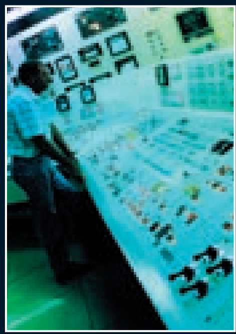
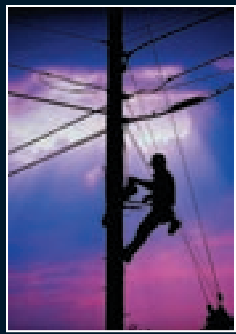
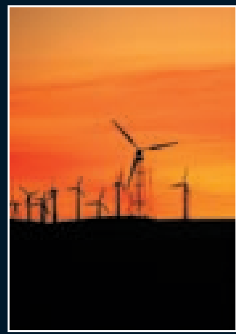




LARGE SCALE INTEGRATION OF WIND ENERGY IN THE EUROPEAN POWER SUPPLY: analysis, issues and recommendations

Executive Summary

RATIONALE

1. *We now live in an era of energy uncertainty. The days of cheap and abundantly available energy are over.*

2. *Europe is running out of indigenous energy resources in the form of fossil fuels at a time when a paradigm shift in energy prices is occurring. It is clear that this century will be characterised by intensified competition for energy which will inevitably push up prices, lead to periodic scarcity and precipitate a scramble for reserves among the world's main economic blocks.*

3. *Europe's dependency on imported fossil fuel has become a threat to economic stability because of the impact of increased fuel prices on the cost base, most notably on the price of electricity. It is essential that Europe develops its own internal energy resources to the maximum extent possible, as well as promoting energy efficiency.*

4. *Europe is an energy intensive region heavily reliant on imports; already today, it imports 50% of its energy needs and that share is likely to increase to 70% within two decades unless Europe changes direction. By 2030, oil imports would rise from 76% to 88% and gas imports from 50% to 81%, compared to 2000. Indigenous fossil fuel resources, such as the North Sea, are in rapid decline.*

5. *Europe is the world leader in renewable energy and in the most promising and mature renewable technology, wind power, it has both a competitive and comparative advantage.*

6. *Wind energy will not only be able to contribute to securing European energy independence and climate goals in the future, it could also turn a serious energy supply problem into an opportunity for Europe in the forms of commercial benefits, technology research, exports and employment.*

7. *The economic future of Europe can be planned on the basis of known and predictable cost of electricity derived from an indigenous energy source free of all the security, political, economic and environmental disadvantages associated with oil and gas.*

8. *There is an urgent need to address inefficiencies, distortions and historically determined institutional and legal issues related to the overall structure, functioning and development of the broader European electricity markets and power infrastructure.*

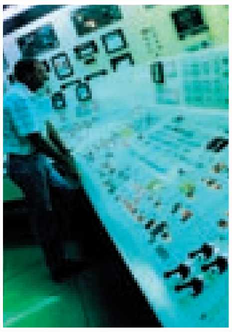
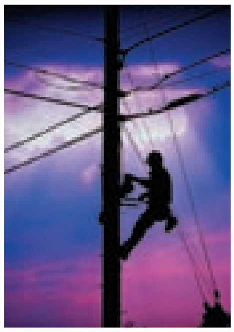
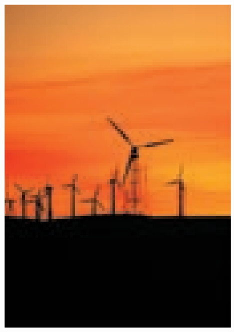
9. *The Commission has concluded that current electricity markets are not competitive for four main reasons: lack of cross-border transmission links; existence of dominant, integrated power companies; biased grid operators; low liquidity in wholesale electricity markets. These four barriers are also the main institutional and structural deficiencies preventing new technologies such as wind power to enter the market.*

10. *The major issues of wind power integration are related to: changed approaches in operation of the power system, connection requirements for wind power plants to maintain a stable and reliable supply, extension and modification of the grid infrastructure, and influence of wind power on system adequacy and the security of supply.*

11. *The need for infrastructure investments is not based on wind energy only; consequently, grid extensions, grid reinforcement and increased backup capacity benefit all system users. An integrated approach to future decisions is needed.*

12. *A large contribution from wind energy to European power generation is feasible in the same order of magnitude as the individual contributions from the conventional technologies.*

14. *The capacity of European power systems to absorb significant amount of wind power is determined more by economics and regulatory rules than by technical or practical constraints. Already today a penetration of 20% of power from wind is feasible without posing any serious technical or practical problems.*

LARGE SCALE INTEGRATION OF WIND ENERGY IN THE EUROPEAN POWER SUPPLY: analysis, issues and recommendations

Executive Summary

Foreword

Wind power is ready to be a mainstream energy supply technology across Europe.

One of the core challenges for wind power to contribute to the European energy supply at a penetration level comparable to that of conventional power sources, is how to effectively integrate significant amounts of wind power into European electricity systems.

The detailed analysis of the technical, economic and regulatory issues, which need to be addressed to move Europe towards a more secure energy future through increased wind power production, is contained in the EWEA report: *"Large scale integration of wind energy in the European power supply : analysis, issues and recommendations"*, (December 2005).

The analysis, conclusions and recommendations are based on a review of over 180 sources - published data, reports, research findings from all stakeholders across the power industry, operators, utilities and experts. This report is the most comprehensive and up-to-date assessment of the topic of large scale integration of wind energy in Europe.

The Executive Summary here presents the main findings of the report, its rationale, conclusions and recommendations.

Frans Van Hulle,
Technical Director, EWEA

Executive Summary

1. Background

Turning the energy challenge into a competitive advantage

Europe stands out in a global context as an energy intensive region heavily reliant on imports. Today, we are importing 50% of our energy needs and that share is likely to increase to 70% two decades from now unless Europe changes direction. Most of our oil comes from the Middle East and virtually all of our gas from just three countries: Russia, Algeria and Norway. Our economy is relying on the ready availability of hydrocarbons at affordable prices. Europe is running out of indigenous energy resources in the form of fossil fuels at a time when a paradigm shift in energy prices is occurring. Most observers agree that the era of cheap fuels is over and signs are emerging that competition for ownership of oil and gas is becoming fiercer and will intensify heavily in the coming years. The era of energy uncertainty has come.

It is clear that this century will be characterised by intensified competition for energy, which will inevitably push up prices, lead to periodic scarcity and precipitate a scramble for reserves among the world's main economic blocks. The continued economic and social progress of regions like Europe will depend in the short term on their ability to compete robustly for existing fossil fuels and, in the longer run, on their ingenuity in developing new energy sources which are independent of international competition and benign for the environment.

The cost of crude oil has doubled within the past two years from $25/bbl to $50/bbl, and a new peak of $70.85/bbl was reached in August 2005. The price of gas has followed the same trend which has a fundamental impact on the cost of generating electricity in Europe. It is clear that world oil and gas prices have risen much more quickly than anticipated, and it is evident that the EU dependency on imported fossil fuel has become a threat to economic stability because of the impact of increased fuel prices on the cost base, most notably on the price of electricity. Forecasts of economic growth are being revised downwards as the impact of higher fuel prices strengthens. The level of fuel risk in electricity systems has increased. In the era of low fossil fuel prices, this strategy delivered cheap electricity, but in an era of high fuel prices it can only deliver expensive electricity.

In its Green Paper on Security of Energy Supply in 2000, the Commission warned that the EU had a *"structural weakness regarding energy supply"* and stated that the EU *"must take better charge of its energy destiny."* The Commission baseline scenario highlighted that, by 2030, oil imports would rise from 76% to 88% and gas imports from 50% to 81%, compared to 2000. Indigenous fossil fuel resources, such as the North Sea, are in rapid decline and dependency on imports is correspondingly increasing.

It is essential that Europe develops its own internal energy resources to the maximum extent possible, as well as promotes energy efficiency. Europe is a world leader in renewable energy and in the most promising and mature renewable technology, wind power, it has both a competitive and comparative advantage. In 2004, European wind turbine manufacturers had a global market share of more than 80%. Wind energy will not only be able to contribute to securing European energy independence and climate goals in the future, it could also turn a serious energy supply problem into an opportunity for Europe, in the forms of commercial benefits, technology research, exports and employment. Without reliable, sustainable, and reasonably priced energy there can be no sustainable long-term growth and Europe will become economically disadvantaged.

The fact that the wind power source is free and clean is, of course, economically and environmentally significant but the more fundamental point at issue is that the cost of the electricity is fixed, once the plant has been built. The long-term implication is that the economic future of Europe can be planned on the basis of known and predictable cost of electricity, derived from an indigenous energy source free of all the security, political, economic and environmental disadvantages associated with oil and gas.

Wind power and European electricity

According to the International Energy Agency (IEA), the European Union will invest €100 billion in transmission networks and €340 billion in distribution networks for reinforcement, asset replacements and new connections over the three decades from 2001 to 2030. **Irrespective of whatever policy is chosen by the EU, massive investments in generation plants and grids are required.** For policy-makers, the question is the priority to be assigned to different fuels. The vision presented here is that wind power meets all the requirements of current EU energy policy and simultaneously offers a way forward in an era of high fuel prices.

Wind energy technology has made major progression since the generation of wind turbines from the early 1980s. Twenty five years of technological progress have resulted in today's wind turbines being a state-of-the-art modern technology - modular and quick to install. At a given site, a single modern wind turbine annually produces 180 times more electricity and at less than half the cost per kWh than its equivalent twenty years ago. The wind power sector includes some of the world's largest energy companies. **Effective regulatory and policy frameworks have been developed and implemented, and Europe is the undisputed world leader in wind energy.**

Wind provides less than 3% of European power needs, but is capable of delivering 12% by 2020 and in excess of 20% by 2030. Such penetration levels, however, will require that decision makers and stakeholders in the electricity sector work together to make the necessary changes to the grid infrastructure in Europe, which has been constructed and operated in the last century with large centralised coal, hydro, nuclear and, more recently, gas fired power plants in mind.

Wind power is disadvantaged compared to the situation under which conventional power sources such as oil, gas, coal and nuclear power sources were developed and introduced. Until the 1980s, electricity generation, distribution, grid reinforcement, grid extensions, and electricity selling were undertaken by national, vertically integrated monopolies, which were granted exclusive rights and mandates to finance investments and research in new capacity and technologies through state subsidies and levies on electricity bills. As Europe is moving in the direction of more liberalised power markets, those options are no longer available and new technologies are facing a more challenging environment on the path to market penetration and maturity. Meanwhile, public funding for energy research and development is being drastically reduced. Over the last three decades, worldwide, 92% of all R&D funding (€227 billion) has been spent on non-renewables – largely fossil fuels and nuclear technologies – compared to €19 billion for all renewable energy technologies.

2. Overview

In 2000, when fuel prices were far lower than today, the European Commission's Green Paper on Security of Supply recognised the potential of renewable energy sources:

"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."

It continued:

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

In 2003, the European Commission estimated that wind energy will be the main contributor to meeting the 2010 targets for renewable electricity in the European Union.

One of the core challenges for wind power to contribute to the European power mix at a penetration level comparable to that of the conventional power sources is how to effectively integrate significant amounts of wind energy into the European electricity systems. More specifically, this report analyses the technical, economic and regulatory issues that need to be addressed to move Europe towards a more secure energy future through increased wind power production.

Observing comments from some electricity sector stakeholders and policy makers, one could get the impression that wind power is a "grid trouble-maker" and that wind power constitutes the greatest technical challenge the European power system has ever had to face. *Wind power is unreliable; wind power cannot to any significant degree contribute to European electricity production; wind power threatens the safe operation of the electricity grids; what happens when the wind stops blowing?*

The "intermittency " myth

Wind power is sometimes incorrectly described as an intermittent energy source. This is misleading because, on a power system level, wind power does not start and stop at irregular intervals, which is the meaning of intermittent. **Wind is a technology of variable output. It is sometimes incorrectly expressed that wind energy is inherently unreliable because it is variable.**

Electricity systems – supply and demand - are inherently highly variable, and are influenced by a large number of planned and unplanned factors. The changing weather makes millions of people switch on and off heating, lighting, e.g. a sudden thunderstorm. Millions of people in Europe switch on and off equipment that demands instant power - lights, TVs, computers. Power stations, equipment and transmission lines break down on an irregular basis, or are affected by extremes of weather such as drought, which particularly impacts hydro and nuclear energy. Trees fall on power lines, or are iced up and cause sudden interruptions of supply.

The system operators need to balance out planned and unplanned changes in constantly changing supply and demand in order to maintain the system's integrity. **Variability in electricity is nothing new; it has been a feature of the system since its inception.**

Both electricity supply and demand are variable. The issue, therefore, is not one of variability or intermittency per se, but how to predict, manage and ameliorate variability and what tools can be utilised to improve efficiency. Wind power is variable in output but the variability can be predicted to a great extent. This does not mean that variability has no effect on system operation. It does, especially in systems where wind power meets a large share of the electricity demand.

Wind power in the system should not be analysed in isolation

Wind cannot be analysed in isolation from the other parts of the electricity system, and all systems differ. The size and the inherent flexibility of the power system are crucial aspects determining the system's capability of accommodating a high amount of wind power. The role of a variable power source like wind energy needs to be considered as one aspect of a variable supply and demand electricity system.

Grid operators do not have to take action every time an individual consumer changes his or her consumption, e.g. when a factory starts operation in the morning. Likewise, they do not have to deal with the output variation of a single wind turbine. **It is the net output of all wind turbines on the system or large groups of wind farms that matters.**

Furthermore, wind power has to be considered relative to the overall demand variability and the variability and intermittency of other power generators.

The variability of the wind energy resource is important to consider only in the context of the power system, rather than in the context of an individual wind farm or turbine. The wind does not blow continuously, yet there is little overall impact if the wind stops blowing somewhere – it is always blowing somewhere else. **Thus, wind can be harnessed to provide reliable electricity even though the wind is not available 100% of the time at one particular site.**

In terms of overall power supply, it is largely unimportant what happens when the wind stops blowing at a single wind turbine or wind farm site.

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All power sources are fallible

Because the wind resource is variable, this is sometimes used to argue that wind energy per se is not reliable. No power station or supply type is totally reliable – all system assets fail at some point. In fact, large power stations that go off-line do so instantaneously, whether by accident, by nature or by planned shutdowns, causing loss of power and an immediate requirement. For thermal generating plants, the loss due to unplanned outages represents on average 6% of their energy generation. **When a fossil or nuclear power plant trips off the system unexpectedly, it happens instantly and with capacities of up to a thousand MW – that is true intermittency.** Power systems have always had to deal with these sudden output variations of large power plants as well as the variable demand. The procedures put in place can be applied - and in some countries they are - to deal with variations in wind power production as well.

By contrast, wind energy does not suddenly trip off the system. Variations in wind energy are smoother, because there are hundreds or thousands of units rather than a few large power stations, making it easier for the system operator to predict and manage changes in supply as they appear within the overall system. The system will not notice the shut-down of a 2 MW wind turbine. It will have to respond to the shut-down of a 500 MW coal fired plant or a 1,000 MW nuclear plant instantly.

The main conclusions are that **the capacity of the European power systems to absorb significant amounts of wind power is determined more by economics and regulatory rules than by technical or practical constraints.**

It is more accurate to state that larger scale penetration of wind does face barriers; not because of its variability but because of a series of market barriers in electricity markets that are neither free or fair, coupled with a classic case of new technologies threatening old paradigm thinking and practice.

Already today, it is generally considered that wind energy can meet up to 20% of electricity demand on a large electricity network without posing any serious technical or practical problems.

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Large-scale grid integration of wind power

For small penetration levels of wind power in a system, grid operation will not be affected to any significant extent. Wind power supplies less than 3% of overall EU electricity demand but there are large regional and national differences.

The already established control methods and backup available for dealing with variable demand and supply are more than adequate for dealing with the additional variable supply such as wind power at penetration levels up to around 20% of gross demand, depending on the nature of a specific system. For larger penetration levels, some changes may be needed in power systems and their methods of operation to accommodate the further integration of wind energy.

In Denmark, the country in the world with the highest penetration of wind power, 21% of total consumption was met with wind power in 2004. **In the west-Denmark transmission system, which is not connected to the eastern part of the country, some 25% of electricity demand is met by wind power in a normal wind year** and, on some occasions, the wind has been able to cover 100% of instantaneous demand.

The integration of large amounts of wind power is often dismissed as impossible and many grid operators are reluctant to make changes in long established procedures to accommodate wind power. In Denmark, the grid operator was initially sceptical about how much wind power the system could cope with. The attitude of many grid operators to wind power can best be illustrated by the following quote from Eltra, the TSO in west-Denmark, at the presentation of its annual report.

"Since the end of 1999 - so in just three years - wind power capacity in the Jutland-Fyn system has increased from 1,110 MW to 2,400 MW. In installed capacity that is twice the capacity of the «Skydstrup» power Plant near Aarhus. Seven or eight years ago, we said that the electricity system could not function if wind power increased above 500 MW. Now we are handling almost five times as much. And I would like to tell the Government and the Parliament that we are ready to handle even more, but it requires that we are allowed to use the right tools to manage the system».

In the western Energinet (formerly Eltra's) supply area, wind energy covers some 25% of electricity demand in a normal wind year and it is not a technical problem to handle more – it is a regulatory issue. The tools for managing more wind power in the system are developed and grid operators should be allowed to use them.

Ultimately, experience with wind power in the areas of Spain, Denmark, and Germany that have large amounts of wind power in the system shows that **the question as to whether there is an upper limit for renewable penetration into the existing grids will be an economic and regulatory rather than a technical issue.**

In those areas of Europe where wind power development is still in its initial stage, many lessons can be learned from Denmark, Germany and Spain. However, it is important that stakeholders, policy makers and regulators in those emerging markets realise that the issues that TSOs in those three countries are faced with will not become an issue until much larger amounts of wind power are connected to the national grids.

One of the biggest mistakes in parts of the public debate about integrating wind power is that it is treated in isolation. Wind power has distinct technical features just like any other electricity generation source. Nuclear power and some of the gas and coal-fired power plants are very inflexible and are maintained at constant generation level. Seen in isolation, this is an undesirable feature because electricity demand varies significantly and constantly throughout the day. Other coal and gas plant, and hydro, are more flexible and outputs can be changed more rapidly. Integrating wind power has other distinct features. The point is that no technology, neither "base load" nuclear power nor variable production wind power, should be dealt with in isolation. It is the combined effects of all technologies, as well as the demand patterns, that matters for grid operators.

The European Dimension

There is an urgent need to address inefficiencies, distortions and historically determined institutional and legal issues related to the overall structure, functioning and development of the broader European electricity markets.

A re-orientation in the European power systems to take the characteristics of large-scale wind power into account is technically and economically feasible, and in line with overall European objectives.

The major issues of wind power integration are related to changed approaches in operation of the power system, connection requirements for wind power plants to maintain a stable and reliable supply, extension and modification of the transmission infrastructure. More cross-border links - interconnectors - will enable collection of wind power from resourceful onshore and offshore areas and make optimal use of geographical aggregation, and solve institutional and legal barriers to increased wind power penetration. Conclusions on these issues are presented below.

Before the 1980s, electricity generation, distribution, enforcement, grid expansion and selling were undertaken by national, vertically integrated monopolies that were granted exclusive rights. This historic legacy of the European power sector continues to influence the possibility to develop and integrate new technologies into the power mix. In the 1990s, the European Commission challenged the existence of such monopolies as being contrary to the Treaty's rules on the free movement of goods. This eventually resulted in the adoption in 1996 of the first electricity Directive and the first Directive on gas in 1998.

Following the adoption of the 1997 Treaty of Amsterdam, the European Union bases its energy policy on three core principles, namely:

- **Environmental protection** – in both energy production and energy use to maintain ecological and geophysical balances in nature;
- **Security of Supply** – which aims to minimise risks and impacts of possible supply disruption;

- **Competitive energy systems** - to ensure low cost energy for producers and consumers.

Furthermore, the growing import dependence of European energy supply, with its associated risk of economic disruptions, is a growing concern and measures to reduce it and increase indigenous energy production are needed.

Since 2001, the Commission has monitored the development of market opening through the Benchmarking Reports on the Implementation of the Internal Electricity and Gas Markets. In its fourth Benchmarking report, published in January 2005, the European Commission warns that governments must do more to open up electricity and gas markets.

The Commission points out four key reasons for the lack of success in achieving a competitive market:

- **Lack of cross-border transmission links**
- **Existence of dominant, integrated power companies**
- **Biased grid operators, and**
- **Low liquidity in wholesale electricity markets**

From the European Commission's point of view, the electricity grid and the structure of the power sector are the main stumbling blocks to effective competition in the European electricity markets. It sees market concentration and dominant incumbents as *"the most important obstacle to the development of vigorous competition"*.

Further, it notes that *"the internal energy market will need to develop in a manner consistent with the Community's sustainability objectives. This means that the necessary incentives to support the penetration of renewables, the reduction of emissions and demand management need to be maintained."*

The four main barriers outlined above are not only barriers to creating effective competition in European power markets, they are also the main institutional and structural deficiencies preventing new technologies such as wind power to enter the market.

Increased cross-border transmission is a precondition for effective competition. It will also reduce the cost of integrating wind power on a large scale dramatically and reap substantial "geographic spread" benefits of variable output wind generation.

Besides reducing the aggregated variability of wind power, the direct benefit of geographical aggregation of wind power output is the increased amount of firm electricity which can be used to retire conventional power plant.

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3. Conclusions

A large contribution from wind energy to European power generation is technically and economically feasible, in the same order of magnitude as the individual contributions from the conventional technologies developed over the past century. These large shares can be realised while maintaining a high degree of system security, and at modest additional system costs. However, some redesigning of the power systems, including their methods of operation, is needed. The report details that the constraints of increasing wind power penetration are not inherently technical problems with wind technology per se. The barriers are mainly a matter of regulatory, institutional and market modifications, and should be dealt with in a broader power market context.

The major issues of wind power integration are related to changed approaches in operation of the power system, connection requirements for wind power plants to maintain a stable and reliable supply, extension and modification of the grid infrastructure, and influence of wind power on system adequacy and the security of supply. Finally, institutional and legal barriers to increased wind power penetration need to be addressed and overcome. Conclusions on these issues are presented below.

System operation: power and energy balancing

The possibilities and detailed strategies for managing variable-output wind power vary between national and regional power systems. Like any other form of generation, wind power will have an impact on power system reserves. It will also contribute to a reduction in fuel usage and emissions. The impact of wind power depends mostly on the wind power penetration level, but also depends on the power system size, generation capacity mix, the degree of interconnection to neighbouring systems and load variations.

Large power systems can take advantage of the natural diversity of variable sources. **A large geographical spread of wind power will reduce variability, increase predictability and decrease the occurrences of near zero or peak output.** Power systems have flexible mechanisms to follow the varying load and plant outages that cannot always be accurately predicted. The same mechanisms are used to integrate wind power with its characteristic fluctuations. Wind farms have the inherent advantage over conventional power plants of being smaller in total output capacity. On the wind farm level, their power output variation is always smaller than, for example, the variation caused by an outage of a conventional plant. On regional aggregated level, wind power variations are smoothed and the occurrences of zero wind power are rare.

On the second to minute time scale, wind power has very little if no impact on the reserves (primary reserve). This is because the large number of individual turbines will have their second-to-second variations uncorrelated and it will smooth out, together with the load variations.

On the 10 minute to hour time scale wind power will affect the (secondary) reserves when the magnitude of wind power variations becomes comparable to the load variations. When about 10% of total electricity consumption is produced by wind power, the increase in reserves is calculated for various national countries and regions to 2-4% of installed wind power capacity, assuming proper use of forecasting techniques.

On time scale of hours to days, wind power will affect the scheduling of conventional power plants. On this time scale the impacts of wind power are dependent on forecast accuracy as well as on how flexible the conventional power producers in the system area are.

Accurate methods for short-term forecasting of wind power are widely available as there is a whole range of commercial tools and services in this area, covering a wide range of applications and customised implementation.

On an annual basis, reducing the forecast horizon from day-ahead to a few hours ahead reduces the required balancing energy due to prediction errors by 50%.

Wind energy is thus variable but predictable. Predictability favours the economic balancing of wind power in the system together with the fluctuations of electrical demand and other power generation sources, especially at wind power penetrations above 5%. The predictability qualities of wind energy must be analysed in a directly comparable way to that adopted for conventional plant which is not variable but is intermittent since large generating sets can be and are lost in an entirely unpredictable manner.

Balancing solutions as of today mostly involve existing conventional generation units (thermal and hydro). Other solutions for managing increased variability in the power systems include load management, interconnection and energy storage.

New technology and innovation enable wind farms of today to function as (virtual) power plants with the capability of delivering a range of grid supporting services, such as frequency and voltage control. Whereas not necessary at low penetrations, these advanced wind farm properties will prove to be increasingly useful at high levels of wind power penetration.

Grid codes and excessive technical requirements

It is evident that clear rules are needed to ensure that the power system keeps operating well and safely when generators are connected. In this respect the wind energy technology is developing to keep up with ever stricter technical requirements. There are however continuous changes of grid codes, technical requirements and related regulation, often introduced on very short notice and with minimum involvement of the wind power sector.

Grid codes and other technical requirements should reflect the true technical needs for system operation and should be developed in cooperation between TSOs, the wind energy sector and government bodies.

Present grid codes often contain very costly and challenging requirements (such as fault-ride through capability and primary control) that have no technical justification, e.g. because the level of wind power penetration is insignificant (i.e. in most areas of Europe).

They are often developed by vertically-integrated power companies, i.e. within companies in competition with wind farm operators, in highly non-transparent manners.

The technical grid code requirements and regulations vary considerably from country to country. The differences in requirements, besides local 'traditional' practices, are caused by different wind power penetrations and by different degrees of power network robustness.

It has been suggested to introduce harmonised grid codes for wind energy at a European level. In theory it could provide fewer burdens on the wind turbine manufacturers if each turbine model would not have

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to be adjusted for each market. However, it would be difficult to arrive at an all-encompassing European code for wind turbines because the technical requirements would have to reflect very different national conditions in terms of energy mix, interconnection, geographical size of the systems and wind power penetration levels. The immediate danger is that very strict requirements reflecting the technical needs in the few high wind penetration regions of Europe would be expanded to regions of Europe where such requirements have no technical justification and, thus, impose unnecessary cost on manufacturers as well as consumers in most European countries.

In any case, a harmonised grid code for wind power should be coordinated at EU level by an independent European regulator and/or the European Commission with the participation of the relevant stakeholders, including the wind turbine manufacturers. That said, it is difficult to comprehend why vertically-integrated power companies push so strongly for a European grid code for wind power when no harmonisation seems to be needed for other generating technologies.

As a rule, the power system robustness and penetration level and other generation technologies should be taken into account and an overall economically efficient solution should be sought. For example, it is more economic to provide primary and secondary control from conventional power plants, and wind farm operators should be demanded to provide such service only in cases where limits in existing reserves are foreseen for some critical situations. Another example of economic thinking would be to fulfil the requirement for reactive power by installing and controlling devices such as FACTS directly in the transmission network.

Costly technical requirements should only be applied if there is a true technical rationale for them and if their introduction is required for reliable and stable power system operation. The assessment of the need for requirements should be made by government bodies or TSOs that are fully separated, both legally and in terms of ownership, from any generation activities, to avoid biased decisions.

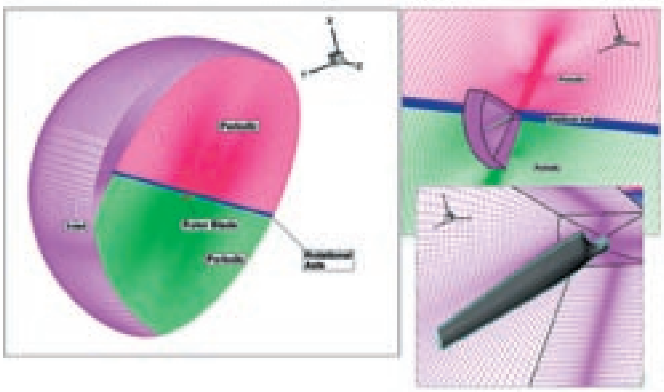
The wind turbine manufacturers are keen to establish a close working relationship with grid operators, customers and regulators to find acceptable compromises.

Besides the technical requirements, there is the issue of interconnection practice. There is a need for a transparent method to define the maximum interconnection capacity at a given network point as well as a definition of the maximum time for the TSO or DSO to perform relevant studies. Such method could ideally be defined by a neutral authority for example a regulator.

■ Dynamic system studies provide basis for improved connection practices of wind power

In general, from dynamic system studies carried out for various countries (Denmark, Germany, Spain) it is concluded that power systems dynamics are not a principal obstacle to increasing the penetration of wind power, provided that adequate measures are taken both in wind turbine technology design and in the operation and technology of the grid.

R&D: wind tunnel computer simulation



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R&D should continue to further improve the knowledge on dynamic interaction of system and wind power plants. Also, continued research work is needed to improve the dynamic models for the latest wind turbine types and for entire wind farms. Such modelling efforts become increasingly important because several TSOs have started to demand that wind farm developers submit a dynamic simulation model of the wind farm before granting connection permits. The models are used to carry out a dynamic grid integration assessment.

Grid upgrades and costs are not an isolated wind power issue

The grid infrastructure in Europe needs upgrading – on country, cross-border and trans-European levels – not only to accommodate increasing amounts of wind power cost efficiently, but also other power generating technologies. The IEA estimates that more than half of the new capacity required to meet rising electricity demand in the EU between 2001 and 2030 will be for gas. It is very rarely part of the public debate how adequate transmission and distribution is secured for the large additions of gas and coal power plant in Europe over the coming decades.

The need for infrastructure investments is obviously not arising exclusively from an increased use of wind power, which seems to be the underlying message from many market participants. **Consequently, grid extensions, grid reinforcement and increased backup capacity benefit all system users, not only wind power.** Furthermore, it is impossible to allocate the cost to individual projects or technologies. Therefore, it does not make sense to look at the future infrastructure challenges in the light of one single technology. It would be tantamount to making decisions on road building by only looking at the characteristics of bicycles, ignoring lorry and car traffic.

Wind power is not, and should not be, the only technology that benefits from improvements in the overall grid infrastructure and system operation. Therefore, an integrated approach to future decisions is needed which, of course, should take into account the specifics of wind power technology as well as the specifics of other technologies.

Grid extensions and reinforcements will benefit the whole power system and are a precondition for creating real competition in the emerging EU internal electricity market – a challenge currently being blocked by numerous distortions in the conventional power market such as the lack of effective unbundling of transmission and generation companies. Grids are natural monopolies and should be regulated as such, but this is presently not the case in most Member States.

The process of upgrading the grid systems is a very complex one and requires short-term and long-term measures to enable a smooth integration of wind power. Short-term measures include mainly optimisation of existing infrastructure, and so-called soft measures like adapted management procedures.

In the longer term, a European super-grid is proposed to accommodate large amounts of offshore wind power and to utilize continental-wide smoothing effects of wind power to a maximal extent, as well as to improve the functioning of the emerging internal electricity market. The wind is always blowing somewhere, smoothening fluctuations, and enabling more accurate short-term forecasts.

■ Improving cross-border transmission just by changing market rules

Cross-border transmission of wind power appears to be less of a technical issue than a trade and market issue. The problems wind power is facing presently are mainly caused by the fact that there is not yet a slot of cross-border capacity for variable-output power from renewables. Making such a slot available would enable cross-border trade in wind power according to internal electricity market principles.

While the European RES-E Directive makes it possible for Member States to grant priority dispatch for renewables in the national regulatory frameworks, there is no such notion as priority allocation of cross-border capacity for electricity from renewables. According to the principles of the internal electricity market, this allocation should be market-based, rather than historically determined.

Fuel replacement and capacity credit of wind power benefit security of supply.

Wind energy will replace energy produced by other power plants, which improves the energy adequacy of the power system. This is especially beneficial when wind is saving limited energy sources like hydro power and imported fuels like gas, coal and oil, decreasing the effect of price peaks on the national economy.

In addition to producing energy, wind power replaces conventional generating capacity. At low to moderate wind power penetration levels, its relative capacity credit is equal to the average wind power produced during times of peak demand (between 20% and 35% of installed onshore wind power capacity, depending on the site conditions). At higher wind power penetration levels, wind's relative capacity credit becomes lower than the average wind power output in times of peak demand.

In addition to the above, **adding wind power to the existing system is contributing favourably to the security of supply by virtue of technology diversification and indigenous production.**

The economic impacts of wind power integration are beneficial

■ Additional balancing costs for wind power

Comprehensive national studies have focused on determining the additional balancing costs as a function of increasing wind penetration in the national power system (Nordic region, Germany, UK, Ireland, Spain). Despite the differences in assumptions, optimisation criteria and system characteristics, the studies arrive at similar results. There is a gradual increase of the additional balancing costs with wind power penetration. **Because of the positive effect of geographical smoothing, results from these studies show that power systems in large geographical areas can integrate wind power at lower cost. Likewise, good interconnection to neighbouring systems reduces balancing costs.**

Both the allocation and the use of reserves cause extra system costs. This means that only the increased use of dedicated reserves, or increased part-load plant requirement, will cause extra costs. **According to several national studies made so far, there is no need for additional conventional plant and that extra reserve needs for wind power can be obtained from the existing conventional power plants.** Estimates regarding the costs of increase in secondary load following reserves suggest €1–3/MWh (of wind) for a wind power penetration of 10% of gross consumption and €2-4/MWh for higher penetration levels. The costs are quite sensitive to the accuracy of wind power forecasting, as well as the practice of applying forecasts in the market rules.

■ Additional network costs from national studies

A number of national studies (Austria, Denmark, Germany, France, Netherlands) have determined the additional grid reinforcement requirements and corresponding costs due to wind power. Such studies perform load flow simulations of the corresponding national transmission and distribution grids and take into account different scenarios of national wind integration, utilising the most favourable sites. These **country-specific studies (both in view of onshore and offshore) indicate that the grid extension/reinforcement costs caused by additional wind generation are in the range of €0.1 to €4.7/MWh wind, the higher value corresponding to a wind penetration of 30% in the system (UK).** When properly socialised in an unbundled market, these cost levels, as reflected in the end user price are low – even up to high wind penetrations.

■ Overall system economic effects

Generation costs constitute the largest fraction of the cost of power. Expected cost developments of wind power and conventional generation are such that **in a scenario with substantial amounts of wind power, the additional costs of wind power (higher installation costs, increased balancing, network upgrade) would be outweighed by the benefits.**

The expected continuing decrease of wind power generation costs (reduction of 20% for onshore and 40% offshore by 2020 as compared to 2003 levels) is an important factor. The economic benefit of wind becomes even larger when the social benefits of CO_2 emission reduction and other environmental benefits are taken into account.

Large national studies in UK, Germany and Denmark confirm that **system integration costs, under the most conservative assumptions (low gas price compare to the current level, low to zero social benefit of CO_2) are only a fraction of the actual consumer price of electricity** and are in the order of magnitude of €0 to €4/MWh (consumer level). It is recommended that similar studies are undertaken at European level.

In addition, wind power by virtue of its relative price stability compared to fossil fuels, reduces portfolio generation costs. Wind and other zero fuel cost technologies therefore have a positive effect on the overall energy mix. **Several studies have shown that when added to a risky, fossil-dominated generating portfolio, wind and other fixed-cost, zero fuel cost renewables reduce overall generating cost and risk.**

Balancing costs, grid extensions cost and grid reinforcement cost come along with all electricity generating technologies, not only with wind power. Still, it is impossible to find any study on the system cost (balancing requirements, grid extensions and reinforcements) of other technologies than wind power, hence proper cost comparisons are not possible. **As a minimum requirement, grid operators, conventional power producers and international institutions should study the additional system costs for all other technologies than wind power.**

Likewise, **most countries and institutions continue to ignore the risk element of volatile fuel prices when making cost comparisons between different electricity generating technologies.** Rather than using the commonly applied levelised cost approaches, it is recommended to adopt cost calculating methods allowing a proper economic interpretation of (easily quantifiable) cost and risk of volatile oil, gas and coal prices.

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4. Recommendations

This report makes the following recommendations related to the integration of wind power into the European electricity infrastructure:

1. Improved system operation

Imbalance payments and settlement on individual turbine level should always be avoided. It is the overall variability of output from all wind farms that is relevant to system operation. The institutional and market set-up should take into account that balancing costs should reflect the aggregate imbalance rather than the individual wind farm or wind turbine output variation, as is often the case.

Long gate-closure times should be reduced for variable output technologies. There is no technical justification for having wind power predict future production 48 hours in advance as demanded by some grid operators. The shorter the gate-closure time for wind power is, the lower the overall cost to consumers.

More effective balancing and settlement procedures that do not discriminate against variable output technologies must be introduced.

Distribution grids must be more actively managed.

Curtailment of electricity production should be managed according to least-cost principles from a complete-system point of view. As wind power is free, constraining of wind power should be the last solution and restricted to a minimum.

The balance market rules must be adjusted to improve accuracy of forecasts and enable temporal and spatial aggregation of wind power output forecasts.

Imbalances payments should be settled according to monthly net imbalances as established in e.g. California and Spain.

2. Fair and adequate grid connection requirements

Often grid codes contain very costly and challenging requirements that have no technical justification. They are often developed by vertically-integrated power companies, i.e. within companies in competition with wind farm operators, in highly non-transparent manners. Furthermore, there are continuous changes of grid codes, technical requirements and related regulation, often introduced on very short notice and with minimum involvement of the wind power sector.

The general frameworks for integrating wind power should acknowledge that technical requirements - such as grid codes, curtailment practices, reactive power etc. - depend to a large extent on the wind power penetration levels and the nature of the existing infrastructure, e.g. interconnectors and the overall generation mix.

Grid codes and other technical requirements should reflect the true technical needs and be developed in cooperation with independent and unbiased TSOs, the wind energy sector and independent regulators.

Grid codes and grid access requirements should take into account that, at low penetration levels, excessive requirements such as fault-ride-through capability and voltage control possibilities are often imposed on wind power generators without being technically justified. Costly requirements should be included only if they are technically required for reliable and stable power system operation. The assessment of the requirements should be made by independent bodies – not by transmission operators that are affiliated with vertically-integrated power producers.

3. Grid infrastructure upgrade

A large geographical spread of wind power on a system should be encouraged through planning and payment mechanisms and the establishment of adequate interconnection. From a system and cost point of view that will reduce variability, increase predictability and decrease / remove situations of near zero or peak output.

The cost of grid extension should be socialised. One reason to do it is that grids are natural monopolies.

Grid connection charges should be fair and transparent and competition should be encouraged.

In future developments of the European power systems, increased flexibility should be encouraged as a major design principle (flexible generation, demand side management, interconnections, storage etc.). Besides, public private partnership and use of structural funds should play an important part.

The benefits of distributed generation, e.g. reduced network losses and reduced need for grid reinforcements, must be recognised.

4. Proper credit to wind contribution to system adequacy

Proper, uniform standards for the determination of wind power's capacity credit must be developed. As this report shows, for small penetrations of wind power – which is still the case in most European power systems – the capacity credit of wind power will be equal to the load factor in times of peak demand. For very high penetration levels, the capacity credit is reduced but never anywhere close to zero. European transmission system operators associations should – instead of referring to wind power as "non-usable power" recognise wind power's proper capacity credit, established on solid proof, by 20 years of experience and extensive research.

5. Solving institutional inefficiencies

Solving the historic structural inefficiencies in the European power sector will not only form the basis for real competition in the European power markets, it will also go a long way in removing grid barriers for wind power and other renewables and develop a European electricity supply system based on indigenous, clean, cheap and reliable technologies to the benefit of European consumers and the overall competitiveness of the Community.

In order to solve current inefficiencies, possible actions include:

- Reduction of market dominance and abuse of dominant positions
- Effective competition policies in the power sector
- Full legal and ownership unbundling between transmission/distribution, production and trading activities
- Improvement and expansion of cross-border interconnections between Member States
- Undistorted third-party access to the grids at fair tariffs and removal of discriminatory practices
- Adequate grid codes that reflect the nature of the technologies, developed in cooperation with industry and regulators

Electricity grids are natural monopolies and, hence, transmission and distribution must be effectively, i.e. legally and ownership-wise, separated from electricity production and electricity trading. The current structure leads to biased grid operators in many countries, which are more concerned with optimising profits for their affiliated power producers and traders, than to find the most cost-effective solutions to operate and extend the grids and provide fair third-party access to new technologies.

The existing guidelines for trans-European energy networks (TEN-E Guidelines) could provide a good framework for upgrading the European grid infrastructure, which has been characterised by underinvestment during the 1980s and 1990s. However, it requires dramatically increased efforts in terms of both funding and focus in application of the guidelines. The challenge of creating the necessary infrastructure for reaping one of Europe's largest indigenous energy sources – offshore wind power – should be coordinated at a European level. To that extent the TEN-E framework could be applied more effectively. On average the funding available under the framework has only contributed to 1.5% of total investment costs.

The nascent trans-national grids must be prepared to absorb offshore wind power and utilise continental smoothening effects. The Trans-European Networks for Energy (TEN-E) provide a vehicle to realise this concept but much more European cooperation is needed in this area.

The European Commission has suggested that a European policy for offshore wind energy may be needed. Furthermore, in October 2005 policy makers, NGOs and industry from a number of European countries signed the Copenhagen Strategy which *"calls on the Council of Ministers to ask the European Commission to initiate a policy for offshore wind power, in the form of an Action Plan for offshore wind power deployment"*. An Action Plan for offshore wind power that addresses offshore infrastructure would be a first step towards radically improving European energy independence and lead EU closer to real competition in the Internal Electricity Market. A European super-grid should be developed to bring large amounts of offshore wind power to European consumers, similar to the way European gas pipelines have been constructed.

6. New and continued research and development efforts

There is great need to increase funding to both short-term and long-term R&D in wind energy development at national and European level, in order to further develop onshore and offshore technology, enable the integration of large-scale renewable electricity into European energy systems and maintain European companies' strong global market position in wind energy technology. Cross-border collaboration, European co-ordination and greater interaction between public and private stakeholders are required to develop the necessary critical mass to meet the technological challenges. It is also vital to ensure that the funds applied are spent efficiently in order to maximise research output for a given amount of funds. This should be facilitated by the establishment of a Wind Energy Technology Platform under the 7^{th} EU Framework Programme for research.

Specifically on grid integration of wind energy, more research is needed in the following areas:

a. Improved forecast methods;
b. Methods for investigating dynamic interaction between wind farms and power system;
c. Transmission network studies on transnational level;
d. Uniform methods for national system studies for balancing (reserve capacities and balancing costs);
e. Investigation of solutions to increase power system flexibility;
f. Systematic output monitoring to validate theories on capacity credit.

7. Stakeholder involvement

Wind power is capable of supplying a share of European electricity supply comparable to the levels currently being met by conventional technologies such as fossil fuels, nuclear and large hydro power. Such penetration levels, however, would require cooperation between decision-makers and stakeholders in the electricity sector on making the necessary changes to the European grid infrastructure that has been developed with traditional centralised power in mind.

Stakeholders in this process should include:

- **Wind industry:** wind turbine and component manufacturers, project developers, wind farm operators, engineering and consulting companies, R&D institutes and national associations;
- **Power sector:** transmission and distribution system operators and owners, power producers, energy suppliers, power engineering companies, R&D institutes, sector associations;
- **Public authorities:** energy agencies, ministries, national and regional authorities, regulators, European institutions;
- **Users:** industrial and private electricity consumers, energy service providers, consultants and R&D institutes.

The table below outlines some of the issues and challenges that need to be addressed in order to remove barriers and develop strategies for well-planned and improved large-scale integration of wind power in the power system.

Issues		Stakeholders			
		Wind industry	Power sector	Public authorities	Users
Grid connection requirements	Insufficient understanding of wind farm and grid interaction at distribution system operator level, leading to long delays in connection approvals for developers and wind turbine manufacturers	✓	✓		
	All aspects of dynamic interaction of system and wind power plants not yet fully understood	✓	✓		
	Large variety of grid code requirements, often with no technical justification, throughout Europe creating complex situation for wind turbine manufacturers	✓	✓	✓	
	Implementation of unduly heavy grid code requirements in countries with low wind power penetration	✓	✓	✓	
Contribution to system adequacy	The valuation of the capacity credit of wind power in a correct way in system planning	✓	✓	✓	
	Collection of operational data for determining wind power capacity credit for strategic system planning	✓	✓		
Grid infrastructure	Optimisation of existing grid infrastructure transmission system, taking into account voltage variations and power flows induced by wind farms (FACTS) and the utilisation of the lines by wind power		✓		
	Socialisation of grid extension cost (Grids are natural monopolies)			✓	
	Transparent and fair grid connection charges		✓	✓	
	Planning of system-wide infrastructure improvements in view of long authorisation times required		✓	✓	
	Strategy for a European super-grid for collecting offshore wind power (TEN-E Framework)	✓	✓	✓	
	Construction and allocation of transmission and interconnection capacity	✓	✓	✓	
Operation of the system	Further development of methodologies used in system studies	✓	✓		
	Introduction short gate-closure times			✓	
	Efficient use of forecast in connection with balancing (high-quality forecast tools, and smart implementation, i.e. not day-ahead, but as close to delivery as possible)	✓	✓		
	Making the power system more flexible (storage, demand side, interconnection) to avoid curtailment and thus wasting of wind power generation		✓	✓	✓
	More active management of distribution grids in view of improved accommodation of embedded generation		✓	✓	
Institutional and legal issues	Full legal and ownership unbundling		✓	✓	
	EU policy on offshore wind energy (Action Plan)			✓	
	Implementation of fair payment rules and gate closure times	✓	✓	✓	
	Facilitation of grid investments through the TEN-E Framework			✓	
R&D, demand side management and storage	Further research and development in the area of storage technologies	✓	✓	✓	✓
	Implementation of demand side management (in technology, incentives etc.)		✓	✓	✓

MAIN CONCLUSIONS

1. System operation: power and energy balancing

- A large geographical spread of wind power will reduce variability, increase predictability and decrease the occurrences of near zero or peak output. Power systems have flexible mechanisms to follow the varying load and plant outages that cannot always be accurately predicted.
- Accurate methods for short-term forecasting of wind power are widely available as there is a whole range of commercial tools and services in this area. On an annual basis, reducing the forecast horizon from day-ahead to a few hours ahead reduces the required balancing energy due to prediction errors by 50%.

2. Grid connection: grid codes and excessive technical requirements

- Grid codes often contain very costly, challenging and continuously changing requirements and are developed in a highly non-transparent manner by vertically-integrated power companies, who are in direct competition with wind farm operators.
- Costly technical requirements should only be applied if there is a true technical rationale for them and if their introduction is required for reliable and stable power system operation. These are not needed at low wind power penetration levels.
- Power systems dynamics are not a principal obstacle to increasing the penetration of wind power.
- R&D should continue to further improve the knowledge on dynamic interaction of system and wind power plants.

3. Grid upgrades and costs are not an isolated wind power issue

- Grid extensions and reinforcements will benefit the whole power system and are a precondition for creating real competition in the emerging EU internal electricity market. Grids are natural monopolies and should be regulated as such.
- In the longer term, a European Super Grid is proposed to accommodate large amounts of offshore wind power and to utilize continental-wide smoothing effects of wind power to a maximal extent, as well as to improve the functioning of the emerging internal electricity market.
- Cross-border transmission of wind power is not a technical issue but a trade and market issue. Making slots available for renewable electricity would enable cross-border trade in wind power according to internal electricity market principles.

MAIN CONCLUSIONS

4. Fuel replacement and capacity credit of wind power benefit security of supply

- Wind energy will replace energy produced by other power plants, which improves the energy adequacy of the power system.
- Wind power replaces conventional generating capacity. The capacity credit of onshore wind power throughout Europe varies between 20% and 35% of the installed wind power capacity. High wind power load factors in peak demand season and good wind power exchange through interconnection have a positive effect on the capacity credit.
- Adding wind power to the existing system is contributing favourably to the security of supply by virtue of technology diversification and indigenous production.

5. The economic impacts of wind power integration are beneficial

- Additional balancing is very low and estimated at €1–3/MWh (of wind) for a wind power penetration of 10% of gross consumption and €2-4/MWh for higher penetration levels.
- The grid extension/reinforcement costs caused by additional wind generation are in the range of €0.1 to €4.7/MWh wind, the higher value corresponding to a wind penetration of 30% in the system (UK). When properly socialised in an unbundled market, these cost levels, as reflected in the end user price are low – even up to high wind penetrations.
- System integration costs, under the most conservative assumptions, are only a fraction of the actual consumer price of electricity and are in the order of magnitude of €0 to €4/MWh (consumer level).
- These additional costs of more wind power would be outweighed by the benefits from the expected continuing decrease of wind power generation costs - a reduction of 20% for onshore and 40% offshore by 2020 as compared to 2003 levels.
- The economic benefit of wind becomes even larger when the benefits of CO_2 emissions reduction and other environmental benefits are taken into account.
- Wind power reduces portfolio generation costs. When added to a risky, fossil-dominated generating portfolio, wind as a fixed cost zero fuel technology reduces overall generating cost and risk.
- Balancing costs, grid extensions and reinforcements come with all electricity generating technologies, not only with wind power. It is impossible to find any study on these system costs of other technologies than wind power, hence proper cost comparisons are not possible. Other parties should study and publish the additional system costs for all other technologies than wind power.
- Most countries and institutions continue to ignore the risk element of volatile fuel prices when making cost comparisons between different electricity generating technologies. Rather than using the commonly applied levelised cost approaches, it is recommended to adopt cost calculating methods allowing a proper economic interpretation of (easily quantifiable) cost and risk of volatile oil, gas and coal prices.

MAIN RECOMMENDATIONS

1. Improved system operation

- Imbalance payments and settlement on individual turbine level should always be avoided. It is the overall variability of output from all wind farms that is relevant to system operation.
- Long gate-closure times should be reduced for variable output technologies. There is no technical justification for having wind power predict future production 48 hours in advance as demanded by some grid operators. The shorter the gate-closure time for wind power is, the lower the overall cost to consumers.
- More effective balancing and settlement procedures that do not discriminate against variable output technologies must be introduced.
- Distribution grids must be more actively managed.
- Curtailment of electricity production should be managed according to least-cost principles from a complete-system point of view. As wind power is free, constraining of wind power should be the last solution and restricted to a minimum.
- The balance market rules must be adjusted to improve accuracy of forecasts and enable temporal and spatial aggregation of wind power output forecasts.
- Imbalances payments should be settled according to monthly net imbalances as established in e.g. California and Spain.

2. Fair and adequate grid connection requirements

- Grid codes and other technical requirements should reflect the true technical needs and be developed in cooperation between independent and unbiased TSOs, the wind energy sector and independent regulators.
- A European-wide grid code for wind power is not required.

3. Grid infrastructure investments

- A large geographical spread of wind power on a system should be encouraged through planning and payment mechanisms and the establishment of adequate interconnection. From a system and cost point of view, that will reduce variability, increase predictability and decrease or remove situations of near zero or peak output.
- The cost of grid extension should be socialised, as it is the case for all other electricity technologies. One reason to do it is that grids are natural monopolies.
- Grid connection charges should be fair and transparent and competition should be encouraged.
- In future developments of the European power systems, increased flexibility should be encouraged as a major design principle. Public private partnership and use of structural funds should play an important part.
- The benefits of distributed generation, e.g. reduced network losses and reduced need for grid reinforcements, must be recognised.

MAIN RECOMMENDATIONS

4. Proper credit to wind's contribution to system adequacy

- Proper, uniform standards for the determination of wind power's capacity credit must be developed. For small penetrations of wind power the capacity credit will be equal to the load factor in times of peak demand. For very high penetration levels, the capacity credit is reduced but never anywhere close to zero.
- European transmission system operators associations should – instead of referring to wind power as "non-usable power" recognise wind power's proper capacity credit.

5. Solving institutional inefficiencies and improve power market competition

Solutions include:

1. Reduction of market dominance and abuse of dominant positions
2. Effective competition policies and authorities in the power sector
3. Full legal and ownership unbundling between transmission/distribution, production and trading activities
4. Improvement and expansion of cross-border interconnections between Member States
5. Establishment of undistorted third party access to the grids at fair tariffs and removal of discriminatory practices
6. Adequate grid codes that reflect the nature of the technologies, developed in cooperation with the wind energy sector and regulators

- Electricity grids are natural monopolies and, hence, transmission and distribution must be effectively, i.e. legally and ownership-wise, separated from electricity production and electricity trading.
- The existing guidelines for trans-European energy networks (TEN-E Guidelines) can provide a good framework for upgrading the European grid infrastructure which has been characterised by underinvestment during the 1980s and 1990s.
- The nascent trans-national grids must be prepared to absorb offshore wind power, and the TEN-E can provide a vehicle to focus on this area.
- A European policy for offshore wind energy is needed. An Action Plan for offshore wind power that addresses offshore infrastructure would be an important step.
- A European "super-grid" should be developed to bring large amounts of offshore wind power to European consumers, similar to the way European gas pipelines have been constructed.

6. New and continued research and development efforts

Under the 7th EU Framework Programme for Research, more research is needed in the following areas:

1. Improved forecast methods
2. Methods for investigating dynamic interaction wind farms and power system
3. Transmission network studies on transnational level
4. Uniform methods for national system studies for balancing (reserve capacities and balancing costs)
5. Investigation of solutions to increase power system flexibility
6. Systematic output monitoring to validate theories on capacity credit

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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 250 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 co-ordinates 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 industries and research associations under one roof.

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