About EWEA

EWEA is the voice of the wind industry - actively promoting the utilisation of wind power in Europe and worldwide.

EWEA members from over 40 countries include 200 companies, organisations, and research institutions. EWEA members include manufacturers covering 98% of the world wind power market, component suppliers, research institutes, national wind and renewables associations, developers, electricity providers, finance and insurance companies and consultants. This combined strength makes EWEA the world's largest renewable energy association.

The EWEA Secretariat is located in Brussels at the Renewable Energy House. The Secretariat co-ordinates international policy, communications, research, and analysis. It manages various European projects, hosts events and supports the needs of its members.

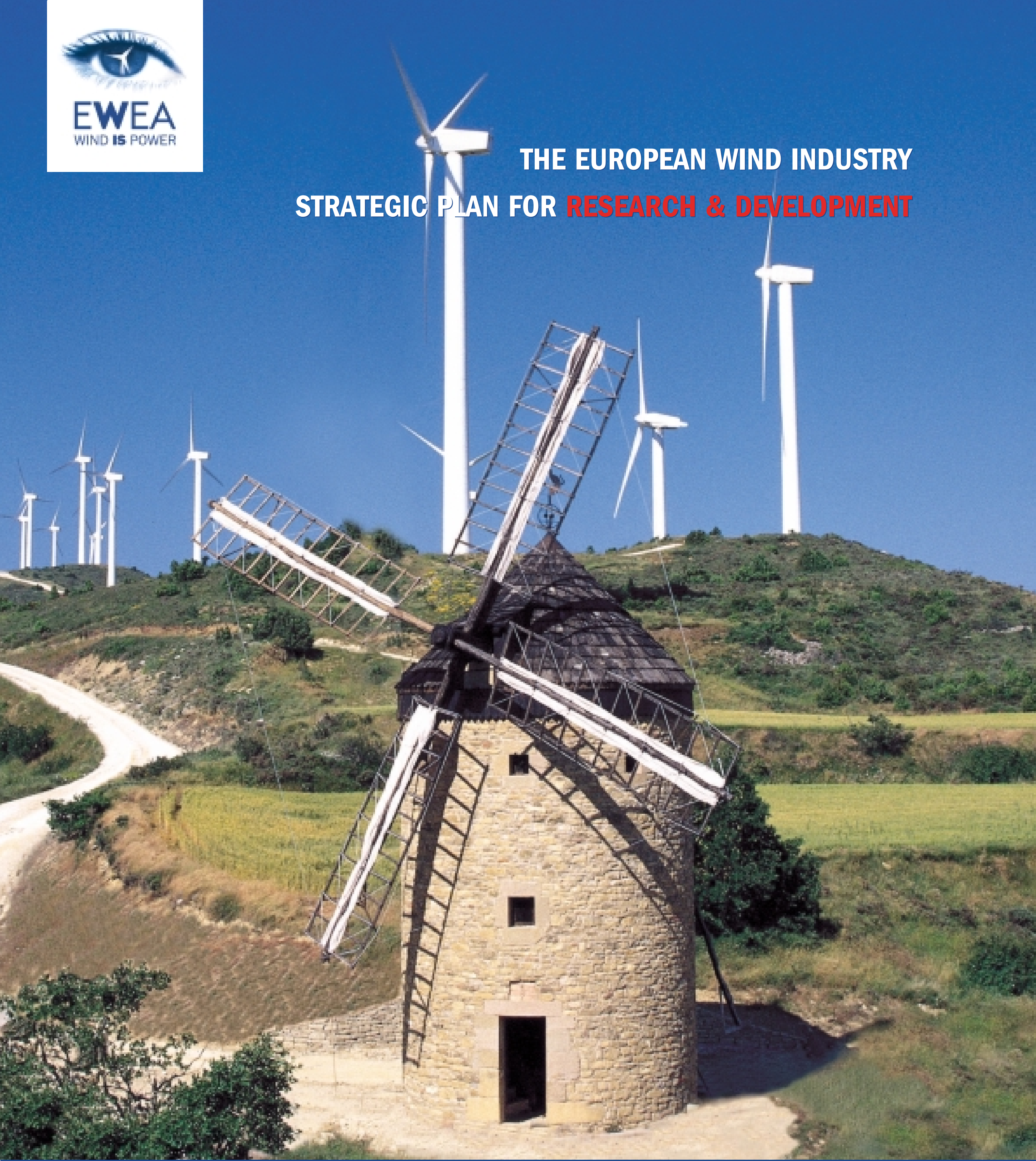
EWEA is a founding member of the European Renewable Energy Council (EREC) which groups the 6 key renewables industry and research associations under one roof.

The European Wind Energy Association
Renewable Energy House
Rue du Trône 26
1000 Brussels - Belgium

tel. +32 2 546 19 40
fax +32 2 546 19 44
ewea@ewea.org
www.ewea.org

EWEA
WIND IS POWER

THE EUROPEAN WIND INDUSTRY
STRATEGIC PLAN FOR RESEARCH & DEVELOPMENT



FIRST REPORT: CREATING THE KNOWLEDGE FOUNDATION FOR A CLEAN ENERGY ERA

REPORT

01/2004

This first report results from the European Commission funded project "Wind Energy Thematic Network" - contract number ENK6-CT-2001-20401

The report represents work in progress. The final report will be released in 2005.

For further details visit ***www.wind-energy-network.org***

The wind Energy Network meets every six months to work on the R&D Strategic Plan, to be finalised in 2005

PROJECT PARTNERS

www.neg-micon.com

NEG Micon, representing turbine manufacturers

www.neg-micon.com

Pauwels, representing components manufacturers

www.pauwels.com

Investitionsbank Schleswig Holstein, representing financiers & insurers

www.ib-sh.de

ECN, representing R&D, testing & certification centres

www.ecn.nl

Risø, representing R&D, testing & certification centres

www.risoe.dk

BWE, representing end users: turbine owners

www.wind-energie.de

RES, representing end users: developers

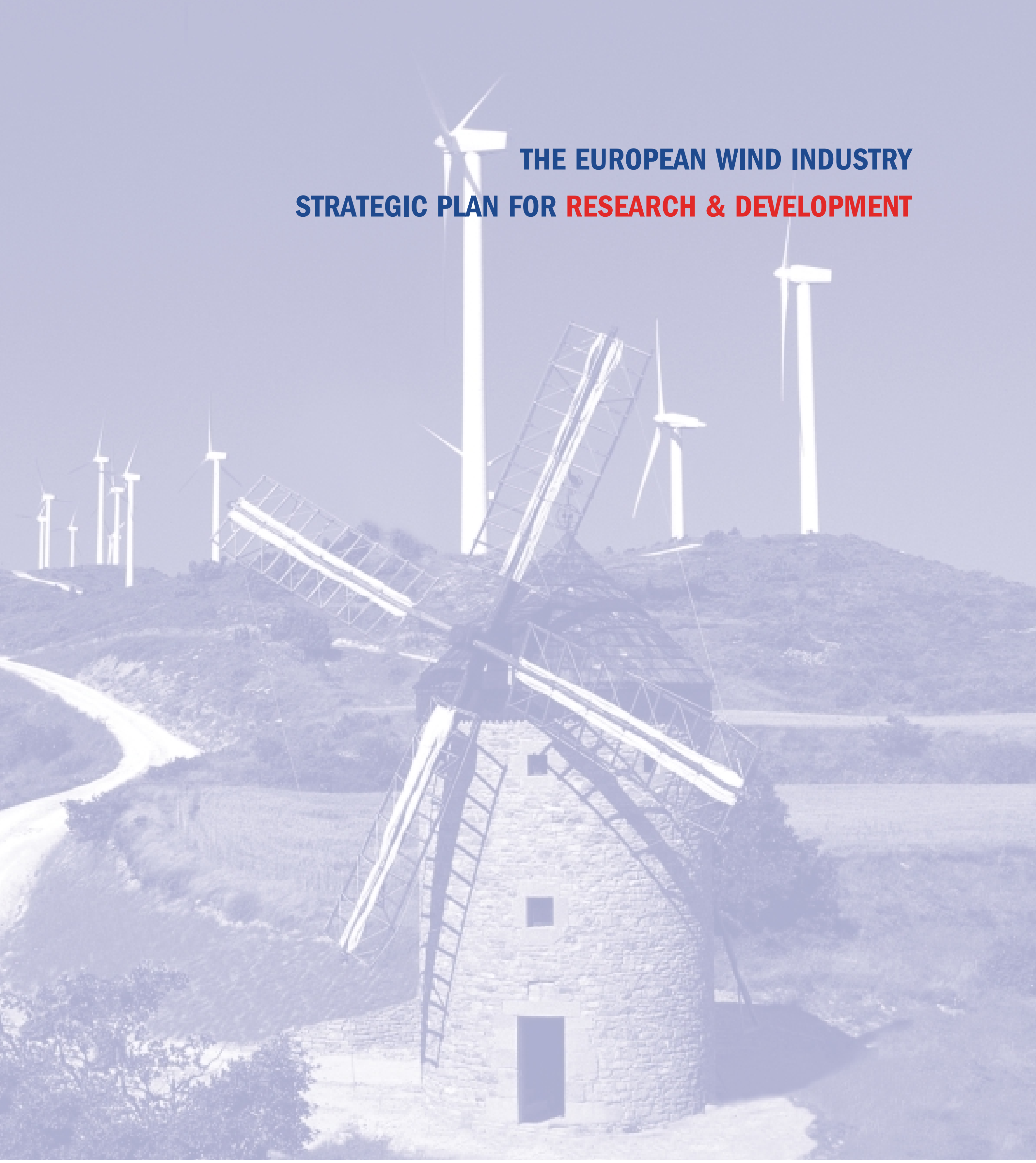
www.res-ltd.com

Elsam, representing end users: utilities & others

www.elsam.com

THE EUROPEAN WIND INDUSTRY

STRATEGIC PLAN FOR RESEARCH & DEVELOPMENT



FIRST REPORT: CREATING THE KNOWLEDGE FOUNDATION FOR A CLEAN ENERGY ERA

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INTRODUCTION

The Wind Energy R&D Network and EU R&D Programmes

The Wind Energy R&D Network brings together over 200 actors from across the wind energy sector, and enables dialogue between industries and other stakeholders with the common goal of substantially increasing the share of wind energy technology in global electricity markets. 31 GigaWatts (GW – 1000 megaWatts) of wind power capacity was installed globally at the end of 2002. Given the right framework conditions, in terms of market facilitation and R&D efforts, the EU could be leading a global industry installing 1,200 GW of capacity with a sales value of more than €600 billion up to 2020, bringing about a new era in European and global sustainable energy production.

This first report is a milestone towards the finalisation of the industry's R&D Strategy which will be released in the spring of 2005. It represents the results of consultations and workshops wherein a large number of actors from the wind sector have been involved, and hence its recommendations have very broad support in the European wind industry, from turbine manufacturers to wind farm developers and financiers. It lays out recommendations for national and EU based R&D, and proposes a pathway for future initiatives that, combined with other policy measures, can maintain and possibly strengthen Europe's global leadership in wind power technology.

This report should also be seen as a contribution to the European Commission's communication "A European Union strategy for sustainable development" which "invites industry to identify what it considers the major obstacles to the development and wider use of new technologies in sectors such as energy, transport and communications". This report does not constitute a complete list of barriers and obstacles to the development of wind power. It should be seen as vital R&D initiatives to complement other renewable energy policy initiatives.

Long-term commitment from EU and national R&D programmes, combined with close cooperation between industry and research institutions, has been a principal contributor to Europe's dominant position in wind turbine manufacturing and wind power industry R&D in general. The Wind Energy Network itself is a good example of the Community's support for wind energy R&D, being a European Commission funded project under the Fifth Framework Programme. However, EU support for long-term R&D in wind energy has been dramatically reduced in its Sixth Framework Programme. Priority for medium and long-term research in the field of sustainable energy systems (budget: €405 million) is instead given to fuel cells, hydrogen, CO_2 sequestration from fossil fuels, photovoltaics and biomass. As this paper shows, there is still much need to support long-term R&D in wind energy development, not least to develop new offshore technology. This was also the message from the IEA R&D Wind Executive Committee in its report: Long-Term Research and Development Needs for Wind Energy for the Time Frame 2000 to 2020. The report was presented in April 2002 and states that, although costs have already fallen dramatically, if wind energy is going to supply 10% of the world's electricity needs by 2020, cost reductions in the technology of 30 to 50% are still necessary. Research and development work could contribute up to 40% of those cost reductions, states the report.

This paper supports the view of the IEA R&D Wind Executive Committee and should be viewed as initial input to the future debate on the successor to the sixth Framework Programme. This is the first R&D strategy based on a broad input from a large number of actors in the wind energy sector. International co-operation among research institutes, manufacturing industry, financial institutions and end users – through the Wind Energy Network - will identify opportunities and barriers facing wind development, and specify R&D actions to overcome these.

Economic Efficiency through Reduction of Uncertainties

Economic efficiency can be increased through reduction of uncertainties throughout the wind energy production cycle, ranging from wind energy prediction to component reliability. It is a general objective of the wind industry to reduce these uncertainties. This leads to greater technical efficiency at reduced costs, and can be gauged via the technology indicators detailed at the end of this report.

The costs of services provided by finance and insurance companies can be reduced, and fears regarding security of supply will be allayed, if uncertainties in assessing both technical and economic risks can be decreased.

Requirements include improvements in:

1. Resource assessment and wind speed measurement
2. Wind turbine reliability
3. Performance predictions
4. Prediction of O&M costs
5. Increased maintainability of machines
6. Lifetime design methods
7. Grid assessment

Objectives of the Strategic Plan for Research & Development

1. Optimise R&D in the wind power sector, and develop a common position on its R&D needs.
2. Identify and prioritise R&D activities, and formulate a cross-industry strategy, bearing in mind commercial realities such as the need for commercial confidentiality and the changing nature of the R&D sector.
3. Provide co-ordinated advice from the combined wind sector to European Institutions.
4. Ensure the continuing support of the European Commission, Parliament and Council, through the European Commission Framework Programmes, such as FP6 and its successors, and retain European global leadership in wind power technology.
5. Demonstrate to EU institutions how wind power can help attain overall EU objectives, such as those under the Lisbon strategy, and the Barcelona Objective, and how wind power can help resolve issues such as security of energy supply, tackling climate change, and economic development.
6. Help the industry to reach the levels of wind penetration into the electricity supply system described in the EWEA feasibility study: Wind Force 12 - *A Blueprint to Achieve 12% of the World's Electricity from Wind Power by 2020.*

The Vision: a Strong European Wind Power Industry, Advancing Technology and Front-Line R&D

European collaboration and leadership can create a €75 billion wind power industry within two decades. Europe is the seedbed of wind power technology.

Wind Power Status in Europe by the End of 2002

- Generated enough power to supply the equivalent needs of 10.3 million European households, 25.7 million people.
- Supplied 2% of European electricity needs.
- 90% of the global wind power market was supplied by European manufacturers.
- 87% of global wind power capacity installed in 2002 was in Europe.
- 75% of total global wind power capacity is installed in Europe.
- The average growth rate of the European wind industry in the last five years has been 35%.
- By mid 2003, installed wind power in Europe was close to 25,000 MW.

The Market

Wind power is an outstanding European success story - over 70% of global wind capacity is installed in Europe, and European companies make 90% of the turbines sold worldwide. Market assessments and industry analysis predict that Europe will be the most significant market over this decade. For example, BTM Consult predicts that of 55,000 MW of new wind capacity installed 2002-2006, 67% will be in Europe. Europe is also leading an entirely new technology frontier in offshore wind development and deployment.

In the second decade of this millenium, other regions of the world are likely to exceed Europe in terms of installed wind power capacity, which could unlock a vast potential for exports if the European dominance in the sector is nurtured and maintained.

The success of wind power is based not just on energy policies and industry capability, but also on a concerted R&D programme which has been instrumental in achieving current European industry success levels. It is sometimes forgotten that in the 1980's the USA led the world in terms of installed wind capacity, although even then the hardware was largely European. Today, EU companies and institutions continue to dominate the industry, and the EU has taken the lead in installed capacity, via sustained long-term policy commitment and R&D leadership.

As the industry grows stronger and is dispersed around the globe, present EU dominance will face stiffening competition in technology, markets and knowledge leadership. Its strength can only be achieved with increased R&D into, inter alia, new technology, policy support options, and markets. According to the IEA, "*In order to achieve a 10 to 20% part of the worldwide energy consumption provided by wind, major steps have to be taken…it is for this objective that there is a need for long-term R&D*[ii]."

The EU Context

The EU faces many challenges on energy policy in the coming years – issues such as **security of supply**, **economic growth**, **increased global competition**, **employment**, **fuel price volatility**, and **sustainable development** including **climate change** have already been identified as key challenges for the European Union and its member states.

The wind power sector has the potential to respond positively an forcefully to all these challanges.

The Treaty Establishing the European Community calls for: "*balanced and sustainable development of economic activities*," and for "*a high level of protection and improvement of the quality of the environment*" (Article 2). Article 6 calls for the integration of environmental protection requirements in the implementation of Community policies with a view to promote sustainable development. Article 174 of the Treaty stipulates that the Community bases its policy on the environment on the principles that preventive action should be taken, that environmental damage should as a priority be rectified at source, and lays out the "Polluter Pays Principal."

The Lisbon Strategy

In March 2000, meeting in Lisbon, the European Council set out the ten-year Lisbon Strategy towards making Europe "*the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion*".

The European Council sets the direction of the Union's economic, social and environmental action at its annual Spring meetings. On March 20 - 21 2003, Heads of State or Government, Foreign and Finance Ministers and representatives from the accession countries discussed the Lisbon process. At this meeting the European Council identified environmental protection as a catalyst for creating European growth and employment and a priority in meeting the Lisbon goals:

12. To push ahead with reform, the European Council identifies the following priorities:
Environmental protection for growth and jobs. To achieve the Lisbon goals requires every member state to perform to its full economic potential; but this must go hand in hand with improvements in our environment and quality of life. Thus, pressing ahead with action in the environmental field remains as important as ever. This is an important factor for innovation and the introduction of new technolo-gies, which lead to growth and employment. Environmental targets will work as a catalyst for innovation and modernisation in key sectors such as energy and transport and promote new instruments in clean and more resource-efficient technologies.

At the same meeting, the European Council also "*renewed its commitment to stronger cohesion across the Union and the Union's leadership in promoting sustainable development around the world*".

Under the heading: "*Ensuring delivery on the environmental dimension of sustainable development*" the Presidency's conclusions from the European Council meeting states that:

53. Economic and social development will not be sustainable in the long run without taking action to curb environmental pressures and preserve natural resources within the framework of the comprehensive sustainable development strategy launched at Göteborg. This must include action aimed at decoupling environmental degradation and resource use from economic growth. Despite some progress, the worrying trends observed when the Strategy was launched have not been reversed, and a new impetus must therefore be given.

54. Against this background, the European Council:

- *invites Member States to accelerate progress towards meeting the Kyoto Protocol targets, including the reduction of greenhouse gas emissions, the increase in the share of renewable energy, setting an EU-wide indicative target for renewable energy of 12% of primary energy needs and of 22% of electricity needs by 2010 and encouraging national targets; increased energy efficiency, inviting the Environment Council to examine setting indicative targets in a cost-efficient manner and with minimum distortionary effects; and achieving a final agreement on the emissions trading Directive;*

- *urges the Council to adopt, before the Thessaloniki European Council, the "Intelligent Energy for Europe" programme and welcomes the agreement recently achieved on the Directive on the promotion of bio-fuels for transport, endorsing the setting of national indicative targets consistent with the reference value of 5,75% for the use of bio-fuels by 2010 for transport purposes. It welcomes the Commission's intention to present proposals, in the light of its forthcoming Communication, developing a Community framework for pricing of transport infrastructure and a proposal for euro vignette by June 2003;*

- *welcomes, subject to the opinion of the European Parliament, the agreement of Finance Ministers on energy taxation on the basis of the Presidency compromise as amended in the Ecofin Council meeting on 19 March;*

- *urges the Council (Ecofin) to encourage the reform of subsidies that have considerable negative effects on the environment and that are in-compatible with sustainable development.*

The Renewables Directive

The European Council's invitation to accelerate progress towards increasing the share of renewable energy, setting an EU-wide target for renewable energy of 12% of primary energy needs and 22% of electricity needs by 2010, and encouraging national targets, refers to Directive 2001/77/EC on the promotion of electricity from renewable energy sources (The Renewables Directive).

At an informal meeting between Environment and Energy ministers in Montecatini, Italy in July 2003, Environment Commissioner Margot Walström proposed an additional 2020 target for renewable energy of 25%.

The Renewables Directive entered into force on 27 October 2001 and aims at increasing the share of electricity from renewable energy sources from 14% in 1997 to 22% by 2010. It sets indicative targets for the share of electricity from renewable energy for all member states. It states that:

> *"(1) The potential for the exploitation of renewable energy sources is underused in the Community at present. The Community recognises the need to promote renewable energy sources as a priority measure given that their exploitation contributes to environmental protection and sustainable development. In addition this can also create local employment, have a positive impact on social cohesion, contribute to security of supply and make it possible to reach Kyoto targets more quickly. It is therefore necessary to ensure that this potential is better exploited within the framework of the internal electricity market."*

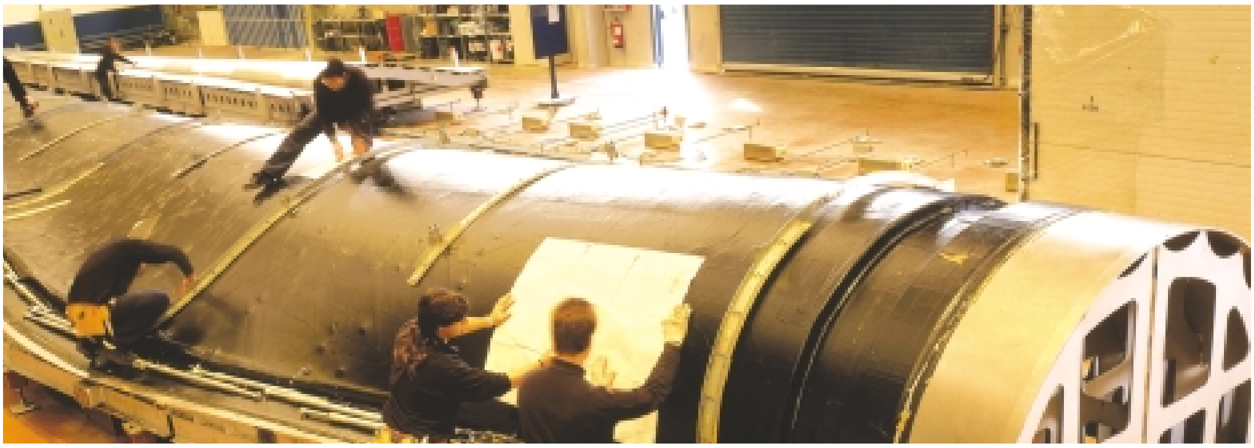
> *"(2) The promotion of electricity produced from renewable energy sources is a high Community priority as outlined in the White Paper in Renewable Energy sources for reasons of security and diversification of energy supply, of environmental protection and economic cohesion."*

The Renewables Directive provides the wind power industry with crucial assurance that the European Community is determined to further progress the development and integration of renewable energy technologies. It sends a powerful signal to the industry of long-term political commitment, which in turn reduces investment risk, and thereby the cost to society of developing, integrating and deploying renewable energy capacity.

A similarly powerful commitment to wind power research and development would complement these policies and would further the development of the technology, in particular offshore technology, reduce costs, and contribute to sustaining Europe's leading position on the global market.

Internal Electricity Market

The EU is currently in the process of completing the Internal Electricity Market, which is expected to be fully liberalised by 2007. It is generally recognised that the Internal Electricity Market is unlikely to create a perfect market or a level playing field in the short term. However, the RES-E Directive ensures that short-term distortions of European electricity markets do not undermine the opportunity to develop those renewable energy technologies that will facilitate a future European energy supply that is



indigenous, cheap, clean and independent of fluctuating oil and gas prices.

Towards a Level Playing Field

For many years, The European Wind Energy Association has called for a level playing field in the electricity sector, including the internalisation of external costs in electricity prices, and the removal of state subsidies to conventional energy sources. The European Commission and the European Parliament have actively pursued the same goals by, for example, proposing common energy taxes and reductions in the level of state aid to conventional energy technologies. EU decisions on energy and electricity require unanimity and, consequently, arriving at goals can be time consuming.

Progress has been made on common energy taxes. However, the minimum level of taxation for electricity - debated at the time of writing - is close to be the lowest common denominator (0.05 - 0.1 Eurocent/kWh), and considerably lower than originally proposed by the European Commission in 1997 and the European Parliament in 1999. At such a level, common enenergy taxes are unlikely to have any effect on the electricity market in the short term, and will contribute very little to the “Polluter Pays Principle”.

Until a level playing field between electricity generating technologies in the European Union beomes a reality, the Renewables Directive is a good substitute. It allows the wind power sector to develop renewable energy technologies that will secure the availability of cheap, clean energy to secure future European indigenous energy supply.

Security of Energy Supply

According to a Commission Green Paper on Security of Energy Supply, in two decades Europe will be importing 70% of its energy (up from 50% today), unless it changes direction. The recoverable wind resource in the North Sea alone is large enough to meet more than current EU electricity consumption.

Offshore wind energy is in its infancy - only some 400 MW of the total 25,000 MW of wind power installed in Europe is situated offshore. Nevertheless, wind power in general, and offshore wind power in particular, has the potential to plug the gap in European energy supply, while at the same time contributing greatly to the goals set out in Lisbon: Economic growth, high quality jobs, technology development, global competitiveness, and European industrial and research leadership. Furthermore, wind power and other renewable energy technologies will have a large impact in meeting EU Kyoto commitments and contribute to sustainable development. The Commission’s Green Paper on Security of Supply recognises this:

“Renewable sources of energy have a considerable potential for increasing security of supply in Europe. Developing their use, however, will depend on extremely substantial political and economic efforts. (...) In the medium term, renewables are the only source of energy in which the European Union has a certain amount of room for manoeuvre aimed at increasing supply in the current circumstances. We can not afford to neglect this form of energy.”

“Effectively, the only way of influencing [European energy] supply is to make serious efforts with renewable sources.”

Wind Industry Targets

The EWEA target for wind power installed in Europe by 2010 has increased from 25,000 MW in 1991, through 40,000 MW in 1997 to 60,000 MW in 2001, and to 75,000MW in 2003.

The EWEA publication, *Wind Force 12 – a blueprint to achieve 12% of the world's electricity from wind power by 2020*, outlines a scenario wherein 12% of global electricity production is produced from wind energy in 2020, with 100,000 MW installed in Europe by 2010, and 230,000 MW by 2020. The scenario is an assessment of what the wind power industry is capable of delivering with current state of the art technology and continued political support, rather than a forecast. To reach the levels of development envisaged by Wind Force 12, political action at global, regional, national and local level is needed.

As mentioned, the EU indicative target for 2010 is to provide 22.1% of electricity from Renewable Energy Sources[ii].

EWEA Installed Capacity Targets in the EU-15

	Onshore (MW)	Offshore (MW)	Total (MW)
2010	65,000 MW	10,000 MW	75,000 MW
2020	110,000 MW	70,000 MW	180,000 MW

New Role for the R&D Sector

Industry design and development departments have grown to such an extent that the character of interaction and the relations between industry and R&D institutions have changed. This is causing a development in R&D institutions: to turn towards longer term, strategic R&D: wind turbine and system technology in the future – 2 to 10 years ahead, as well as continuing specialised R&D services to industry.

Demand for wind energy systems has developed very quickly, and, due to short times to market, manufacturers have, in some cases, been unable to put aside sufficient resources for fundamental research, consequently having difficulty in fully incorporating R&D findings in their designs. Full integration of R&D findings can lead to further cost reductions.

This report considers the direction that research should take into the future, and changing interactions between industry and research institutions.

Priority R&D areas

1. Economic, Policy & Market Issues
e.g. assessment affecting wind farm investments and market barriers

2. Environmental & Social Impacts
e.g. enhancing local incentives by developing participation models

3. Wind Turbine & Component Design Issues
e.g. basic research in aerodynamics, structural dynamics, structural design and control

4. Testing, Standardisation, & Certification
e.g. common accepted certification procedures for wind turbines and wind farms

5. Grid Integration, Energy Systems & Resource Prediction
e.g. forecast of wind resource

6. Operation & Maintenance
e.g. advanced condition monitoring

7. New Potentials
e.g. in complex terrain and remote areas where satellite technology can be used, among others, in the formulation of wind atlases – showing the wind resource

8. Offshore Wind Technology
e.g. research into the control and efficiency of very large wind farms and more cost effective foundations, transport and installation techniques

9. Mega Watt and Multi-Megawatt Wind Turbines
e.g. application of new materials with improved strenth-mass ratio and development of lighter components

Research tasks falling into these nine categories should be undertaken across the wind community and supported in the successor programmes to FP6 to achieve more optimal efficiency and a more aggressive development. These nine areas are addressed in the following sections.

The market has taken over from technology in driving turbine development: the first large turbines were developed as technology demonstrators under state funded research programmes, and never made it to market, while today's turbines are developed primarily on the basis of lower price per kWh.

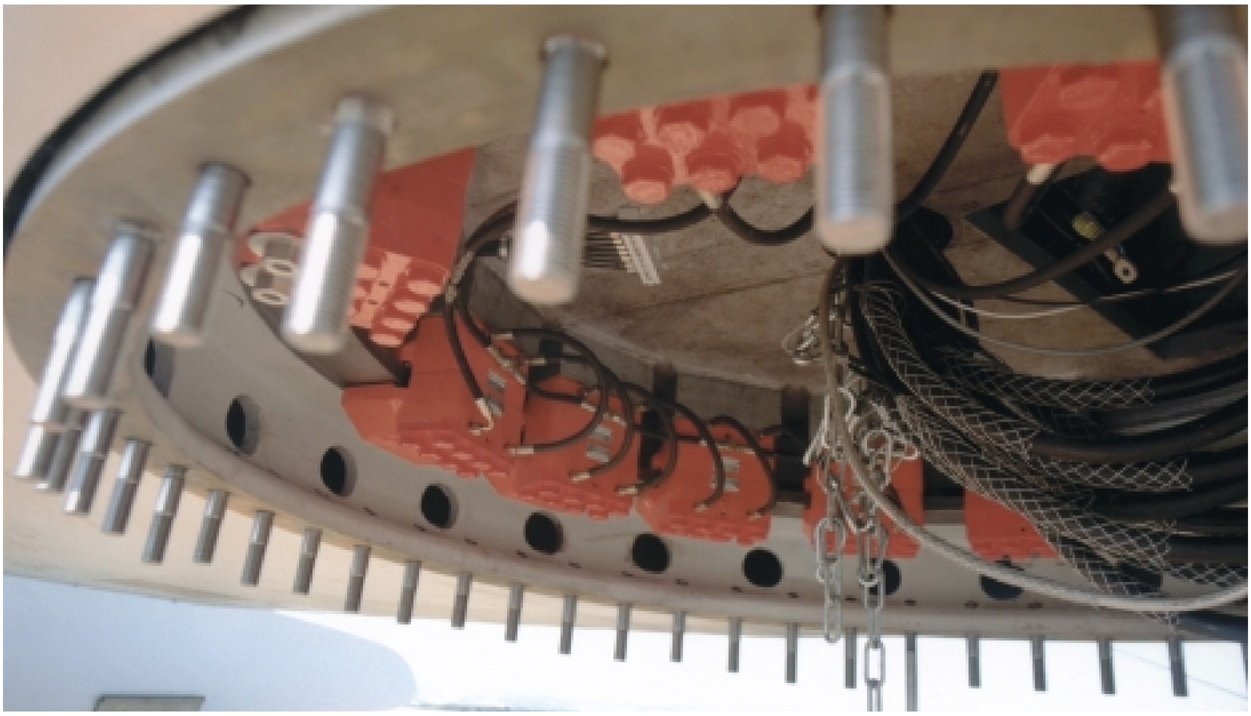
Wind Turbine Market Segments

Wind turbine systems exist in a range of capacities, depending on the application, and different methods of distinguishing between them may be employed. For the purposes of this report, the technology is divided into four categories or market segments as shown below. These divisions are important, as very different conditions apply to the different sectors, and each segment has particular R&D needs.

Cooperation in a European research area is the way forward: for example, institutes can contribute to the development of standards and measurement techniques; manufacturers, developers, financiers, etc., should come together to discuss scope and needs in such forums as the Wind Energy Network.

Category/Market Segment	Type of Application	Installed Power
A	Onshore, grid connected farms	larger than 1.5 MW
B	New offshore	larger than 1.5 MW
C	Onshore grid-connected turbines	0.5 MW to 1.5 MW
D	Onshore decentralised turbines for weak grid/hybrid/stand-alone operation	0.1 kW to 500 kW

There are wind turbines on the market outside these four market segments, but these are seen as the most important segments in the future.



CATEGORY A - ONSHORE WIND TURBINES LARGER THAN 1.5 MW

Many different design concepts are in use, the most common at present being three-bladed, stall or pitch regulated, horizontal axis machines operating both at near-fixed speed and variable speed. Turbines are clustered into farms, which require specific systems R&D. Focal points are design development to reduce costs and weight, control systems, improvement of power quality, system and grid stability, operational management systems (maintenance based on conditioning monitoring and early failure detection), system reliability and output forecasting. Power transmission is also an important issue.

CATEGORY B - NEW OFFSHORE WIND TURBINES LARGER THAN 1.5 MW

A few design concepts are installed in a few offshore wind farms, the most common at present being three-bladed, active stall or pitch regulated, horizontal axis machines operating at near-fixed rotational speed. As in category A, turbines are normally clustered into farms with the same R&D focal points. Here, specific offshore aspects are also important e.g. wave and ice loads, special emphasis on O&M due to its influence on the total energy production costs. As with Category A machines, power transmission is an important issue.

Enercon E-112 4.5 MW prototype

CATEGORY C - ONSHORE WIND TURBINES OF 0.5 MW TO 1.5 MW

Most of the generating capacity of early wind farms and individual privately owned turbines fall into this category. Category C machines are mostly installed on land, and were the basis of the learning curves on which predictions of future generating costs and long term wind capacity targets were based. Areas of improvement include more efficient designs (lower costs), power quality, control systems and system design for autonomous hybrid units.

CATEGORY D

For remote areas with weak grids in both the industrialised and developing world, machines of approximately 0.1kW - 500 kW still find a sizeable market that at present is undeveloped because the majority of the established industry is focusing on the booming market for larger machines. Some niche-oriented manufacturers are focusing on this market segment. EWEA is at the time of writing involved in the formulation of the Small Wind Industry Implementation Strategy. For further information on this issue, please consult www.ewea.org

1 SOCIO-ECONOMIC, POLICY & MARKET ISSUES

Cost reduction of a market product can be characterised by means of the progress factor. This is the actual cost relative to previous cost, on each doubling of cumulative production volume. As the Danish wind industry has been operating at a high level longer than any other, it provides the basis here for calculation of the progress factor. From 1980 to 1995 the progress factor was fairly constant at a level of 80%. Of the 20% cost reduction, about 15% has been due to design improvements and more efficient manufacturing, and about 5% to improved siting.

There is an overall need for cost reduction, risk management, and research that can increase the value of wind energy. Milestones towards cost reduction need to be defined.

1.1 Development Costs

As turbines become larger and more powerful, requiring more advanced technology, expertise and refinement, greater development costs, such as increased engineering and testing hours, become apparent.

New turbine models are increasingly complex, yet little time is dedicated to prolonged testing, after a turbine has been deemed ready for market - due to market pressure for the new larger turbines. As a result, potential industry experience based on predecessor designs is reduced, and extensive workshop testing of components is required, as well as increased testing of turbine prototypes, before products may go to market.

Increasingly complex control requirements due to the advanced design of wind turbine systems and farms are also contributing to an increase in development costs; wind farms have not only to ensure efficient operation in varying meteorological conditions, but have also to answer the general requirements of the transmission and distribution (T&D) networks to which they are connected: such as high power quality and steady output under unstable grid conditions. Often these requirements do not take into account the distributed nature of wind power generation, as distribution and transmission systems were developed for large centralised fossil fuel and nuclear power plants.

There is a tendency towards higher project management costs as well as costs associated with Environmental Impact Assessments (EIA) and grid connection. Project management costs can be reduced through the development of norms and standards. The costs of Environmental Impact Assessments can be reduced through greater coordination between researchers, industry and government as well as through the development of knowledge databases. Grid connection costs can be reduced by redesigning the EU grid and grid codes to better reflect the distributed nature of the technology.

1.2 Manufacturing Costs - Non Site Bound

Manufacturing costs have decreased over time due to the development of more and more production friendly designs, more efficient production and economies of scale. Furthermore, implementation of ISO 9000 systems and "Just in Time Production" are lowering manufacturing costs and increasing quality and reliability. Also, specialisation in the manufacturing of turbine components from sub-suppliers makes it possible to reap economies of scale and further reduce wind power production costs.

1.3 Project Costs - Site Bound

Project costs include turbine investment costs, civil works, transportation and erection costs, grid connection and EIA costs. Further costs include insurance, legal and financial costs, and planning and permitting costs. Many factors, ranging from O&M (performance), wind speeds, availability, amortisation periods and real interest rates affect the level of these costs.

Reduction in project costs can be expected through rigorous technical and economic standardisation, facilitating the specification of components, and their certification. This means greater transparency and increasing competitive pressure, and consequently, greater efficiency in the market place.

TRANSPARENCY

Despite EU efforts to remove legal barriers between member states, many country specific regulations remain, hampering transparency and the free market. Greater European-wide harmonisation is vital for a future internal market in wind power. On another level, the issue of commercial confidentiality is likely to limit opportunities for full transparency.

The creation of (public) archives for data relevant to the assessment of wind-energy projects, such as the legal framework and wind site data will help increasing transparency. These would require large amounts of data collection, and possible actors would have to be found, although it should be noted that many project developers consider wind site data to be confidential.

Greater transparency could be achieved through the following:

- Categorisation of turbine types on the basis of manufacturer data; further use of ISO/IEC and CEN/Cenelec standards; and development of new standards.
- Development of a risk assessment standard for wind turbine projects.
- Certification of standards for wind energy projects addressed to financiers and insurance companies.
- Increased transparency in respect of weather related issues on the one hand, and with regard to operational damage on the other, taking into account the perspective of the insurance industry.
- Standardisation of a claims record, by manufacturer and turbine type, for use of insurers and developers; and the generation of an accidents and incidents database.
- A continuously updated web based database of member state rules and regulations: policy instruments, planning and construction regulations, permit and environmental issues, tax law, corporate law, etc.

PROJECT CERTIFICATION & FINANCIAL RISK ASSESSMENT

A positive project rating, in terms of financial risk assessment, can reduce the costs of financing and insuring wind farm projects. On the other hand, duplication in the assessment of wind farms can cause inefficiently high transaction costs. The development of a standardised and all-encompassing risk assessment system that would cover the majority of a given project would reduce the extent of individual assessments. Similarly, this system should be used for the accreditation of project actors.

In contrast to the desired decrease in insurance costs, a rise may be seen if current assessment methods are not altered. An alternative might be the creation of emergency/self help funds, or the distribution of the insurance burden over the industry as a whole through the creation of an association for mutual insurance. Further research would be required into establishing what reserves are necessary to minimise liquidity risks, and into what areas would be covered by such insurance: political risk, legal changes, force majeure, weather related damage, etc.

Increased certification will reduce the extent of individual assessment of projects, and will enable the wind industry to take advantage of economies of scale: if every project has to supply its own expertise in technical, legal, and economic areas, redundant work is done.

Certification of wind-energy projects can facilitate not only financing/insurance through the elimination of risk uncertainty for banks, etc, it would also facilitate access to private investor equity.

Essential issues in the scope of certification are:

- *External conditions for specific sites*
- *Wind turbines and sub-system components*
- *Condition monitoring*
- *O&M monitoring*
- *Project administration*

CAUSES OF EXCESSIVE PROJECT COSTS (SITE-BOUND)

Difficulties encountered during the implementation of wind power projects, which drive up the risks of financing and insurance of projects - and overall costs - include:

1. Delivery difficulties and delays during construction and maintenance. For O&M, components should be routinely available for delivery within 72 hours.
2. Missing technical data on risks of project failure, leading to generalised treatment of risk based on data from other RES industries such as hydropower.
3. Short guarantee periods. Three options remain to the wind farm operator at the end of a guarantee period:
   a. *Extend original contract with manufacturer*
   b. *Continue maintenance independently, for which great expertise is required.*
   c. *Take on the services of a specialist O&M provider*
4. Insufficient wind resource data. Sites might be classified along the lines of the agribusiness industry.

1.4 Increasing the Value of Wind Power

At present, value is not only determined by avoided fuel cost of fossil-fuelled plants through installed wind capacity: increasing predictability in power output, and increase in capacity factor has raised the value of wind electricity. Equally relevant are cost components in electricity production, such as environmental benefits, and consumer preference for green electricity, which are not internalised in electricity prices.

Key routes towards increasing the value of wind electricity include:

- Development of output forecasting models
- Improved controllability of large wind farms
- Effective quantification of external benefits of wind energy

As the cost-value ratio is optimised, the economic drive to realise wind energy plants will grow. For society, wind energy – like other renewable energy technologies – represents many different values: displacement of fossil fuels that yield hazardous greenhouse gas emissions; increased security of supply through supply diversification; independence of volatile coal, gas and oil prices; reduced depletion of non-renewable natural resources; and sustainable employment. It is not obvious how these advantages are to be internalised in electricity prices, particularly given the subjective nature of value judgements. R&D is required to establish a methodology by which these values may be quantified.

1.5 Education & Human Resources Development

1.8 million job-years will be required to meet the EWEA target of 12% wind electricity worldwide in 2020, as laid out in its report "*Wind Force 12 – A Blueprint to achieve 12% of the World's Electricity from wind power by 2020*". Education and training are required in both technical and non-technical capabilities in order to provide a skilled workforce to satisfy future demand. In 2003, the European Academy of Wind Energy was established with the aim, inter alia, of providing for this demand. Visit www.eawe.org for further details.

Key Objectives

- Establish where skill shortages will occur along growth curve
- Joint international R&D programmes in universities
- Develop training schemes to supplement work-based training.
- Establish specialised professorships at universities
- Develop educational material for primary and secondary schools

Education institutions should also incorporate wind energy technology into their curricula to generate sufficient numbers of highly qualified wind energy personnel to satisfy rapidly increasing demand for such.

2 ENVIRONMENTAL & SOCIAL IMPACTS

It is essential to continually express to the general public the predominately positive social aspects of wind energy, in order to maintain and improve its support for wind power. R&D efforts should aim to increase public involvement, and to further minimise social impacts.

Clear understanding both of the external, social and environmental costs of conventional power generation; and of the external costs of large wind penetration, is needed in order that accurate comparison may be drawn. The external environmental costs of fossil and nuclear electricity production are as yet insufficiently expressed (and are generally not accepted by policy makers in the EU countries). As a result, external costs are seldom taken into account when energy policy is developed. The effect is that decisions on energy and electricity supply are not economically efficient when seen from the wider socio-economic perspective.

Development of local economic incentives would increase public support for wind power. EU, national and local governments should develop favourable tax regimes that would have local benefit. If turbines were to be equated with local income, or tax breaks, their significance would become more positive. Success stories, where wind has been responsible for local economic and community based regeneration, should be expressed to politicians and the broad public.

Social R&D Objectives

- Development and verification of public participation models.
- Assessment of the positive social effects of wind energy, such as local employment, investment, taxes, etc.; and the creation of local networks to express these local benefits.
- External costs: an accepted methodology for the assessment of environmental savings through the use of wind energy is needed, to establish a quantifiable and cogent benefit.
- Clear understanding of the external social and environmental costs of conventional power generation, as well as of possible external costs of large wind penetration, is needed so accurate comparisons may be drawn.

Environmental concerns vary substantially between offshore and onshore sites and the two sectors should be approached individually.

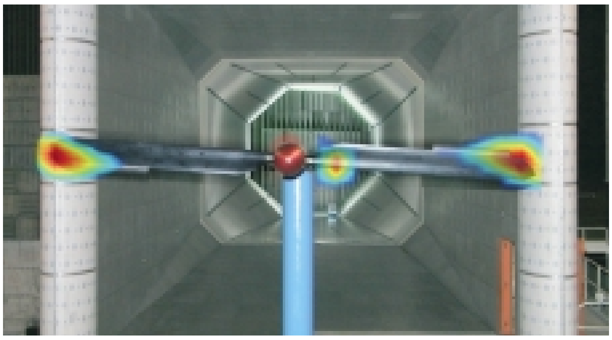
Environmental R&D Objectives

- Recommendations for limits on stroboscopic effect/shadow flicker (taking into account seasonal variations) in residential areas and other sensitive areas.
- Methods should be developed to integrate turbines visually into the landscape on an individual turbine and wind farm basis. This may be approached in two ways: through design of individual turbines; and their effective siting in the landscape, with the use of camouflage and stealth techniques.
- The reduction of noise impacts to decrease the minimum required distance between turbines and residential areas. This would increase the potential for wind energy utilisation in populated areas. Methods to predict the noise level generated by turbine blades, gearboxes, generators and transformers need to be improved through more fundamental R&D, leading to the production of low noise blades, gearboxes, and generators.
- Turbine interference on telecommunications/radar needs to be quantified. At present, large areas with high wind potential are restricted by the military. Real dialogue is needed among industry and the military, to establish an acceptable level of understanding in relation to national defence.
- The identification of areas where potential impacts exist on bird populations, habitats & flight paths, as well as ways of mitigating such impacts.
- A standard for turbine design involving the use of life cycle analysis to identify recyclable materials, and to specify how to dispose of non-recyclable elements, e.g. stand alone systems involving the use of batteries.
- Identification of potential cumulative environmental impacts of increased numbers of wind farms, across the EU.
- Decommissioning alternatives.

Decomissioning

Recycling opportunities should be explored as the disposal of certain materials, such as glass fibre and epoxy, might not be the best solution. Research into the use of wood and thermoplastics, which might be fully recyclable, is underway, as well as methods to treat polyester reinforced glass fibre with no environmental impact. The impetus for such research is not purely environmental. Local laws may impose severe conditions and production restrictions on materials used in wind turbine manufacturing.

The value of scrap metal yielded during decommissioning can contribute to the covering of decommissioning costs. Further investigation is required into the value of other potentially recoverable materials. An increasing amount of data will become available for such investigations in the near future as more turbines come to the end of their operating lifetimes, and are replaced.



Visualisation of Acoustic Noise Emission of Motor (DNW, University of Stuttgart, ECN)

3 TURBINE & COMPONENT DESIGN ISSUES

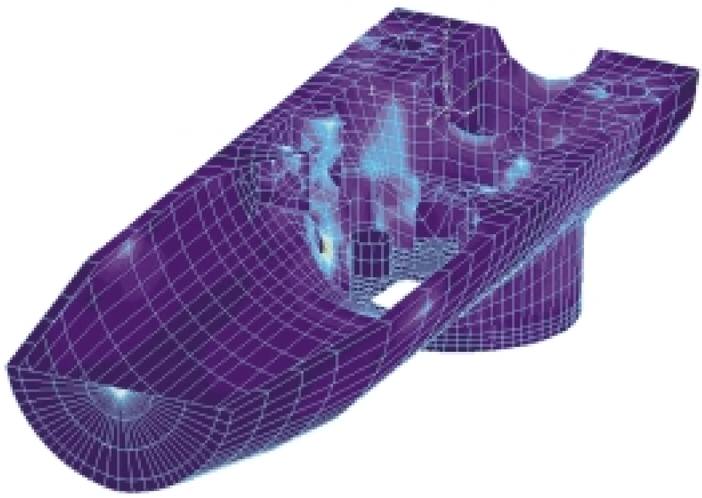
Continued R&D efforts are needed in order to improve the technical and economic efficiency of wind turbines and their components. Two areas of competition drive research to increase efficiency and decrease production costs of turbines: competition within the sector, and competition with other technologies for electricity production.

Enormous progress has been made to date in increasing efficiency, and in the cost reduction of turbine production. All categories of turbines are, to a varying degree, on the frontier of technology research, and room for fundamental medium and long term research must be created and maintained if further significant turbine production costs are to be made through design. To achieve this, an R&D programme specifically addressed to wind energy is needed, to enable the industry to deliver on the expectations of the EU community.

With sufficient support to R&D, turbine cost reductions of 15-20% may be realised, through the implementation of research results in turbine design.

Fundamental R&D must be combined with market driven development, and a doubling of accumulated capacity to achieve this cost reduction.

As seen in other sectors, involvement in knowledge networks will depend on the benefits and incentives it offers. By its nature, networks will have to overcome the fundamental differences in approach between manufacturers and research institutions. For example a bottleneck consisting of conflicting methodologies between traditional, fundamental R&D and market driven R&D may be seen to be delaying the arrival of new ideas in the market place. Sufficiently strong incentives to be involved will compensate for such difficulties.



Horizontal integration between the manufacturing sector and research institutions can be limited. The two are arranged on different time scales, and short-term commercial pressures do not go hand in hand with the longer timescales that tend to accompany fundamental (basic, applied and innovative) R&D. R&D institutions such as those involved in the European Academy of Wind Energy continue to provide essential services to the wind industry, yet there is a need for further cooperation. Within the European Research Area, a wider network for manufacturers, sub-suppliers and research institutions should be encouraged, yielding integrated, active research and aggressive implementation of research findings.

It may be useful for the Manufacturers group of the Wind Energy Network to further subdivide into the four market segments, from micro turbines to multi megawatt machines, as R&D potentials differ among these areas. These should focus on fundamental research issues connected to applications where potential cost reductions are identified.

R&D Objectives

- External design conditions (wind climate assessment etc.), aerodynamic and aeroelastic design, structural design, loads and safety.
- New materials with higher strength as well as higher internal damping.
- Advanced manufacturing technologies.
- Feasibility studies of new wind turbine concepts and innovations, e.g. flexible blades & hubs, and variable speed generator systems, to display potential for reducing cost per kWh.
- Methods of reducing O&M costs in the design phase.
- Reliability models leading to higher wind farm availability – particularly relevant regarding offshore turbines.
- Development of more efficient testing and verification methods to both shorten turbine development periods, and improve the quality of verification process.
- Integration of demand side requirements in the design of turbines, e.g. electrical control system interaction with grid requirement.
- Fundamental R&D into site-specific control of turbines to cope with variations in external conditions, e.g. high turbulence levels. One solution is to build in methods for fine tuning the aerodynamic and structural performance of rotor blades and associated fast field diagnosis instruments. E.g. if prohibitive vibrations appear during operation, control systems can be used to actively damp vibrations after the turbine is put in operation.
- Component design, such as longer blades, and electrical components.

Type D Turbines: RAMS - Reliability, Availability, Maintainability, Serviceability

A main barrier to the development of the market in small and micro turbines is maintenance & reliability together with economic development. It is unclear how best to maintain a low cost system installed in a remote location. This problem is exacerbated by the fact that the principal demand for these systems is in areas where either there is no electricity or where it is in limited supply, and where very often users do not have the resources to maintain, repair or purchase spare parts. R&D Priorities should be to concentrate on system packages (wind/diesel, wind/sea water desalination, battery charging, heating, pumping, etc.) and improving and simplifying the maintenance of those systems and where possible, a standardisation of components throughout the industry. A promising R&D topic in the long run is electrical energy storage in order to balance load fluctuations and bridge low windspeed periods.

Component R&D

Manufacturers need to invest more in wind turbine reliability and quality, specifically the medium to long-term performance of some components such as gearboxes, transformers and controllers.

Longer blades: this is an area which needs to be approached in a specialised way in which design, manufacturing, reliability, transport, logistics and end-of-life need to be investigated and developed. It should start with current materials but the use of new materials should be investigated. Research into increasing tip speed and correspondingly reducing tip noise should also be conducted.

Electrical components: the reliability and O&M of switchgear, transformers, cables, and over-voltage protection need to be investigated in depth. There is to some extent a trade off between cost and reliability. The risk exists that some players will go for lower cost designs sacrificing performance and reliability, which may hurt the industry. Once again the need for standardisation and certification is paramount.

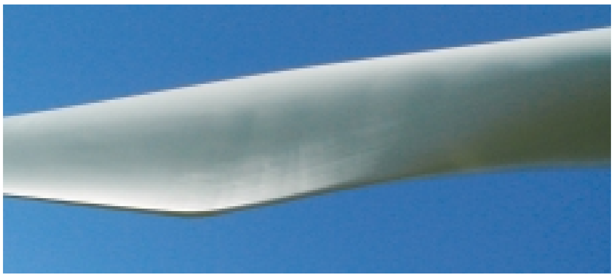
4 TESTING, STANDARDISATION, CERTIFICATION & SAFETY

Also discussed in the section on Socio-economic, policy & Market issues, standardisation, testing and certification are themselves the potential results, or indeed overall objectives, of the R&D process; they are essentially R&D results applied to specific areas. Standardised certification and testing techniques lead to increased transparency in the wind power market, and thereby reduce costs. For example, a certification system covering not only power-curves, but the entire turbine and project development process, along the lines of ISO 9000, would increase the insurability of the entire sector. Existing design certification might be supplemented by requiring testing of components under specific test protocols, as is the case with blades under the Danish approval scheme. Project certification can be done to a degree under the IEC-CAP standard, however, the CAP standard is not sufficient as it stands.

More transparency should be achieved in a step-by-step process. This might start with the creation of labels or a "charter of manufacturers" (open to manufacturers in France), eventually leading to fully-fledged certification/standardisation.

R&D Objectives

- Identification of standards lacking, and initiation of appropriate actions for new standards and background research.
- Background R&D into a standard for service and maintenance concepts, including labour safety.
- Guidelines and standards describing the steps in project development, according to sector (deep/near offshore; mountainous/isolated/coastal onshore, etc,).
- Procedures for the regular exchange of standardised parts should be agreed upon by the industry.
- Development of turbine type categories on the basis of ISO/IEC and CEN/Cenelec standards.
- Co-ordination of system development & testing programmes in place in major European R&D centres, with the full involvement of the manufacturing industry.
- Background R&D into standards for project performance testing (production verification).



High quality and efficient standardisation and certification are vital given the number of turbine types. Low quality turbines on the market would hamper the wind industry's reputation; as the market is sensitive to negative reporting. Standards designed for one market segment can be inappropriate in another, and standards across the segments should normally be limited to essential operating and safety standards.

Standardisation of sub-systems to increase the modularity of systems can speed up market development, giving a potential for reductions in production costs of wind systems, and also the design and engineering costs.

5 GRID INTEGRATION, ENERGY SYSTEMS, & RESOURCE PREDICTION

European utilities increasingly consider wind power to be a viable and reliable source of energy in the grid's supply portfolio. However, on the one hand reluctance exists to implement wind capacity; on the other hand, the total capacity of wind generation that can be absorbed locally and regionally by grids requires further understanding. Finally, the significant process of restructuring Europe's electricity sector should take into account specificities of large-scale implementation of wind energy across the EU. Generation, transport and distribution are gradually being separated, and privatisation may reduce new RES installations if public support is insufficient.

Integration of Wind Energy into Existing Energy Systems:

Technical Barriers/Issues

- Forecasting techniques can increase penetration by predicting available wind power, and assist in scheduling other power plant to cater for wind variability.
- Trans-European grids should ensure power flows from resource-rich regions of Europe to realise their full potential.
- In general, more technical co-operation is required with distributors and grid operators to facilitate increasing European wind power penetration on the European grid.

Political Barriers/Issues

- Sharing of costs of transmission upgrades between developer, locality and utility:at the moment there is no clarity as to who pays for project-specific grid upgrades, and utilities/distributors may be seen to take advantage of developers to finance grid upgrades, which have traditionally been the sole responsibility of the grid operators.
- More transparency is required in grid operation to enable cost effective grid connection solutions for wind projects.
- Grid operators may not be structured or have sufficient resource to be able to respond effectively to requests for grid connection from wind farm developers. This can lead to negative attitudes in the challenge of connecting new wind plant to a grid.
- In general, information on electrical grid technical characteristics is not freely available, which effectively delays or impedes free access to the grid. An independent body should provide technical information on grid characteristics for the benefit of developers planning wind parks.

R&D Objectives

- Development of scenarios for a redesigned EU grid system with high wind penetration. On the basis of the scenarios, development of methods to enable grids to cope with large-scale implementation of wind power.
- Optimise technical and economic planning tools for integration of 75,000 MW of wind power into the European grid by 2010.
- Increased predictability of system output. To develop electrical output prediction tools (meteorological forecast) to predict wind farm output 24-48 hours in advance.
- Increased accuracy, prior to installation, of wind farm electricity output using tools such as anemometry, terrain calibration, and the translation of power wind speed curves from test sites to installation sites.
- Increasing both power quality and consistency - increasing the value of wind generated electricity.
- Energy management and storage systems for stand alone applications.
- Develop demand side management tools enabling consumers to focus their electricity use during periods of high wind farm electricity output.

An increase in predictability of wind farm output will minimise the requirement for spinning reserve due to, for example, potential drops in output. Furthermore improved levels of grid interconnection among European countries will further reduce a need for spinning reserve, as intermittency becomes less of an issue with increased geographical spread. Analysis of spinning reserve requirements and intermittency should be conducted on the basis of the requirements of the entire electricity system rather than on a technology-by-technology basis, to achieve economic and technological optimal solutions.

Wind Farm Performance

The fact that wind turbines are clustered into bigger units requires specific R&D into large wind farm performance. On the one hand, national grids have to be able to absorb large amounts of varying electricity output and on the other hand, wind energy plants need to meet specific requirements such as the amount of reactive power produced, harmonic distortion, predictability and controllability of the power output.

6 OPERATION & MAINTENANCE

Operation and maintenance (O&M) requirements are driven by site conditions, quality of components and wind turbine design. Costs and electricity output depend on availability, and therefore on the reliability and accessibility of the wind turbine in question. In particular, wind turbines located in offshore locations and in mountainous terrain are subject to potentially very high costs due to availability losses through O&M. In this respect, fast development of early failure detection systems is essential. Data describing the properties of the wind turbines (e.g. vibrations due to different modes of vibration) may be used as inputs for improving the reliability of the wind turbine design.

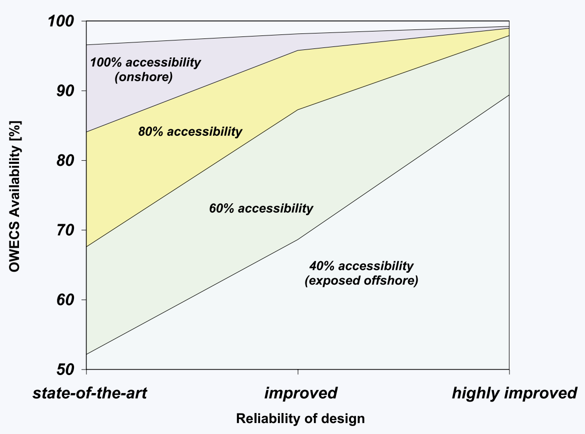
Scheduled maintenance managed by remote condition monitoring. Much research isneeded regarding early failure detection and condition monitoring to establish trends for predicting part failure. Statistical data on machine performance and component outage events is a necessary basis for maintenance optimisation.

O&M is not limited solely to turbines and their components, but has wider implications, on wind farm infrastructure for example, including access roads, and grid connection. The latter can be particularly costly in the case of offshore cabling.

The box below highlights some key O&M areas, and two further issues need to be resolved or circumvented:

- Increased costs of greater O&M investment must be justified in terms of greater return through increased availability.
- Commercial confidentiality hinders the availability of O&M statistics. Industry might consider approaching the issue in two ways:
  1. Through highlighting generic concerns via the Wind Energy Network to fundamental research establishments.
  2. Through high-level focused technical discussion on a strategic bi-/multi-lateral basis.

Availability as a Function of Reliability and Accessibility (Offshore Wind Energy: Ready to Power a Sustainable Europe, Concerted Action on Offshore Wind Energy in Europe, December 2001)



R&D Objectives

- Accelerated development of early failure detection and condition systems.
- Cross industry analysis of turbine and component performance and maintenance statistics.
- Resolution of confidentiality issues.
- Increased understanding of the drivers behind O&M costs in offshore sites.
- Developments in preventative maintenance.
- Standardisation of components, and turbine documentation for easy replacements.
- Harmonised methods and certification of O&M companies to a high standard.
- Establish customer priorities – “must haves” and “nice to haves”.
- Certification of service and maintenance concepts.
- Better techniques for assessing wind turbine and wind park performance in situ.

7 NEW POTENTIALS

Already, in some densely populated countries with a high level of installed wind capacity, the best sites, in terms of available wind resource, are being exploited. There is limited space due to other interests (e.g. nature, military). Initiatives should be taken to improve the perceptions of local populations and involve them in the decision making process. In densely populated coastal countries, offshore sites are the 'new' option, while in mountainous land locked countries, sites are found in complex terrain, such as funnels, hills and mountains. Other areas include those with icing climates, and possibly built up areas.

R&D Objectives

- Offshore resource assessment, also showing exclusion zones: shipping lanes, grids, pipelines, military, flora & fauna, water depth.
- Complex terrain resource assessment, also showing sensitive areas.
- Cold and icing climates resource assessment.
- Testing sites design conditions and methods to be adapted to mirror new site requirements.
- Market surveys of developing country markets (particularly category D turbines).
- Complement the European Wind Atlas with resource data of the North Sea, other offshore areas, and high potential mountainous sites.
- Dedicated wind turbine types for low wind speed inland locations; for high wind speed/high turbulence locations; and for cold climates and offshore locations.

Complex Terrain

There is an urgent need for more reliable methods for the prediction of wind conditions in complex terrain. At present there is very limited support for R&D in this area. The wind energy community is collaborating with meteorological institutes, and carrying out its own research. Also the short-term prediction of the output of farms in complex terrain is limited because of a lack of knowledge and tools.

Remote Areas

The potential for wind turbines in icing environments needs further investigation. Particular issues to include in R&D programmes include: blade heating versus power performance, and safety aspects of ice-throw from the blades.

Developing World Markets

In the developing world, priority should be given to market development, before dedicated R&D efforts can be fully utilised. Following identification of possible markets, market demand should be built and financiers reassured through large-scale demonstration programmes. In parallel, technology oriented R&D programmes should be re-initiated, and carried out by industry in co-operation with R&D institutes.

8 OFFSHORE WIND

Broadly speaking, offshore wind technology falls into two baskets: shallow sea - normally near shore - and deep offshore, differentiated in terms of water depth, distance from shore, maximum wind speeds and wave heights. Apart from resulting impacts on design specifications as well as transport and installation equipment, these external conditions greatly affect the accessibility of wind farms, and thus O&M strategies and costs.

With poorer site accessibility, greater reliability is a pre-condition for success. Downtime for offshore turbines is an even more serious issue than for large onshore turbines, as it is compounded by lower accessibility: 1 day of downtime for an onshore turbine may translate into 2.5 days of downtime for an offshore machine.

R&D Objectives

- Monitoring of environmental impacts of near- and far-offshore projects. Near-shore projects in particular may risk impacting environmentally sensitive areas.
- Potential conflicts of interest: defence, fisheries, shipping, oil & gas exploration & pipelines, and sand mining, etc.
- Legal research into offshore ownership in coastal waters, Exclusive Economic Zones, etc.
- Higher tip speed designs, as noise issues are less significant offshore.
- Minimisation of O&M-related downtime. The distance offshore and the water depth at the site have significant impacts on O&M.
- Special designs of systems and components for erection, access and maintenance of offshore turbines.
- Design studies of systems rated above 5 MW for offshore including possibly multi-rotor systems.
- Offshore meteorology – shore and long-term forecasting; hardware for measurements.
- Development of alternative, and deep water, foundation structures.
- Combined wind and wave loading.

At sea, wind turbine developers are faced with many different environmental requirements; there is a need for standards to specify these requirements, and regarding the assessment of the impact of wind farms on the environment.

R&D efforts should be concentrated on fully exploiting the inherent advantages of offshore sites: the absence of noise emission constraints (tip speeds of rotors can be higher, leading to smaller transmission ratios and lighter drive trains) can lead to lighter and cheaper machines. Lower turbulence intensities similarly mean longer lifetimes and relatively cheaper constructions.

Integration of wind and wave loading into the structural dynamics codes is necessary to avoid over dimensioning - the combined wind and wave-loading spectrum is lower than if they are treated separately - applying this in the design will again lead to lighter, more economic, structures. There is a need for background R&D to investigate and establish realistic recommendations, which are both safe and not overly conservative.

Parallel Development

Offshore and onshore R&D should be integrated to a degree. Although the parameters involved in onshore and offshore R&D differ, the issues are essentially the same. For example, loading must be analysed for both offshore and onshore turbines, and although different data sets exist in each case, the software necessary to analyse them can be of similar type. Such integration would also help avoid potential conflicts of interest between industry in the coastal countries of northern Europe and southern Europe, the former typically having a larger offshore resource, and it would reduce duplication in R&D efforts. Furthermore it should be borne in mind that although the offshore sector is growing fast, by 2020 it is estimated that three quarters of installed capacity will still be onshore[iv].

9 MEGAWATT & MULTI-MEGAWATT TURBINES

The most important arguments for the development of larger machines are: for the exploitation of offshore sites, where a higher wind resource exists (typically 40% more energy content in the wind compared to onshore); relatively lower foundation and grid costs; and reduced visual impact on the landscape per unit of installed power. Demand drives the trend towards larger machines while R&D is increasingly expensive and complex as turbines increase in size and use more advanced technology, and yet new models are released with increasing frequency.

R&D Objectives

- Fundamental wind turbine design research (aerodynamics, aeroelasticity, structural design, loads and safety, control, etc.).
- Development of test facilities to follow turbine developments.
- Adequate testing and certification of new turbine technologies, for insurance and finance purposes, such as "0-series" turbines (turbines for areas with low wind resource).
- Modelling of O&M requirements for large turbines, before installation.
- Effective output forecasting methods for large turbines.
- Transport requirements for blades: e.g. built in segments to reduce transportation size.
- Partnership between fundamental and market driven research is essential in ensuring reliability of multi megawatt turbines.

It is not yet clear how to prove and certify large MW turbines, as standards have not yet been fully developed, and therefore much is left to individual interpretation. Reduced insurance and investor confidence results from this, and increased project costs would follow.

Grid Integration

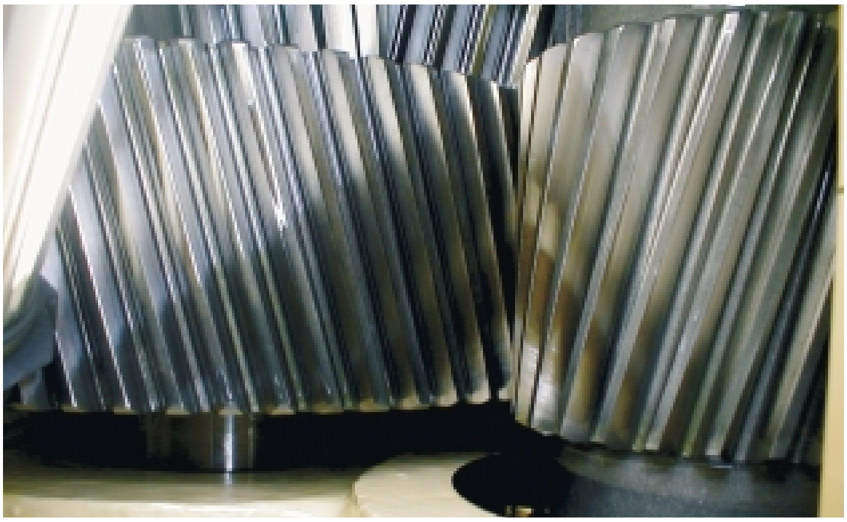
European and national governments are greatly concerned with security of supply, and will increasingly require proven standards in power output. Turbines should remain on grid as much as possible, with, consequently, the need arising for developments in low wind speed operation. Transmission and Distribution network operation should be remodelled taking wind energy into account as large-scale as well as decentralised contributors to total electricity production, rather than considering wind as an element to be considered in isolation. (This subject is dealt with in greater detail above, in section 5.)

10 INDICATORS FOR TRACKING TECHNOLOGY DEVELOPMENT

European Commission state-of-the-art indicators have been developed[v] by the Directorate General for Transport and Energy. A summary of these indicators is provided in the box below.

1. **Advances in Research** (largest rated power, largest blade length & width).
2. **Performance Indicators** (efficiency, load factor, energy recovery factor, specific energy production, technical availability, economic lifetimes, design lifetimes, noise levels).
3. **Specific Area/Sectorial Indicators** (blade weight, Blade weight over length ratio, top weight/rotor area).
4. **Technological & Scientific Development** (turbine type, number of blades, blade materials).
5. **Technology Wide Indicators** (including hub height, diameter range, largest onshore and offshore wind farms in operation).
6. **Cost Indicators** (manufacturing cost per kWh, offshore production cost, typical onshore & offshore turn-key costs, wind turbine costs including tower and excluding transformer, cost/m^2 of swept area, typical onshore & offshore O&M, typical onshore & offshore pay-back time on investment, onshore & offshore decommissioning costs, typical externalities, typical space requirements).
7. **Market Size and Industry Related Indicators** (total EU installed capacity, total worldwide installed capacity, actual installation rate, average WECS size, manufacturing capacity, production employment, total employment, typical length of time from order to operation).

For further information on wind energy technology, indicators, visit www.cordis.lu/eesd/src/indicators.htm



Notes

[i] See www.ewea.org for the full report

[ii] IEA Topical Expert Meeting "Long Term R&D Needs 2000 - 2020" The Netherlands, March 2001

[iii] Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 - on the promotion of electricity produced from RES in the internal electricity market

[iv] See www.ewea.org for full information on industry installation and electricity generation targets up to 2020

[v] Komninos Diamantaras, DG TREN, European Commission: *Energy Technology Indicators*

Conclusions: What R&D is required?

The Wind Energy Network, comprising discussions participated in by a large cross section of the wind energy sector, puts forward the following initial R&D recommendations and conclusions. These will be refined and built on in the final report of this study, to be released in the summer of 2005.

Broad Requirements

1. Long term wind energy R&D Broad Requirement programmes
   to increase economic and technical efficiency of the wind energy sector and the European electricity sector as a whole.
2. Fundamental long term R&D
   in such fields as aerodynamics & aeroelastics, structural dynamics & design, loads & safety, integration into the European electricity transmission and distribution system, and resource assessment & forecasting techniques.
3. European Standards for use by developers, investors & insurance companies
   on risk, economic viability, performance, reliability, and O&M of wind farms
4. European certification and accreditation systems
   for components, turbines and projects. Includes testing of components and turbines.
5. European codes of practice for access of wind power into transmission grids
6. Standard European planning procedures for site assessment
   taking into account wind regime, environmental and societal impact, accessibility, etc.
7. Full public participation in wind energy exploitation
   through exploration of local beneficial impacts.
8. R&D into the efficiency and control of very large wind farms
9. R&D into the dynamics of very large wind turbines
10. Concept development of integral optimised concepts of large wind farms both on land and offshore

Specific Tasks include:

1. Development of tools to identify new sites
   such as offshore, remote and complex terrain.
2. Remodelling of European-wide grid systems
   taking into account large-scale electricity production from wind, and the benefits of distributed generation.
3. Databases of member states' rules and regulations
   including national policies on planning, permitting and environmental issues.
4. Databases of environmental impact issues
   to include public opinion surveys, ecological impacts, etc.
5. Evaluation of market stimulation programmes & policy instruments
6. Evaluation of European harmonization requirements in general
   to prepare the sector for eventual inclusion in the Internal Electricity Market.
7. Reduction in installation, generation and O&M costs
   to optimise the cost/value ratio, and facilitate development of megawatt and multi-megawatt machines.

A strong research and development framework at the European level, encouraging the integration of fundamental and market driven R&D, is key for the European industry to reach its objectives, thus enabling it to maintain its global leadership. Furthermore, if the example is set at the European level, national and local governments will be encouraged to support research efforts and findings to further accelerate progress towards industry objectives.

R&D within a framework is essential to maintain the pace of development of the wind power industry, which will be key in the fulfilment of the political goals and targets of the European Union, and of the broader international sphere.