administrative procedures will no longer present obstacles to wind energy development, as they will be more coordinated and efficient
- Wind power will be optimally integrated into the environment, and informed decisions and planning will ensure that the impact on the local environment is minimised
- On average, 10 to 15 GW of additional capacity must be manufactured, delivered and implemented every year to realise this vision. This is equivalent to more than 20 turbines of around 3 MW being installed per working day.

To ensure that the technology and market for wind energy develop in a highly efficient manner, it will be crucial to mobilise research resources across Europe. This huge challenge will require investment to be coordinated at European and national levels. It will also be necessary to coordinate public research and industry resources.

TPWind expects wind energy to develop in three phases:

PHASE 1: **Short term (2020)** – The market matures in western Europe and develops in central and eastern Europe. Competition from low labour cost countries increases further. Large-scale deployment of offshore wind energy begins. The installed capacity reaches 180 GW, including 40 GW offshore.

PHASE 2: **Medium term (2020-2030)** – Wind energy continues to mature in all its applications, both onshore and offshore. The main developments are further cost reductions and high penetration technology. Deep offshore technology develops on an industrial scale. Exports from Europe grow. The capacity installed reaches 300 GW in 2030, when annual installations reach 20 GW, of which half is offshore and 7.5 GW is re-powering.

PHASE 3: **Long term (2030-2050)** – The main European markets are in offshore and re-powering. Exports from Europe are strong.

TPWind is a key initiative for addressing the huge challenge faced by the European wind industry. The Strategic Research Agenda and Market Deployment Strategy define the priorities, which will ensure the sustainable and long-term development of the sector.

3. Strategic Research Agenda

3.1. Strategic Research Agenda (SRA): structure

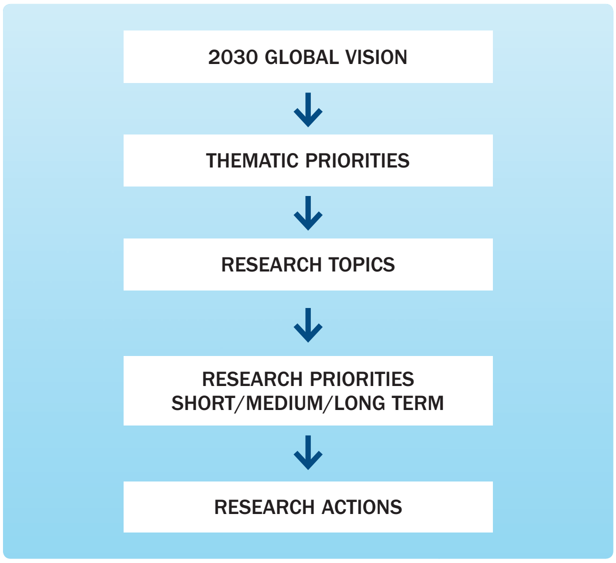
The SRA is divided into five thematic priorities for research, in order to support the implementation of the 2030 vision. These thematic priorities are:

- Wind resources, design wind conditions, and forecasting
- Wind turbine technology
- Wind energy integration
- Offshore deployment and operation
- European research infrastructures

In the following sections, for each thematic priority, a 2030 objective is given. The aim is to meet each objective by carrying out the relevant research and each thematic priority is therefore allocated various research topics. For each topic, short-, medium- and long-term research priorities are defined, and research actions are then established to meet these priorities. This approach is illustrated in the diagram opposite.

The current publication provides the research priorities for each research topic. Details of research actions and additional background information are available online at http://www.windplatform.eu.

Figure 2: Illustration of SRA analysis. Thematic priorities are supported by research topics, which are divided into research priorities and research actions.



3.2. Wind conditions

3.2.1. 2030 objectives

The aim is to develop more efficient methods for determining wind resources and identifying regions rich in poorly-exploited wind resources, in order to enable increased and more cost-effective wind farm assets.

Therefore, TPWind proposes an ambitious long-term '3% vision'. Current techniques must be improved so that given the geographic coordinates of any wind farm (flat terrain, complex terrain or offshore; or in a region covered by extensive data sets or largely unknown), predictions **with an uncertainty of less than 3%** can be made concerning:

- the annual energy production ('resource')[5];
- the wind conditions that will affect the design of the turbine ('design conditions'); and
- a short-term forecasting scheme for power production and wind conditions.

The '3% vision' will have the following impact:

- Technology: improved standards, improved software packages, site-optimised turbines, with the aim of achieving optimal use of the entire EU wind energy resource
- Economy: a reduction of the lifetime cost of energy, due to better site information and reduced project risk

The three main research objectives – resource, design conditions and short-term forecasting – are supported by six supplementary research topics:

- Siting of wind turbines in complex terrain and forested areas
- Wakes in and between wind farms
- Offshore meteorology
- Extreme wind speeds
- Wind profiles at heights greater than 100 m
- Short-term forecasting

5 The year-on-year variation of annual energy production at a given site is much larger than 3% – here 'resource' refers to the long-term average annual production.

Photo: Gamesa

These six research topics require two main tools for investigation and application: remote sensing (for example, lidars, sodars or satellites) and computational fluid dynamics methods (CFD). Ideally, the results of the research should be applied worldwide, by means of an easy-to-use numerical wind atlas for resource and extreme winds.

By 2030, the wind energy industry is expected to make use of fast, accurate, high-resolution and comprehensive wind atlas calculations in a wide range of climatic conditions and settings, including coastal, offshore and highly complex terrain. Most of the world will have been mapped by 2030, and the maps will be verified against measurements obtained from conventional anemometry and remote sensing.

The comprehensive wind atlas calculation includes annual and seasonal/monthly climatological mean and extreme wind statistics, with estimates of variability and uncertainty. The resulting data should be in a form that can be used subsequently in other software, such as GIS.

The available wind statistics will include wind speed distributions and turbulence parameters, which are all necessary for wind turbine specifications and will lead to refined classification schemes. For wind integration studies, statistics should also allow for the creation of realistic wind speed time series for sites.

Uncertainty estimates are based on the accuracy, or lack of accuracy, of past estimates. The measurements are affected by local orography, roughness and roughness change, as well as sheltering. Wind conditions are less well validated in complex terrain, coastal/offshore locations and above the surface layer than in simple, flat terrain. A high degree of collaboration between the wind energy and meteorology communities is a prerequisite for the continual development of wind atlases and improved understanding of wind conditions in these locations.

While the wind atlas work is not classified as a separate research topic, more work needs to be done with the aim of:

- rigorously quantifying uncertainties;
- increasing verification with measurements – remote sensing in particular;
- measuring the applicability of numerical weather prediction instead of re-analysis or similar data; and
- finding the best trade-off between the number of wind classes and the resolution of the data.

3.2.2. Siting in complex or forest terrain

3.2.2.1. Objective

The objective is to be able to accurately calculate (with a deviation of less than 3%) the external wind load acting on a wind turbine and its lifetime energy production anywhere on earth. Current techniques are inadequate, especially in areas of complex terrain, which include complex orography, forests, or a combination of both.

3.2.2.2. Research priorities

The following research priorities have been identified:

- A full-scale measurement campaign (Askervein II[6]) is urgently needed in order to enhance the current knowledge of complex terrains and forested areas

6 The original Askervein Hill project consisted of two field experiments conducted during September and October 1982 and 1983 on Askervein, a nearly Gaussian hill on an island in the Scottish Outer Hebrides. This collaborative study of boundary-layer flow over low hills was carried out under the auspices of the International Energy Agency Programme on Wind Energy Conversion Systems. 50 towers were used for wind measurements. Most of the instruments were 10 m cup anemometers but, in the 1983 study, two 50 m towers, a 30 m tower, a 16 m tower, and thirteen 10 m towers were used for three-component turbulence measurements. Results from this experiment provided data which enabled the development of nearly all current linear flow models for the following 25 years.

- Advanced models for wind resource and turbulence estimation
- New measurement techniques based on remote sensing are needed for high temporal and spatial resolution measurements and heights above 100m
- Standards for wind resource assessment

3.2.2.3. Impact

A field campaign on the scale of the proposed Askervein II experiments is expected to have a long-lasting impact. This was certainly the case with the original Askervein study, whose measurements, dating from the early 1980s, are still used widely today, although with many limitations. The reduced risk resulting from the better tools developed on the basis of new experiments will enable wind energy to become more cost-effective.

3.2.3. Offshore meteorology

3.2.3.1. Objectives

By 2030, offshore wind energy production will cover 10% of EU electricity consumption. Implementation of the TPWind vision requires a massive development of offshore wind power; today, the share of total wind energy capacity associated with offshore wind farms is marginal. Offshore meteorological conditions differ substantially from onshore conditions. However, meteorological knowledge, as well as experience from wind power applications for offshore sites is rather limited. It is important to improve understanding of the meteorological processes that are specific to the atmosphere above the sea, and to develop standardised methods, models and measurement techniques that can be applied to offshore wind power.

TPWind's first priority in the context of offshore wind meteorology is to improve the knowledge and understanding of processes that are specific to, or more important in offshore conditions, such as wind/wave/current interaction, atmospheric stability and the land/sea transition. This improved knowledge will be used to develop new models and to extend existing ones. It will be used to develop methods for:

- determining the external design conditions for offshore wind turbines
- the assessment of the wind resource; and
- short-term forecasting.

Photo: LM Glasfiber

An important bottleneck for model development and verification, as well as for the development of the design basis for offshore wind farms, is the lack of offshore meteorological measurements. The development of measurement methods adapted to the offshore environment is therefore of special importance.

3.2.3.2. Research priorities

The following research priorities have been identified:

- Establishment of a method for determining external design conditions for offshore sites
- Development of standard models for resource assessment and wind potential studies
- Development of dedicated and highly accurate offshore short-term forecasting models using all available information from numerical weather prediction (NWP) models and measurements
- Development of fully integrated wind/wave/current interaction models for wind power applications
- Establishment of basic knowledge about offshore-specific atmospheric effects (for example, land/sea transition, high wind profiles and atmospheric stability)
- Improvement of NWP models and other meteorological models (mesoscale, large-eddy simulation (LES)) for offshore conditions, including new surface layer models
- Development of a rapid, straightforward and relatively low-cost measurement method for offshore wind farm

sites from fixed and floating platforms using remote sensing techniques
- Development of satellite-based remote sensing techniques for wind measurements offshore, promoting services and adapting sensors to the future needs of the wind industry

3.2.3.3. Impact

A profound understanding of the atmospheric conditions offshore is a prerequisite for an optimal use of the offshore wind resource. Such an understanding would facilitate a specific design for offshore wind turbines, potentially reducing the cost of electricity generated by offshore wind farms. Methods for wind potential studies and resource assessment are extremely important for the identification of sites and for the reduction of technical and economic risks and thus for the successful development of offshore wind power.

High accuracy and reliability in forecasting are essential for the integration of large offshore wind farms into the electricity grid, as this makes power generation more predictable. If wind energy is inefficiently integrated into the electricity system, there is a risk that the targets for installed offshore wind energy will not be reached.

Remote sensing measurement techniques, providing precise measurements without masts, will substantially reduce the cost of resource assessment. Such techniques will also improve wind park siting, since additional measurements can be taken at the early stages of development.

3.2.4. Wakes

3.2.4.1. Objectives

The overall objective is to improve the understanding of wakes inside and between wind farms, and to use this improved understanding in the design and financial analysis of offshore wind projects. The specific objectives are to:

- increase the availability of data sets from large wind farms;
- modify or develop models in order to produce results that come closer to the observed power losses from wakes, in both complex terrain and offshore; and
- evaluate the downwind impacts of large wind farms, especially in an offshore environment.

3.2.4.2. Research priorities

The following research priorities have been identified:

- Collection and analysis of measured data that will enable an improved understanding of the physics of wakes, and will help improve the calibration and validation of models
- Development and/or improvement of models to assess and deal with the impact of wakes

3.2.4.3. Impact

If future power losses from wakes are underestimated in wind farms that are currently being developed and built, the impact on overall power output is likely to be in the region of 5-10%. Improving wake prediction is therefore a top priority.

3.2.5. Extreme wind speeds

3.2.5.1. Objectives

The objective is to produce a worldwide extreme wind atlas, including guidelines for the determination of the 50-year extreme wind speed (v_{ref}.) and extreme statistics.

3.2.5.2. Research priorities

The following tasks have been identified:

- The compilation of a global extreme wind database based on the re-analysis of data from different global models (REMO, NCEP/NCAR, ECMW and so on) and use of this database to generate an extreme wind atlas
- Improvement of methods for increasing the spatial resolution of the extreme wind atlas, through the use of CFD models based on an in-depth understanding of the structure of these extremes
- Development of a "measure – correlate – predict" method for on-site determination of v_{ref}, based on re-analysis data and on-site data (typically one to three years' data, which can be compared to the long-term re-analysis data)
- Development of methods for determining an extreme wind atlas in regions with tropical cyclones and hurricanes
- Investigation into the relationship between v_{ref} and three-second gust values, including the coherent structure of the extreme events

- Identification of other sources of extremes and quantification of values in terms of probabilities
- Creation of a classification scheme for extreme high frequency wind changes, and provision of a proper statistical prediction
- Short-term prediction of incoming extreme high frequency wind gusts

3.2.5.3. Impact

The ability to properly predict extreme winds, and the reduction of the statistical uncertainty of extreme values, will substantially increase the economic efficiency of wind farms in many areas of the world. An improved understanding and characterisation of high frequency extreme wind events will improve the estimation of mechanical loading and will enable optimal site-specific wind turbine design.

3.2.6. Wind profiles above 100 m and advanced measurement techniques

3.2.6.1. Objectives

A comprehensive analysis of wind measurements over flat terrain has demonstrated that the wind profile based on traditional surface layer theory and stability scaling is valid up to a height of about 50 to 80 m. Above this level, the measurements of mean wind, shear and turbulence deviate progressively from the theory. The objective is to investigate and model the behaviour of the wind profile beyond the surface layer, i.e. above 100 m, through:

- the formulation of a model for the wind profile in the entire boundary layer; and
- measurements and theoretical tools to specify the parameters characterising the wind profile in the entire boundary layer.

3.2.6.2. Research priorities

The following tasks have been identified:

- Collection and analysis of data to understand and characterise the boundary layer and wind profile dimensioning parameters
- Implementation of CFD (LES and RANS) modelling of the wind profile over simple and complex terrain, and investigation of modelling the effect of the Brunt-Vaisala frequency (vertical temperature profile) and baroclinicity on the wind profile
- Background research and development of international standards for remote sensing techniques to be used in the wind industry

3.2.6.3. Impact

With the increasing size of wind turbines, the industry must investigate and develop new methods of characterising wind and turbulence profiles at heights of over 100m. Cornerstones in the design and calculation of energy yield are software programmes, such as WAsP and WAsP Engineering. It is crucial to ensure that these programmes always use the most advanced designs for wind and turbulence profile modelling of ever-larger wind turbines. Improved tools for modelling wind profiles will lead to more efficient siting, better energy yield and improved structural integrity.

3.2.7. Short-term prediction

3.2.7.1. Objectives

The vision is to have an accurate forecast over a timeframe of one to two weeks. Research is needed both in the field of wind power forecasting and in the general field of meteorological forecasts.

In the future, forecast models will make optimal use of all available information (for example, weather predictions, on-line power and wind measurements, remote sensing measurements). One important step in this direction would be to combine the numerical weather prediction model (NWP) and the wind power forecast model, which are currently separate entities. This means that all relevant information from the NWP model could be used for the wind power forecast; and the information available in the wind power forecast system, such as real-time measurements of power and wind, could be used for weather prediction.

3.2.7.2. Research priorities

The following tasks have been identified:

- Data collection, and the development of new measurement techniques, are needed to:
  - enable very short-term forecasts for system integration and safe grid operation; and

– increase prediction model accuracy regarding average and extreme errors in forecasting.

- Advanced models must be developed in order to:
  – increase prediction model accuracy regarding average and extreme errors, and extreme events;
  – investigate prediction uncertainty, especially in the field of multi-model combined forecasting[7];
  – integrate prediction into the day-to-day management of the power system; and
  – integrate wind power forecasting and wind power measurements from wind farms into numerical weather forecast models.

3.2.7.3. Impact

It is expected that by 2030 wind power forecasting systems will serve different needs with specific models. There will be a distinction between the application of forecasts for market integration of wind power and for grid operation. For grid operation, the relevant information is the wind power feed-in at the grid nodes of the system operator at transmission and distribution level.

7 Please note that a better understanding and modelling of forecast uncertainty will also improve forecast accuracy in the medium to long term.

3.3. Wind power systems

3.3.1. 2030 objectives

The aim of the research prioritised by TPWind in this section is to ensure that by 2030 wind energy is the most cost-effective energy source on the market. This can only be achieved by developing technology that enables the European industry to deliver highly cost-efficient wind turbines.

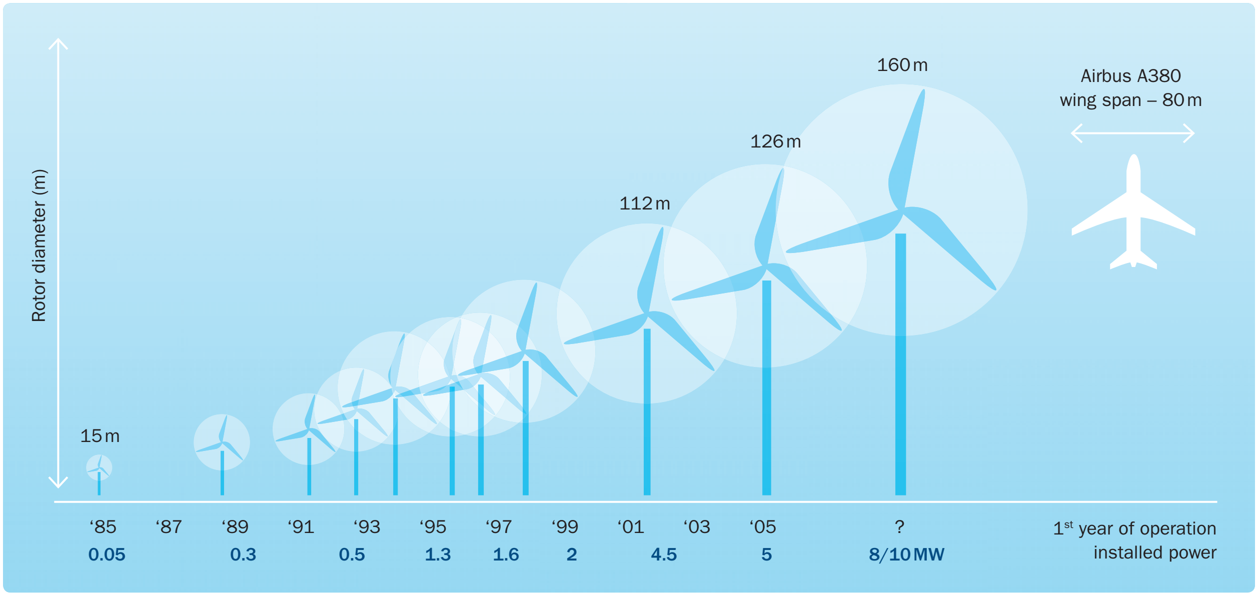
TPWind focuses on aspects of wind turbine technology, both offshore and onshore, which have the potential to increase the competitiveness of wind energy, and to minimise the lifetime cost of electricity generated by wind power systems.

Research priorities should aim to reduce the cost of energy and its uncertainties. All priorities need to be considered in terms of their potential impact on the:

- cost of energy, specifically initial investment, operation and maintenance costs;
- energy efficiency of the entire wind power system; and
- availability in terms of reliability, accessibility and life-time.

Environmental issues such as decommissioning costs should also be considered.

Figure 3: Size evolution of wind turbines over time.



A wind power system is a sophisticated combination of components and sub-systems that have to be designed in an interdisciplinary and integrated manner. In addition, the size and complexity of wind turbines is increasing rapidly over time (See Figure 3).

Research topics are categorised according to the technical disciplines and cross-sector criteria on which the integral design and operation of wind power systems are based. The seven research areas are:

- Wind turbine as a flow device
- Wind turbine as a mechanical structure/materials
- Wind turbine as an electricity plant
- Wind turbine as a control system
- Innovative concepts and integration
- Operation and maintenance
- Standards

Photo: Danny Plug, WindCat Workboats

3.3.2. Wind turbine as a flow device

3.3.2.1. Objectives

With the increasing size and complexity of wind turbines, rotor design models must include physical aspects that were not significant for smaller turbines. In order to design these large rotors, a full understanding of aerodynamic phenomena is required. This must include the external conditions, such as the wind speed distribution on the rotor plane for different wind turbine configurations and sites.

The objective is to enable the development and verification of accurate design and analysis tools that describe all relevant phenomena, and which are efficient and fast enough for design applications.

3.3.2.2. Research priorities

The research priorities are to:

- create advanced (e.g. CFD and aeroelastic) models that take into account the physical phenomena that become particularly important for large and more flexible rotors; and
- carry out experimental verification of advanced models.

3.3.2.3. Impact

The rotor is not only the primary energy conversion component of a wind turbine; it also creates the main dimensioning loads for the rest of the wind turbine structure. As such, results from rotor-related research have an impact on energy production and structural loading, and thus affect the wind power system’s energy costs.

3.3.3. Wind turbine as mechanical structure/materials

3.3.3.1. Objectives

The objective is to improve the structural integrity of the wind turbine through:

- an improved estimation of design loads;
- new materials;
- optimised designs;
- verification of structural strength; and
- reliability of components, such as drive trains, blades and the tower.

3.3.3.2. Research priorities

The research priorities are to:

- improve knowledge of design loads for the components of the wind turbine system;
- investigate and identify the physical characteristics of new materials, including recycling possibilities; and
- further develop design and verification methods for structural strength and reliability of components.

3.3.3.3. Impact

An improved knowledge of design loads, material characteristics and component strength and reliability will enable designers to optimise structure and safety. This knowledge will lead to more structurally efficient wind turbine components and an optimum use of materials, and will have a positive impact on the lifetime cost of energy.

3.3.4. Wind turbine as an electricity plant

3.3.4.1. Objectives

The objectives are to:

- develop better electrical components;
- improve the effect of the wind turbine on grid stability and power quality; and
- minimise the effect of the grid on wind turbine design.

3.3.4.2. Research priorities

The research priorities are:

- Improvement of high-voltage electronics in order to increase efficiency and reduce costs
- Enhancement of power converters to maximise system efficiency, make it easier to control and improve the power quality
- Development of new, light-weight, low-speed and low-maintenance generators, including high-temperature super conductors
- Refinement of wind turbine design standards, taking into account grid code requirements

3.3.4.3. Impact

Improved power electronics, power converters and new generators will have a positive impact on the lifetime cost of energy, and will enhance the grid compatibility of wind turbines.

3.3.5. Wind turbine as a control system

3.3.5.1. Objectives

The objective in the area of control in wind turbines and wind farms is to optimise the balance between performance, loading and lifetime. This will be achieved through advanced control strategies, new control devices, sensors and condition monitoring systems.

3.3.5.2. Research priorities

The research priorities are:

- Optimisation of the electricity output and capacity factor, both for the individual wind turbine and the wind farm
- Reduction of mechanical loads on the wind turbine structure
- Development of control algorithms to ensure the aeroelastic stability of the wind turbine
- Development of new control sensors, such as Lidar, in order to forecast the flow in the rotor plane and the integration of this forecast into control strategies
- Development of integrated control and maintenance strategies incorporating condition monitoring systems

3.3.5.3. Impact

Advanced control strategies will lead to new and improved wind turbine designs, which incorporate an optimum balance between loads and lifetime. This will lead to greater confidence in design reliability over the lifetime.

3.3.6. Innovative concepts and integrated design

3.3.6.1. Objectives

The objective is to achieve a step change reduction in the lifetime cost of energy by researching highly innovative wind turbine concepts. With the support of an integrated design approach, this will be made possible through incremental improvements in technology, together with higher risk strategies involving fundamental conceptual changes in wind turbine design.

3.3.6.2. Research priorities

The research priorities are:

- Development of innovative wind turbines and sub-system concepts, for example, advanced rotor designs for the next generation of wind turbines
- Development of integrated design methods

3.3.6.3. Impact

Integrated design tools will lead to a full systematic design methodology to enable the optimisation of the entire wind turbine system. It also leads to realistic industrial design requirements for the turbine components. This systematic approach, coupled with the development of innovative new, higher risk concepts, have the potential to dramatically reduce the lifetime cost of energy.

3.3.7. Operation and maintenance

3.3.7.1. Objectives

Operation and maintenance (O&M) strategies become more critical with upscaling and the offshore deployment of wind power systems. The objective of this research is to optimise O&M strategies in order to increase availability and system reliability.

3.3.7.2. Research priorities

The research priorities are:

- Failure identification, through investigation into the physical effects of faults in wind turbine components and their development
- Integration of condition monitoring and fault prediction capabilities into the wind turbine's control system
- Development of maintenance strategies involving preventative, risk-based inspection using condition monitoring

3.3.7.3. Impact

The research will lead to improved O&M strategies that will increase confidence in the prediction of O&M costs over the lifetime of the wind project, as well as reducing these costs.

3.3.8. Standards

3.3.8.1. Objectives

The objective is to continue developing standards for wind turbine design in order to allow technology development, whilst retaining confidence in the safety and performance of the technology.

3.3.8.2. Research priorities

The research priorities are to:

- undertake the necessary background research to enable the development of new design standards; and
- integrate experience from operational wind farms to allow the continuous refinement of these standards.

Photo: EWEA

3.3.8.3. Impact

The proposed research will improve confidence in future investment in wind farms, and in their development and operation.

3.4. Wind energy integration

3.4.1. 2030 objectives

The 2030 objectives focus on the large-scale integration of wind power (300 GW), by enabling high penetration levels (>20%) with low integration costs, while maintaining system reliability (security of electricity supply).

The scope considered by TPWind when developing its research priorities extends from single (large) wind farms (onshore and offshore) to the large-scale integration into power systems. The layout and basic structure of the grid as well as the operational practices need to be adapted to large amounts of variable electricity supply.

The objectives are supported by three research topics:

- Wind power plant capabilities
- Grid planning and operation (accelerated/improved extension and reinforcement as well as improved operation of the existing grid)
- Energy and power management

3.4.2. Wind power plant capabilities

3.4.2.1. Issues

One way of enabling a high penetration of wind power is for wind power plants to be operated, as far as possible, like conventional power plants (for example, through limited ramp rates and by providing frequency response).

This approach has significant economic and financial impacts due to the need to follow grid codes and provide ancillary services. These impacts need to be assessed to determine cost-effective ways of ensuring reliability at high wind penetration levels using wind power plant capabilities. It may turn out that frequency control is more economical using conventional plants, but this can only be determined by careful analysis and costing. With high penetration levels, there will be periods when wind power will substitute for large quantities of conventional power, and frequency control has to be provided by wind farms. This requires an objective approach to grid code requirements, which is a good basis for harmonising grid codes at EU level.

The present grid codes are *ad hoc* and Transmission System Operators (TSOs) are concerned that the rapid growth of wind power could lead to a degeneration in system operation (in particular power quality and system reliability), and maybe even to system instability.

Research is required in order to understand the extent to which wind farms should be used to provide ancillary services. Present grid codes stipulate fault ride through capability, in addition to ramp rate control and contributions to voltage control and frequency response. These need to be treated independently, as they relate to quite different aspects of power system operation.

3.4.2.2. Research priorities

The research priorities are:

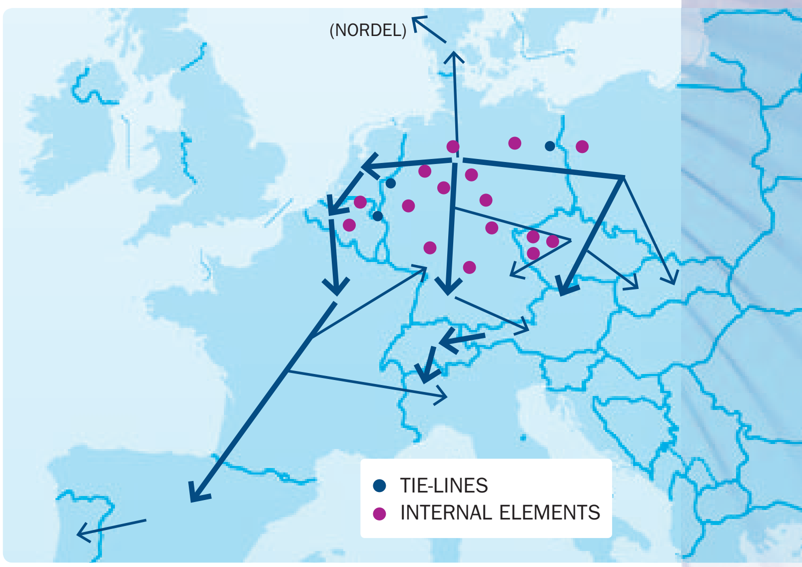
- Grid code requirements for cost-effective and reliable power systems
- Ensuring that higher wind power penetration is compatible with grid code requirements
- Means of verification of specific capabilities (for example, fault ride through) and methods of proving compliance

3.4.3. Grid planning and operation

3.4.3.1. Issues

Today, one of the main barriers to the large-scale deployment of wind technology is limited transmission capacity. Profit-yielding wind spots are often far away from load centres (for example, offshore) and are accessible only if sufficient transmission capacity is affordable.

Figure 4: First phase of European Wind Integration Study – (n-1) bottlenecks in scenario 2008.



To manage a large-scale fluctuating production, the grid infrastructure and interconnections should be extended and reinforced through strong planning and the early identification of bottlenecks at European level. Today's experiences in Germany, for example, show the risks of bottlenecks when new transmission line projects are not accepted. Due to the increase in installed wind power, new transmission lines are unavoidable. Measures such as a higher loading of existing infrastructure, or the curtailment of wind power in-feed could only be applied occasionally.

Figure 4 illustrates identified (n-1) bottlenecks[8] as a result of the first phase of the European Wind Integration Study (EWIS) for scenario 2008. If the grid is not extended, the European targets concerning RES integration will remain unachievable. Hence, a new strategy for increasing public acceptance of ongoing and future grid extension measures is needed.

8 (n-1) bottlenecks: lines potentially congested in case of single failure in the grid system.

In addition to new transmission lines, a more efficient and reliable utilisation of existing infrastructures is required, while maintaining system reliability (security of electricity supply[9]).

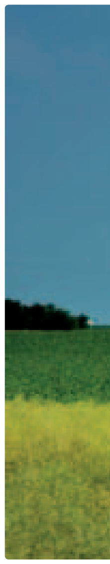
As wind generation has a lower capacity factor than conventional power plants, the existing rules and methodologies for determining transmission capacity should be verified. One solution may be to install transmission capacity that is less than the maximum wind capacity, and manage the infrequent overloads through advanced control of wind farms and wind farm groups.

Another solution might be to ensure that wind power is prioritised over conventional power or controllable RES, such as biogas-fired CHP. This would require the inclusion of political and economic cost-benefit analysis in transmission planning techniques. It should be stressed that putting higher loads on the existing infrastructure and curtailing wind power is only useful in areas where this would occur rarely. For extensive wind power development and situations where curtailment would occur frequently, reinforcement of the grid is usually the only way to achieve long-term targets for wind.

In addition to the extension and reinforcement of the existing transmission grid, further investigation is required into whether an offshore grid could help with the integration of the upcoming large offshore wind farms. Legal frameworks should be developed to advance new offshore trans-national connections, eventually establishing an offshore "super grid". Planning tools should enable a rational step-by-step development, progressing from single branches to a meshed offshore grid structure.

The integration of wind power is partially hampered by a lack of suitable dynamic models for use in transient stability programmes to assess the influence of wind generation on power system operation. Future grid planning and operation will require more coordinated supervision, and a better understanding and improved predictability of the state of the power system. Thus, there is a need for advanced simulation and analysis tools, combined with dynamic calculations concerning the interconnected European power system. Planning tools should be developed to enable the design of an efficient grid structure. The grid should facilitate:

- the connection of offshore wind farms;
- trans-national exchange;
- levelling of demand and supply; and
- improved power system operation efficiency.



Planning tools should also be developed for assessing grid connection of onshore and offshore wind farms. Various connection options should be assessed, including anything from connection capacity (which should balance the cost of connection versus the probability of load or generation case) to the choice of connection technology (HVAC, LCC HVDC or VSC HVDC).

In this context, wind power will be managed as an integral part of European grid operation. In this regard, TSO collaboration and coordination – the interoperability of the control centres – should be improved.

Operational tools and techniques that take wind characteristics into account should be provided, including IT and data acquisition for online operational data, production prediction and generic wind farm and wind turbine interaction models.

3.4.3.2. Research priorities

The research priorities are:

- Research issues pertaining to the acceleration of the sustainable extension and reinforcement of the European grid, to achieve transmission adequacy with high penetration of wind power
- Improved operation and interoperability (for example, the development of operational tools for data acquisition)
- Models/simulation tools for investigation into the transient stability of the European grid
- Transmission studies for offshore wind power (for example, new transmission concepts)
- New power system architecture (for example, cell concept for agent-based systems)

3.4.4. Energy and power management

3.4.4.1. Issues

Wind power variability and forecast errors will impact the power system's short-term reserves. At higher wind power

9 According to Article 4 of the EC Directive 2005/89 (18 January 2006) concerning **measures to safeguard security of electricity supply and infrastructure investment**, the TSOs should maintain an appropriate level of technical transmission reserve capacity for operational network security.

Photo: EWEA, Martin Herve

penetration levels, all sources of power system flexibility should be used and new flexibility and reserves sought. As the firm capacity value of wind power in the grid is considerably lower than the value of conventional capacity, this must be taken into account when establishing the long-term reserves. Nowadays, the margin between installed generation capacity and peak load (long-term reserve capacity) is at a historic low. In Europe, 365 GW of electricity-generating capacity will be retired in Europe and an additional 400 GW will need to be installed by 2030 to satisfy the growing power demands.

The potential for improving flexibility in the existing generation capacity has not been fully explored and estimates are often very conservative. So, existing flexibility in power systems should be explored and quantified to make use of all possibilities. Furthermore, additional possibilities for flexibility must be explored, both by generation and demand-side management, together with the development of storage in anticipation of future high levels of wind penetration.

On the production side, the possibilities of increasing the use of flexibility in existing power plants, as well as new flexibility in new generating capacity should be explored. Virtual power plants – pooling large wind farms with other RES and storage devices (including electric cars and demand-side management) – will further improve flexibility and support load, since capacities previously unavailable for power balancing will be exploited. For wind energy, wind and power production predictions and the corresponding uncertainties should be available to TSOs in real time, to enable smart management of the grid. As a consequence, prediction tools should be provided in various timeframes and on various spatial scales (local, regional, national and European). For systems operation, prediction tools should be improved, especially for extreme cases (storm fronts). The challenging situations where high wind power infeed at low loads has caused curtailment of wind power will increase with higher wind power penetration levels. Operating the power system with good real-time and day-ahead information on wind power infeed, along with the possibilities of flexibility offered by other sources of power generation and demand will lessen or overcome this problem.

For demand-side management, there is considerable potential for increased power system flexibility. A new European market for electrical vehicles could address major problems with fluctuating power production by loading during the night and using flexible arrangements for loading during the day. Moreover, this market could contribute power production to the grid (storage solution). In countries with a large share of district heating, this network is suitable for the conversion of wind power to heat through heat pumps and electric boilers. This can also be used for the heating of single family houses using electric heat pumps.

In addition, storage options should be operated at European level, rather than providing dedicated local wind power flexibility. Flexibility to manage the power system needs to take into account the net variability from load and generation variations and the extent to which wind power variations can be smoothed out in a pan-Euro-

Photo: EWEA

pean context. The required capacity, economic value, and operational system management needs to be addressed. Different technologies should be considered, and the best option would depend on the selected grid management strategy, and the system cost and efficiency. In this regard, possible options might be large hydro power (reservoirs, pumped hydro), heat storage (heat pumps, electrical boilers), plug-in vehicles or other technologies.

The future EU grid management strategy will obviously differ from the one that currently exists. In the context of variable production, variable demand and variable storage capacity, probabilistic decision methods should be promoted. Also, a more centrally-planned management strategy would mean that available grid capacities could be used more effectively and reinforcements could be planned more efficiently.

The emphasis should be on developing good market solutions for the efficient operation of a power system with large amounts of renewable generation. The market should ensure the use of existing system flexibility, for example, existing hydro with storage. Market solutions should promote the development of stronger transmission systems and enhanced exchange, in order to enable system-wide load and generation levelling and the utilisation of reserves.

3.4.4.2. Research priorities

The research priorities are:

- development of improved system and portfolio management tools;
- assessment and demonstration of benefits and costs of several options for providing ancillary services and power balancing for higher wind penetrations;
- assessment of the impact of high wind penetration on power system operations;
- assessment of the impact of high wind penetration on generation capacity;
- development of scenarios for a system with 100% renewables: interaction of wind/solar/wave/hydro/biomass, electricity and fuels.

3.4.5. Impact

The direct impacts of research in this field are:

- increased power system reliability for high levels of wind penetration;
- increased power system efficiency; and
- improved value of wind power.

The current balancing costs – the increased use of regulating/balancing power due to wind power - are estimated to be in the range of €1-8/MWh. It is assumed that research activities can lead to cost reductions in the range of €0.1-1/MWh. The estimated cost reduction potential will thus become €0.5 – 5 billion by 2020. However, the effects of the thematic priorities are more important than cost reductions, because they will create the conditions that will allow TPWind's 2030 objectives to be met.

3.5. Offshore deployment and operations

3.5.1. Introduction

Following the declaration of the European Policy Workshop on Offshore Wind Power Deployment (Berlin, 2007), TPWind was asked to:

- develop a roadmap for the large-scale deployment of offshore wind energy;
- identify key hurdles to the successful deployment of offshore wind energy; and
- identify and prioritise the critical areas for research.

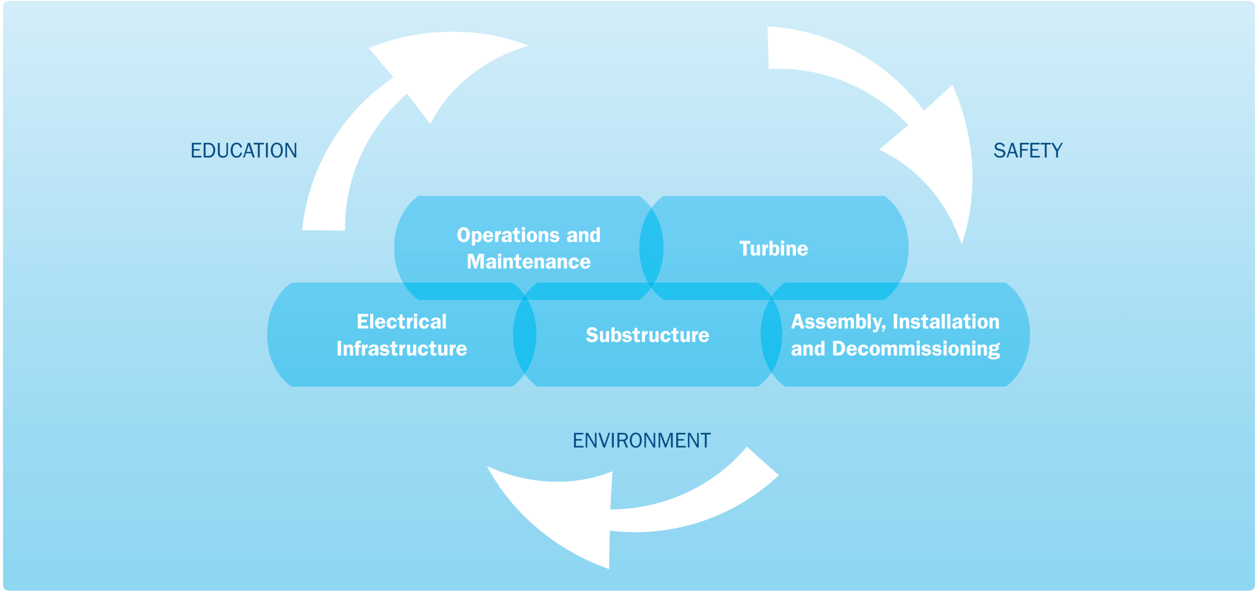


Figure 5: Illustration of common themes and key priorities.

The focus of the offshore section is restricted to issues specific to the development of the offshore wind industry. The other sections of this document address issues common to the onshore and offshore deployment of wind turbines.

3.5.2. 2030 objectives

The objective of offshore wind research is to enable the delivery of:

- more than 10% of Europe's electricity demand from offshore wind;
- offshore generating costs that are competitive with other sources of power generation;
- commercially mature technology for sites at any distance from shore with a water depth of up to 50 m; and
- technology that has been proven through full-scale demonstration for sites in deeper water.

Five research topics have been prioritised:

- Sub-structures
- Assembly, installation and decommissioning
- Electrical infrastructure
- Turbines
- Operations and maintenance

In addition to the five research topics, there are three common themes that underpin each of these topics, which are critical to delivering an offshore wind industry in Europe that is a world leader. These are **safety, environment and education**, and they are illustrated in Figure 5.

Within each area, there are short- to medium-term research actions, which must be addressed to allow the rapid deployment of offshore wind along the European coastline. Over the medium to long term, significant research is required to deliver the necessary technical and performance improvements, as well as cost reductions.

3.5.3. Common themes

There are three common themes which affect the entire offshore priority area. These are safety, environment and education. Everything we do must be undertaken safely, with no harm to people, equipment or the environment. Safety and environment are paramount in all of our activities and all of the work undertaken in each priority area must pay due regard to these issues.

3.5.3.1. Safety

Safe operation of offshore facilities, and the safety of the staff involved in the installation, hook-up, commissioning, and operations and maintenance of these facilities are vital. Research in this area will include the examination and review of turbine access systems, and escape and casualty rescue. Access to the turbine depends on a number of criteria including location, weather conditions and the specific demands of the machines and individual operators.

3.5.3.2. Education

Education is critical for delivering safety. Well-trained, well-educated people will be equipped with the skills and knowledge to carry out their roles safely, to ensure that there is no damage to people or the environment. However, education has far broader objectives: it must deliver trained people with the necessary skills to develop the industry. These will range from skilled workers needed to manufacture, build and operate the facilities to graduates that understand the technical, commercial and social context of the industry. These graduates will also be equipped to provide the technology, drive and direction needed to maintain European leadership in offshore wind.

3.5.3.3. Environment

The environment is a very broad theme, but there are two main issues. Firstly, there is the natural environment of the land and sea in which we must develop wind resources. This will lead to the construction of substantial infrastructure in the seas around Europe, which must be done responsibly with no adverse ecological impacts. This will require the development of better-informed policies, leading to improved planning and regulation, which will safeguard the natural environment, while promoting efficient development. Secondly, there is the physical environment that dictates the conditions for which the machines are designed and built, and in which they will operate. This includes collecting and understanding all the climatic, meteorological, oceanic and geotechnical data.

Better knowledge of the physical environment, coupled with improved data, will significantly reduce development risks and financial uncertainty. An understanding of meteorological and oceanic data will improve resource quantification and assessment of the physical environment to which the turbines and structures will be exposed during their lifetime. It will also clarify the conditions that could be encountered during installation. Better geotechnical data, including improved techniques for the assessment of soil parameters and their variation across the development site, will minimise foundation and installation risks, as well as improving the assessment of the load-bearing capacity of the seabed.

Figure 6: Building the DOWNVInD Jacket. Photo: REpower

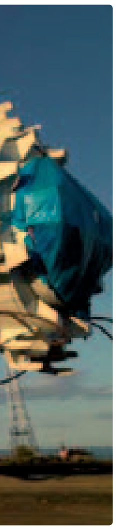
3.5.4. Sub-structures

Sub-structures represent a significant proportion of offshore development costs. Thus, novel sub-structure designs and/or improved manufacturing processes that reduce costs will be critical to improving the economics of offshore developments. Figure 6 shows the first jacket sub-structures deployed in the wind industry. These were developed as part of the European FP6 DOWNVInD programme.

The offshore structures developed to date use 2–3 MW turbines in water depths of up to 20 m, and most of those to be developed in the near future will do the same. These will be largely based on monopile technology. However, as turbine size increases and the industry migrates into deeper waters outside territorial seas, alternative sub-structure designs will be required. These are likely be fixed structures with three or four legs (tripods/quadropods) or gravity structures.

In the longer term, floating designs suitable for deployment in much deeper waters will be required. By 2030, the concepts must be identified, fully engineered and demonstrated.

Efficient, easy to manufacture sub-structure design is essential for a vibrant offshore wind sector. However, to reduce the unit cost of sub-structures, new and improved materials and manufacturing technologies are required for welding, casting and concreting. These must be coupled with more efficient manufacturing processes and procedures, making use of automation and robotics, for example.



In the near term, the major deployment issue is the development of the production facilities and equipment for manufacturing the sub-structures in the necessary quantities, on schedule and to the required standards, at an acceptable price. This will require significant investment in new manufacturing yards and in the associated supply chain. It will also mean the deployment of new and improved manufacturing processes, procedures and equipment to increase production efficiency and reduce costs.

The industry needs to acquire data on the behaviour of existing structures. This information will support research into the development of improved design tools and techniques and better design standards. These will be used to:

- extend the lifetime of structures;
- reduce costs; and
- develop risk-based life-cycle approaches for future designs.

3.5.5. Assembly, installation, and decommissioning

There are two major challenges in the assembly and installation of large-scale offshore wind farms. The first challenge is the transfer of equipment from suppliers across Europe to wind farm sites. This will involve the transportation and assembly of the major components (turbines, towers, blades, substructures and piles), as well as installation equipment. This is a complex and repetitive logistical process, which will require efficient transport links, large drop-off areas and good harbours.

The second challenge is installing the turbines in a hostile offshore environment. Again, this is a repetitive process, which needs to be performed in several stages, each of which will require specially designed vessels and equipment. Experience in other industries has shown that significant cost reductions can be attained by reducing the amount of work done offshore, improving the efficiency with which the work is carried out and transferring activities onshore. Figure 7 shows the assembly and installation of turbines in the European FP6 DOWNVInD programme.

To achieve the large-scale deployment of offshore wind turbines necessary for meeting the European targets, substantial investment in new vessels and installation equipment will be required. During the recent European offshore wind energy conference (Berlin, December 2007), it was suggested that at least three vessels would be needed to achieve the 2010 targets, rising to 12 by 2012.

Photo: REpower

Figure 7: Assembly and installation of the DOWNVInD Turbines.

The installation industry will need to develop safe, efficient, reliable processes that are easy to replicate. In turn these will reduce costs, minimise risks, guarantee standards and deliver investor confidence. In order to achieve these goals, the industry will require a variety of vessels and installation equipment to cope with the range of turbines, sub-structures and environmental conditions that will be encountered. As noted above, mobilisation and assembly will require good harbours with suitable drop-off areas; these are a scarce resource in many of the areas designated for offshore development. Substantial investment will be required to develop suitable facilities.

In the short term, research programmes will focus on optimising existing assembly and installation methods. In the longer term, they will focus on the development of new installation concepts, integrating ease of installation into sub-structure and turbine design through a life-cycle approach, covering the complete process from installation to decommissioning.

Finally, research will be required to develop techniques for the dismantling of offshore wind farms and to quantify the cost of doing so. This will ensure that, where possible, dismantling costs are incorporated into the wind farm design.

Photo: DOWNVInD

Figure 8: Installation and pull-in of cables at the DOWNVInD Turbines.

Photo: DOWNVInD

Figure 9: Manufacture of the DOWNVInD Prototype 5 MW turbines by REpower.

3.5.6. Electrical infrastructure

The electrical infrastructure consists of all of the equipment and cables connecting the offshore wind farm to the grid: the onshore connection facilities, export cables, transformer stations and infield cables, and turbine transformers and switchgear. Figure 8 shows the cable lay in and pulling in of the cables in the European FP6 DOWNVInD programme.

The manufacturing and installation of the cables represent a significant cost in offshore developments and have proved to be high-risk areas during installation and operations. Better infield cabling design, improved cabling technologies and installation processes could result in significant cost reductions and improvements in operational reliability. In the longer term, pre-installation of the cable on the sub-structures, combined with connector technologies (wet or dry) could speed up the installation process and reduce costs, diminishing the need for offshore terminals and access to the structure during installation.

There are two major electrical infrastructure issues that may make it more difficult for Europe to meet its offshore wind targets. These are the integration of the offshore wind capacity into the grid system, and the manufacturing and installation of the equipment and cables.

The integration of offshore wind into the grid represents a major challenge. The current grid infrastructure will not allow the full potential of offshore wind to be realised. This potential can only be realised through the construction of interconnected offshore grid systems and regulatory regimes that are better able to manage the intermittency and flexibility of wind power generation.

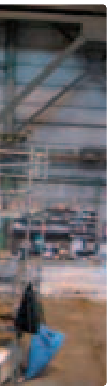
The scale of development envisaged will require significant investment in manufacturing facilities to produce the cables and equipment required, and in vessels to install the equipment.

Research programmes will concentrate on the development of improved design tools and life-cycle approaches to reduce costs, increase reliability and extend the lifetime of facilities.

3.5.7. Turbines

The economics of offshore wind favour larger machines, which differ from those used onshore. The offshore environment may allow the relaxation of a number of constraints on turbine design, such as aesthetics and noise level. However, addressing marine conditions, corrosion and reliability issues creates new challenges in the offshore sector. This will lead to a significant modification of onshore machines in the near term and the development of specific offshore designs in the medium and long term. Figure 9 shows the assembly of the first REpower 5M for the European FP6 DOWNVInD programme.

The key factors affecting the deployment of offshore wind are the current shortage of turbines, and their reliability. The shortage in turbines can be overcome by investment in new facilities to manufacture the components and assemble the turbines, as well as the training of an appropriately skilled workforce. The reliability of the equipment can be improved through better design and component quality, operating experience (and the effective sharing of this experience). The sharing of experience in a competitive commercial market is not easy and mechanisms to achieve this must be explored and implemented. Finally, onshore



and offshore test facilities must be developed to ensure turbines are properly tested before being commercial deployed offshore.

The key focal points for research will be turbine design and simulation, understanding the external climate, wake effects and opportunities to increase reliability and reduce costs. Better tools for turbine design and improved simulation techniques should lead to larger turbines and improved reliability. Combined with an understanding of wake effects, these technologies should allow array layout to be optimised, and energy losses and machine wear and tear to be minimised.

3.5.8. Operations and maintenance

Operations and maintenance (O&M) strategies, which maximise the energy yield from turbines while minimising O&M costs, are essential for the commercialisation of offshore wind. These strategies must address the complex logistics of offshore wind farms through the use of advanced condition and risk-based maintenance philosophies and non-intrusive maintenance techniques. In addition, better management systems, which monitor and control the turbines, and assist with the scheduling and implementation of offshore work programmes, will be required.

Effective access systems will be essential for the operation of the offshore facilities and the safety of personnel involved in the installation, hook-up, commissioning and O&M of the turbines. These systems must be capable of transferring people and equipment safely to the turbine. They must provide a suitable means of escape and casualty rescue and be robust in northern European weather conditions.

A variety of access solutions will be needed. These will range from helicopters, through an array of different-sized boats, to jack-ups capable of lifting the heaviest components into and out of the nacelle. This will require the development of specialist vessels that can replace and repair major equipment, such as gearboxes and blades. Figure 10 shows two of the systems access systems developed: the access catamaran developed by Windcat Workboats and the Ampelmann system by TU Delft.

In the short term, research programmes should focus on the development of condition and risk-based maintenance systems, designed to improve operational ef-

Photo: Windcat

Photo: Ampelmann

Figure 10: Two new access systems, Windcat Workboat (top), and Ampelmann (bottom).

ficiency and reduce costs. They should also address the challenge of access, developing and testing novel systems and vessels to deliver a variety of access options, providing operators with a choice of systems with a range of operating parameters.

In the longer term, the major research areas should be in the development of systems to reduce human intervention. This can be achieved by designing turbines with remote functionality and redundancy. It will involve reducing scheduled maintenance efforts by more integrated bearing lubrication and monitoring systems, reducing the need for scheduled local checks.

However, there will always be a need for maintenance, so the key components should be designed to be replaced with minimal dismantling and minimal use of external lifting equipment. This may involve the installation of lifting points, cranes, hoists and winches to ensure that components in all areas (including the hub) can be removed.

One of the key challenges will be to balance the cost of investment in components with high reliability and low O&M costs, with those of cheaper components with higher expected O&M costs over the wind turbine's lifetime. This can be addressed by the use of a full life-cycle approach to turbine design, which increases system efficiency and reduces costs.

Photo: LM Glasfiber

3.5.9. Impact

The implementation and delivery of the market deployment actions are critical to achieving the European targets for offshore wind. Improvements to the education system and the development of consistent safety standards will create a pan-European workforce that is ready and able to develop the offshore wind industry. The resolution of the conflicts between Europe's environmental objectives and its renewable energy aspirations will provide a host of potential projects. This will provide developers and contractors with the confidence to invest in offshore wind and to provide the infrastructure, technology and equipment needed to further develop the industry.

The onshore wind industry has delivered substantial, year-on-year cost savings as the technology has developed. The offshore wind industry can mirror this if the actions listed above are implemented. The power of compound interest means that real reductions of only 1% or 2% per annum could result in cost savings of 25% to 50% by 2030.

3.6. Research infrastructure

The EU FP7 *Capacities* programme addresses research infrastructure. TPWind has therefore investigated the infrastructure priorities needed to support the thematic priorities. These priorities are summarised below.

3.6.1. Wind conditions

Implementation of the 2030 vision for wind conditions requires extensive measurement campaigns. There is, therefore, a proposal to set up an *Askervein II* experiment to enhance the current knowledge of the wind flow in **complex terrains, forested areas and offshore/near-shore environments**.

Several large-scale measurement campaigns are proposed, based on high-quality measurements of wind speed, direction and turbulence at various heights and positions. The measurement system should include measurement instruments on 50 masts as well as lidars, sodars, ceilometers and scintillometers, in order to monitor the spatial and temporal evolution of the wind field at high resolution, from 30 m above ground level.

3.6.2. **Wind power systems**

As wind turbines are large structures, most of the research infrastructure is correspondingly large and costly. This applies particularly to wind tunnels, blade fatigue testing facilities, drive train testing, wind turbine test stations and facilities for evaluating wind farm control.

Joint efforts are required to establish such facilities and to make them accessible to both the international research community and wind turbine and component manufacturers. In addition to using these facilities for research, there is also a need for the operational verification and demonstration of new high-risk concepts. Moreover, the full-scale, comparative testing of wind turbines under extreme climate conditions provides confidence to financiers that are planning to invest in the sector. This need could be met by a jointly-operated test site at a location where the climate is extreme.

The priorities are:

- New dedicated wind tunnels for wind energy, and keeping existing wind tunnels operational and accessible for wind energy research
- New blade test facilities
- Drive train test facilities
- Other component test facilities for extreme environmental loading
- Test fields for specific conditions (e.g. high wind, turbulent and extreme test conditions)

3.6.3. **Wind energy integration**

Facilities are needed for testing the grid compliance of wind turbines and wind farms. These facilities can be mobile or at specific locations, and will be used to undertake research into the following fields:

- Grid code requirements for cost-effective and reliable power systems
- Active and reactive power control
- Fault ride through
- Monitoring of voltage dips

3.6.4. **Offshore deployment and operations**

Extensive European R&D infrastructure has been developed for renewable technologies and oil and gas. This will provide an excellent base for the development of the R&D skills needed to promote offshore wind. However, the offshore attributes of the oil and gas sector must be combined with the renewable attributes of the wind sector, and the overall capability expanded to meet the needs of a growing industry. Together, these sectors will be able to address the common themes of safety, environment and education. By combining and augmenting their skills and knowledge, the sectors will be able to address the offshore priorities of sub-structure, assembly installation and decommissioning, electrical infrastructure, the turbine itself and O&M.

The effective sharing of data and knowledge between projects will be critical to the deployment of offshore wind. In particular, the careful acquisition and sharing of environmental data could define best practice and accelerate the consenting process, while the acquisition of structural performance and climate data (meteorological/oceanic) would improve the design of the sub-structures and the installation and operation of offshore wind farms.

TPWind recommends selecting and supporting ten different offshore monitoring programmes across Europe.

These monitoring programmes would run alongside commercial developments. They would gather data during the installation and operational phases of a project, in order to quantify the environmental impact of the developments. The location for these programmes will be selected to reflect the variations in ecology, structural design and development techniques that will be encountered by the industry in the coming decade.

4. Market Deployment Strategy

In order to implement the TPWind 2030 vision and enable the large-scale deployment of wind energy, the support of a stable and well-defined market and political and regulatory framework is needed. The implementation of the TPWind vision is supported by six thematic priorities:

- Enabling market deployment
- Reducing costs
- Adapting policies
- Optimising administrative procedures
- Integrating wind into the natural environment
- Ensuring public support

For each thematic priority, policy recommendations and/or study recommendations are provided.

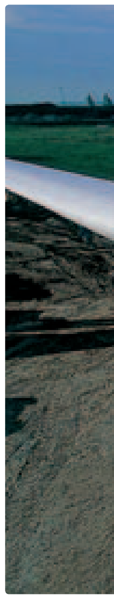
4.1. Enabling market deployment

4.1.1. Removing electricity market barriers

International and local electricity marketplaces should be implemented to promote the participation of wind as well as demand-side management and flexibility. Fair market rules should enable small producers to participate.

Electricity market regulation should be adapted to provide suitable gate closure times. These markets are currently designed with long gate closure times and high penalties for imbalances. Operating day-ahead electricity markets means high prediction errors and imbalances for wind power producers, especially for individual producers. Imbalance payments with penalties can result in individual producers paying far higher imbalance payments than they would if charges were based on the actual levels of imbalance in the system as a whole.

Sophisticated trading structures for wind power have not yet been fully developed in the electricity market. Pricing efficiency could be improved through enhanced wind forecasting tools. Forecasting methods are key to enhancing the value of wind; however, these methods are still being developed and are tied to improvements in wind data collection. Up until now, forecasting tools have been developed to meet grid operating requirements and for trading benefits. A distinction should be made between the application of forecasts for the market integration of wind power and grid operation.



Local and international electricity markets must be integrated (see the regional initiative of the European Regulators Group for Electricity and Gas – ERGEG[10]). Electricity markets must guarantee access to buyers/sellers all over Europe. This is essential if consumers are to benefit from the spatial smoothing effect of wind generation and will probably reduce any risks that wind power may introduce to power trading.

Wind power should be further developed as an adapted market commodity, which is tradable, exchangeable and transparent like other forms of energy. IT tools, legal framework, costs and market designs should enable market access to electricity from small (wind power) producers.

Wind power will reduce the average electricity market price, since on windy days more expensive generation is offset by wind power. This will, however, result in more volatile and unpredictable market prices in the short term. Market assumptions and improved forecasting methods for future price estimates are needed so that producers can ensure that their investments will pay off and that their portfolios match the needs of the system (long lead times for investments).

Open questions remain regarding the impact of a large penetration of wind energy on the current electricity markets, and balancing issues on the future European electricity market. The impact of wind on electricity market prices, such as price fluctuations and different average price levels in day-ahead and real-time markets should still be assessed, since these can affect conventional generation technology investments.

The research priorities are to:

- develop electricity market rules and international and local markets to accommodate wind power;
- analyse the potential for complementary trading mechanisms (such as derivatives) for wind power;

10 ERGEG Electricity Focus Group (EFG) is available at: http://www.ceer- eu.org/portal/page/portal/ERGEG_HOME/ERGEG

Photo: LM Glasfiber

- understand the electricity market requirements for forecasts and develop corresponding forecasting methods (analysis of trading and balancing should be carried out to assist in forecasting developments); and
- investigate access to the electricity market for newcomers and new services.

4.1.2. Securing revenues

A stable market, in combination with clear wind power objectives and a stable and centrally-coordinated incentive scheme, is essential for power producers wishing to make long-term investment decisions.

Markets should make use of all possible power system flexibility to keep imbalance costs low. This includes markets for ancillary services, which encourages participation from the demand side. Bringing virtual power plants to the market may demonstrate more predictable and controllable demand/generation profiles, especially when not limited to a community, region, country or distribution system.

The research priority is to optimise the potential for revenue benefit from wind farm ancillary services (e.g. voltage control and reactive power management).

4.1.3. Creating a level playing field

Fair and efficient economic regulation is crucial for the wind industry. In this respect, wind power's environmental credentials, contribution to energy independence and industrial development should be taken into account. In line with EU legislation, this would lead to recognition at EU and national level that wind energy is clearly a technology that helps sustainable development and which deserves to be categorised as a public interest investment.

In the current energy pricing system, wind energy is at a disadvantage compared to competing conventional technologies, as a large part of its value is not taken into account by existing electricity markets. The true cost of CO_2 emissions, as well as environmental damage caused by the extraction and use of fossil resources (known as 'externalities'), are not reflected in energy prices. The wind industry is therefore looking for a level playing field where such externalities are internalised. If this were the case, wind energy would already be competitive[11]. The industry also believes that on a long-term basis, the price of electricity from wind will be more stable than the price of electricity produced from conventional sources.

The competitiveness of wind compared to traditional energy sources is very much influenced by fuel prices. Significant increases in the price of fossil fuels and uranium used for nuclear power generation are predicted in the years to come, due to growing demand for the remaining resources. The prices of oil and gas have tripled since 2001. Experts from Goldman-Sachs see a medium-term oil price of well above $70/barrel[12], although current oil prices are significantly higher than this figure.

Wind energy, however, is largely independent of fuel prices (except for the fuel used in the manufacture of the turbines themselves) and has very low external costs. Being largely independent of fuels, wind energy reduces dependency on imported fuels, which helps to secure the European energy supply. Unlike fossil fuel production, wind does not depend on unstable regions for fuel supply, and this also brings cost reductions, as security risks such as political and military conflicts, are avoided.

11 One of the studies is made by Emerging Energy Research: http://vestas.com/en/modern-energy/political-initiatives/reports/eer-analysis.aspx.

12 Dow Jones market Watch 7th March 2008: http://www.marketwatch.com/news/story/goldman-sachs-raises-possibility-200/story.aspx?guid=%7B4B702F7F-41F8-45F0-A133-630F12F2C764%7D

As use of wind energy technology increases, its cost will decrease further due to economies of scale. Coupled with the rise in oil prices, this will result in wind being a competitive alternative to conventional resources.

The policy priorities are to:

- internalise the external costs of energy generation in energy pricing; and
- recognise wind energy as a public interest investment.

Photo: Vestas

Priority studies are to:

- undertake market modelling to investigate the virtual power plant concept in the market environment and evaluate the impact of wind on market prices; and
- analyse how different electricity market structures will affect wind energy sales in the market and optimise revenues. In this regard, it is necessary to have an overview of the future market environment. Trends in the costs of conventional electricity (fossil and nuclear) should be determined in order to compare the different pricing support schemes. In these cost calculations, externalities should be included (for example, CO_2 emission costs in future carbon markets and radioactive waste management), as well as direct and indirect subsidies;
- analyse the application/implementation of the "polluter pays" principle in electricity generation (for example, identify which methodologies can be used to internalise the environmental and social damage created by electricity generation and consumption); and
- evaluate a way to establish a level playing field for all energy technologies.

4.1.4. Adapting the grid infrastructure

The objective is to make wind as manageable and as cost-efficient as possible for network operators. One approach to enabling a high penetration of wind power is for wind power plants to be operated, as far as possible, like conventional power plants.

One of the main barriers to the large-scale deployment of wind energy is a lack of grid capacity across Europe. The grid networks are not adapted to the distributed nature of wind energy (or that of other renewables) and the current lack of investments prevents modernisation from taking place at the necessary pace.

The best wind farm locations are often far away from electricity system load centres and there is a geographical variation in the wind resource. This creates specific challenges in balancing the supply and demand of energy at European level. To meet this challenge, it is necessary to develop an electricity grid system that is well-integrated and strongly interconnected, to implement common market policies and align existing markets, and to develop large-scale energy storage solutions.

Considerable diversity in European grid codes creates unnecessary obstacles and costs for developers, manufacturers and grid operators.

The policy priorities are to ensure:

- policy support for long-term strategic planning on grid infrastructure investment for national grids and interconnections;
- political support for long-term coordination on grid development at European level;
- political support and ambition for an inter-continental grid connection;
- policy development and the application of best practice balancing, forecasting, market rules and allocation methods to optimise the power market operation with respect to wind energy integration; and
- that a European energy regulator is established, and sustainability is included as an important priority in the remit of the regulator at the European and Member State level.

Priority studies are to:

- develop a European road map for strategic development of the grid structure in the short term, taking large-scale wind energy integration into account;
- study technical solutions to improve wind energy penetration in the grid (for example, storage, interconnections and grid management strategies);
- develop location scenarios and an optimum approach to large-scale offshore grid connections for offshore wind; and
- analyse the effect of high penetration levels of wind energy on power systems and investigate the consequences in terms of costs and benefits.

4.1.5. Removing policy and administrative barriers to grid development

Key barriers to a well-integrated electricity grid system are identified as:

- A lack of strategic planning and coordination on grid development at European level
- An apparent lack of political will and ambition to develop a grid that meets the needs of the renewable energy sector
- The lengthy consenting process for large-scale grid development, especially in the case of international grid developments, and particularly with respect to offshore grids

At present, the development of grid systems is not strategically planned or coordinated at European level. Some Member States do not have a strategic plan for developing their national grid system and the current Trans-European Network activities are not ambitious enough and are inadequately coordinated.

Securing a reliable energy supply in a system that is being fed by a large amount of wind energy requires long-term coordination in grid and infrastructure planning across Europe. The major potential contribution of wind energy to future energy supply justifies a short–term, ambitious political initiative to enable the appropriate grid development.

The lack of political action on strategic grid development that supports wind energy may be partly due to the fact that sustainable development is not within the remit of grid operators and regulators. As a result, the grid upgrades required to facilitate a rapid increase in wind energy capacity have not been prioritised. Changing this situation will require modifications to the remit of grid operators and regulators, as well as policy changes that specifically focus on meeting the needs of wind development.

The lengthy permission process for grid extensions is holding back the large-scale development of the grid that is needed for large-scale wind energy penetration. This lengthy permission process is partly due to a long consultation process. While public consultation is supported by the wind industry in principle, and indeed is central to the European legal system, it is necessary to undertake a realistic review of the benefits of consultation as it is currently being carried out, and the impact of this on the timescale of the permission process. This review should consider a serious streamlining of public consultations on prioritised grid developments.

Priority studies are to:

- assess and evaluate the technological and economic feasibility of strategies for creating a European-wide grid network;
- develop a strategic roadmap for wind energy developments and grid infrastructure. This would involve identifying areas for large-scale wind farm developments, with streamlined authorisation procedures and where developers can be confident of obtaining their permits, and use these areas for long-term grid infrastructure planning.

4.2. Reducing costs

4.2.1. Investment cost

In the past few years, energy demand has gone up significantly and the price of energy has increased as a result. In the case of wind energy, after a period in which costs decreased in line with the expected learning curve, there has recently been an increase in wind energy costs due to very high demand.

Other reasons for the rising costs include the increase in the overall price of materials and supply chain bottlenecks. The wind energy sector and policymakers should focus on reducing the cost of investment, which would lead to reductions in the lifetime cost of energy, making wind more competitive.

Key issues relevant to future investment costs include the following:

- Bottlenecks in the supply chain, which limit the favourable effects that economies of scale should have on costs. The supply chain structure must evolve to meet demand, benefiting from economies of scale.
- Due to high demand, logistics and service suppliers will suffer from the same supply bottlenecks as equipment suppliers, leading to higher investment costs.
- Uncertainties remain regarding the future cost of raw materials and the subsequent impact on the cost of wind energy. Alternatives should be sought so that variability in the price of raw materials can be managed successfully.
- As installed capacity increases, wind power will move to more challenging environments (for example, sites with a lower wind resource, turbulent sites, cold climates, deep waters and further offshore). In order to lower costs, technological improvements are required. The challenge is how these engineering issues can be most efficiently managed, while still supporting growth.

The policy priority is that governments provide long-term national siting plans for wind projects. This would have a positive impact on development and ultimately on investment costs.

The priority study is to investigate the relationship of supply and demand to costs, as well as supply chain bottlenecks. Once these issues are understood, improvements and alternatives can be developed with the involvement of manufacturers and sub-suppliers. These might include further standardisation of components, or sharing out component manufacturing.

4.2.2. Operating costs

Operating costs can be reduced substantially by improving reliability and optimising operational services and component supply.

Operating costs account for a significant proportion of the overall lifetime costs affecting competitiveness. Improvements in the efficiency of costs related to site use, maintenance, grid charges, insurance and local taxes may make a significant contribution to reducing overall costs.

Photo: EWEA, François-Jerome Bris

The market would also benefit from a greater number of maintenance and service companies operating in the wind sector.

Reductions in operating costs in the offshore market might be achieved by developing specific offshore systems.

Priority studies are to:

- review associated project costs across EU markets in order to understand the influence of non maintenance-related costs, such as insurance, local taxes and grid costs;
- investigate project supply services, in order to identify insufficiencies and shape policy; and
- gain a better understanding of offshore O&M costs and the potential for improvements. Further experience may be gained from the offshore industry.

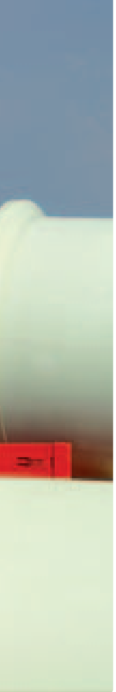
4.2.3. Cost of capital

The cost of capital is closely linked to the financial sector's confidence in the technology, future revenue and market sustainability. Reducing exposure to risk in different categories will in turn reduce the cost of capital.

Priority studies are to investigate the sensitivity of the cost of capital to different risk categories in wind energy projects.

4.3. Adapting policies

In order for wind energy markets to develop further, ambitious wind energy targets need to be set and appropriate measures taken in the EU. This means that all parties



can rely on clear rules, targets and instruments in their decision making. Policy has to be consistent, stable and long–term, to allow for the most efficient investment.

The Renewable Energy Directive sets an EU target for energy from renewable sources of 20% by 2020, an increase of 11.5% on current levels. It corresponds to 35% of EU electricity coming from renewable energy sources. This target is split between the Member States, which are required to provide action plans that lay out how they will meet their share of the EU target.

The following points are noted:

- The target could be more ambitious; with a supportive framework in place, wind power alone could reach a target of some 25% by 2030
- Long-term legally binding wind and renewables targets should be implemented at national level
- As the overall European target is binding, TPWind proposes that sanctions be imposed on Member States that do not comply with the national targets or action plans
- The Renewable Energy Directive does not encourage the breaking down of targets for the power, heat and transport sectors. This leads to a situation in which the targets are not resource-orientated, and this will inhibit the utilisation and value of Europe's wind resource
- A stable and predictable environment should be created to help achieve the above-mentioned targets. Stable and long-term support schemes have been proven to provide long-term investment. **This point is essential, since such an environment would significantly boost investor confidence.**

The policy priorities are:

- An ambitious European target for wind energy should be set by 2030. This target should be shared between Member States according to their potential
- Sanctions should be placed on Member States that do not reach their target or fulfil their action plans

4.4. Optimising administrative procedures

The key issues with the current administration of applications for wind farms and auxiliary infrastructures in many parts of Europe are inconsistencies and uncertainties in the requirements and judgments of administrative authorities, and delays in the consenting process.

Despite policies supporting wind energy at European and national level, it is also difficult to obtain planning permits in many Member States.

In some Member States, there is a lack of clarity on the administration requirements and processes for wind farm applications, particularly in relation to applications for repowering existing wind farms. Repowering projects create new challenges over and above those of developing new wind farms on a site. The administration of applications for repowered wind farms needs to be urgently clarified, as repowering will become more common in the coming years in countries where the first commercial wind farms are reaching the end of their design lives and prime sites for wind farms are becoming scarce.

The policy priorities are to:

- encourage Member States to produce binding strategic plans for developing onshore and offshore wind farms and auxiliary developments. Within the identified areas, acquiring planning permission should become more straightforward and administrative procedures should be streamlined. The national strategic plans need to identify priority wind energy zones as a bottom-up exercise, matching EU targets for wind energy in 2030;
- establish a one-stop shop in each Member State to offer authoritative guidance on the administration of wind farm applications; and
- set up an offshore wind convention at EU level in order to identify suitable areas for the development of offshore wind farms and the necessary grid. When identifying these areas, technological constraints and conflicts with other commercial activities must be considered, as should environmental impact.

Priority studies:

- As a matter of urgency, guidance should be produced on the administration of applications for repowered wind farm developments
- Conducting a review of how Environmental Impact Assessments of wind farm and auxiliary infrastructures are administrated. This review should focus in particular on how to streamline applications, for example by using the scoping stage to identify key issues and to rule out further assessment of impacts that are not relevant to development. This review should suggest specific time limits for the individual steps in the consenting process.

4.5. Integrating wind into the natural environment

There is a link between the types of biological environment at the global, regional and local level. Planning authorities are generally reluctant to engage in this discussion because of a lack of tools for comparing and weighing up local environmental impact and the global effect of CO_2 reductions. In extreme cases, this means that wind farm projects are rejected because of minor adverse local effects, which has a larger negative impact on the global environment.

At present, Environmental Impact Assessments (EIAs) are inefficient. The results of EIAs are not widely disseminated, and a consensus has yet to be reached on whether EIAs could use studies that have already been carried out, rather than doing full and separate studies for each one. As a consequence, wind farm developers repeat investigations and there is a duplication of efforts and costs for all concerned.

Results of environmental monitoring across Europe need to be gathered and reviewed in order to identify existing gaps in knowledge that could be the focus for future research.

Wind farms have various types of impact for which more research is needed into the removal, reduction and mitigation options. These include the following issues, which are of concern to a greater or lesser extent in the various Member States:

- Radar issues (especially in relation to military operations)
- Impact on bats
- Noise from large turbines (with focus on low frequency noise, impact on people and on the acoustic communication of biota)
- Impact of offshore wind farms on migrating birds, seabirds, marine mammals, and other biota
- Cumulative effects, including population-level impacts of wind farms

Post-operational monitoring is not comprehensively evaluated against the areas of the EIA and the results are rarely shared widely or referenced in future assessments. As a consequence, much of the value of post-operational monitoring is not realised.

To ensure that future monitoring adds to the existing knowledge base, attention should be given to the following points:

- Monitoring that checks that design limits comply with external conditions
- Monitoring to clarify concerns remaining after the Environmental Impact Assessment
- Monitoring that is goal and target-orientated – a clear scoping is essential
- Termination of monitoring when enough data has been collected
- Avoiding monitoring that relates more to scientific research than to the impact of wind farms
- Comprehensive evaluation of monitoring results in relation to the areas covered in the EIA, as well as the publication and sharing of these results

The policy priority is to identify priority development zones for the strategic planning of wind farms.

Priority studies:

- Carry out research into the environmental impact of electricity generation and consumption, particularly in regard to offshore wind farms and the global benefit of developing offshore wind farms compared to electricity from other sources
- Research into, and development of, guidance on the assessment of the environmental impacts of wind farms from local to global level
- A centralised source of data on the environmental baseline and impact should be established. This source would guide developers on how data could be used and where the use of information from this source would remove the need for collecting new data
- Research and guidance on the sharing and use of post-operational monitoring findings in future EIAs, particularly bird impact studies
- Research into identified gaps regarding the impact on birds, bats and sea and freshwater life
- Research into technological tools for monitoring the impact of wind turbines on birds, bats and underwater life
- Research into different solutions and tools for adressing the impact on radar (aviation, telecommunications); their cost-effectiveness and funding of such solutions and tools, for example, transponders
- Development of landscape design tools and impact assessment tools that are tailored specifically for wind farm developments

Photo: energypicturesonline

- Research into predicting, reducing and monitoring noise emissions from wind farms
- Post-operational evaluation of the entire scope of an EIA at regular intervals (for example, one year, five years and ten years after construction), to look at predicted versus actual noise impact. These evaluations should also be shared among a wider community
- Establish a central source of post-operational evaluation data
- Research into and development of guidelines and tools to assess cumulative impacts, including population level impacts and impact thresholds (review existing approached to identifying thresholds)

4.6. Ensuring public support

Compared to conventional sources of energy generation, wind energy is popular with the general public. The industry can help to sustain this by further implementing best practices, based on public consultation, remaining willing to address public acceptance issues and demonstrating improvements to reduce or mitigate impacts of public concern.

Whilst there is large-scale support for wind energy, wind farm applications can be delayed or blocked by an apparent or perceived resistance from communities at a local level.

In order for wind farms to be accepted by the public, it is essential to improve public awareness about wind energy. It is also important to involve local communities in the process of wind farm developments in their area, and ensure that they also reap some benefits. Decision-makers need to be kept well informed of the real level and nature of public support, not just the perceived level.

Priority studies:

- Investigate the motivation behind public opinion and people's concerns
- Review case studies, looking at local opinion before and after the wind project is installed
- Review existing key myths/concerns regarding wind energy and identify where further research is needed
- Review the range of mechanisms used across Europe for transforming global benefits into tangible benefits for local communities and identify how these can affect public opinion
- Review of current best practice guidance on effective consultation processes and the manner in which this guidance is disseminated

4.7. Human resources

The wind energy sector is currently facing a shortage of qualified personnel. This is a critical issue given the scale of wind energy developments needed to meet the 2020 targets and TPWind's 2030 vision. A sufficiently large and well-skilled work force will be essential for maintaining technological leadership in wind.

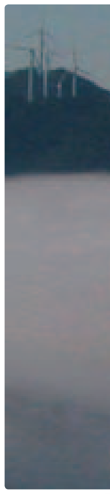
There is an opportunity for new jobs to be created in turbine design and manufacturing. As is the case in other industries, work in designing and manufacturing wind turbines is concentrated around factories and companies and is dependent on industrial development. A critical mass of wind farm developments is needed to support manufacturing facilities and local production should develop alongside a growing market. As wind power development in Europe continues to expand, local production and development are expected in more and more countries. It is important that this development continues and that the industry continues to look to create new jobs and encourage innovation.

While the industry has a shortage of skilled labour to meet current demand, it is also creating thousands of new jobs within the wind and related sectors. A pool of additional jobs is created with the construction and operation of a wind farm. Moreover, the turbine supply market has grown rapidly, but has not been followed by growth in the operational and maintenance service sector. Today, many manufacturers are reducing their coverage of turbine maintenance services and there is not a corresponding increase in the number of independent service providers. There is likely to be a shortage of service personnel in the future, which could potentially push up costs.

For offshore, education is a critical part of delivering safety: well-trained, well-educated people will be equipped with the skills and knowledge necessary to ensure operational safety and guarantee the protection of the offshore workers and environment. However, education has far broader objectives: it must deliver a trained workforce with the skills required to develop the industry further. These will range from skilled workers needed to manufacture, build and operate the facilities to graduates who understand the technical, commercial and social context of the industry and are equipped to provide the technology, drive and direction needed to maintain European leadership in offshore wind.

The career potential of the offshore wind industry has not yet been fully appreciated by students and academics. The industry is on the cusp of becoming fully commercial, but the necessary engineers, technicians and programmes for development are currently unavailable. The initial development of the offshore wind industry will require the redeployment of engineers and technicians from other industries and will require the rapid development of basic safety and familiarisation training.

The current personnel shortage needs to be resolved and many more skilled workers are needed in this sector.



The policy priority for the whole sector, with the support of the European Commission and Member States, is to organise initiatives to attract people on all levels. In this respect, the environmental benefits (such as CO_2 reduction) and career opportunities are strong arguments for attracting skilled personnel.

Priority studies:

- Research into the range of skills needed in the industry to meet the 2020/2030 targets and identification of the education and training needed. Development of concrete short-term educational programmes to meet the high and increasing demands of the renewable energy industry
- Cost-benefit study on developing regions that can provide services such as construction, operation and maintenance
- Research into the benefits of wind energy development in terms of the creation of local and regional jobs and local economic benefits

5. RD&D Funding

Photo: EWEA, Marie Leberre

One of the key TPWind considerations is the assessment and procurement of adequate funding to finance the identified RD&D activities and infrastructures, as well as any technology demonstrators.

TPWind aims to:

- assess the current existing mechanisms for wind energy RD&D financing at European level, as well as the available global level of funds;
- explore opportunities and propose additional instruments (finance and project configurations) for a larger critical mass and more coordinated RD&D actions by stakeholders; and
- establish the approximate global level of funding required in order to keep European wind energy competitive and a global leader. This amount should be distributed according to R&D priorities established by the SRA.

TPWind is dedicated to increasing the overall European RD&D activity in the wind sector by:

- fostering the launch of new sources of funding in the public sector; and
- encouraging increased funding from the private sector.

5.1. EC and Member State support schemes

5.1.1. Support at European Commission level

The European Commission (EC) provides an analysis of the R&D budget evolution over FP5 and FP6[13] (Table 1). Three main areas are compared for FP5 and FP6:

- Large size wind turbines
- (Grid) integration and management of wind power
- Wind farm development and management

Table 1: EC funding for wind energy RD&D in FP5&6

Wind technology paths (Strategically important areas and topics)	**EC funding**					
	FP5			FP6		
	Number of projects	Eligible cost in M€	Total EC contribution in M€	Number of projects	Eligible cost in M€	Total EC contribution in M€
Large size wind turbines	10	27.68	14.98	4	37.95	19.46
Integration and management of wind power	7	12.99	7.15	4	7.75	4.43
Wind farm development and management	3	4.02	2.23	2	34.03	7.70
Total budget for wind energy	**20**	**44.69**	**24.36**	**10**	**79.74**	**31.59**

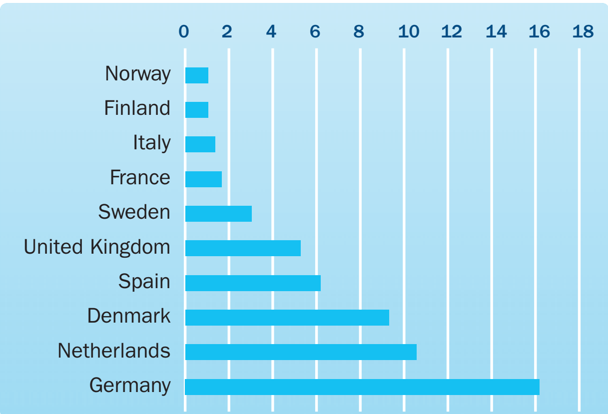
13 European Commission, DG-Research, 2006. *"The State and Prospects of European Energy Research Comparison of Commission, Member and Non-Member States – R&D Portfolios"*.

Due to two integrated projects (DOWNVInD and UpWind), the average project size increased significantly between FP5 and FP6. The EC contribution also increased by almost 27%, and reached €31.59 million, an average of €7 million/year.

5.1.2. Support for wind R&D at Member State level

Several studies have been undertaken to investigate Member State funding of RD&D in the wind sector. On the basis of IEA data[14], the distribution of support for wind energy research in European countries is shown in Figure 11. This graph illustrates the average RD&D budget for the period 1998-2006 for European countries with a significant budget (ten European countries have average budgets of over €1 million). The average budget exceeds €3 million/year in only six of these countries, which were unique in setting up globally recognised research laboratories and test facilities, and/or leading turbine or component manufacturers. These figures clearly demonstrate that a **high-quality research structure is built on long-term and adequate R&D budgets.**

Figure 11: Average funding 1998-2005 for European countries with an average budget of above €1 million/year (in M€ 2006).



14 http://www.iea.org/Textbase/stats/rd.asp

The SET-Plan concludes:

"Some Member States are already progressively increasing national energy research funding. Others should follow suit, ***with the aim of doubling the overall effort in the EU within three years. The Commission will monitor progress towards this objective within the context of the Lisbon process.****"*

5.2. Current private sector efforts

Collecting and analysing the available information on RD&D investment from wind turbine and component manufacturers is far from straightforward. Some manufacturers merge figures for wind into their overall RD&D investment data, whereas data from other manufacturers is not available for public consultation. However, conservative estimates provide a figure for 2007 of €170 million of R&D investment per year across the EU.

2006 figures are available for some wind turbine manufacturers[15], making a total of €186 million. This figure does not include all manufacturers or sub-suppliers. The ratio of R&D expenditure to net sales varies significantly, from 0.4 to 3.1%. Clipper Windpower (89%) is an exception, as the manufacturing capacity is located in the US.

The SET-Plan concludes:

"Achieving our ambitious goals will ***require a fundamental departure from current practice throughout the innovation system****, striking the right balance between cooperation and competition at national, European and global levels.*

A long-term and stable policy framework is essential, but to take best advantage of this opportunity, ***industry should be prepared to increase investment and take greater risks.***

15 European Commission, 2007. *"Monitoring industrial research: the 2007 EU industrial R&D investment scoreboard".*

		R&D Investment (€m)	Net Sales (€m)	R&D/Net Sales ratio (%)	
COMPANY	COUNTRY	2006	2006	2006	2005
Acciona	Spain	22.60	6,272	0.4	0.1
Gamesa	Spain	33.12	2,391	1.4	1.6
Nordex	Germany	11.25	514	2.2	2.9
Repower Systems	Germany	14.02	459	3.1	3.1
Vestas Wind Systems	Denmark	88.60	3,854	2.3	2.4
Nordex	Germany	11.25	514	2.2	2.9
Clipper Windpower	UK	5.33	6	88.8	193.0

Photo: energypicturesonline

Setting up strategic alliances is necessary for industry to share the burden and benefits of research and demonstration."

5.3. **Budget expectations**

A first proposal for the RD&D budget was provided by TPWind in its report for the EC's Strategic Energy Technology Plan[16].

The expected cumulative installed power capacity by 2030 is 300 GW. The 2007 cumulative installed capacity was nearly 56 GW. Reaching 300 GW implies installing an average of 11 GW/year. If the average investment cost is €1.3 million per MW[17], the yearly average investment level would then be €14.3 billion per year.

To comply with the decision made at the Barcelona European Council[18], the RD&D effort of the sector should be at least of 3% of annual turnover. This is a minimum figure, as it includes all the Member States' RD&D activities. The RD&D expenditure from other high-tech industries is higher than the average of 3%.

Based on a 3% investment, the R&D effort should be an average of €430 million per year. As two-thirds of this budget should be invested by the private sector and one-third by the public sector, the average public annual support should then be €143 million per year. Finally, if 50% of this support is provided by national (Member State) programmes, and 50% from EC programmes, the average effort both for EC and national programmes should be €72 million per year.

The average Member State contribution is in line with this 3% effort, although it varies significantly over time and does not always correspond to the size of the manufacturing industry in that country.

If the Barcelona objectives and the 20% renewables target are to be achieved and the EC maintains its previous financing trends in 2006-2020, then the cumulative financing gap in total RD&D financing is estimated at €1 billion. For the FP7 financing period (2007-2013), this gap is estimated to be €450 million.

In parallel to wind energy R&D support, a set of accompanying technologies (some of them shared with other RES) is required to meet the European 20% for 2020 objective: large-scale grid connection solutions, wide offshore deployment and massive energy storage. Additional R&D funding will be allocated to these areas.

5.4. **Current inadequacies**

The funding of schemes at national level should be stabilised and adjusted to reflect their relevance to local manufacturing.

The current EC funding model for wind R&D appears to be outdated. This is not only due to a lack of budget, but also to the nature of the current instruments. The EC's Framework Programmes are not competitive in the EU (in comparison with Member States' own funding models) or on a global scale (in comparison with DoE Programmes), as they involve a noticeable administrative burden and high levels of bureaucracy. The meagre budget that is available for wind energy does not cover the application and reporting process, especially where manufacturers are concerned. Moreover, the success rate (10-20%) for grant applications is low in compari-

16 http://www.windplatform.eu/fileadmin/ewetp_docs/Documents/SET_Plan_process/TPWind_Contribution_to_SET_Plan.pdf
17 Onshore figure 2006. For accurate calculations, offshore investment costs will be included.
18 Source: European Commission, 2002. *"More Research for Europe – Towards 3% of GDP."* COM(2002) 499 final.

Photo: EWEA, Ahmadi Markus

son with national programmes (50% or more, due to effective pre-screening procedures, for example).

During the 1980s, the prevailing energy paradigm led to the fostering of EU-wide cooperative R&D activity through the EC's R&D Framework Programmes. In 2010-2020 the new paradigm will focus more on the pursuit of global technological leadership, maximisation of the funding devoted to R&D activity, IP concerns, consortium operational efficiency and the focusing of results. It must be innovative, in order to minimise the so-called "European paradox."

Failure to minimise this paradox might mean that the ambitious 2020 objectives are not achieved. TPWind's considerations are fully in line with the SET-Plan, which concludes:

*"**Some technology challenges require critical mass and large-scale investment and bring with them a risk which cannot be met by the market by Member States acting individually or by the current model of European collaborative research.** The EU can respond to this challenge by evolving towards a new model of focused cooperation, making use of the full potential of the European Research and Innovation Area and the Internal Market.*

*Achieving our ambitious goals will **require a fundamental departure from current practice throughout the innovation system**, striking the right balance between cooperation and competition at national, European and global levels."*

5.5. Actions

In the light of the recently changed energy, socio-political and environmental paradigm, there is a serious and urgent need to redefine the priorities for energy RD&D financing.

Current instruments should be revised to take account of the new situation, and those that are compatible should be adapted and, where appropriate, new instruments should be developed. The overall objective is to achieve the wind energy RD&D funding level necessary to assure European technological leadership.

This will be done by satisfying the following sub-objectives:

- Adapting the European Commission's instruments and programmes for financing wind energy RD&D
- Fostering public-private and private-private collaboration in RD&D
- Using public funding to leverage private funding for wind energy RD&D
- Maximising the application of RD&D results to increase the global competitiveness of European products and technologies

The forthcoming European Wind Initiative, which is outlined in the Strategic Energy Technology Plan (SET-Plan), is a key opportunity to reinforce European world leadership in RD&D financing and execution frameworks. The SET-Plan states:

"European Industrial Initiatives aim to strengthen industrial energy research and innovation by mobilising the necessary critical mass of activities and actors. Geared towards measurable objectives in terms of cost reduction or improved performance, they will focus and align the efforts of the Community, Member States and industry to achieve common goals. They will target sectors for which working at Community level will add most value – technologies for which the barriers, the scale of the investment and risk involved can be better tackled collectively.

*The Commission proposes to launch the following new priority initiatives, **starting in 2008**:*

European Wind Initiative: focus on large turbines and large systems validation and demonstration (relevant to on and off-shore applications).

*The European Industrial Initiatives **will be implemented in different ways, depending on the nature and needs of the sector and the technologies.** For technologies with a sufficient industrial base across Europe they may take the form of public-private partnerships, while for other technologies, which are prioritised by a few countries, they may take the form of joint programming by coalitions of those interested Member States. Where appropriate, a combination of 'technology push' and 'market pull' instruments may be used. The European Technology Platforms will assist in the preparation phase.*

*Implementation of the SET-Plan will help overcome the fragmentation of the European research and innovation base, leading to a better overall balance between cooperation and competition. **Encouraging more focus and coordination between different funding schemes and sources will help to optimise investment, build capacity and ensure a continuity of funding for technologies in different phases of development.***

*Two challenges need to be addressed: **mobilising additional financial resources, for research and related infrastructures, industrial-scale demonstration and market replication projects;***

…Further resources increases are similarly required to finance the proposed European Industrial Initiatives and the European Energy Research Alliance.

*The Commission intends to present a Communication on financing low carbon technologies at the end of 2008. The Communication will address resource needs and sources, examining all potential avenues to leverage private investment, including private equity and venture capital, enhance coordination between funding sources and raise additional funds. In particular, it will examine the **opportunity of creating a new European mechanism/fund for the industrial-scale demonstration and market replication** of advanced low carbon technologies and will consider the costs and benefits of tax incentives for innovation.*

In preparing this Communication, the Commission will draw on the expertise of governments, industry and the research, energy and financial communities"

Therefore, TPWind proposes to collaborate with the EC in the way specified above, in order to make sure that the design and implementation of the aforementioned instruments help achieve TPWind's objective for RD&D funding.

6. TPWind Members

6.1. Executive Committee

CHAIRPERSON
- *Henning Kruse* – Siemens Wind Power

VICE-CHAIRPERSONS
- *Takis Chaviaropoulos* – CRES
- *Angeles Santamaria* – Iberdrola

ALTERNATES
- *Christian Nath* – Germanischer Lloyd
- *Josep Prats* – Alstom

6.2. Steering Committee

- *Jos Beurskens* – ECN
- *Claudio Borri* – CRIACIV at Universita di Firenze
- *Joerg Buddenberg* – EWE AG
- *Peter Flamang* – Hansen Transmissions
- *Carlos Gascó* – Iberdrola
- *Lars Gertmar* – ABB
- *Christoph Hessel* – GE Wind Energy
- *Olav Hohmeyer* – Flensburg University
- *Hannele Holttinen* – VTT
- *George Kariniotakis* – Ecole des Mines de Paris
- *Allan MacAskill* – Talisman Energy (UK) Ltd
- *Frank Nielsen* – LM Glasfiber
- *Erik Lundtang Petersen* – Risø / DTU
- *David Quarton* – Garrad Hassan and Partners Ltd
- *Peter Raftery* – Airtricity
- *Grzegorz Skarzynski* – Polish Wind Energy Association
- *Finn Stroem Madsen* – Vestas
- *Sven-Erik Thor* – Vattenfall
- *Mauro Villanueva-Monzon* – Gamesa
- *Arthouros Zervós* – NTUA

6.3. Secretariat

- *Nicolas Fichaux* – EWEA
- *Peter Hjuler Jensen* – Risø / DTU
- *Siobhan Green* – Garrad Hassan and Partners Ltd
- *Jorgen Holt* – Garrad Hassan and Partners Ltd
- *Gregor Giebel* – Risø / DTU
- *Jens Carsten Hansen* – Risø / DTU
- *Jorgen Lemming* – Risø / DTU

6.4. Working Group 1: Wind Conditions

CHAIRPERSON
- *Erik Lundtang Petersen* – Risø / DTU

VICE-CHAIRPERSON
- *Ignacio Martí* – CENER

- *Frank Albers* – Windtest grevenbroich gmbh
- *Rebecca Barthelmie* – University of Edinburgh
- *Tomas Blodau-Konick* – Repower Systems AG
- *Pompilio Caramuscio* – ENEL
- *Lars Christian Christensen* – Vestas Asia Pacific A/S
- *Neil Douglas* – Natural Power Consultants
- *Eric Dupont* – EDF R&D
- *Gerd Habenicht* – Renewable Energy Systems Ltd
- *Jørgen Hojstrup* – Suzlon Energy A/S
- *Leo Enrico Jensen* – DONG Energy
- *Lars Landberg* – Garrad Hassan and Partners Ltd
- *Bernhard Lange* – ISET
- *Henrik Madsen* – DTU
- *Miriam Marchante Jimenez* – Gamesa
- *Pep Moreno Santabarbara* – Alstom
- *Jose Palma* – FEUP, Faculty of Engineering
- *Joachim Peinke* – ForWind
- *Evangelos Politis* – CRES
- *Thierry Ranchin* – Ecole des Mines de Paris

6.5. Working Group 2: Wind Power Systems

CHAIRPERSON
- *Jos Beurskens* – ECN

VICE-CHAIRPERSON
- *Jaco Nies* – GE Wind Energy

- *Peter-Heinrich Boysen* – Nordex Energy GmbH
- *Alex De Broe* – 3E
- *Daniel Doncaster* – SKF (U.K.) Ltd
- *Jochen Giebhardt* – ISET
- *Angel Gonzales Palacios* – Gamesa
- *Koen Hoedemaekers* – Hansen Transmissions
- *Peter McKeich Jamieson* – Garrad Hassan and Partners Ltd
- *Peter Hjuler Jensen* – Risø / DTU
- *Sebastian Johansen* – Fortum Generation
- *Martin Kühn* – Endowed Chair of Wind Energy, Stuttgart

- *Carsten Hein Westergaard* – Vestas
- *Bedii Ozdemir* – Istanbul Technical University
- *Jordi Puigcorbé* – Alstom
- *Peter Quell* – REpower Systems AG
- *Maria Elena Rodriguez* – Iberdrola
- *Don R.V. van Delft* – Knowledge Centre WMC
- *Gijs van Kuik* – DUWIND
- *Javier Villanueva* – CENER
- *Pantelis Vionis* – CRES

6.6. Working Group 3: Wind Energy Integration

CHAIRPERSON

- *Hannele Holttinen* – VTT

VICE-CHAIRPERSONS

- *Kurt Rohrig* – ISET
- *Frans Van Hulle* – EWEA

- *Thomas Ackermann* – Energynautics GmbH and KTH/Stockholm
- *Peter Christensen* – Vestas
- *Friedrich Koch* – REpower Systems AG
- *Juan Carlos Perez Campion* – Iberdrola
- *Ulrich Focken* – Energy & Meteo systems
- *Michael Nørtoft Frydensbjerg* – Siemens Wind Power
- *Paul Gardner* – Garrad Hassan and Partners Ltd
- *Emilio Gomez Lazaro* – UCLM
- *Stefan Hartge* – GE Wind Energy
- *Hans-Jürgen Haubrich* – IAEW of RWTH Aachen University
- *David Infield* – Strathclyde University
- *Javier Juanarena Saragueta* – Gamesa
- *Matthias Müller-Mienack* – Vattenfall
- *Aksel Hauge Pedersen* – DONG Energy
- *John Olav Tande* – SINTEF
- *Bart C. Ummels* – Delft University of Technology
- *Maher Chebbo* – SAP
- *Achim Woyte* – 3E
- *Yao Liangzhong* – AREVA T&D

6.7. Working Group 4: Offshore Development and Operation

CHAIRPERSON

- *Allan MacAskill* – Talisman Energy (UK) Ltd

VICE-CHAIRPERSON

- *Jan van der Tempel* – Delft University of Technology

- *Kimon Argyriadis* – Germanischer Lloyd
- *Georg Barton* – E.ON Energy Projects GmbH
- *Neil Birch* – RWE npower
- *Loïc Blanchard* – EWEA
- *Göran Dalén* – WPD Scandinavia AB
- *Jonathan Duffy* – Airtricity
- *Niels Emsholm* – Dong Energy
- *Erik Asp Hansen* – DNV
- *Dorte Buus Jensen* – Vestas
- *Joergen Lemming* – Risø / DTU
- *Colin Morgan* – Garrad Hassan & Partners Ltd
- *Finn-Gunnar Nielsen* – StatOil
- *Luc Rademakers* – ECN
- *Heiko Ross* – BARD Engineering GmbH
- *Peter Schaumann* – Forwind
- *Marc Seidel* – REPower Systems AG
- *John Dalsgaard Sørensen* – Aalborg University / Risø / DTU
- *David Still* – Clipper Windpower Europe
- *Jens Tambke* – Oldenburg University

6.8. Working Group 5: Wind Market and Economics

CHAIRPERSON

- *Carlos Gascó* – Iberdrola

VICE-CHAIRPERSON

- *Bernard Chabot* – ADEME

- *Lise Backer* – Vestas
- *Isabel Blanco* – EWEA
- *Imar Owen Doornbos* – Ministry of Economic Affairs
- *Klaus Rave* – Investitionsbank Schleswig-Holstein
- *Jacob-Jan Ferweda* – WindVision Belgium NV
- *Christian Grütte* – Leonardo Venablers S.L.
- *Ozgur Gurtuna* – Teknosfer Space and Energy Ltd
- *Christopher Knowles* – European Investment Bank
- *Luigi La Pegna* – Enel S.p.A.
- *Ignacio Lainez* – NEO Energía / EDP Group
- *Antoni Martínez* – Fundació bTEC
- *Rune Moesgaard* – Danish Wind Industry Association
- *Peter Niermeijer* – RECS International
- *Juan Diego Diaz Vega* – Gamesa
- *Guy Teuwissen* – APER
- *Luc Van Nuffel* – Electrabel
- *Frits Van Oostvoorn* – ECN

6.9. Working Group 6: Wind Policy and Environment

CHAIRPERSON
- *Arthouros Zervós* – NTUA

VICE-CHAIRPERSONS
- *Rosa Klitgaard Andersen* – Danish Wind Industry Association
- *Geert Palmers* – 3E

- *Tony Philipp Adam* – Nordex Aktiengesellschaft
- *Steffen Andersen* – Dong Energy
- *Lars Bach Jensen* – Vestas
- *Martin Berkenkamp* – GE Wind Energy
- *Conall Bolger* – Airtricity
- *Christian Dahlke* – Federal Maritime and Hydrographic Agency
- *Gabriela Dominguez* – Gamesa
- *Miguel Ferreira* – Megajoule
- *Andreas Friedrich* – Vattenfall New Energy GmbH
- *Claudia Grotz* – German Wind Energy Association
- *Øyvind Isachsen* – NORWEA
- *Debra Justus* – International Energy Agency
- *Dimitrios Kanellopoulos* – Public Power Corporation
- *Cristian Lanfranconi* – Renewable Energy Producers Association
- *Steffen Nielsen* – Danish Energy Authority
- *Anna Stanford* – Renewable Energy Systems Ltd
- *Frauke Thies* – Greenpeace
- *Albert Jansen* – SenterNovem

6.10. Finance Working Group

CHAIRPERSON
- *Mauro Villanueva-Monzon* – Gamesa

- *John Callaghan* – The Carbon Trust
- *Joaquin Jose Cervino* – European Investment Bank
- *Melchior Karigl* – European Investment Bank
- *Juan Carlos Fernandez* – CDTI
- *Matthias Heinicke* – REpower Systems AG
- *Addy Lommerde* – Fortis Bank (Netherlands) NV
- *Allan MacAskill* – Talisman Energy (UK) Limited
- *Lene Nielsen* – Danish Energy Authority
- *Frank Stubenrauch* – Projektträger Jülich
- *Jaap 't Hooft* – SenterNovem
- *Andrea Tinagli* – Green Alliance SGECR
- *Andreas Wagner* – Stiftung Offshore Windenergie

Notes

About TPWind

The European Technology Platform for Wind Energy (TPWind) is the indispensable forum for the crystallisation of policy and technology research and development pathways for the wind energy sector; as well as a new opportunity for informal collaboration among Member States, including those less developed in wind energy terms.

TPWind Secretariat
Renewable Energy House
Rue d'Arlon 63-65
1040 Brussels – Belgium
secretariat@windplatform.eu

Supported by the
European Commission

SIXTH FRAMEWORK PROGRAMME