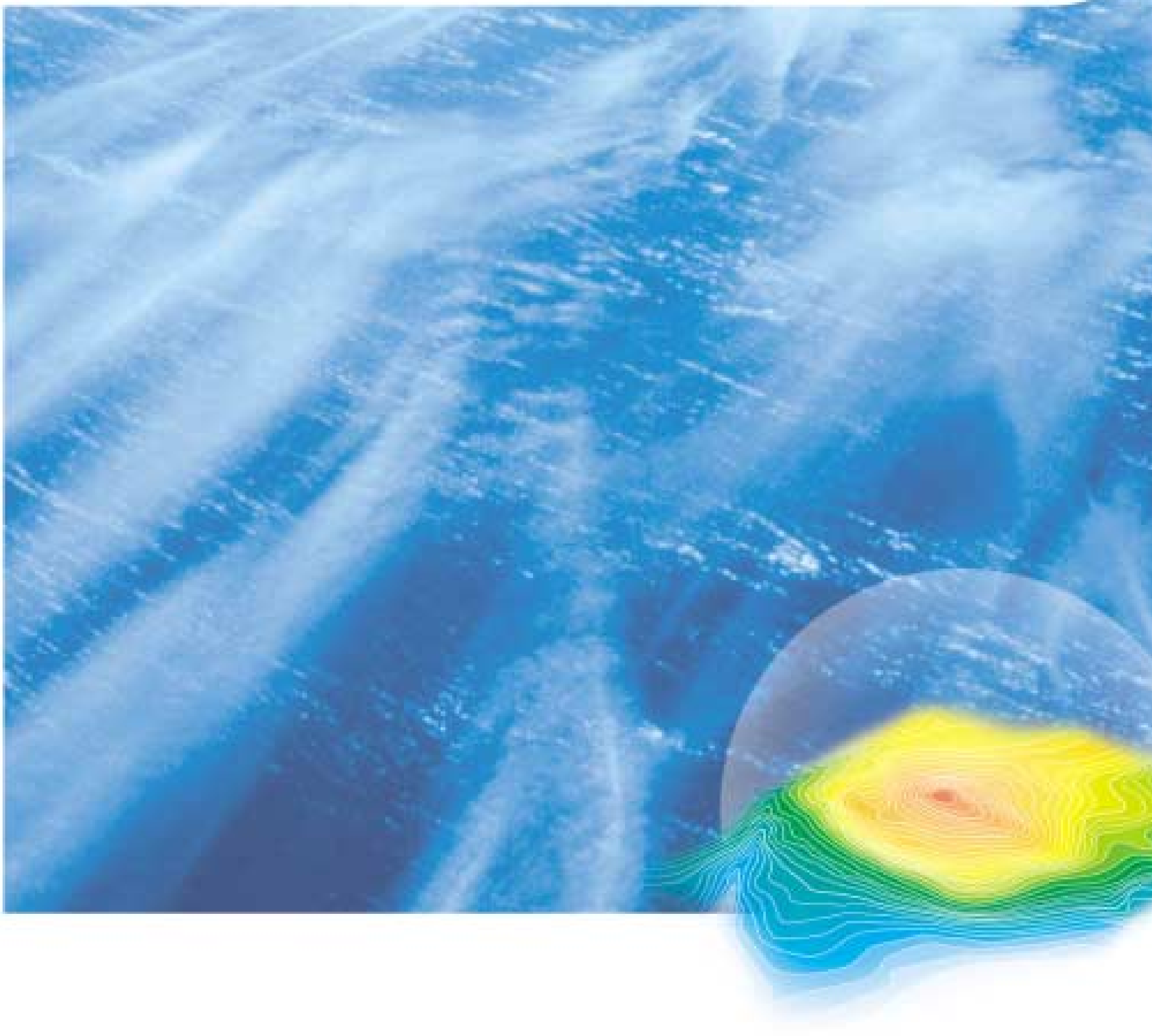


Offshore Wind Energy and Industrial Development in the Republic of Ireland

Offshore Wind Energy and Industrial Development in the Republic of Ireland

Report prepared by Risø National Laboratory on behalf of Sustainable Energy Ireland

October 2004

Table of Contents

Glossary **5**

Executive Summary **6**

1 Introduction **12**

2 Targets for Wind Energy Development **13**

2.1 The Consultation Document and Targets analysed 13

2.2 Barriers and opportunities 14

2.2.1 The Legal Framework and Infrastructure 15

2.2.2 Planning and Procedures for offshore wind farms 16

2.2.3 The Electricity Market in Ireland 17

2.2.4 The Electricity Grid 27

2.3 The Wind Energy Industry 32

3 The Wind Energy Market **33**

3.1 The world market in overview 33

3.1.1 Introduction 33

3.1.2 Building up wind power industry 36

3.1.3 Larger Projects – utilities and leading energy companies enter 37

3.1.4 Up-scaling of wind turbines – rapid change of size segments 37

3.1.5 Off-shore wind farms: A growing market segment 38

3.1.6 Expected growth of the market until 2008 39

3.2 The regional UK and Irish market 39

3.2.1 The UK market 40

3.2.2 The Irish market 42

3.3 The National Irish Market 43

3.4 Market size and conditions 46

3.5 Total investment for the scenario's until 2010 and 2020 47

4 Offshore Technology **53**

4.1 State of the art offshore wind farm deployment 53

4.2 Economy of the two large offshore wind farms 56

4.3 Danish legal framework and planning 57

4.4 Present technology 59

4.4.1 Concepts for offshore foundations 61

4.4.2 Erection of the Horns Rev wind farm 67

4.5 Future development 70

5 Key requirements for Offshore Wind Development **72**

6 Industrial Development **73**

6.1 The value chain for offshore wind power 73
6.1.1 Project preparation 73
6.1.2 Foundation 73
6.1.3 Wind turbines for offshore wind farms 74
6.1.4 Electric connection - sea cable & transformer station 74
6.1.5 Improved control and on-line monitoring - SCADA 74
6.1.6 Others 74
6.1.7 Share of cost within the value chain (% of total cost) 75
6.1.8 Employment potentials 76

6.2 Players and competences required 76
6.2.1 Project preparation 77
6.2.2 Foundations 77
6.2.3 Offshore wind turbines 77
6.2.4 Electric connection - sea cable and transformers 78
6.2.5 Control systems for operation of offshore wind farms 78

6.3 Profile of Irish Industry's competences 79
6.3.1 Project preparation 79
6.3.2 Foundations 79
6.3.3 Wind Turbine Manufacturing 79
6.3.4 Electric connection – sea cable and transformers 79
6.3.5 Control systems and maintenance 80

6.4 Barriers and opportunities 80
6.4.1 Knowledge barriers 81
6.4.2 R&D and education 82

6.5 Key requirements for industry development 82

7 Policy Options **85**

7.1 How can Wind Power be supported? 85

7.2 Feed-in Tariff 85

7.3 Tradable Green Certificate Scheme 86

7.4 Environmental Adder Scheme 87

7.5 Tendering System 87

8 References **89**

Appendix 1. Brief Terms of Reference **90**

Appendix 2. Meetings with Stakeholders **92**

Appendix 3. Policy Instruments AER **93**

Appendix 4. Irish Companies with a potential in Wind Energy **96**

Appendix 5. Irish Companies within Marine Business **97**

Glossary

AEP	Annual Energy Production
AER	Alternative Energy Requirement (DCMNR competition for renewable energy)
BNE	Best New Entrant
CER	Commission for Energy Regulation
D	Wind turbine rotor Diameter
DCMNR	Department for Communications, Marine and Natural Resources
EPC	Engineering, Procurement and Construction
ESB	Electricity Supply Board – Irelands Utility
EWEA	European Wind Energy Association
IEA	International Energy Agency
IRR	Internal Rate of Return
MAE	Market Arrangement for Electricity
NPV	Net Present Value
O&M	Operation and maintenance
PPA	Power Purchase Agreement
RISØ	Risø National Laboratory, DK-4000 Roskilde, Denmark
ROC	Renewable Obligation Certificate (Scotland)
SEI	Sustainable Energy Ireland
STATCOM	Static var compensator
SWOT	Strengths, weaknesses, opportunities and threats analysis
RAS	Remedial Action Scheme
ROE	Return On Equity
TSO	Transmission System Operator
UCTE	Union for the Co-ordination for Transmission of Electricity
WAsP	Wind Atlas Analysis and Application Program

Executive Summary

Background

In 1999 the Irish Government issued the Green Paper on Sustainable Energy setting out a target of adding 500 MW new capacity from renewable energy in the period 2000-2005. For the period 2005 to 2020 the Minister of Communications, Marine and Natural Resources issued a Consultation Document in December 2003, inviting the public to comment on proposed targets and policy options for renewable energy. It is envisaged that the major contribution to meet the targets for renewable energy will come from wind energy installed either onshore or offshore.

The study was financially supported by the Renewable Energy Research Development and Demonstration Programme (RE RD &D) administered by Sustainable Energy Ireland (SEI) and carried out by Risø National Laboratory in cooperation with BTM Consult and the Danish Energy Authority.

Objectives of the study

To support the Government of Ireland and SEI in analysing and developing targets, programmes and policies in connection with implementation of wind energy in the Republic of Ireland.

The present study has examined:

- Task A: Key requirements for Ireland to meet potential future targets for the deployment of offshore wind energy.
- Task B: Potential opportunities for the development of an industry supplying the wind energy market in Ireland and overseas.

Methodology

The study was conducted as a desk study supplemented by a number of interviews with major stakeholders in Dublin in December 2003. The study was organised in two tasks: task A and task B.

The applied methodology for task A, offshore wind energy has been to focus on barriers and opportunities for development of offshore wind in Ireland.

Concerning task B, the development of an Irish industry the market volumes were developed from the scenarios of task A. The market volumes were quantified in the relevant sectors through a value chain analysis for offshore wind. A number of potential niches for Irish industry players were identified through a review of existing competences compared to the competences originating from the value chain analysis.

Findings of the study

Offshore Wind Energy

The specific 2020-targets for offshore wind have been identified for two scenarios:

Low-wind scenario: 1630 MW wind capacity of which 500 MW offshore (2020)
High-wind scenario: 2000 MW wind capacity of which 670 MW offshore (2020)

Given the challenges from the Kyoto Protocol and Irelands dependence of imported fossil fuels even the high-wind scenario (corresponding to expected 20% wind power penetration in 2010 and 30% in 2020) is considered rather unambitious, and it could be considered to be even more ambitious. Ireland has excellent offshore wind resources and a number of appropriate potential sites for installation of offshore wind power. The most obvious offshore wind power sites are located off the coastline south and southeast of Ireland, where also the population and the electricity consumption is concentrated. The 500 MW offshore target might be met by one single project like e.g. Arklow Bank less than 100 km south of Dublin. This project is envisaged to and has obtained planning consent to a total installed capacity of 500 MW.

The main barriers identified in the study are:

- Electricity price and support scheme
- Grid access
- Introduction of liberalised electricity market

Electricity price

In order to attract investors it is necessary that the level of support leave room for an appropriate risk premium for investors. Within the last couple of years the Danish support system for onshore wind turbines based on the spot market price of power plus a premium of 1.3 c€/kWh, the total price paid per kWh not exceeding a cap of 4.8 c€/kWh, has proved not to be successful in generating new capacity established on Danish wind conditions since no wind turbines were erected under these conditions. Denmark has a low-cost and fairly competitive market for establishing wind power and therefore it seems obvious that a tariff of approximately 5 c€/kWh simply is too low to attract investors in wind power plants. On the other hand the Danish feed-in tariff system in place from the early 1970'ies till 1999 with a price of approximately 8 c€/kWh was in general regarded as attractive by investors and proved to be sufficient to assure a stable market for wind energy with double-digit growth rates for two decades.

For offshore projects the investment and the operation and maintenance costs are significantly higher than onshore. Although the offshore wind resource generally is better than onshore the cost of generated power will be 30-50% higher for moderate water depths. Furthermore the offshore market is still in the pioneering / demonstration stage and the risk is relatively high and allowance for a risk premium should be considered. In this respect the tendering system applied in the Irish AER scheme appears to be successful with regard to bring down the price paid to wind power in Ireland, but less successful with regard to promote market growth and with regard to predicting fulfilment of government targets and planning of initiatives to stimulate development. Apparently the lowest bid criteria applied have tempted some project developers to offer a too low price per kWh to actually be able to implement their projects. That seems to be one of the main reasons for Irish wind deployment being behind schedule for reaching the 2005 target. It is recommended to revise the bidding system to include more attractive incentives as well as penalties for not performing.

Grid access

Infrastructure is the key for all industrial development. Grid access is essential for development of wind energy capacity.

The ESB system and the Danish Eltra system are quite similar in terms of installed conventional generating capacity and loads. In terms of operational characteristics the two power systems are also similar with respect to transient stability and transmission system limits in the case of replacement or maintenance of critical units in the system. Also the power quality issue in the distribution system is quite similar to the challenges faced in Denmark, Germany and several other countries. The main difference between the two systems is that the ESB system is part of an island system, while the Eltra system is interconnected to the large European system. This has a strong influence on the frequency control, and on the potential curtailment of wind power in the case of large-scale wind power penetration in the system. In the Eltra system 2400 MW wind power has been successfully integrated as well as 1600 MW decentralised combined heat and power plants (with prioritised access to the grid). A first step to alleviate the Irish island status is implementation of the planned 1000 MW inter-connector to the large UK grid, which is expected to support further development of wind energy capacity.

Liberalised electricity market

The power sector in Ireland is in a transition process to become privatised, structured into a state controlled TSO and private power producers. Most stakeholders find the structure well designed for (large) wind power development, but experiences from other countries are that the market transition is a long process and might easily last 10 years. During the transition process the actors are reluctant to take major decisions, the future is uncertain and the risks are considered too high by the investors. In this period the Government should consider providing additional comfort to investors.

The key requirements for development of offshore wind energy and for reaching the targets were found to be:

- Maintain a stable legal and planning framework and appropriate pricing for offshore development
- AER bidding scheme should include penalties for not delivering power
- Grid development - including interconnection to UK
- Open up for ESB National Grid can apply Remedial Action Scheme (RAS)[1] in the transmission system
- Additional comfort to investors during the electricity market transition period

[1] A way to handle the so-called N-2 contingency situation in a transmission system e.g. cases where one power producing unit is removed for maintenance and another unit fails. A RAS scheme prescribes what should be done to re-establish the robustness of the system in such critical load situations. One mean can be to curtail some of the wind power in the critical situations, e.g. during minimum load and maximum wind. Today RAS is not allowed in Ireland under the existing transmission planning criteria [4].

Industry Development

Assuming that the optional target of 20% RE in 2010 is met mainly by wind this corresponds to 1533 MW wind capacity and an estimated cumulative investment 2004-2010 in onshore wind of EUR mill 800; for offshore it is EUR mill 600. The associated employment potential is estimated to be some 500 jobs in the period 2004-2010.

In order for Ireland to get "onboard in time" with regard to industrial development and employment it is important to remove barriers and create conditions that will facilitate early deployment of wind energy meaning that ambitious goals should be set, preferably with an initial high activity level.

The consolidation trend in the wind turbine market of companies merging into few and very large companies like GE Wind, Gamesa and Vestas, that can operate internationally on a competitive level is expected to continue. It cannot be expected that new and small companies will play a significant role in the international main stream market, except in niches as specialized suppliers of sophisticated products and services. In order to attract and maintain private players in the industry a minimum market volume should be established and *maintained* over a long period of time. The potential market in Ireland, if seen alone, appears to be insufficient to support an industry of even a modest size. However, the activity level in the UK offshore market is expected to be significant over the next decade or more, and will provide a good basis for development of competences and markets for Irish companies. As it is generally accepted that industrial development without a good home market is vulnerable and less robust, a home market for the wind industry is an important requirement for industry development in Ireland to allow Irish entrepreneurs to get started and survive the early years.

In the development of an Irish wind industry it is important to focus on products and services that can supply and improve already existing technology, and develop and utilise the Irish knowledge resources with the highest technical competences, e.g. in the software and electronic sector plus the marine and ocean engineering sector. In doing that cooperation should be established with the already established international companies that produce the state-of-the-art wind turbines.

If the Irish market develops to a sufficient size and at the same time can have a stable growth rate the producers of wind turbines or the major components might find it interesting to move part of their production to Ireland to be close to the Irish/UK market.

Key requirements for development of an Irish wind industry are:

- Clear and consistent signals to the industry about targets and operational conditions for Irish wind energy deployment.
- Infrastructure (grid) and planning conditions in place.
- Focus on the total Ireland/UK market when developing the industry.
- Focus on products and services that can supplement and improve already existing technology.
- Cooperate with major international wind turbine manufacturers to decide on development of value-added services.
- Initiate coordination of activities with IDA and Enterprise Ireland
- Public funding of information, education and R&D programmes
- Facilitate networking between small companies.

Wind energy deployment in Ireland has so far been accomplished with a significant involvement of the private sector. With this in mind it is important to establish a framework that makes it attractive for investors to enter and stay in the market. In order to provide cost-effective solutions it is important that the framework also serves to minimize the risk for investors.

If the objective is to build up a certain wind power capacity in Ireland and meet the relatively modest targets suggested in the Consultation Document a mix of onshore development now and offshore later is likely to provide the lowest risk and thus the lowest overall cost.

On the other hand if the objective is to get a share of the industrial development within wind and attract investments, and combine this with the objective above a much more aggressive approach is recommended with higher initial targets.

In general Government support, clear targets and consistent and coherent policy regarding wind are essential prerequisites for success. A proper coordination between entities responsible for environmental policies (e.g. responsibility for Kyoto obligations and targets), energy policy (renewable energy planning, power system development) and employment and industry policies will facilitate the development and pave the way to meet the targets.

1 Introduction

The Irish Government is currently considering its future policy and programmes on renewable energy for the period 2005 until 2020 taking into account their global climate change commitments and the European Directive " On the promotion of electricity produced from renewable energy sources in the internal electricity market" (2001/77/EC). The present study on Offshore Wind Energy and Industrial Development in The Republic of Ireland by Risø National Laboratory is supported by a grant from the Renewable Energy Research, Development & Demonstration Programme (RE RD&D) managed by Sustainable Energy Ireland (SEI). The work was carried out in cooperation with the Danish Energy Agency and BTM Consult Aps. A summary of the Terms of Reference for the study is included in Appendix 1.

As a part of the study interviews with major stakeholders were conducted in December 2003 in Dublin. The list of the stakeholders consulted is included in Appendix 2. The purpose of the interviews was to provide knowledge and insight in the complex Irish business climate for wind energy. In particular meetings with Enterprise Ireland and the Marine Institute have led to development of a list of companies interested in entering wind energy business and a list of companies with experience and competences offshore. These two lists are enclosed as appendices 4 and 5 respectively.

2 Targets for Wind Energy Development

The Irish Government strategy on renewable energy is laid out in the Green paper on Sustainable Energy of 1999 and the National Climate Change Strategy of 2000. Ireland is also committed to an indicative target, within EU Directive 2001/77/EC, to cover 13.2 % of total electricity consumption from renewable energy sources by 2010. Wind power is expected to cover the major part of that. By the end of 2002 wind power covered 1.7% of the total national electricity consumption, with 137 MW of wind power capacity installed and by the end of 2003 the wind power capacity had increased to a total of 186 MW. In the years 2000-2003 approximately 158 MW was installed. Thus in order to reach the target for wind energy deployment set for 2005 (additional 500 MW in the period 2000 to 2005) – an average of 230 MW will have to be installed in each of the years 2004 and 2005.

2.1 The Consultation Document and Targets analysed

On behalf of the Irish Government the Minister of Communications Marine and Natural Resources has issued a Consultation Document [4] on December 22 2003 inviting the public to give their comments – in particular the wind energy and energy sector in general. The consultation period ended in March 2004. The title of the document is "Options for Future Renewable Energy Policy, Targets and Programmes" and the main issues are the proposed targets for renewable energy in the Republic of Ireland for the period 2005 to 2020.

The proposed targets from the Consultation Document for 2010 and 2020 are structured in two scenarios below. In the low scenario it is assumed that a low-target scenario for the period 2005 to 2010 is followed by another low-target scenario for the subsequent period 2011 to 2020 and vice versa for the scenario.

The two basic scenarios are therefore:

Low Scenario for 2005 to 2020: 978 MW in 2010 and 1633 MW in 2020

- Contribution to the 13,2 % penetration is fulfilled (Target 1) in 2010 with 978 MW online - hereof 203 MW are installed offshore corresponding to 20,7 % of the total wind power capacity.

- The development is continued by 655 MW in the period 2011 to 2020 (Target 1) - hereof 290 MW are installed offshore corresponding to 44,2 % of the added capacity.

- By 2020 the total installed capacity is 1.633 MW of which 493 MW are installed offshore (30 %)

Larger projects are in favourable in terms of improved economic feasibility - particularly for offshore installations. It is therefore not considered to install many small projects. The optimal size for offshore projects is assumed to be in range of 100 to 200 MW. In the first phase (2004-2010), however, we have included a demonstration phase which naturally includes smaller projects.

High Scenario for 2005 - 2020: 1533 MW in 2010 and 2003 MW in 2020

- Contribution to the 20% penetration target by 1.533 MW - hereof 453 MW offshore corresponding to 29,5 % for the period.

- The development is continued with another 470 MW in the period 2011 to 2020 - hereof 220 MW are installed offshore, which is around 47 % of the installation.

- By 2020 the total installed capacity is 2003 MW of which 673 MW are installed offshore (33.5 %).

2.2 Barriers and opportunities

Ireland is well endowed with a good wind resource; both in absolute numbers and especially on a per capita basis it is amongst the highest potential in Europe. The theoretical technical resource, defined as the total resource limited by our technical ability to extract usable energy using best available technologies, is greater than Ireland's energy needs. Annex 3 of the Consultation Document has quoted estimates of the practicable annual resource as 6.7 TWh, which is the technical resource constrained by practical, social and economic factors. The technical resource is estimated at 613 TWh per year compared to Irelands annual electricity consumption of 27 TWh in 2003.

The barriers for a fast and smooth development of wind energy in Ireland are many. The list of barriers *quoted* below is based on the papers given at a conference "Before the wells run dry", on Ireland's Transition to Renewable Energy, held at the Tipperary Institute in Thurles over three days in Autumn 2002. The event was organised by Feasta, the Dublin-based Foundation for the Economics of Sustainability, the Renewable Energy Information Office of Sustainable Energy Ireland and the Tipperary Institute itself. The viewpoint from the Irish wind energy sector can be summarised as follows:
qoute

- Availability of Power Purchase Agreements (PPA's): The competitive and restrictive way in which PPA's are offered under the AER programme has meant that at least one site has seen its planning permission expire because construction could not go ahead without a PPA.

- Poor Prices: At roughly 4.8 eurocent per kWh, the price offered under the AER programme is by far the cheapest in Europe, and is lower than the price at 5.2 eurocent per kWh currently paid to ESB Power Generation for its electricity from its portfolio of power stations. This figure excludes the price paid for electricity generated, which is purchased under a separate Public Service Obligation (PSO).

- Inadequate Indexation; Although AER1 and AER3 contracts were subject to full Consumer Price Indexation (CPI), the AER5 price is subject to only 25% indexation, a source of discontent within the IWEA. In contrast ESB Power Generation not only gets its higher price of 5.2 eurocents but also gets full indexation and is allowed to pass on any increases in its fuel costs.

- Planning Problems. Overall, the IWEA feels that obtaining planning consents from county planners is not a major obstacle to the development of wind energy, even though individual members of the IWEA contend that certain local authorities are anti wind. Our major problem is with An Bord Pleanala, whose decisions often are seen as a lottery. However, with the 355MW of contracts offered under AER5 it has by and large overcome the planning issues. Since the industry started it has 700 MW inshore wind projects with full planning permission.

- Grid connections; Connection to the ESB grid is increasingly becoming a major issue as wind projects compete for access to the network. The capability of the Distribution and Transmission network to connect wind energy onto the system is limited in most places, particularly in the more outlying regions of Ireland, where the wind resource is often the best.

- Financial issues: With the prices paid for wind generated electricity so low, there is enough cash flow to service the bank loan element of the typical financial model with 20% equity and an 80 % bank loan, but no money to allow for any return on the equity component. The result is that the wind industry is forced to avail of whatever tax incentives are available and what clever tax experts can engineer.

2.2.1 The Legal Framework and Infrastructure

The conditions for development and deployment of wind energy in a particular country are laid down in the country's legal framework, which defines the targets and milestones for future deployment, the planning laws and requirements, consideration for local interests versus central planning, environmental protection, land owner opportunities and restrictions, rules for power supply and grid access, technical approval schemes for wind farm construction and requirements for grid connection, financial support mechanisms etc. A good legal framework covering all the aspects of wind energy implementation is a precondition for a successful implementation of wind energy deployment plans.

In the present report only the framework in Ireland related to offshore wind energy development and industrial development will be considered.

The Electricity Regulation Act of 1999 initiated the process of electricity market liberization in Ireland, and the completion of the deregulation process is planned for 2005.

From the late 1980s an obligation was placed upon the then state monopoly electricity company, ESB, to purchase electricity from renewable energy producers. In 1995 the first government price support scheme for RE was introduced, known as the Alternative Energy Requirement, AER. Through a competitive bidding process projects obtained a fixed price power purchase agreement for a period of 15 years. AER1 in 1996 authorized contracts for wind generation capacity totalling 30 MW. AER 3 in 1999 authorized contracts totalling 90 MW, and AER 5 in 2002 authorized 353 MW of wind power projects. Due to a low uptake of AER 5 contracts a new and final round, AER 6, was announced in November 2002 with more favourable price caps and contract terms.

By end of 2002 a total of 137 MW wind power capacity was installed and by end of 2003 the wind power capacity had increased to a total of 186 MW. The installation rates were very low during 2001 and 2002, with 9 MW and 11.9 MW respectively, and 49 MW during 2003. Difficulties with the provision of grid connections were a major cause for delays in 2002. Also in 2003 there has been a delay due to grid shortage. In December 2003 the Commission for Energy Regulation, CER, put a hold on further connections to the grid until problems with the grid capacity has been resolved. According to article 7 of EU Directive 2001/77/EC the member states shall take the necessary measures to ensure that operators in their territory guarantee the transmission and distribution of electricity produced from renewable energy sources. The acute problems experienced with the above mentioned weakness of the grid is expected to be resolved in the event of 2004 when a code for grid connection of wind power systems will be completed. Also recent commitment by the Irish government to initiate development of a 1000 MW electricity interconnection project to Wales consisting of two 500 MW interconnectors is believed to help solving the shortage of grid capacity and at the same time increase and improve competition and integration with the UK and European market. It is expected that the interconnectors will be constructed, managed and owned by the private sector, and be well underway by 2006. According to SEI one 500 MW interconnector would represent 10 % of the Irish electricity market.

Apart from the above-mentioned delays due to grid connection problems, the very low deployment rate compared to actual AER contract awards has been explained by complicated local planning requirements. The national planning guidelines have been implemented in a non-uniform way at a local level – especially at the beginning of the process. – However, planning approval is not considered to be the major constraint to achievement of the 2005 targets, since the planning approval for wind farms awaiting deployment was 850 MW by end of 2002, which is far beyond the target for 2005.

In spite of that it is necessary to continue improvement of planning procedures, education of project developers, environmental impact assessment requirements, involvement of local issues and planning and support for local grid improvement, particularly for larger wind farms.

The bid system for AER projects where the winner is the project with the lowest price per kWh may have tempted project developers to offer a too low price to be able to actually implement the project.

2.2.2 Planning and Procedures for offshore wind farms

On land the 26 local counties administer the procedure for planning and approval of wind farms. The planning application is filed with the planning office of the county council in question. In case of disputes a national appeal authority An Bord Pleanala has been established.

For offshore wind farms the planning procedure is set out by Irish Government and administered by the Department of Communication, Marine and Natural Resources

The Foreshore section in the Department deals with:

- Foreshore Legislation;
- Foreshore Leases and Licences;
- Offshore Electricity Generating Stations.

The foreshore is classed as the land and seabed between the high water of ordinary or medium tides (shown as HWM on Ordnance Survey maps) and the twelve mile limit (12 nautical miles equals approximately 22.24 kilometres).

In this context a foreshore *license* is issued with the purpose of investigating the suitability of a particular site with respect to serve as the venue of an offshore power generation station. Provided the site is attractive for the developer he will have to apply for foreshore *lease*, which allows him to proceeed with the actual construction and operation of the wind farm.

The number of Foreshore Leases and Licences (including Foreshore Licences for aquaculture purposes) have increased from a level of between 50 and 100 to nearly 200 licenses and 100 leases granted in the year 2000. It should be noted that the majority are for aquaculture projects.

A potential developer of an offshore wind farm can in principle choose an area offshore on his own discretion. Certain areas are prohibited for use due to established shipping lanes, air navigation, telecommunication, defense or other public needs. The application for an offshore license is filed with the Department of Communications, Marine and Natural Resources (DCMNR). Before applying for a foreshore license it is recommended that the developer consult with Dúchas, the Irish National Heritage Service, which has responsibility for both wildlife and national monuments, including shipwrecks. Provided the license is granted the annual rent is Euro 5 subject to a deposit of 100.000 Euro. During the life of the foreshore license the developer has to carry out site investigations, in particular investigate the sea bottom, measure the wind resource and prepare the Environmental Impact Statement (EIS). Applicants to the AER VI programme had to have a license before they could bid.

Within a time limit of 4 years the developer will subsequently have to apply for a lease to build on the chosen site. A pre-requisite for the application for a lease is the EIS, an authorization to construct, a license to generate and a license to supply electricity. The latter two are obtained from CER (Commission of Energy Regulation).

The lease will be granted provided all requirements by the authorities including PPA and license to generate and supply power to the grid are met. The annual lease payment for an offshore wind turbine farm is either Euro 3,800/MW installed or 2.5% of the gross revenues generated (the higher figure). The deposit for the license will be returned if the lease is obtained.

In general the planning system for offshore projects appears to be well designed and efficiently administered.

2.2.3 The Electricity Market in Ireland

Introduction

This chapter will discuss the relations between wind power and a liberalised power market. The main intentions are to emphasise some of the experiences gained in the Danish system by moving from a planning system into a free power market and try to relate these experiences to the situation in Ireland. Especially the consequences of a high penetration of wind power are discussed, including the impact on power prices and regulation. Seen from a reader's point of view, part of the descriptions in this section might be redundant. Nevertheless, a comprehensive discussion is chosen to explain the general assumptions behind the analysis.

Wind Power in a Liberalised Market Context

In relation to the power system, wind power has two main characteristics that significantly influences the functioning of wind power in the system:

1. Wind power is an intermittent energy source, which is not so easy to predict. The daily and weekly variations are significant, which introduces a high uncertainty in the availability of wind-generated power even within relatively short time horizons.

2. Wind power has high up-front costs (investment costs) and fairly low variable costs. Because part of the variable costs consists of annual fixed expenses, such as insurance and regular service visits, the marginal running costs are seen to be even lower.

Bearing these two main characteristics in mind, a number of questions arise when wind power is introduced into a liberalised market:

- How much wind power can be introduced into the system without excessively increasing the probability of system failures or even breakdowns?
- How will wind power influence the price at the power spot market in the short and long-term?
- What is the need for regulating the intermittent power production from wind plants in relation to the time from gate closure to real-time dispatch?
- What is the cost of wind power not fulfilling its bid to the market, i.e., the cost of regulating wind production into the system?

In what follows, we will try to answer the above-mentioned questions by using the experiences gained in Denmark and trying to relate these to the proposed liberalisation of the Irish power market.

The Consequences of High Shares of Wind Power in the Power System

How a high share of wind power influences the power system is illustrated in the following by using a small example relating to the Western part of Denmark. This area is chosen because it has a number of specific characteristics, some of them relating to wind power:

- Western Denmark is part of an internordic power exchange market comprising Denmark, Sweden, Finland and Norway. Western Denmark is connected to Norway, Sweden and Germany by approximately 2800 MW interconnectors. When this transmission capacity becomes totally utilised, the area is separated from the rest of the market and constitutes its own price area.
- It has a very high share of wind-produced energy – in 2002, almost 20% of the total power consumption was covered by wind power. Presently, most of the wind-generated power is covered by prioritised dispatch.
- It has a high share of decentralised combined heat and power (approximately 1600 MW), which is paid according to a three-level tariff and also is covered by prioritised dispatch. This means that the decentralised plants are producing according to an almost fixed profile and not in accordance with the price signals from the power market. Thus, the decentralised combined heat and power capacity influences the power system in almost the same way as wind power, in reality, equivalent to making the share of wind power significantly higher than the 20%.

Almost 2500 MW of wind power exists by now in the power system of Western Denmark and, thus, wind power has a significant influence on power generation and prices. The importance is illustrated in Figure 1 below, showing the share of wind-generated electricity in total power consumption in the Jutland/Funen area during December 2002. In total, 33% of the domestic electricity consumption in this area was for that month supplied by wind power.

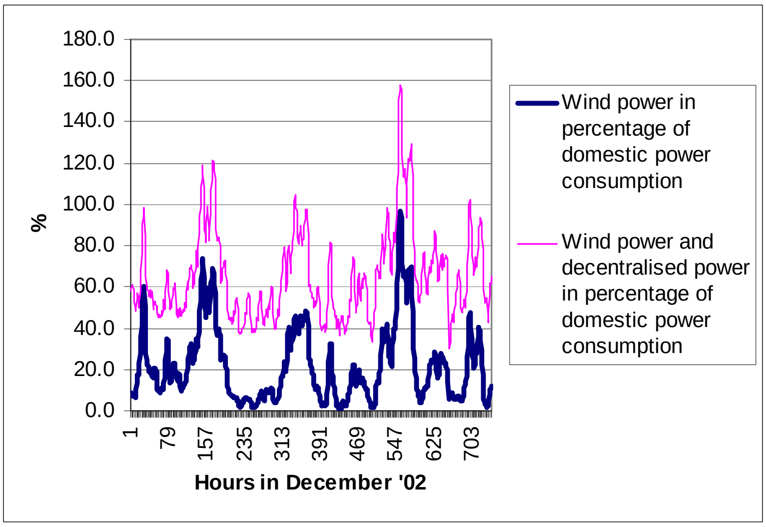


Figure 1: Wind-generated power and decentralised power as percentage of total power consumption on an hourly basis in December 2002, Jutland/Funen area of Denmark.

As shown, the share is close to 100% at certain points in time, indicating that all power consumption at that time could be supplied by wind power in this area. As mentioned above, a large part of the power generated by wind turbines is still covered by priority dispatch in Denmark, whilst this is also the case for power produced by decentralised combined heat and power plants. This implies that these producers do not react on the price signals from the spot market – wind producers under priority dispatch are paid the feed-in tariff for everything they produce, while decentralised CHP plants are paid according to a three-level tariff, highest in the daytime and lowest at night-time. Thus, the last-mentioned ones will only produce at the low tariff if there is a need to fill up the heat storages. Therefore, total prioritised production was for a number of hours in December higher than domestic power demand, thereby adding to the problem of congestion of transmission lines. In reality, the prioritised decentralised CHP production behaves in almost the same way at the power market as wind power does and, therefore, the situation in Western Demark is equivalent to a significantly higher share of wind-generated power.

The consequences are clearly shown in *Figure 2*, where deviations between the NordPool system price and the realised price in Western Denmark are depicted[2]. As shown, the Western Denmark price is significantly below the System price for a large number of hours. The expected solution in Denmark is to change the prioritised status of the decentralised CHP plants, thus, moving these to act on the power market as other conventional power plants. In that case, an even higher share of wind power could be accepted in Western Denmark.

Nevertheless, although it sometimes has been difficult to tighten up the loose ends of the power system until now, there have been no system failures on account of too much wind power in the system.

2 The power price in Western Denmark becomes lower than the System price, when transmission lines from the area are totally utilised for export of power and there still is an excess of supply over demand forcing conventional power plants to reduce their load.

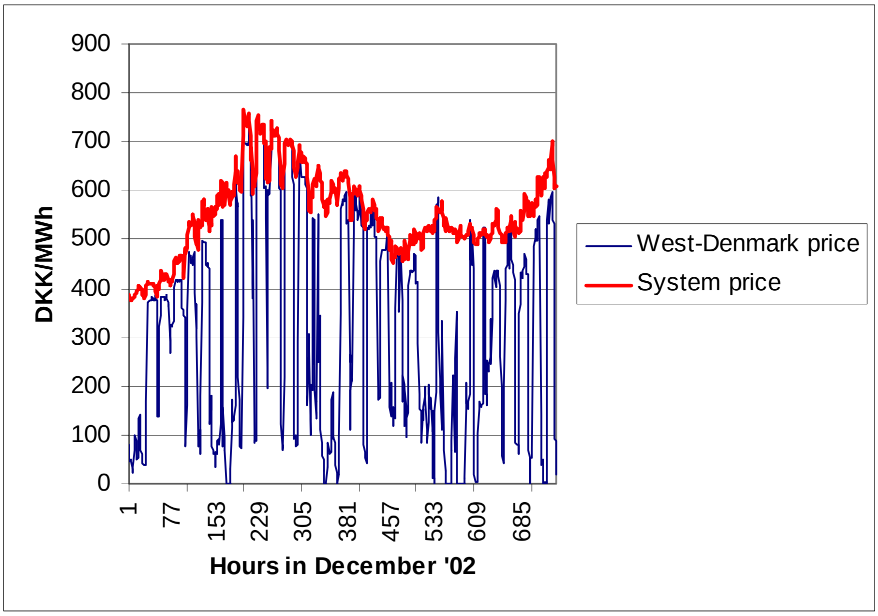


Figure 2: Deviations between the System price of NordPool and the price of power in Western Denmark.

When comparing with Ireland, at least three issues should be taken into account:

- That Ireland has a smaller capacity of interconnectors to abroad;
- That gate closure[3] in Ireland is expected to be at most four hours (in the introductory period) ahead of dispatch, reduced, if possible to one hour when the market is up and running. In Denmark, the period is 12-36 hours in advance;
- That the majority of wind power in Denmark is at present covered by prioritised dispatch. In Ireland, only small wind farms will expectedly be prioritised in production, while the larger ones can somehow react on market prices.

These three issues will to a certain degree compensate for each other. The lower the transmission capacity to other countries is, the more difficult it is to integrate wind power, whilst the closer the bidding is to dispatch, the more certain wind power will fulfil its bid. If larger wind farms have the same market conditions as conventional power plants, they would probably be closed down when the power price approaches zero and, thus, make it easier to integrate wind power in the system.

Thus, Danish experiences indicate that:

It should be possible to utilise wind power supplying at least up to 20% or more of domestic power consumption without implying major failures of the power system[4].
Of course, a stronger interconnection of the power supply with other countries will make it easier for Ireland to handle high shares of wind power.

Wind Power and Prices at the Spot Market

Wind power influences the prices at the power market in two ways:

3 After gate closure it is not possible for the actors at the power market to change their bids.

4 Problems generated due to eventual internal transmission line congestions not being taken into account.

1. As mentioned above, wind power normally has a low marginal cost and, therefore, enters close to the bottom of the power supply curve. This, in turn, shifts the power supply curve to the right implying a lower system power price, depending on the price elasticity of power demand. If no congestion in the transmission of power exists, the System price of power is expected to be lower during periods of high wind compared to periods of low wind.

2. Congestions in power transmission might arise, especially in periods with much wind-generated power. Thus, if the available transmission capacity cannot cope with the needs to export power, the supply area is separated from the rest of the power market and makes up its own pricing area. With an excess supply of power in this area, conventional power plants have to reduce their production, because wind power is normally not capable of lowering its power production. In most cases, this will imply a lower power price at this sub-market.

In the following, the impact of wind power on spot market prices will be illustrated again by using the case of Western Denmark.

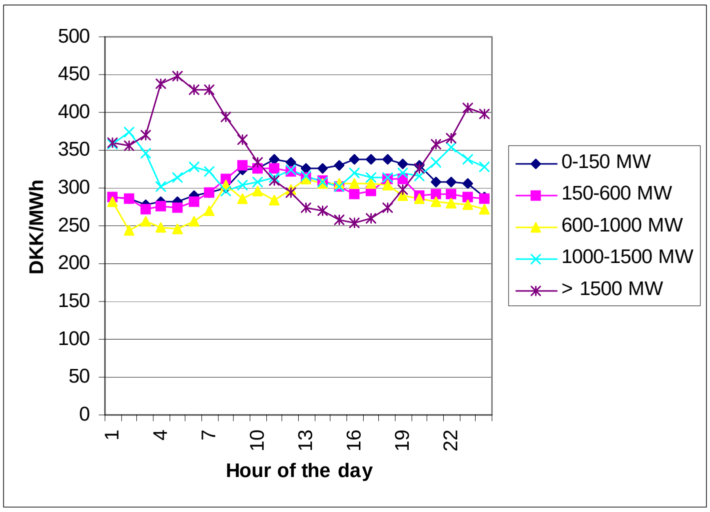


Figure 3: The impact of wind power on the spot power System price, the case of Western Denmark.

How the large capacity of wind power in the Western Denmark system influences the power System price is shown in *Figure 3*. Five levels of wind power productions and the corresponding power System prices are depicted for each hour of the day during periods where there were no congestions of transmission lines. Thus, "> 1500 MW" means that the installed capacity of wind power within the considered hour has produced more than 1500 MWh and correspondingly for the other four levels. For each of these five levels the average is calculated within each hour and plotted against the average power price at the market. As shown, the more wind-generated power, the lower the power System price, although at very high levels of wind-produced power, the System price is reduced significantly in the daytime whilst increased at night-time. This last-mentioned issue is difficult to explain, but it could be a consequence of spot market bidders expecting these high levels of wind power during night-time. Nevertheless, a significant impact on the System price is found, which could be expected to increase in the long-term if even larger shares of wind power are to be attained.

The second of the above-mentioned hypotheses is concerning power prices in cases where transmission line capacities are totally utilised. As shown in *Figure 1* above, the share of wind-generated electricity in total power consumption in the Jutland/Funen area during December 2002 is close to 100% at certain points in time, indicating that all power consumption at that time

could be supplied by wind power in this area. If the prioritised production from decentralised CHP plants is added on top of wind power production, an excess supply of power exists in a number of periods. Part of this excess supply might be exported, but when transmission lines are totally utilised, the problem of congestion appears. In that case, equilibrium between demand and supply has to be found within the specific power area, requiring conventional producers to reduce their production, if possible. The consequence to the market is illustrated in
Figure 4 below.

Again, five levels of wind power productions and the corresponding power prices in the area are depicted for each hour of the day during periods where there were congestions of transmission lines to neighbouring power areas. As shown, a highly significant relationship between wind production and the power price is found. Thus, the more wind-generated power, the lower the power price is in the area.

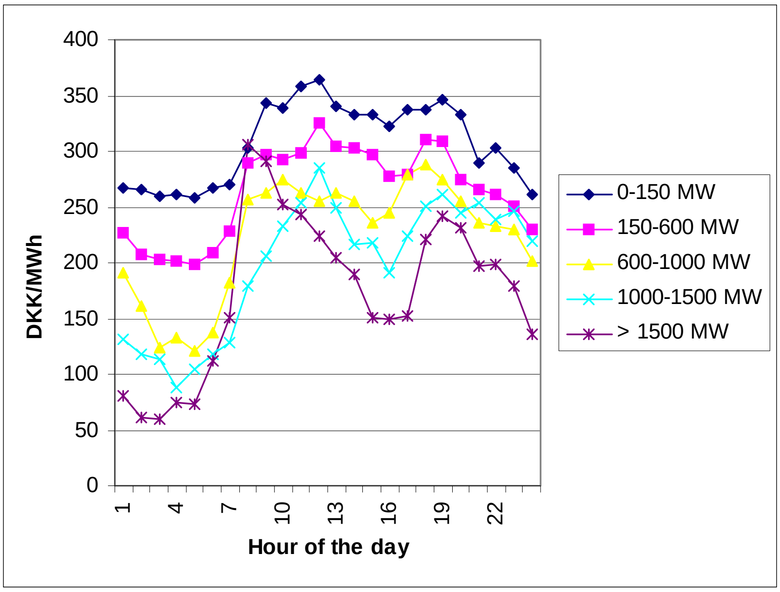


Figure 4: The impact of wind power on the spot power price of Western Denmark, when congestions exist in the power system between countries.

How much wind power influences the power price at the spot market will heavily depend on the amount of wind power produced and the size and interconnections of the power market. Danish experiences show that:

- Even within the large Nordic power system, wind power has a small, but significant negative impact on the power price. The more wind power supplied, the lower the power System price.
- When Western Denmark is separated from the rest of the power market due to congestion of transmission lines, wind power has a strong and significantly negative impact on power prices, both during daytime and night-time.

Within the Irish system, a similar negative correlation between the amount of wind power and the price of power can probably be expected if high shares of wind power are introduced into the power system.

The Need for Regulating Wind Power

When wind power cannot fulfil the bids given to the power market, other producers have to increase or reduce their power production accordingly in order to make sure that demand and supply of power is equalised (balancing). But other actors at the spot market might have a need for balancing power as well, due to changes in demand, power plants having to shut down, etc. Recently, the Danish TSO's have entered into a common Nordic balancing market, but until 2003, most if not all of the balancing was performed within the separate TSO areas[5].

The capacities shown in *Figure 5* are related to all types of power balancing , i.e., not only regulation undertaken due to wind power bids not being fulfilled[6]. Nevertheless, although not very significant, there is a clear tendency that the more wind power produced, the higher is the need for down-regulation. Correspondingly, the less wind power produced, the higher is the need for up-regulation. Note that what is shown in *Figure 5* is that the forecasts for wind-produced energy tend to be too low, when much wind power is produced, and tend to be too high, when only small amounts of wind-generated power enter the system. On average the need for regulation corresponds to approximately 150 MW of installed capacity capable of regulation.

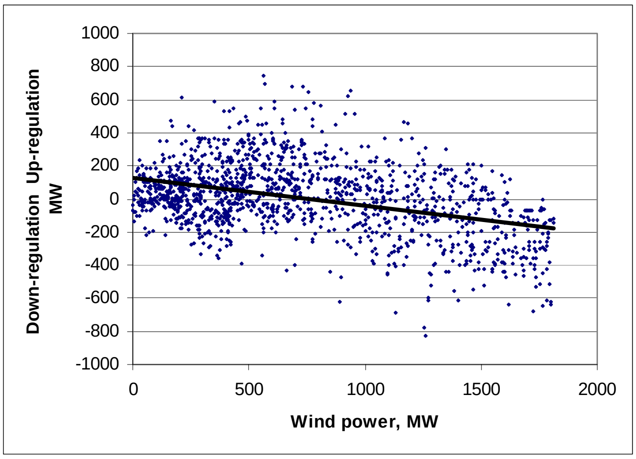


Figure 5: Regression analysis of down or up-regulation against the amount of wind power for the Jutland/Funen area. Hourly basis for January-February 2002.

Figure 6 below shows that wind power strongly increases the need for regulation in a comparison between power areas. Observe that the bidding for the spot market is carried out 12-36 hours in advance at the Nordic power market and, therefore, wind power bids will be much more off track than what will expectedly be seen in an Irish system with expectedly one hour to gate closure.

5 In the Nordic region, Norway, Sweden and Finland each have their own TSO. Because there is no interconnection over the Great Belt, Denmark is divided into two TSO areas, similar to the pricing areas in Denmark

6 In the available data, it is not possible to sort out the specific unfulfilment of wind power.

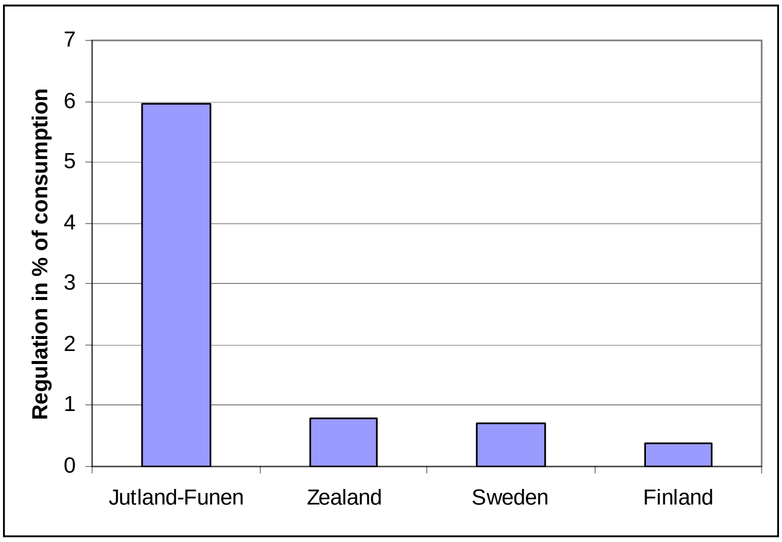


Figure 6: The need for regulation depending on the amount of wind power in the power system.

Sweden and Finland comprise large areas and have a very low capacity of wind power. Zealand (the Eastern part of Denmark) has less than 10% of wind-generated power of domestic power consumption, while Jutland-Funen (Western part of Denmark), as mentioned, has coverage of more than 20% of total power consumption. The consequences for the regulation need are clearly illustrated in Figure 6, where regulation in percentage of consumption in the Western Denmark area is more than 6 times higher than in the other areas.

Thus, in general:

- It should be expected that the more wind power in the power system, the higher the need for regulation.

Though it should be taken into account that the time of gate closure in the Nordic system is 12-36 hours ahead, significantly more than the four or perhaps only one hour as expected in Ireland. The closer the time of gate closure is to the actual time of dispatch, the smaller should the divergence expectedly be between actual wind power production and the stated production bids.

The Cost of Regulating Wind Power into the Power Market

In the Nordic power market, a wind turbine owner producing more than his bid will receive the spot price for all his production, but he will have to pay a premium for other power plants in order to regulate down because his production is exceeding his bid. If he produces less than his bid, he will correspondingly have to pay a premium for the part other generators have to produce in up-regulation. The costs of regulation within the Jutland/Funen area of Denmark are shown on an hourly basis in *Figure 7* for January and February 2002. Thus, the amounts of wind power produced at the specific hour are shown at the x-axis, while the cost per MWh of regulation is shown at the y-axis.

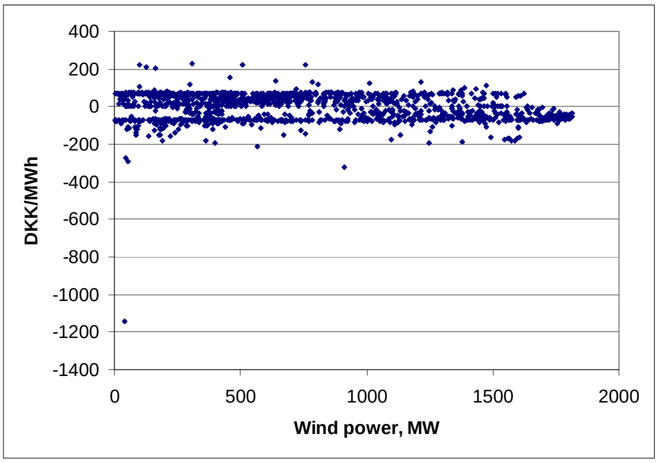


Figure 7: The cost of regulation in the Jutland/Funen area. Hourly basis for January-February 2002.

The picture is quite clear with a "band" of costs, both for up and down regulation almost independent of how much wind power is generated within the specific hour. Thus, although the need for regulation is increasing with higher quantities of wind power produced, the regulating costs are seen to be almost independent of the level of required regulation. The average cost of regulating up is calculated to 0.8 c€/kWh regulated, while the cost of regulating down correspondingly amounts to 0.6 c€/kWh regulated during the January-February 2002 period.

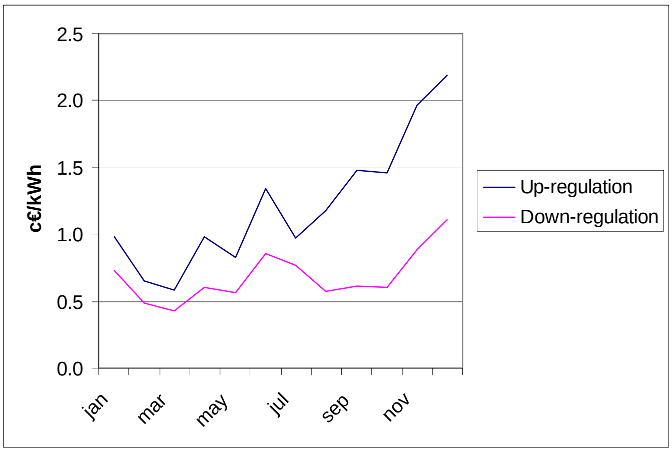


Figure 8: The cost of regulation calculated as monthly averages for the year 2002 for the Jutland/Funen area.

Figure 8 shows the regulation costs for the whole of 2002 calculated as monthly averages. As the figure shows, the cost of up-regulation is constantly above the cost of down-regulation, probably because the marginal cost of up-regulation is higher than for power producers regulating down. Moreover, the cost of regulation – again, especially up-regulation – is not surprisingly increasing with the general level of the spot price, which greatly increases towards the end of 2002[7]. For 2002, the average up-regulation cost is calculated to 1.2 c€/kWh regulated, while the cost of down-regulation amounts to 0.7 c€/kWh regulated.

7 At the end of 2002 there was a draught in Norway and Sweden and for that reason the power System prices became extremely high.

As mentioned, the regulated quantities do not only relate to wind power, but to the total system, including non-fulfilment of bids from demand and conventional power producers as well. But, well-knowing that the estimate is upper bound, the monthly regulation costs for the Western part of Denmark for 2002 are in *Figure 9* related to wind power only. Finally, for comparison, the costs are in *Figure 9* correspondingly related to the total power supply.

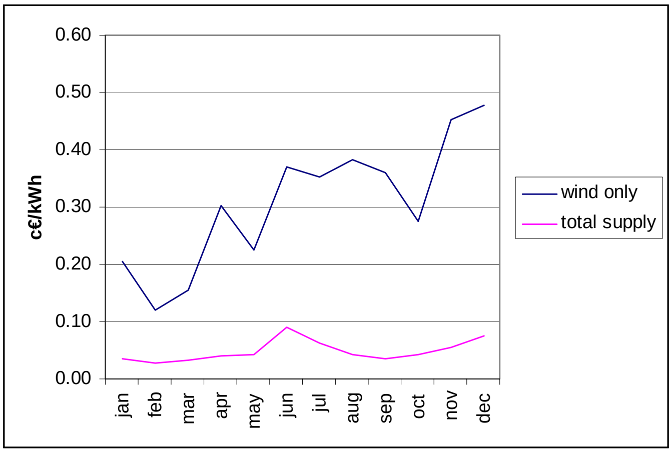


Figure 9: Regulation costs calculated as monthly averages for the Jutland/Funen area for 2002, if costs are borne by wind power only or are related to the total power supply.

As shown in *Figure 9*, regulation costs per kWh borne by wind power only are lowest during periods with plenty of wind-generated power, i.e., during the Winter/Spring of 2002, and higher in the Summer-time, where less wind power is produced. However, the Autumn/Winter of 2002 with the high spot prices is again seen to be an exception. The average regulation cost if borne by wind power only is calculated to 0.3 c€/kWh for the year 2002[8]. As mentioned above, these estimates constitute an upper bound for the regulation costs for wind energy, because the regulated quantities not only relate to wind power. If the regulation costs are distributed across the total power supply, the costs per kWh are, of course, much lower, and if calculated as an average for 2002, the cost amounts to 0.05 c€/kWh.

Can these cost estimates be compared in a reasonable way to an Irish situation? Some similarities and some dissimilarities do exist:

- The regulation in Denmark is mostly based upon domestic fossil fuel-fired power plants, as will be the case for Ireland;
- Between the Government and the Danish Power Companies, a stand-by agreement is made, involving a lump-sum payment to the Power Companies. In the cost above, only variable costs are included, thus, stating a lower limit of these regulation costs;
- On the other hand, competition for regulation is limited at the Danish Power market, indicating that the costs calculated above could be lowered if an efficient competitive regulatory market was established.

Thus, a cost-level ranging between 0.7 and 1.2 c€/kWh regulated seems, in general, to be an appropriate "guesstimate" of the costs associated with the regulation of wind power.

8 It is not known whether 2002 is a representative year for regulating costs.

2.2.4 The Electricity Grid

Background

The electricity grid in the Republic of Ireland is operated as an island grid synchronised only with the grid in Northern Ireland. The maximum load is just over 4000 MW [5], while the minimum load is just less than 1500 MW. In the Eltra system, the extreme loads are quite similar. In 2001, the maximum one hour average was 3560 MW while the minimum one hour average was 1637 MW. As this is one hour averages, the actual maximum load would be a little greater and the actual minimum load would be a little less.
According to ESB home page, the total generation capacity in the ESB system is 4700 MW, and this figure is expected to grow with 500 MW over the next 5 years. Most of the generation capacity is controllable steam plants. For comparison, the Eltra area has 3100 MW central combined heat and power (CHP) and 1600 MW decentralised CHP, together with 2400 MW wind power. Only the central CHP provides power control. It is seen from these figures that there is a larger reserve in the Eltra system than in the ESB system.
Although the two systems are quite similar in size, the conditions for operation are very different, because the Eltra system is interconnected to the UCTE grid, i.e. the continental European power system supplying approximately 450 million people, while the ESB system is operated as an island system together with the Northern Ireland system. The interconnection capacity of Ireland is approximately 500 MW HVDC to Scotland. However, 11 February 2004, RoI Minister for Communications announced a set of new energy initiatives aimed at increasing security of electricity supply, including the development of a 1,000 MW electricity interconnection project to Wales. For comparison, Eltras interconnections are approximately 1200 MW HVAC to Germany, 1000 MW HVDC to Norway and 600 MW HVDC to Sweden.

Table 1: Key figures for ESB and Eltra grid (end 2003)

	ESB	Eltra
Conventional capacity	4700 MW	4700 MW
Maximum load	4000 MW	3560 MW
Minimum load	1500 MW	1637 MW
Wind Power	186 MW	2400 MW
Tie lines AC	0 MW	1200 MW
Tie lines DC	500 MW	1600 MW

The figures are comprised in Table 1. Comparing the figures, it is obvious that the Eltra system has much better technical possibilities than the ESB system to export wind power during high wind / low load situations. However, since the wind energy development in North Germany is also very strong, and because the wind variations in the Eltra area are strongly correlated with wind variations in North Germany, the export capacity to Germany is limited in periods with high wind, and this limitation will be stronger with the planned wind energy development in the northern Germany.
Thus, the ESB system is an island system, while the Eltra System is more an "end-of-line" system. As a consequence, some of the technical challenges related to the integration of wind energy are much more severe in the ESB grid than the Eltra grid, but also many aspects are quite similar, and the experience from integration of wind energy in the Danish system and other systems can be very useful to ESB. The main difference is probably on the issues, which are related to the frequency control, because the frequency is much softer in the island system.

Garrad Hassan has made a study of the impact of increased levels of wind penetration on the electricity systems if RoI and NI [3]. According to that study, the main limits are:

1. Transmission system limitations, which will prevent the system from handling so-called N-2 contingences, e.g. cases where one unit is removed for maintenance and another unit fails. According to the figures in the executive summary of the Garrad Hassan report, this is far the most severe limitation, "probably at a few hundred MW".
2. A power control limit where the first wind will be curtailed as the available wind power + minimum loads on generators exceed the demand in low-load / high wind load cases. This limit is estimated by Garrad Hassan to be at approximately 800 MW in 2005.
3. Transmission system limitations, which will prevent the system from handling so-called N-1 contingences, e.g. cases where only one unit fails. This limit is according to the executive summary of the Garrad Hassan report approximately 3300 MW.
4. The power control limit where almost all the wind power will be curtailed as the available wind power + minimum loads on generators exceed the demand in most load cases. This limit is estimated by Garrad Hassan to be at approximately 4000 MW.

As planning and implementation of transmission system reinforcements is often a lengthy process (can take more than 4 years), the first limit is not straight-forward to overcome. However, Garrad Hassan suggests applying a so-called Remedial Action Scheme (RAS) to cope with delayed transmission system reinforcements. This type of RAS is used in US. As an example of the RAS, if a unit is taken out for maintenance, then the system is weakened, and consequently it becomes less robust. Still, the weakened system should be able to handle the failure of another unit. If it is not able to do so, then the RAS prescribes what should be done to re-establish the robustness in critical load situations. One mean can be to curtail some of the wind power in the critical situations, e.g. during minimum load and maximum wind.
In the following, some of the technical limitations for wind power integration will be discussed in more detail.

Fault ride through

The so-called "fault-ride-through" capability of wind power is a key issue in the integration of large-scale wind power in power systems. The purpose of the fault-ride-through capability is to ensure that the wind turbines are able to stay connected to the grid during a grid fault, i.e. avoid tripping of the wind turbines due to undervoltages, overcurrents, overspeeds or any other limits in the wind turbine protection systems, which are exceeded as a consequence of a short circuit in the grid. If the wind turbines are not able to ride through the fault, the consequence is sudden loss-of-generation, which must be replaced by fast reserves from other generators in the system.
Similar fault-ride-through capabilities are required of the conventional generators in the system to ensure that the system is able to operate if one unit in the transmission system is fails. This is also denoted the N-1 criteria, or a single contingence. As a consequence, no generation unit must trip because of a short-circuit on the terminals of any other generation unit.
In Denmark, it has been a requirement that wind turbines connected to the distribution system disconnect from the grid in the event of an undervoltage, typically due to a grid fault, i.e. the opposite of fault-ride-through. This has been required to avoid disconnections of loads in addition to the disconnection of wind turbines. Wind turbines connected to the distribution system shear a distribution transformer with loads. If standard wind turbines with directly connected induction generators would stay on the grid during the fault, they would consume a large transient reactive current to energize the generators when the voltage recovers. This reactive current will be up to 7 times the total rated current of the wind turbines, which is often enough to activate the overcurrent protection of the distribution transformer. As a consequence, both wind turbines and loads

will be disconnected. This can be avoided if the wind turbines simply disconnect before the voltage recovers.
However, when the installed wind power in the grid increases, the possible loss-of-generation increases similarly. Thus, facing the development of large offshore wind farms in Denmark, the Danish TSO's issued the first requirements for connection of large wind farms to the *transmission system* in 1999, including the requirement that the wind turbines are able to ride through faults in the transmission system. The assessment of the fault-ride-through capability is done by the TSO, as they have the complete transient simulation models of the grid. However, the wind farm owners, and consequently the wind turbine manufacturers, must provide the TSO with transient models of the wind turbine, which enables the TSO to simulate the wind turbines including the relevant protection system details of the wind turbines.
New requirements for grid connection of wind turbines in the *distribution system* are now under development in Denmark. The present status is that a draft is under hearing. The new requirements will also include fault-ride-through requirements to the wind turbines connected to the distribution system.
In several other countries, fault-ride-through requirements are under development. In Scotland, a proposal is under hearing. The draft Scottish code is probably the most demanding on the wind turbines. The main parameters for fault ride-through are the duration and the depth of the voltage dip. In the draft Scottish code, the requirement is to ride through a voltage dips to 0% in 300 ms. The 300 ms have been selected as the maximum backup clearance time in the transmission system. 0 % is obviously the ultimate worst case. In Denmark, the required duration is only 100 ms corresponding to the normal fault clearance time, and the voltage dip will depend on the individual case, which must be simulated. Thus, there is a difference between the requirements, which is due to a combination of objective technical difference in the protection systems and more subjective assessments.
The majority of the wind turbines operating in the Danish systems today are without fault-ride-through capabilities. This would be a problem to an island system like the Irish, because the instantaneous power reserves (primary control) in the system are less. The instantaneous reserves must be sufficient to supply the rated power of the largest unit in the system, which is only 400 MW in the Irish case [5].
However, when fault-ride-through is required, the requirement to depths and duration of voltage dips are not very much affected by the grid being an island grid. These parameters depend much more on the settings in the protection system.
The frequency limits, within which the wind turbines are required to stay connected, could more likely be affected by the grid being an island grid, because the frequency is "softer" on an island grid.
The conclusion is that wind turbines already today have to meet requirements on fault-ride-through capabilities in grid codes for several TSO's, and the wind turbine manufacturers are able to supply wind turbines, which meet these requirements [2]. If wind turbines do no have sufficient capabilities themselves, STATCOMs and other auxiliary equipment can be used to mitigate the voltage problems due to grid faults, and thus improve the fault-ride-through capability of wind farms.

Transmission system restrictions

The ESB transmission system is meshed, which makes it more robust than a radial system. This meshed structure is quite common for transmission systems, and it makes the system more robust than a radial system. However, the protection system in a meshed system is not as simple as the protection system in a radial system. The protection system in a meshed system is designed for power flow in any direction.
The transmission system limitations are as seen above according to Garrad Hassan the most critical for large scale integration. However, reinforcement of the transmission system takes several years. Therefore, in the Garrad Hassan report, the RAS is proposed to cope with delayed transmis-

sion system reinforcements. The economical and legal consequences of RAS are not investigated further in the Garrad Hassan report, and according to the Consultation Document [4], RAS is currently not permitted under existing transmission planning criteria.
However, it would be expected that the costs, which are mainly due to curtailment of wind power, will be relatively small for e.g. 700 MW wind power, because wind power will only be curtailed if a unit is out for maintenance *and* this causes the remaining system (without the removed unit) to not fulfil the N-1 criteria *and* the curtailment of one or more wind farms can re-establish the N-1 reliability.
The other transmission system restrictions, which are investigated in the Garrad Hassan report, are

1. Limits for wind power due to technical minimum loads on conventional generators. Most of the conventional plants have to be operated at minimum half rated power.
2. Voltage control problems. This is often a design criteria in transmission systems as well as distribution systems.
3. Thermal limits in transmission cables and transformers. This showed to be the dominant constraint.

Generally, these restrictions lead to much higher limits for wind power than the N-2 criteria discussed above. According to Garrad Hassan, the voltage control showed not to be a major issue. Actually, some existing voltage control problems were eliminated when wind power was added to the system.

Frequency support and power control

In Eltras requirements for connection to the transmission system, power control of the wind farms is another new key-requirement (in addition to fault-ride-through). The purpose of the power control is according to Elsam (the owner of the Horns Rev wind farm, the first large offshore wind farm in Danmark) to enable the wind farms to operate at reduced power during periods with reduced transmission capacity in the grid (e.g. due to service or replacement of components in the main grid) [6]. This is very close to the RAS formulation mentioned above, only with the Elsam formulation, it is acceptable permanently not to reinforce the transmission system (i.e. not just postpone the reinforcement) although curtailment of wind power would be necessary during services or replacements of components. From a cost/benefit point-of-view, it seems sound to avoid expensive grid reinforcements if they are only needed in special cases, where they can be met by less costly curtailments.
The power control implemented in the Horns Rev wind farm level includes

1. Absolute power limitation, i.e. an overall limit for the output power
2. Balance control, i.e. the possibility to limit power as an instrument for the TSO to involve the wind farm in the secondary balance control
3. Gradient limitation, i.e. limitation of the power ramp rate. It is only possible to limit the ramp rate for increasing power.
4. Delta control

Besides these controls, the wind turbines are able to participate in the primary control, i.e. the instantaneous power control based on the system frequency. According to Elsam, this feature has been implemented in the wind turbines, because it provides the fastest response to frequency changes. However, it seems that the fast communication between the wind turbines and the wind farm controller should be sufficient to implement primary control in the wind farm controller instead.
Normally, if the primary control in the Horns Rev wind turbines is activated, it would support the UCTE frequency, i.e. contribute with a very small contribution in a very large system. However, if the Eltra area, or even a smaller area is isolated in island operation, the primary control is intended to help controlling the frequency on the island system. This feature can also be used in normal operation of the Ireland grid, where “islanding” of a system of the same size as the Eltra system is the normal operation condition.

Reactive power and voltage control in transmission system

In Eltras requirements for connection to the transmission system, it is required that the wind farms can be controlled to unity power factor, i.e. zero reactive power. However, if the wind turbines are equipped with additional reactive power control devices, the TSO should have access to this control to support the voltage control in the transmission system.
In Horns Rev, Eltra can control the reactive power through the wind farm main controller. Besides, the wind farm can contribute to the voltage control in the wind farm connection point to the transmission grid.
Although Garrad Hassan concluded that the voltage control in the transmission system is not a major issue in the ESB grid, it well be useful to have similar voltage controllability in large wind farms in Ireland.

Distribution system restrictions

The wind energy development Europe in the 1980'ies and 1990'ies' (primarily Denmark and Germany) was mainly based on connections to the distribution system. For this type of grid connection, the main issue is the influence of the wind turbines on the power quality or the voltage quality in the distribution system.
In Denmark, the main focus was on the influence of the wind turbines on the voltage profiles in the distribution system. But also the influence on the protection scheme and requirements to limit the inrush current were included in the early Danish requirements. In Germany, much focus was on the flicker emission and harmonic emission from wind turbines.
In 2001, a Final Draft International Standard for measurement and assessment of power quality of grid connected wind turbines, IEC 16400-21, was issued. This standard includes the experience from a grid connection in a number of countries including Denmark and Germany, and it provides a commonly agreed method to quantify the power quality of a wind turbine. Moreover, it provides methods to assess the influence of one or more wind turbines on the voltage quality in the grid. However, the requirements to the power quality are still a national issue, as there are no limits for power quality specified in IEC 61400-21.
IEC 61400-21 covers very well the main issues relevant for design of grid connection to the distribution system. The standard specifies measurement methods for:

1. Maximum power (relevant to assess voltage profiles, cable and transformer thermal limits and protection)
2. Reactive power (relevant to assess voltage profiles, cable and transformer thermal limits and protection)
3. Voltage drops
4. Flicker emission
5. Harmonic emission from wind turbines with power electronics

The power quality issues, or the voltage quality issues, relevant in Ireland are expected to be quite similar to other countries, because it is related to the local conditions, and is not reflected by the grid being an island grid.

Summary

The integration of wind energy in the ESB electrical power system raises a number of technical challenges. The solutions to some of the challenges can benefit from experience with integration of wind energy in other systems, whereas other issues – particularly related to the system being a relatively small island system – involves challenges where little experience is available. The ESB system is comparable is size to the Eltra system, and advantage can be taken from Eltras experience with large-scale integration of wind energy.

- The main difference between the ESB system and the Eltra system is that the ESB system is part of an island system, while the Eltra system is interconnected to the large UCTE system.

This has a strong influence on the primary frequency control, and on the necessary curtailment of wind power in the case of large scale wind power in the system.

- Transient stability of the wind power installations in the event of grid faults is essential to allow a high level of wind energy in the power system. This is needed to a avoid substantial loss-of-(wind)power in the event of a grid fault. Concerning transient stability, the necessary requirements will depend on the design of the protection system, but ESB can take advantage of experience from other systems, including the Danish, German and Scottish systems.
- Transmission system limits in the case of replacement or maintenance of critical units in the system have to be dealt with. As reinforcement of transmission system is normally a lengthy and expensive process, other means like the RAS performed in USA should be considered.
- Power quality issue in the distribution system is quite similar to the problems faced in Denmark, Germany and several other countries, and to the IEC 61400-21 standard on "Measurement and assessment of power quality of grid connected wind turbines".

2.3 The Wind Energy Industry

As of now no manufacturing capacity of wind turbines has been established in Ireland but several of the large international wind turbine manufactures are represented in Ireland. In the context of the present report the term "The Wind Energy Industry" means all aspects of suppliers of goods and services, owners, shareholders, operators i.e.:

- Project developers
- Agents and representatives for foreign manufacturers
- Suppliers of measurement equipment and services
- Planning Consultants
- Project Engineering Consultants
- EPC Contractors
- Onshore support companies
- Offshore support companies
- Offshore transport companies
- Offshore access systems
- Offshore cabling
- Offshore erection of wind turbines
- O&M Service providers
- Owners and shareholders
- Financing companies
- Insurance companies
- Small-scale wind Equipment Suppliers

On land the cost of the wind turbines corresponds to approximately 80% of the total project costs, while offshore the additional services make up more than half of the cost of the project. In chapter 6 the opportunities for the Irish industry is investigated further.

3 The Wind Energy Market

The purpose of this chapter is to give an overview of the market for wind energy worldwide and by end of the chapter to propose relevant scenarios for a likely development in Ireland. Along with the general market overview a more detailed assessment is carried out for the Irish and the British market. This is justified by the fact that players i,e on offshore development in Ireland may see the total market in the area around Ireland and UK as there domestic market.

General trends and key figures from the market is traced from the recent World Market Update 2003 – issued by March 2004 from BTM Consult ApS [15]. This report includes historical update as of the end of 2003 for all major market in the world. The BTM-C report also includes a forecast until 2008 for Ireland a.o. It is worth noting that this forecast does not necessarily fit to the targets from the Consultation Document, which is the basic platform for the scenarios made in this specific report.

3.1 The world market in overview

3.1.1 Introduction

After a modest start up of modern wind power development in the beginning of the 80'ties, a mature industry emerged. An industry with an annual turn over around 7 USD billion corresponding to some 8.300 MW of new capacity installed during 2003 is established today.

The industrial development was started in Denmark and US in the beginning of the 80'ties. Later around 1990, Germany and England became participators in the development.

On R&D level many countries took part in the development already since back to mid 70'ties. USA, Germany, Sweden, Italy, The Netherlands and Denmark had all national funded R&D programmes.

The countries with most success in building up industrial capability and competence, were those where market stimulation programmes were implemented along with governmental funded R&D programmes.

In the early stage of the development it was in Denmark and in US and later on Germany and Spain joined the group of countries with significant industrial activities regarding development and utilisation of wind power in their respective countries.

The development was relatively modest up to 1990. The optimisation of the turbines and upscaling to commercial sizes around 500 kW contributed to an accelerated development from 1995 and onwards.

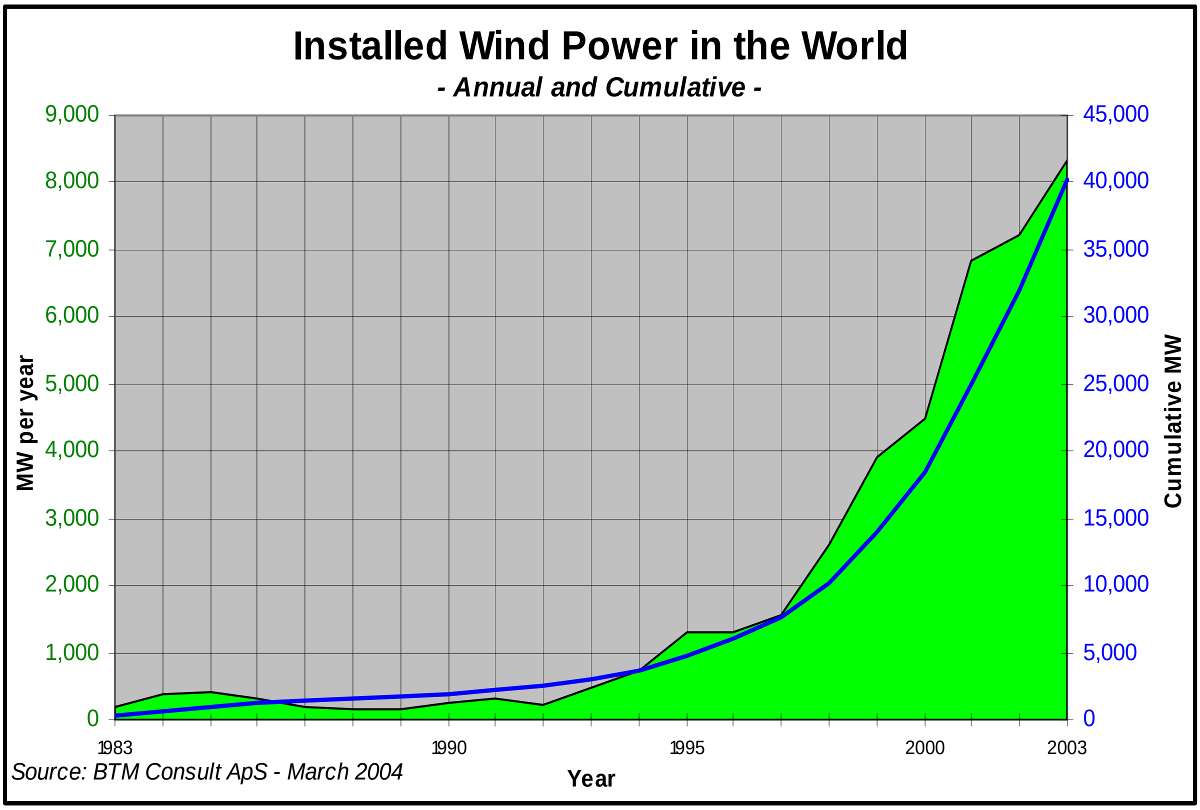
Table 2 gives the growth rates during the past 5 year and Figure 10 shows the development in installation of wind power since back 1983 – expressed in absolute installed capacity and in growth over the previous year.

Table 2: World Market Growth rates 1998-2003

Year:	Installed MW	Increase %	Cumulative MW	Increase %
1998	2,597		10,153	
1999	3,922	51%	13,932	37%
2000	4,495	15%	18,449	32%
2001	6,824	52%	24,927	35%
2002	7,227	6%	32,037	29%
2003	8,344	15%	40,301	26%
Average growth - 5 years		**26.3%**		**31.7%**

Source: BTM Consult ApS - March 2004

Figure 10: Annual & cumulative global wind energy development 1983-2003



There are now more than 68,000 wind turbine generators installed around the world, representing a total of 40,300 MW of installed wind power capacity.

The remarkable growth has taken place by very high growth rates particularly since 1997. The distribution is, however, uneven distributed both with regard to continents as well as to individual countries.

Distribution by continent
The 40,300 MW in the world are distributed as following:

Americas: 6,905 MW
Europe: 29,301 MW
Asia: 3,790 MW
Africa: 211 MW
Rest World: 95 MW

The most significant is the overwhelming representation of wind power on the European continent. That development is a result of – not superior wind resources – that there among countries in Europe has been a political will to utilise these resources, and it has been encouraged by the fact that Europe does not possess plentiful resources of fossil fuel. Europe is heavily dependent on import of fossil fuel from 3'rd countries. The 29,301 MW in Europe by the end of year 2003 represent 72.7 % of the world cumulative wind power capacity.

In Table 3 the distribution among European countries is shown. Obviously a few countries share the majority of the installed capacity. Germany is the country with the most progressive development both in terms of current annual installation and in terms of cumulative capacity achieved. But also Denmark and Spain have achieved a relatively high penetration of wind power and a lot other countries are under way with substantial new installation in coming years.

Table 3: Installed capacity in 2002 and 2003 (Europe)

	Installed MW 2002	Accu. MW 2002	Installed MW 2003	Accu. MW 2003
Austria	44	**130**	285	**415**
Belgium	11	**45**	33	**78**
Denmark	530	**2,880**	218	**3,076**
Finland	4	**44**	9	**53**
France	69	**183**	91	**274**
Germany	3,247	**11,968**	2,674	**14,612**
Greece	104	**462**	76	**538**
Ireland (Rep.)	38	**167**	63	**230**
Italy	106	**806**	116	**922**
Luxembourg	1	**7**	5	**12**
Netherlands	219	**727**	233	**938**
Norway	80	**97**	4	**101**
Poland	30	**54**	1	**55**
Portugal	51	**204**	107	**311**
Spain	1,493	**5,043**	1,377	**6,420**
Sweden	55	**372**	56	**428**
Switzerland	1	**6**	0	**6**
Turkey	0	**19**	1	**20**
UK	55	**570**	195	**759**
Rest of Europe: Other East European and Baltic	28	**48.0**	4.6	**52.5**
Total Europe	**6,163**	**23,832**	**5,549**	**29,301**

Source: BTM Consult ApS - March 2004

Ireland, with its 230 MW online ranks as no. 12 among the 19 countries listed. It seems low, however, with an estimated annual production of some 0.7 TWh it covers nearly 3 % of the national consumption of electricity in 2004. Calculated as percentage of penetration of electricity production, Denmark is leading with an estimated penetration of almost 20 % in 2004, Germany and Spain have both achieved around 6 %.

The world's five leading nations in wind power development (% of cumulative capacity):

Germany:	14,612 MW …..…	36.3 %
Spain:	6,420 MW ……..	15.9 %
US:	6,361 MW……....	15.8 %
Denmark:	3,076 MW………	7.6 %
India:	2,125 MW.……..	5.3 %

Only two countries cover + 50 % of the total installation in the world. The Top-five in total counts for more almost 80 % of the cumulative capacity in the world. These facts indicates two things:

The industry is dependent on a few major markets.
Huge potential for expansion of wind power development remains to be exploited.

As the usage of wind power is concentrated on a few countries, so is the supply side concentrated on a few suppliers/countries.

3.1.2 Building up wind power industry

The most powerful wind turbine industries have established themselves in countries where there has been the framework conditions facilitating a steady development of wind power development. The evidence for that statement is clear: Denmark, Germany and Spain are the three leading nations in industrial production of wind power plants and for Danish wind turbine manufacturers have established a strong export platform to all major markets in the world.

The short history of industrial development of wind power industry indicates that a stable domestic market has been the most important factor for successful industrial growth. This growth can be maintained also when the domestic market slows down. So – in 2004, Danish manufacturers produced 3,219 MW of wind power, where only 218 were installed in Denmark (6.7 % of their total manufacturing). Danish manufacturers market share is 38.5 %, the German's counts for 21 % and the Spanish cover 11.5 %. Outside Europe the American GE Wind Energy is by far the largest manufacturer with a market share of 18 % in 2003.

The world's five leading manufacturers (market share in 2003):

Vestas Wind System, DK:	21.7 %
GE Wind Energy, US:	18.0 %
ENERCON GmbH, GE:	14.6 %
GAMESA Eolica, ES:	11.5 %
NEG Micon, DK:	10.2 %

The Top-five manufacturers cover in total 76 % of the market. The following five on the Top-Ten list of the worlds leading manufacturers cover in total another 18.7 % and the remaining 5.3 % is shared by a group of smaller manufacturers in Europe and in Asia. There is a trend of consolidation in the industry. In 2003 the Spanish company Gamesa acquired Made (No. 2 in Spain). Recently, in March 2004,VESTAS and NEG Micon has joined into one company with a total market share of + 30 %.

Major trends in the commercial wind power market:
The most significant trends in the market are:

- *Specific projects and customers/operators becomes larger*
- *Technology continues to be optimised along with an up-scaling of physical size of wind turbines*
- *Development of wind power plants off shore becomes a major segment in the market.*

3.1.3 Larger Projects – utilities and leading energy companies enter

Projects around the world are getting bigger, making it more common for larger companies to become wind energy developers. Such major players are better able to handle the logistics and necessary financing aspects. Industry growth means that several of the new developers are subsidiaries of power utilities; especially as wind energy becomes more and more attractive from an economic point of view. Even in countries like Denmark and Germany, originally known for their dispersed and small developments, there is now a trend towards larger projects. Offshore projects will also call for a shift in that direction.

The shift from markets with dispersed development, such as Denmark and Germany, to more project oriented markets, such as the US and Spain, will lead to larger projects. The larger projects will require larger and financially stronger players, and utilities will play a major role in the transition of the structure of the industry. There will be joint forces among the so-called wind farm developers and the utilities in the future.

Looking back only 3-4 years, this picture was different. At that time the development was mainly in the German and Danish markets and in the hands of wind power developers — of which there was a large group in Germany. These were specialised consultants and fund managers, which acquired certain specific knowledge in planning, financing and development of wind farms. The Danish development was different, due to the large "co-operative" customer segment. By the end of 2002, around 85% of the 3,000 MW installed in Denmark was owned by small individuals and co-operatives, and just 15% left to the utilities. During 2003, however, the utilities developed more than 80% of the 218 MW added.

An example of new big players on customer side is:

Florida Power & Light (FPL), USA operates/own some: 2,500 MW
Iberdrola S.A ,Spain, operates/own around: 1,800 MW
EHN S.A, (Spain), Energy E2, (DK), Endessa S.A, (Spain), NUON, (NL) are utilities which have more than 500 MW in operation each.

That type of players will be more common in the industry. Candidates to follow such a route of entrance are Scottish Power, UK and Statkraft, Norway.

3.1.4 Up-scaling of wind turbines – rapid change of size segments

Table 4 shows the size segmentation in the market three years back. It's obvious that the turbines become larger, and this trend is not finished yet. The emerging offshore market will ask for even larger turbines. Therefore the + 2.5 MW segment is expected to grow fast within a five years time.

Table 4: Segmentation of product sizes 2001-2003

Year	2001	2002	2003
Total MW supplied	7,056	7,416	8,062
Product (Size range)	% of total MW		
"Small WTGs" <750 kW	32.3%	13.7%	6.9%
"Mainstream" 750-1500 kW	50.8%	55.7%	55.8%
"MW-class" 1501-2500 kW	16.9%	30.0%	36.4%
"Multi-MW Class" >2500 kW	0.0%	0.6%	0.9%
Total	100.0%	100.0%	100.0%

Source: BTM Consult ApS - March 2004

The share of the Main-stream segment - turbines from 750 KW to 1,500 kW - will be maintained around 50 % for some years, but the "Small WTG'" will decline rapidly. The fastest growth will be seen on the "MW-Class" and the "Multi-MW "Class segments. The later caused by future demand from a offshore market taking off in 2006 – 2008.

The average size of turbine supplied to the market in 2003 achieved 1,211 kW, from just around 800 kW two years ago.

3.1.5 Off-shore wind farms: A growing market segment

The two tables: Table 5 and Table 6 gives a status of offshore wind power as of end 2003:

Table 5: Operating offshore wind farms in the World by end 2003

Country	WTG`s	MW	Type foundations	Construction
Vindeby (DK)	11 x 450 kW, Bonus	4.95	Concrete caisson	1991
Lely (NL)	4 x 500 kW, NedWind	2.0	Driven monopile	1994
Tunø Knob (DK)	10 x 500 kW, Vestas	5.0	Concrete caisson	1995
Dronten Isselmeer (NL)	28 x 600 kW, Nordtank	16.8	Driven Monopile	1996
Bockstigen (S)	5 x 550 kW, Wind World	2.75	Drilled Monopile	1997
Utgrunden (S)	7 x 1.5 kW, ENRON	10.5	Driven Monopile	2000
Blyth (UK)	2 x 2 MW, Vestas	4.0	Drilled Monopile	2000
Middelgrunden (DK)	20 x 2 MW, Bonus	40.0	Concrete caisson	2000
Yttre Stengrund (S)	5 x 2 MW, NEG Micon	10.0	Drilled Monopile	2001
Horns Rev (DK)	80 x 2 MW, Vestas	160.0	Driven Monopile	2002
Palludan Flak (DK)	10 x 2.3 MW, Bonus	23.0	Driven Monopile	2002
Nysted Havmøllepark (DK)	72 x 2,3 MW, Bonus	165.6	Concrete caisson	2003
Arklow Bank Phase I (IRL)	7 x 3,6 MW, GE Wind	25.2	Driven monopile	2003
North Hoyle (UK)	30 x 2 MW, Vestas	60.0	Driven Monopile	2003
Total	**Number of WTGs: 291**	**529.8 MW**		

Source: BTM Consult ApS - March 2004
Note: Palludan Flak, also known as "Samsø Vindmøllepark," was not commissioned until the start of 2003. Arklow Bank Phase 1 was installed, but not in operation by the end of 2003.

Offshore projects have just recently taken MW-scale turbines in use. Many of the early projects were equipped with turbines of 500 – 600 kW. Those projects were pilot projects, often heavily subsidised. In spite of weak feasibility they have necessary for building up special competencies and experiences of working in the offshore environment. The major driver for continuing up scaling of offshore turbines is the benefit from saving of "number of foundations".

Table 6: Installed offshore wind power in the World 2002 and 2003

Country	Installed MW 2002	Accu. MW 2002	Installed MW 2003	Accu. MW 2003
Denmark	183	232.9	165	397.9
Ireland	0	0	25	25
The Netherlands	0	18.8	0	18.8
Sweden	0	23.3	0	23.3
UK	0	4	60	64
Total capacity - World	**183**	**279**	**250**	**529**

Source: BTM Consult ApS - March 2004

The world's offshore capacity almost doubled in 2003, and in 2004 around 250 MW of new installation is expected. On short term UK is estimated to be the most important market for offshore installation, + 5 years ahead Germany is likely to be the dominating market for offshore installation of wind turbines.

3.1.6 Expected growth of the market until 2008

The forecasts issued in World Market Update [15] for a horizon until 2008 estimate an average annual growth in installation of 10.4 %. It is based on a mix of mature markets and emerging markets. The contribution from UK and Ireland is shown in the Table 7. There will be a significant higher growth in these areas than in general. The reason for that is of course the historical development characterised by a very modest track record of installation rates.

Table 7: Forecast for Ireland and UK according to WMU 2003 (MW)

Country	2004	2005	2006	2007	2008	Total 2004-08
Ireland	80	120	100	350	275	925
UK	270	630	400	600	1,200	3,100
Total IR+UK	350	750	500	950	1,475	4,025

Source: World Market Update 2003 – March 2004, BTM Consult ApS.

Comment:
The result of above forecast is that Ireland will have 1,155 MW on line by end of 2008. Comparing to the 2010 milestone of the Consultation Document it is close to the 15 % penetration scenario of that report. The total of 4,025 MW for the period 2004-08, represent 7.3 % of the total estimated installation in the world in that period of time.

3.2 The regional UK and Irish market

In this section the historical market in UK and in Ireland is described and expressed in figures. That is done for the market expressed in MW installation year by year and the supply side with identification of leading suppliers and their market shares 5 years back.

3.2.1 The UK market

The UK market includes England, Wales, Scotland and Northern Ireland.

Table 8: Installed wind power in UK 1990 - 2003

Year	Capacity	Number of units
1990	8	Total number of units until end of the year 1991 : 41 units
1991	4	
1992	38	105
1993	80	250
1994	30	64
1995	40	75
1996	73	130
1997	55	107
1998	10	16
1999	24	39
2000	63	79
2001	107	113
2002	55	65
2003	195	109
Total Cum MW *)	759	1.098

Source : BTM-C World Market Update 1995-2003

Figures are rounded!
*) Total is adjusted for recorded decommissioning of capacity.

Table 9: Suppliers to the UK market 1997- 2003

Year:	**2003**	**2002**	**2001**	**2000**	**1999**	**1998**	**1997**	**Until 1996**	**Total MW**	**Share % 1997-03**
VESTAS(DK)	94	44	46	41	14	3	0		242	48,5%
BONUS(DK)	29	4	19	7	8	4	44		115	23,0%
Zond/ENRON /GE Wind (US)	0	3	0	0	0	0	6		9	1,8%
NORDEX (GE)	50	0	40	3	0	0	0		93	18,6%
NEG Micon (DK)	19	3	2	7	0	0	0		31	6,2%
ENERCON (GE)	2	1	0	2	2	0	0		7	1,4%
Others	0	0	0	0	0	2	0		2	0,4%
Total:	194	55	107	60	24	9	50	273	772	

Source : BTM Consult ApS - WMU 1996 - 2003 and previous files.

Historical Development prior to 1996 is shown below:

Market shares in 1996 (Total of 73 MW):

Bonus : 47,3 %
Nordtank: 30,4%
Vestas: 13,5 %
Wind Master: 4,2 % (Dutch supplier no longer in the market)
Wind World 3,9 % (Danish supplier acquired by Micon in 1997)
Enercon: 0,7 %
Source : BTM -C WMU 1996- April 1997

Market share before 1996 (cumulative capacity of 170 MW (1994-1995))

Vestas (DK): 31,0%
Bonus (DK): 19,0%
Mitsubishi (JP): 18,0%
Nordtank : (DK): 14,5 %
WEG (UK): 12,0 %
Wind Master (NL): 3,3 %
Carter (US): 1,8 %
Wind Harvester (UK): 0,3 %
Source : Garrad Hassan % Partners Ltd (1995 - Info to BTM-C report on the UK-market)

Three turbines suppliers have had a dominating market presence and market share since back to 1990, where the UK market emerged along with the introduction of NFFO1 - the first bidding scheme for renewable energy in the UK. The three leading turbine suppliers are: **VESTAS (DK), BONUS(DK) and NORDEX(GE).** Domestic British suppliers as Wind Harvester and WEG (Wind Energy Group) disappeared from the market in the beginning of the 90'ties.

3.2.2 The Irish market

The installation of wind power and the suppliers to the Irish market is identified and quantified in the following two tables based on information from the manufacturers of wind turbines.

Table 10: Installed wind power in Ireland 1992 - 2003

Year	Capacity (MW)	Number of units
1992	6,5	*) 15
1993	0	0
1994	0,5	*) 2
1995	0	0
1996	3,6	*) 6
1997	42,0	75
1998	11,0	15
1999	10,0	15
2000	49,0	72
2001	7,0	7
2002	38,0	27
2003	64	46
Total	**231,4**	**280**

Source : BTM-C World Market Update 1995-2002
*) Numbers estimated!

According to information from IEA and EWEA's latest country updates the total installed capacity in Ireland by end of 2003 was 186 MW. The difference to the above figures from BTM Consult is mainly due to the Arklow Bank project being included with 25 MW and that some of the figures given by the manufacturers also may include wind turbine capacity in Northern Ireland.

Table 11: Suppliers to the Irish market 1997-2003 (MW)

Suppliers:	2003	2002	2001	2000	1999	1998	1997	Until 1996	Total MW	Share %
VESTAS	25	13	4	49	10		25	0	126	55,5
NORDEX		25						0	25	11,0
ENRON (US) GE Wind (US)	 39		3					0	42	18,4
WindMaster (NL)							5	0	5	2,1
NEG Micon							15	0	15	6,5
ENERCON(GE)						5		0	5	2,1
TURBOWIND(B)				0	0	2		0	2	0,8
Others								8	8	3,5
Total:	64	38	7	49	10	7	45	8	228	100%

Source: BTM-C World Market Update 1995-2003

It is obvious that the leading supplier to the Irish market has been VESTAS Wind System, counting for some 60 % of the total installation. Windmaster is out of business today. So is ENRON, but the activity is continued by GE Wind Corp., which took over all ENRON wind Turbine Manufacturing. GE Wind installed their first project offshore in Ireland this year (2003)

3.3 The National Irish Market

Projections to 2010 and 2020 according to targets settled in the Consultation Document is structured in different scenarios. In the scenarios it is assumed that low scenario for the first period of time, 2004 to 2010, is followed by another low scenario for the subsequent period 2011 to 2020 and vice versa if using the high scenario for the first period of time.

Total scenarios are therefore:

Low Scenario for 2004 to 2020:

- Contribution to the 13,2 % penetration is fulfilled (Target 1) in 2010 with 978 MW online - hereof 203 MW are installed offshore corresponding to 20,7 % of the total wind power capacity.
- The development is continued by 655 MW in the period 2011 to 2020 (Target 1) - hereof 290 MW are installed offshore corresponding to 44,2 % of the added capacity.
- By 2020 the total installed capacity is 1.633 MW of which 493 MW are installed offshore (30 %)

Larger projects are in favour of improved feasibility - particularly for offshore installations. It is therefore not considered to install many small projects. The optimal size are assumed to be in range of 100 to 200 MW. In the first phase (2004-2010), however, are seen as a demonstration phase and therefore includes smaller projects.

High Scenario for 2004 - 2020:

- Contribution to the 20% penetration target by 1.533 MW - hereof 453 MW offshore corresponding to 29,5 % for the period.

- The development is continued with another 470 MW in the period 2011 to 2020 - hereof 220 MW are installed offshore, which is around 47 % of the installation.

- By 2020 the total installed capacity is 2003 MW of which 673 MW are installed offshore (33.5 %).

Due to the economy of scale of offshore, most of the development is assumed to take place in the period 2008-2010 (350 MW) along with the expected take off for large scale offshore in UK and in Germany. Additional capacity, 220 MW, is divided in two projects with estimated commissioning in 2012 and 2015 respectively. These late projects are 100 MW and 120 MW.

From an offshore entrepreneur or turbine supplier the Irish offshore market shall be seen in a context including the UK offshore market. Otherwise there will only be projects temporary once in a year and with intervals of two to three years before the next project - expressed in another way - an unstable market. The nearby UK market appears very prosperous, as the UK energy policy recently has launched very ambitious target for renewables in general and particularly for offshore development. The World Market Update 2003 includes a specific forecast until 2008 for offshore development. Ireland is included with (603 MW offshore!) encouraged by the many projects under preparation from different energy consortia. The UK forecast from this material is used in section 3.4 afterwards

*Table 12**:** Scenario for Wind Power development 2004 to 2010*

MW	**Status By 2003** (Accord. To Table 9)	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total 2004-2010 MW**	**Cum capacity end 2010**	Est.of electricity production in 2011 Twh/yr *)
Target 1 (13,2 % penetration of renewable electricity -equalling **975 MW cumulative capacity in 2010**											
Onshore	205	20	75	75	75	100	100	125	570	775	2,036
Offshore	25	60	0	18	0	50	0	50	178	203	0,711
Total Target 1	230	80	75	93	75	150	100	175	748	978	2,747
Target 2 (20 % penetration of renewable electricity - equalling **1541 MW cumulative capacity in 2010**											
Onshore	205	20	80	125	125	150	175	200	875	1.080	2,838
Offshore	25	60	0	18	0	150	0	200	428	453	1,587
Total Target 2	230	80	80	143	125	300	175	400	1303	1533	4,425

Source : Risoe Report I-2166, Oct 2004

*) The average capacitor factor assumed: **On-land** installations: **0.30**. **Offshore** installations: **0.40.**

Table 13: Scenario for Wind Power development 2011 to 2020

MW	**Expected Status by 2010** (Targets Table 11)	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**Total 2011-20 MW**	Cum Capa-city end 2020	Est. electr. prod. 2021 TWh/yr
Target 1 (20% % penetration of renewable electricity - equalling 1.632 MW cumulative capacity in 2020														
Onshore	775	75	60	50	30	25	25	25	25	25	25	365	1.140	2,996
Offshore	203	0	90	0	0	90	0	0	110	0	0	290	493	1,727
Total Target 1	978	75	150	50	30	115	25	25	135	25	25	655	1.633	4,723
Target 2 (30 % penetration of renewable electricity - equalling 2.000 MW cumulative capacity in 2020														
Onshore	1.080	25	25	25	25	25	25	25	25	25	25	250	1.330	3,495
Offshore	453	0	100	0	0	120	0	0	0	0	0	220	673	2,358
Total Target 2	1533	25	125	25	25	145	25	25	25	25	25	470	2.003	5,853

Source : Risoe Report I-2166, Oct 2004

*) The average capacity factor assumed: **Onshore: 0.30 and Offshore: 0.40**

3.4 Market size and conditions

Size of turbines required for the Irish market 2004 to 2020

The continued up-scaling of size of the wind turbines is the most significant trend technological development. The average size of turbine supplied to the market in 2003 achieved 1,211 kW, from just around 800 kW two years ago. Table 4 in the start of this chapter shows the size segmentation 3 years back and the trend continues particularly for the offshore wind turbines. Larger turbines are desired for to reduce cost of seabed foundation. Based on recent trends the average size of turbines commercial available for the coming market are estimated in Table 14.

Table 14: Estimate of size and numbers of turbines for the Irish market.
2004 to 2010 (13.2 % scenario) and 2011 to 2020 (20% scenario)

Periode:	**2004-2010**	**2011-2020**
Onshore Development		
Onshore Total MW	570 MW	365 MW
Average size (est)	1.7 MW	2.0 MW
Number of Turbines	335	104
Offshore Development		
Offshore Total MW	178 MW	290 MW
Average size (est)	3.5 MW	5.0 MW
Number of Turbines	51	58
Total number of turbines required for a 20 % penetration Scenario		
On- and Offshore **Total numbers**	**386**	**162**
On- and Offshore **Total MW's**	**748 MW**	**655 MW**

Mixed Regional Scenario 2004 to 2010.
For the purpose of giving an overview of the perspectives within a region including Ireland and the UK a "Mixed Regional Scenario" is described. That mixed scenario only deal with the period until 2010 and for this report we have chosen the "Target 2 Scenario" along with the latest BTM-C Forecast for offshore (WMU 2003, [15]) for UK until 2008 and extended with another two years to 2010. The additional two years from 2009 – 2010 is roughly estimated to be 1.000 MW/year. It has yet to be seen how the second round from Crown Estate will succeed (launched mid 2003).

The total regional scenario for offshore, UK and Ireland includes a total of more than 4.000 MW wind power capacity.

For a supplier located in Ireland the whole region can be seen as a "domestic market", and that really changes the perspectives, as the UK market is estimated to almost ten times that of Ireland.

Table 15: Mixed Regional Scenario for offshore wind power development until 2010

MW	**Status By 2003** (Acc. to Table 9)	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total 2004-10 MW**	Cum capacity end 2010 MW
UK and Ireland Offshore development 2004 to 2010 **Assumptions :** **1) Target 2 (Table 13 with 20 % penetration)** for **Ireland** and, **2) BTM -C World Market Update 2003 Offshore forecast for UK until 2008 + two years extension to 2010**										
Ireland Offshore Target 2	25	60	0	18	0	150	0	200	428	453
UK Off-shore Acc. WMU 2003	64	184	376	210	324	1000	1000	1000	4094	4168
Total Region	89	244	376	228	324	1150	1000	1200	4522	4611

Source : Risoe Report I-2166, May 2004

3.5 Total investment for the scenario's until 2010 and 2020

There is a long time track record for investment cost of land based wind power capacity, and the decline of cost caused by "learning" is also based on practical experience from materialised projects in the region as well as in Europe as a whole.

For investment in offshore the practical experience is very modest and almost not existing, except from a few large-scale projects in Denmark. Two projects commissioned in 2002 and 2003 (Horns Rev and Nysted Offshore). In the following is a discussion about cost estimation from other studies

Estimate for the scenarios in this report
We have chosen to use the cost figures from the Consultation Document, Appendices 4 and 5. These estimates are based on results from AER VI projects to be installed in 2005 and with consideration taken to cost decline caused by learning and economy of scale.

The figures traced from that report are:

2005-2010, Onshore: EUR 1,100/kW to EUR 880/kW
2005-2010, Offshore: EUR 1,690/kW to EUR 1,217/kW

2010-2020, Onshore: EUR 880/kW to EUR 754/kW
2010-2020, Offshore: EUR 1.217/kW to EUR 1,014/kW

Linear interpolation is used for the calculation year by year. In Table 18 with the total offshore market for UK and for Ireland together, are used the same key figures for cost in the UK and Ireland. This may not be correct. The last Table 18, serves the purpose of *giving an estimate of the* *magnitude of the total offshore market* in the region. For that purpose it is considered to be accurate enough.

Resulting market value assuming the scenarios:

Irland until 2010:	Target 1: EUR mill 807, Target 2: EUR mill 1,415
Ireland 2010 - 2020:	Target 1: EUR mill 623, Target 2: EUR mill 453

The offshore potential in the region until 2010 comes up to EUR bill 6.2, with more than 90 % in the UK waters.

In the following is included a brief review from other studies

Uncertainty about investment cost for future offshore wind power

As mentioned above, there is very modest evidence so far with real cost of building offshore wind power. The turbines used for offshore power in the initial phase are more or less based on proven "onshore" types in the size of 2- 2.5 MW turbines. The cost of these turbines are based on generic development from previous types of 1.3 - 1.5 and 1.8 MW, which are installed in large numbers all over Europe. So - the uncertainty on costs is not to the turbine price, as the modifications are minor compared with the land-based types, as long as we talk about the "2 MW" size range.

Larger turbines - 4-5 MW

But in near future it is likely that the average size of turbine for offshore application will grow to 4 - 5 MW. That size of turbines represents a new generation and the up scaling from to-days 80 m diameter to 110 - 125 m diameter is significant. Along with up scaling the coming new types an sizes will be designed specifically for the offshore market with all the implications hereof.

Construction cost - seabed, water depth. etc.

The actual experience from the two Danish projects, Horns Rev and Nysted Offshore, is a cost range from EUR 1,500 to EUR 1,650 per kW capacity installed. These figures are in line with those from the Consultation Document mentioned above and used for this report's estimates of total investment. It has to be emphasized that the Danish projects are located on banks with maximum water depth of 10 - 12 m as maximum and both projects includes 72 to 80 turbines.

Development of a cost model (Germany) for future large-scale offshore wind farms

Recently a German study was accomplished aiming at creation of a cost model for future offshore wind farms. The study includes a widely sensitivity analysis for parameters:

- Project size - Total MW and number of turbines
- Water depth on the location
- Distance from shore-line/connection point
- Consideration about High Voltage DC connection versus normally used AC connection related to distance and total installed rated power of the project.
- The two prevailing foundation options: **Monopile** and **Tripod** constrictions and there feasibility regarding turbine size and water depth.

Some interesting results and conclusions from this report and the sensitivity analysis are:

- Specific cost for a offshore wind farm declines significantly for wind farms with more than 100 turbines (very large projects!)

- Water depth is the parameter with the greatest impact on specific cost. The study found that it can be justified to go 10 % longer offshore if it is possible to get just 2% reduction of water depth

- The largest turbine is not necessarily the cheapest option. The study found and optimum at 4.7 MW when calculating on wind farms of 300 MW, 1000 MW and 5000 MW.

- The choice of HVDC connection seems to be favourable for distances of more than 30 km offshore.

- Specific cost is in the range of 1,890 to 2,160 EUR/kW, without taking into account reductions from learning/economy of scale.

Source : Plannung von Offshore- Windparks - Bildung eines kostenmodells .., Dr. Steffen Elster, Hamburg - February 2003

It is worth noting that the projects suggested in the scenario for Ireland are much smaller than those in the German study. None of the projects in the scenario will come up to 100 turbines in a single project. In the UK development there are projects around 1000 MW in the Crown Estate second round. The cost estimated in the German study is some 20 % higher than those traced from AER VI. A major reason can be that the German projects are on deeper water and often located 30 km offshore

Danish study of cost for offshore wind farms
The Danish Wind Turbine Owners Association accomplished a study in 2001, where cost estimation on 100 MW size of projects was done. The study calculated on 2 MW turbines (State of the art in 2001) and a future 3 MW turbine to be commercial available in 2005. This study came up with estimates investment cost of EUR 1,156 and EUR 1,102 per kW capacity. For comparison to Irish figures, the Danish figures shall be added some 20 %, as they did not include sea-cable connection and transformer station offshore. Along with that it shall be mentioned that all Environmental Assessments, Wind Resource Assessments etc. was covered from other funds. (*Source : Havmøllelaug, Danmarks Vindmølleforening, August 2001.)*

Table 16: Estimate of the total investment in Wind Power Development in Ireland 2004 to 2010

MW	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	Cumulative Investment by end 2010 EUR mill
Target 1 (13,2 % penetration of renewable electricity - equalling **975 MW cumulative capacity in 2010**								
Onshore	22.0	79.5	76.5	74.3	95.0	91.6	110.0	548.9
Offshore	101.4	0.0	27.5	0.0	69.0	0.0	60.8	258.7
Total Target 1	**123.4**	**79.5**	**104**	**74.3**	**164**	**91.6**	**170.8**	**807.6**
Target 2 (20 % penetration of renewable electricity - equalling **1541 MW cumulative capacity in 2010**								
Onshore	22.0	84.8	127.5	123.3	142.5	160.3	176.0	836.4
Offshore	101.4	0.0	27.5	0.0	207.0	0.0	243.0	578.9
Total Target 2	**123.4**	**84.8**	**155**	**123.3**	**349.5**	**160.3**	**419**	**1,415.3**

Source : Risoe Report I-2166, May 2004

Basic assumptions:

1) MW capacity by year is from Table 12.
2) Estimated key figures of cost (EUR/kW) from Consultation Document, Appendix 4.
3) Linear interpolation of cost between 2004 and 2010

Table 17: Estimate of the total investment in Wind Power Development in Ireland 2011 to 2020 (EUR mill)

MW	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	Cum Investment by end 2020 EUR mill
Target 1 (20% % penetration of renewable electricity - equalling 1.632 MW cumulative capacity in 2020											
Onshore	65.3	51.0	42.0	24.9	20.5	20.0	19.8	19.5	19.3	18.9	301.2
Offshore	0.0	105.8	0.0	0.0	100.4	0.0	0.0	116.0	0.0	0.0	322.2
Total Target 1	**65.3**	**156.8**	**42**	**24.9**	**120.9**	**20**	**19.8**	**135.5**	**19.3**	**18.9**	**623.4**
Target 2 (30 % penetration of renewable electricity - equalling 2.000 MW cumulative capacity in 2020											
Onshore	21.7	21.3	21.0	20.7	20.5	20.0	19.8	19.5	19.3	18.9	202.7
Offshore	0.0	117.6	0.0	0.0	0.0	133.6	0.0	0.0	0.0	0.0	251.2
Total Target 2	21.7	138.9	21	20.7	20.5	153.6	19.8	19.5	19.3	18.9	453.9

Source : Risoe Report I-2166, May 2004 - MW capacity by year is from Table 13

Basic assumptions:
1) MW capacity from Table 13
2) Estimated key figures of cost (EUR/kW) from Consultation Document, Appendix 5.
3) Linear interpolation between 2010 and 2020

Table 18: Estimate of total investment in offshore development in the region : UK and Ireland (EUR mill)

MW	2004	2005	2006	2007	2008	2009	2010	Cum Invest-ment by end 2010 EUR mill
UK and Ireland Offshore development 2004 to 2010 **Assumptions :** **1) Target 2 (Table 12 with 20 % penetration)** for **Ireland** and, **2) BTM -C World Market Update 2003 Offshore forecast for UK until 2008 + two years extension to 2010** **3) Cost estimates from Consultation Report , Appendix 4 and 5**								
Ireland Offshore Target 2	101.4	0.0	27.5	0.0	207.0	0.0	243.0	578.9
UK Offshore Acc. WMU 2003	311.0	605.4	321.3	469.8	1,380.0	1,300.0	1,217.0	5,604.5
Total Region	412.4	605.4	348.8	469.8	1,587.0	1,300.0	1,460.0	6,183.4

Source : Risoe Report I-2166, May 2004

Basic assumptions:

1) MW capacity by year is from Table 13
2) Estimated cost per kW from Consultation Document, Appendix 4
3) Linear interpolation between 2004 and 2010
4) Cost figures from Ireland (Consultation Document) is used for the UK development as well.

4 Offshore Technology

Building a wind power plant, the final cost of energy will depend on a number of parameters. These include efficiency and reliability of the wind turbine, construction costs of the wind turbines, foundations, grid connection etc. However, the fuel of the wind turbines – the wind resources – completely dominates the overall economy of a wind power project. The available wind power is a function of the cube of wind speed. The implication is that a site with annual mean wind 10 m/s has 8 times more wind energy to be captured than a site with 5 m/s mean wind speed. Even minor differences in annual mean wind speed like e.g. 10% will have a considerable impact, since the difference in energy flux will be $\left((1.1)^3 - 1\right) \cdot 100 \approx 30\%$. And that difference in available energy reflects *directly* the cost of energy.

The wind speed and available wind energy offshore is considerably higher than onshore. This fact compensates to a large extent for the higher cost of construction for the offshore wind farm as well as for the higher operation and maintenance costs and is the main reason for building wind farms offshore. Other reasons are more easy planning and erection permissions, lower area costs and less disturbing visual effects on the environment.

4.1 State of the art offshore wind farm deployment

Of the total 530 MW offshore wind farm deployment in the world almost 80 % is at preset installed in Denmark, where the total approved and installed wind farm capacity offshore was 406 MW by end of 2003.

The following description of the state of art of the offshore development is therefore to a large extent based on the Danish experiences.
With a couple of pilot projects in the 1990s and a number of large demonstration projects in recent years, Denmark has taken the lead in exploiting the specially favourable wind conditions at sea for CO_2 free electricity production from large MW wind turbines.

Interest in the potential of the development of offshore wind energy has grown more or less in steps following the increase in size and capacity of wind turbines. Also the lack of adequate sites on land has contributed to a pull in that direction. The overall maximum height of the tower and rotor of the wind turbine of more than 110 metres, which has been reached so far, means that the MW wind turbines will dominate the landscape and that the precondition for continued large-scale development of wind energy in Denmark will be the exploitation of the offshore potential. The mapping of potential major sites for offshore wind farms in 1997 identified an immediate potential of approximately 4,000 MW in Danish waters. However, there are many indications that development of more cost-efficient foundations will open up for new sites to be economically exploited, at larger water depths than foreseen in 1997.

During the 1990s Denmark implemented two pilot projects that provided crucially new know-ledge about the economic and environmental conditions for developing offshore wind farms. These two small demonstration farms owned by the utilities, at Vindeby 4.95 MW and Tunø Knob 5 MW have been in operation since 1991 and 1995, respectively. They were followed by three large-scale demonstration projects at Copenhagen (Middelgrunden, 2000), Horns Rev at Esbjerg in 2002 and Nysted at Rødsand in 2003, respectively, with a total installed output of approximately 360 MW and wind turbines of 2 and 2.3 MW. The two large demonstration projects at Horns Rev and Nysted were constructed according to an agreement between the Danish government and the power sector.

The 40 MW project at Middelgrunden 2 km outside the Copenhagen harbour in shallow water (3-5 m) was put into operation at the beginning of 2001. The farm comprises 20 Bonus wind turbines, each of 2 MW. The wind farm is a 50-50 shared ownership between a private co-operative and the utility of Copenhagen (now E2).

Figure 11: The 40 MW wind farm at Middelgrunden. Ref [18]

In December 2002 the last wind turbine in the 160 MW Horns Rev wind farm became operational. The farm is located 14 km from the coast at Blåvandshuk. The turbines are 2 MW Vestas turbines with a total height of 100-110 m, and the farm occupies an area of 20 km2.

Figure 12: The 160 MW wind farm at Horns Rev consisting of 80 x 2 MW Vestas Turbines. Ref [16].

The Nysted wind farm project, comprising 72 2,3 MW Bonus wind turbines, has also been completed, the grid connection works started in April 2002, the installation of cables and turbines started in May 2003 and in September 2003 the last turbine was put into operation.

Figure 13: The Nysted offshore wind farm consisting of 72 x 2.3 MW Bonus wind turbines. Ref [17].

On February 28, 2003 the Samsø offshore wind farm consisting of 10 Bonus wind turbines was inaugurated. The farm has an installed capacity of 23 MW and is located approximately 4 kilometres south of Samsø. Like Middelgrunden it is owned partly by a utility and private investors. The turbines are 2.3 MW machines. They have a height of 100 meters and are erected on monopiles.

An experimental offshore wind cluster of 4 wind turbines has been established by Elsam on a harbour site in Frederikshavn in 2003. It consist of two 3 MW Vestas turbines, one 2.3 MW Bonus turbine and one 2.3 MW Nordex turbine.

4.2 Economy of the two large offshore wind farms

The increased costs of foundations, grid connection etc. and for service inspections for offshore wind farms will to a steadily increasing extent be balanced by higher wind electricity production and longer lifetimes. The additional costs of electricity production from offshore wind farms for the large-scale demonstration projects in Horns Rev and Nysted have been estimated as 20% compared to good locations onshore. But when the experience from these projects is incorporated in future projects, it is expected that the additional costs will be significantly reduced.

The main data of the two Danish large wind farms at Horns Rev and Nysted are given in Table 19.

Wind farm characteristics	**Horns Rev Wind Farm**	**Nysted wind farm**
Installed capacity	160 MW	165.6 MW

Number of turbines	80	72
Wind turbine type	Vestas 2 MW	Bonus 2.3 MW
Rotor diameter D	80 m	82.4 m
Mean wind speed at hub height	9.8 m/s	9 m/s
Expected annual production	600 GWh	595 GWh
Total project costs	270 mio. Euro	245 mio. Euro
Hub height	70 m	70 m
Weight of nacelle and rotor	99 tons	135 tons
Weight of tower	160 tons	110 tons
Foundation type	Mono-pile	Gravity
Weight of foundation	180-230 tons	1800 tons
Total weight per wind turbine	439-489 tons	2045 tons
Wind farm area	20 km2	24 km2
Water depth	6.5-13.5 m	6-9.5 m
Distance to shore	14-20 km	10 km
Distance between rows	560 m	850 m
Distance between turbines in rows	560 m	480 m
Internal grid voltage	34 kV	33 kV
Transmission to shore voltage	150 kV	132 kV

*Table 19**:** Main data of the two Danish large wind farms at Horns Rev and Nysted*

Further data about the 165.6 MW Nysted wind farm project are given in reference [9]. The budget for the Nysted project in Table 20 gives an overview of the investment cost of the various parts of the project. The yearly electricity production is expected to be up to about 600 GWh with an average wind speed of 9 m/s at hub height.

BUDGET	% of Total cost	Mio. Euro	Euro/kW
Turbines	49	120	
Foundations	18	45	
Internal grid	6	15	
SCADA	4	10	
Trafo & 132 kV cable*	12	30	
Others	12	30	
TOTAL	100	245	~ 1500

*Table 20**:** Budget for Nysted Offshore Wind Farm*

*note: The cost of the transformer and the sea cable was borne by the Transmission System Operator (TSO).

The budget for Operation and Maintenance (O&M) is 1.3 Eurocent per kWh for a 20 years life-time of the project. O&M makes up for more than a quarter of the total cost levelled over the lifetime. Compared to onshore turbines the O&M is considerably larger, which is due to the more difficult handling at sea and the weather dependency for service and repair.

4.3 Danish legal framework and planning

Several investigations of the offshore wind resources have been prepared since 1977. In July 1997 a Plan of action for offshore wind farms was submitted to the Minister of Environment and Energy. The plan was prepared by the two utility associations Elkraft and Elsam and the ministry's Energy Authority and Environmental Protection Agency.

The plan shows how a total capacity of 4000 MW offshore wind power in Denmark by 2030 could be established. The corresponding annual electricity production would be 12-14 TWh which is more than one third of the present electricity demand of 35 TWh. Based on the plan the first major wind farm at Horns Reef in the North Sea was installed in 2002 and followed by a second wind farm in 2003 at Nysted in the Baltic sea. They are both demonstration projects and part of an originally scheduled 750 MW offshore development plan, which was modified in 2001.

Unlike the case for wind turbines on land, where about 80% of the existing capacity in Denmark is privately owned more than 80 % of the wind turbines offshore are owned by the utilities.

The development on land has been driven by grassroots and private investors to the extent that more than 100.000 private persons own a wind turbine or a part of one. The private ownership has had a very positive effect in the sense that it has been comparably easy to get acceptance and permissions in place for the exploitation of wind energy in Denmark.

There has also been an interest for a similar private ownership of offshore wind farms. The 40 MW wind farm project at Middelgrunden was originally initiated by a private grassroot organisation which entered into an agreement with the local utility about a 50-50 percentage share between a utility and private investors. The Samsø project is also a cooperation between private investors and the local utility.

However, the other offshore wind farm projects in Denmark have been initiated by the government and implemented by the utilities under conditions laid down in political agreements in the parliament. The pricing of the electricity has also been part of the agreements, and the extra costs compared to conventional electricity is covered by all consumers. In this way the wind farms, which so far are demonstration wind farms, have been built regardless of the economy in the project.

All the preplanning of wind farms including the lay-out of possible sites and the preparatory investigations of sites and influence on nature and environment has also been carried out under order from the government.

The actual wind projects - once the site has been chosen – has to be approved by the relevant authorities. The Danish Energy Agency has acted as the hub for obtaining the necessary permissions from the authorities involved. That process has proved fruitful since the application of wind energy at sea is novel for many of the bodies involved.

The conditions for connecting wind turbines to the grid and the establishment of future offshore farms in Denmark have now been laid down in the electricity law as a result of the reformation of the Danish electricity sector. According to that law the right to exploit energy from water and wind within the territorial waters and the economical zone (up to 200 nautical miles) around Denmark belongs to the Danish Government.

The Danish Energy Authority grants approval of electricity production from water and wind and permission for pre-investigation of such within the national territorial waters and within the economical zone belonging to Denmark. Permission will only be given for specific areas and the impact on the environment must be documented by an environmental impact assessment for each project.

By end of March, 2004 an agreement between the Danish government and the opposition has been reached on a future energy strategy, which includes the construction of two additional offshore wind farms respectively in the North Sea at Horns Rev and in inland waters at Omoe Staalgrunde. Both farms will be app. 200 MW. The Danish Energy Authority is expected to issue tender documents for the new wind farms by mid 2004.

The agreement also includes a new "repowering program", where smaller (< 400 kW) and relatively old wind turbines on land will be substituted by fewer but larger modern mega-watt wind turbines that fits better into the landscapes. With this new agreement it is envisaged that 25 % of the total Danish Electricity demand will be covered from wind energy by 2010.

The Danish Energy Authority (DEA) has also established a Technical Approval Scheme for wind turbines the requirement of which has to be fulfilled in order to get a permission to erect and connect the wind turbines to the national grid. The approval scheme has existed in many years. In the beginning - when Denmark was the pioneering country in the development of wind energy technology – it was necessary to base the technical requirement on national standards and codes developed for the purpose. In step with the development of an international wind industry and the development of international standards under the International Electro technical Committee (IEC) the approval scheme has become more international. Presently the Danish Approval Scheme is being changed into an international scheme based on international procedures for approval and with a free operation of actors that are certified by a recognized accreditation body.

<u>According to the new set of requirements in DEA's approval scheme project certification of offshore wind farms are mandatory.</u>

Project certification of offshore wind farms typically consists of the following:

- Type Approval of the wind turbine
- Verification of design basis for structural design of the wind turbine structures
- Design verification of the wind turbine structures (site specific approval)
- Manufacturing survey
- Marine verification and Warranty Survey for transport and installation of structures
- In-service inspection planning and inspection of structures

The project certification is normally carried out as a review of the design documentation submitted by the manufacturer.

The revised approval scheme will be put into force by an order from DEA, which is expected to be due by mid 2004. The future wind farms offshore as well as new wind turbines on land will have to follow the new set of codes, which will be based on the international standard IEC WT-1, IEC System for Conformity Testing and Certification of Wind Turbines. More information about the Danish Approval Scheme for Wind Turbines can be obtained from the web site: www.dawt.dk.

Like Ireland the countries Sweden, UK, Germany and Holland all have initiated planning and construction of offshore wind farms in their waters, and others are believed to follow up in step with the technological development.

4.4 Present technology

When moving the wind turbines offshore the physical size of the farm and the height of the wind turbines is no longer limited to the same extent as it is now at many sites on land, where the visual impact and planning restrictions are governing factors.

At sea with the open sky above and more or less out of sight it is a matter of economical calculations and risk evaluation, whether it will be an advantage to have even larger wind turbines than the ones on the market today.

Up till now wind turbines have increased gradually in size on the basis of an up-scaling from previous models. The trend in size expansion is obvious when looking on the development in average power of new erected wind turbines during the last number of years for Denmark, e.g. from 750 kW in 1999, around 800-900 kW in 2000-2001, 1.36 MW in 2002 and 2 MW in 2003. The development is a result of the overall improvement of the competitiveness of wind power by a steadily reduction in the cost of generation, and the advantage gained by the increase of wind resources with height.

The largest wind turbines - although used offshore - have not been developed entirely for offshore applications, but both for sites on land and offshore. However, with the increasing market for offshore deployment it is anticipated that tailor-made offshore wind turbines are now being designed and constructed by the market leaders.

All the wind turbines that are applied so far in the offshore wind farms are based on conventional designs: pitch controlled, variable speed types with a conventional gear drive. The towers are tubular steel towers. The wind turbines are built to cope with the marine climate. Surfaces are corrosion protected, and special filters are used to prevent sea particles entering the ventilation system and the lubrication system. In areas with ice the design around the sea surface is shaped to facilitate ice breaking and protect the construction against loads from ice.

Boat landing facilities are designed for easy access to each of the turbines. In some cases – like for the Horns Rev wind farm - the wind turbines are also equipped with helicopter platforms on top of the nacelle as a supplement to the usual service entry from a boat.

Figure 14 is a sketch of the 2 MW Vestas turbine mounted on the mono-pile foundation pile. It shows the total size and the most important technical areas of interest.

So far the maintenance of wind farms offshore has been a combination of preventive and corrective maintenance. Because the O&M costs are significantly higher than on land a lot of effort is put into optimising the operation and maintenance and e.g. designing spare parts that are easily replaceable that can be changed within a short time and with a minimum of cost. Also condition monitoring is applied e.g. by means of the SCADA system in Nysted enabling early remote problem diagnosis and vibration supervision. The towers are equipped with service lifts, and the nacelle are equipped so that service personnel can stay for a longer period of time in case of rough weather.

The foundations for Horns Rev are steel tube mono-piles, whereas the Nysted farm has concrete gravitation foundations. In the experimental wind farm at Frederikshavn one of the turbines has a special suction bucket type foundation, which under certain circumstances will be cheaper than the other two types of foundation. The "bucket" is buried in the sea bottom, so that the suction inside the bucket helps to keep the foundation in place. This bucket type is still at an experimental stage, and the experience from the Frederikshavn wind farm will help documenting its qualities in full scale. A photograph of the bucket foundation is shown on Figure 17 below. Other foundations that have been considered so far is the tripod concept, where the under water part is a three legged tower standing on the sea bottom. The three legs are fixed to the sea bottom by tubular piles.

The cost of the foundation is a major part of the total budget for an offshore wind farm and hence a lot of investigation and study is devoted to foundation design and construction. The development in this area has already let to considerable reduction in cost from the first experimental projects in Vindeby and Tunoe Knob wind farms to the present ones. And it is believed that further gain will be obtained in the direction of more economical solutions for design, manufacturing, transport and installation of the foundations for offshore wind farms.

4.4.1 Concepts for offshore foundations

Different main concepts are listed below with indications of water depth ranges for their application based on economical considerations. See references [10], [11], [13] and [14]. Some of them have already been applied in practice in Danish waters as mentioned above. Others will be relevant in step with deployment at larger water depths.

Water depth (m)	Concepts for wind turbine structure
0-10	Gravity based type
0-30	Mono pile type
> 20	Tripod / jacket type
> 50	Floating type

Mono-pile concept
The freestanding mono-pile used in Horns Rev (fig. 13) is one of the simplest foundation types for large wind turbines. The mono-pile transfers the loading on the wind turbine to the supporting soils by means of lateral earth pressure. The mono-pile must therefore have a certain length depending on the soil strength in order to have sufficient capacity.

The mono pile foundation consists of a welded steel pile. The interface between the lower part of the mono-pile and the tower will typically be a welded flanged connection or a grouted flanged connection depending of the installation method.

The mono-pile may either be driven into the seabed using a suitable hydraulic hammer, or it may be drilled into the seabed. There could be some differences in the pile diameter depending on which of the two techniques is used. For a driven pile the diameter need to be as small as possible. For a drilled pile the diameter can be made larger and the wall thickness reduced.

Gravity Based concept
The gravity based concept is from a structural point of view a mono tower fixed at the top of a gravity base, thus reducing the free-standing or cantilevering part considerably. The gravity base is designed with the objective of avoiding tensile loads (lifting) between the bottom of the gravity base and the seabed. This is achieved by providing sufficient ballast such that the bottom plate of the gravity base always remains in compression under all environmental conditions.

The concrete gravity based concept used for the Nysted project is shown in the construction phase in figure 14. An ice-cone (not shown) is integrated in the design of the foundation in order to reduce the ice loads.

Suction Bucket Concept
The suction bucket concept used in the test plant in Frederikshavn is a novel concept for offshore wind turbine structures. The suction is used for installation of the bucket. After installation the foundation will act as a hybrid of a traditional pile and a gravity based foundation. The dynamic peak loads are partly taken by the suction effect.

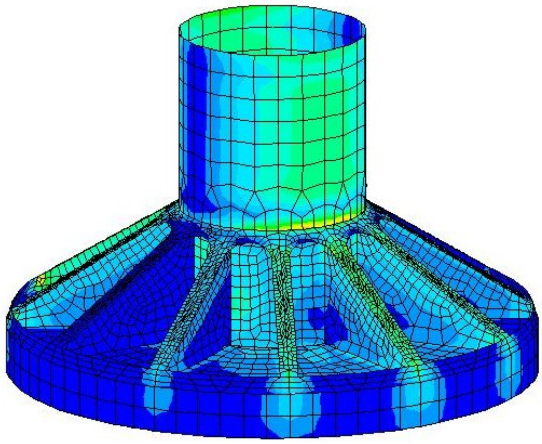


Figure 5. *Steel Suction bucket concept. The skirt is not shown; however it is just a tubular steel section. The suction is used during installation and for dynamic peak loads. Ref [11].*

Tripod Concept

The tripod concept consists of a standard 3-leg structure, made of cylindrical steel tubes with driven steel piles, and is well known from the offshore oil & gas industry. The concept is developed based on the simplicity of the mono-tower and enhanced by the additional stiffness and strength from the braced structure.

The central steel shaft of a tripod structure provides a basis for the transition to the wind turbine tower, similar to the principles for a mono-pile. The tripod can have either vertical or inclined pile sleeves. However, inclined pile sleeves are only used when the structure is to be installed by means of a jack-up drilling rig or a vessel with limited crane reach. The base width and pile penetration depth can be adjusted to suit the actual site conditions.

The concept has not been applied so far for offshore wind farms. They are used for the oil and gas sector, and a number of steel tripods are installed in the Danish part of the North Sea in water depths ranging from 30 to 60 metres.

Figure 2. *Tripod (piles not shown). The shown tripod is for the oil & gas sector, however, the design is equally relevant for an offshore wind turbine. Ref [11].*

Jacket concept

The jacket concept consists typically of a 3-leg or 4-leg structure, made of cylindrical steel tubes with driven steel piles, and is well known from the offshore oil & gas industry.

The jacket can have either vertical or inclined pile sleeves. However, inclined pile sleeves are only used when the structure is to be installed by means of a jack-up drilling rig or a vessel with limited crane reach. The base width and pile penetration depth can be adjusted to suit the actual site conditions.

More than 40 steel jackets are installed in the Danish part of the North Sea in water depths ranging from 30 to 60 metres.

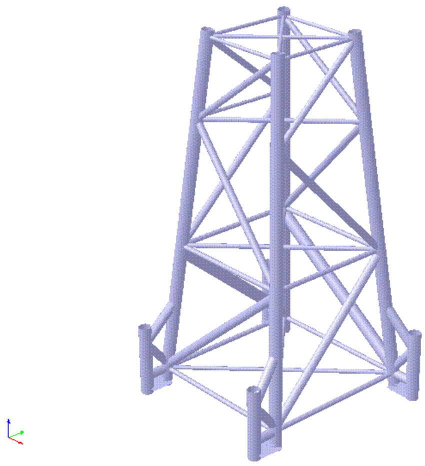


Figure 3. Jacket *(piles not shown). The shown jacket is for the oil & gas sector, however, the design is equally relevant for an offshore wind turbine. Ref [11].*

Floating Concept

Floating units such as tension leg platforms, SPAR, Semi-submersibles and catenary moored units are well known from the offshore oil & gas industry. However, their application within the offshore wind industry is novel. Floating units anchored to the sea bed have been installed in up to 1000 m water depth.

For application of floating support structures for offshore wind turbines more work has to be done for development of feasible concepts. For examples the torsional stiffness of the substructure needs to be considered carefully as well as rotation limitations in the flexible joints between tendon-anchor and tendon-hull.

Figure 6. *Floating support structure – tension leg type. Ref [11].*

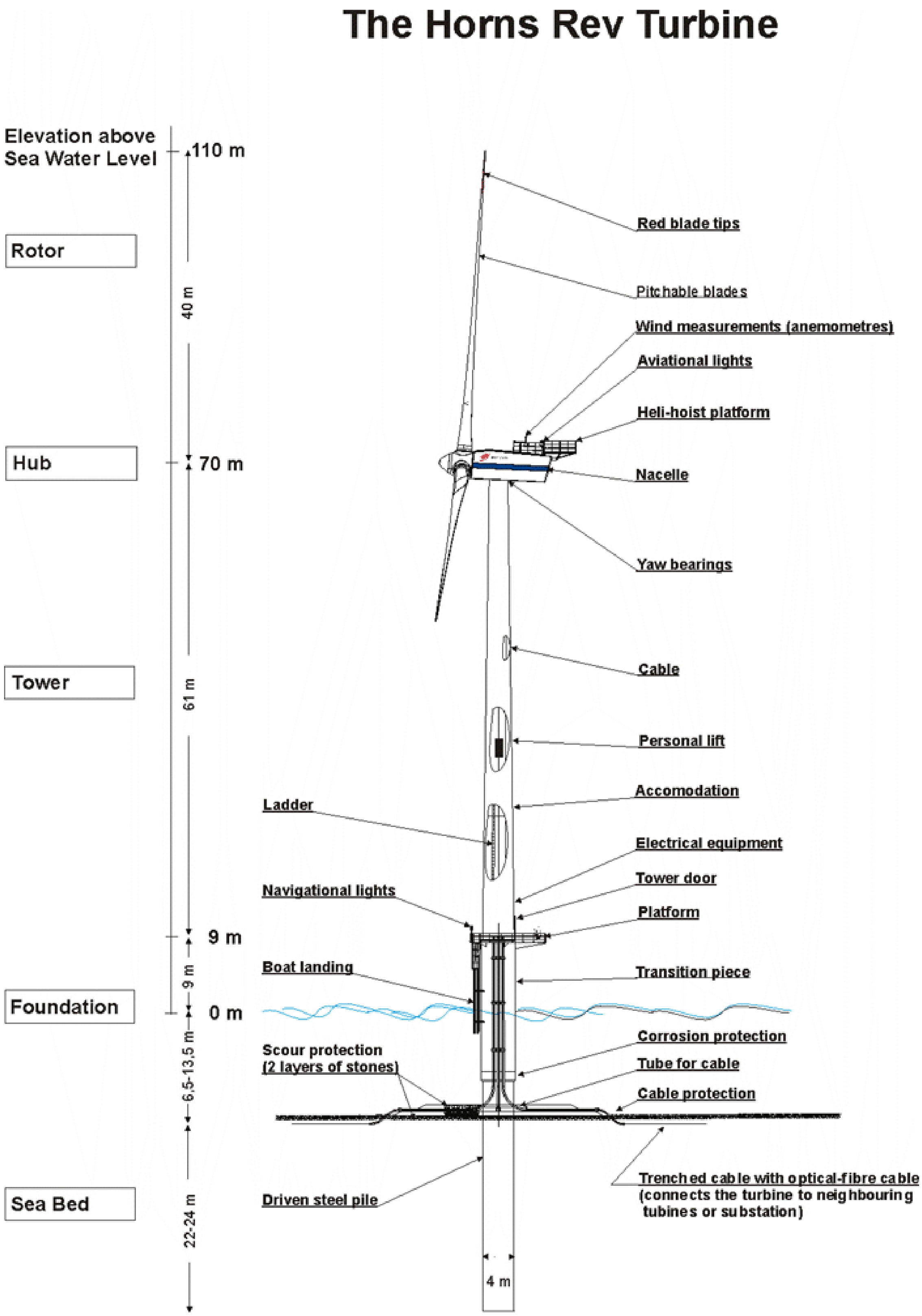


Figure 14: Sketch of the Vestas V90 2MW wind turbine at the HornsRev wind farm. Ref [16].

Figure 15: One of the gravitation foundations for Nysted offshore wind farm during fabrication on a barge. Ref [17]

Figure 16: The 780 ton heavy transformer being lifted in place at the Nysted offshore wind farm. Ref [17].

Figure 17: The bucket foundation for the Frederikshavn test site ready for transportation. Ref [13].

4.4.2 Erection of the Horns Rev wind farm[9]

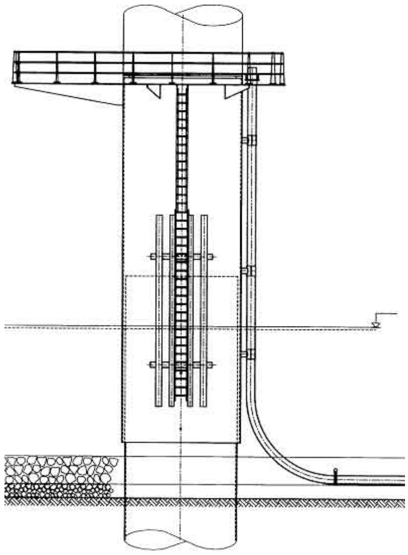
The erection of the turbines commenced in March 2002 and in July the first wind turbine was put into operation. The rough weather conditions in the North Sea required a detailed planning of the project.

1. First, the foundation was placed, which is a cylindrical steel pipe with a diameter of about 4 metres. A pile driver placed on a barge, stabilized by legs, rammed the pipe approx. 25 metres into the seabed.
2. Then, the wind turbines were mounted by means of large specially built vessels with submersible legs. A crane on the vessels lifted the turbines into place.
3. The wind turbines were connected via submersible cables to the offshore transformer substation, which will collect the power.
4. Via a submarine cable, the substation is connected to the onshore power transmission grid.

Pile driving is a fast process, and piles are relatively inexpensive to produce. Geotechnical surveys show that the seabed was made up of sand, and this makes mono-pile foundations particularly attractive.
Mono-pile foundations have also been used for offshore turbines in the Netherlands and Sweden. Similarly, the project's meteorological tower rests on a mono-pile foundation.
The foundation is designed as a cylindrical steel pipe with a diameter of approx. 4 m and a material thickness of 5 cm. A large, hydraulic ram drives the steel pipes into the seabed to a depth of some 25 meters.
A "mattress" of gravel is placed around the foundation to protect against erosion.

9 For additional data see Elsam's web-site www.elsam.dk or www.hornsrev.dk

A typical pile-driving ram.



The transition piece is attached to the mono-pile in a special concrete casting process. The top rim of the transition piece is a flange that accommodates bolting of the turbine tower.

Substation and grid connection
The produced power is fed to a substation built by Eltra. After stepping-up to 150 kV, the power is conveyed to shore. The substation platform is designed as a tripod construction with a steel building with a surface area of approx. 20 x 28 m, placed some 14 m above mean sea level. Among others, the platform accommodates the following technical installations:

36 kV switch gear
36/150 kV transformer
150 kV switch gear
Control and instrumentation system, and communication unit
Emergency diesel generator, incl. 2 x 50 tonnes of fuel
Sea water-based fire-extinguishing equipment
Staff and service facilities
Helipad
Crawler crane
MOB boat (Man Over Board)

Substation model

Cables to the onshore grid
A trenched sub-marine cable connects the Horns Rev offshore wind farm to the onshore transmission system. The sub-marine cable is installed by Eltra who is in charge of making the produced power available to the grid. Triple-core 150 kV cables with sub-marine armouring is used.

Marine support facilities

All the abovementioned activities from the preplanning, via erection of the wind farm till the service and maintenance over its lifetime will require a number of various marine support facilities.
In the preplanning phase the selection of the building site will require an oceanographic and geological study of the site to investigate the topography and quality of the sea bed. A number of drill holes will have to be made to document the quality of the sea bottom for decision about choice of type of foundations and their positioning.

Also investigations demanded in connection with the Environmental Impact Assessment will require marine support of some kind for monitoring of the life pattern of birds, fish and mammals in the area. Boats and divers plus monitoring equipment will be necessary. Measurement of wind data is recommended for most offshore sites. Particularly the wind climate at hub height is important. Erection of masts for wind measurements will require similar support facilities as for erection of the turbines and mounting of the foundation.

The marine support facilities required for construction of the foundation and erection of the turbines are indicated in the above description of the processes. Specialised crane ships and purpose built barges for transport, jack-up rigs for hammering of foundation piles and cable ships for laying of cables between the turbines and from the transformer to the connection point onshore. Also trench digging and transport of material (stones) for scour protection of the foundations will require special vessels.

Operation and maintenance of the wind farm will require adequate connection by boat, by helicopter or both for easy access and maximum utilisation of weather "windows" where access is possible so that the downtime in connection with service and repair can be minimized.

In general the marine support facilities will have to be chosen according to the particular requirements of the individual project, and ingenious solutions may help optimizing the economy of an offshore project significantly.

Reliability of present offshore technology

The use of wind energy technology on land started more than 20 years ago and has now developed into a mature technology with very reliable commercial wind turbines with a high degree of availability.

Offshore wind energy has only recently been deployed in a commercial sense with the larger Danish wind farms in 2001, 2002 and 2003 as described previously. Hence the track record is very limited so far and statistical data about their performances are therefore scarce.
In general the performance of the wind farms when comparing electricity production with the wind energy resources until now meet the expectations. For the Middelgrunden wind farm that commenced operation in march 2001 the total wind energy production up til end

of 2003 has been slightly above expectation when looking at the actual wind resources during the period of operation.

Also it can be noticed that the cost of the projects have been according to the budgets for the projects. In the case of the Nysted offshore wind farm the project was even completed ahead of time and within the budget.

So it seems fair to say that a reliable offshore technology exists which can be planned, budgeted and applied accordingly in a commercial way.

However, it has to be kept in mind that although prototypes of the wind turbines have been tested on land before or in parallel with the erection of the farm at sea, there will still be a number of technical problems to solve when the turbines are mounted in a wind farm in a marine environment. The technical risk will normally be highest during the first years of operation. It is therefore important to have a warranty agreement with the supplier, as well as to consider closely the possibility of insurance.

4.5 Future development

The future development – looking 10 years ahead – will most probably be focused on gradual improvement of already known technology in the whole value chain from planning, selection and documentation of the site over design, construction, manufacturing, transport, erection, monitoring, operation and maintenance plus financing and insurance. In chapter 4.4 some promising but not yet fully developed concepts for foundation designs are described.

The consolidation trend in the wind turbine market of merging of companies into few and very large companies like GE Wind, Gamesa and Vestas, that can operate internationally on a competitive level is expected to continue. It cannot be expected that new and small companies will play a significant role in the international main stream market, except in niches as specialized suppliers of sophisticated products and services.

Some probable technology trends are indicated in Table 21.

Issue	**State of the art**	**Future trends**
Wind turbine size	< 4 MW	5 to 10 MW
O & M costs	100 %, relative to investment	50 % reduction
Water depth	Up to 20 meter	Up to 50 meter
Foundation types	Gravity, mono-piles	Gravity, mono-piles, bucket, Tripods, floating platforms
Rotor Tip speed	60 – 80 m/s	80 – 120 m/s
Structural design	Conventional	Loads control limited, "Intelligent structures"
Acoustic noise	-------	Limited by active control
Materials	Chosen for strength	Function, economy and LCA analysis
Control system	Separate WTG, Park	Combined, wind power plant
Grid	National grid	International, Island operation
Production	According to wind	According to demand
Price of wind electric-	Various support schemes	Market price

ity	and compensation for CO_2	
Transmission	AC	HVDC

Table 21: Future trends in offshore wind technology

The following Table 22 is taken from reference [15] and shows a list of new or planned wind turbines in the 2 to 6 MW class.

When looking ahead to 2010 it might be expected that prototype wind turbines up to 10 MW with rotor diameter of app. 160 meters are realistic.

Make & Type	Rotor dia. [m.]	Capacity [MW]	Power control [method]	Operation [Status]
Bonus xx (DK)	n.a.	± 3-3.5	n.a.	Prototype 2003
DeWind Dxx (UK/GE)	n.a.	3.5-5	DD, VS, Pitch	n.a.
Enercon E112 (GE)	112	4.5	DD, VS, Pitch	Prototype 2002
GE 3.2s (US)	104	3.2	GD, VS, Pitch	n.a.
GE 3.6 Offshore (US)	100	3.6	GD, VS, Pitch	Prototype 2002
NEG Micon NM 92/2750 (DK)	92	2.75	GD, VS, Pitch	Prototype 2002
NEG Micon NM xx/xxxx (DK)	>100	± 4	GD, VS, Pitch	Prototype 2003
NM (DOWEC) 6 MW (DK/NL)	129	6.0	GD, VS, Pitch	Pre-feasibility study
Nordex Nxx (GE)	115-120	5.0	GD, VS, Pitch	Prototype 2004/5
Pfleiderer Multibrid (GE)	125	5.0	HD, VS, Pitch	Prototype 2003
REpower 5M (GE)	125	5.0	GD, VS, Pitch	Prototype 2004
Vestas V90 (DK)	90	3.0	GD, VS, Pitch	Prototype 2002
Vestas Vxx (DK)	n.a.	5.0	n.a.	n.a.
WinWind WW2.6.94 (SF)	94	2.6	HD, VS, Pitch	n.a.
WinWind WW3.90 (SF)	90	3.0	HD, VS, Pitch	Prototype 2003
W.I.P. 5 MW (GE)*	n.a.	5.0	n.a.	Prototype 2003/4

AS = Active Stall
CS = Constant or fixed speed
DD = Direct Drive
GD = Gear Drive
HD = Hybrid Drive
VS = Variable Speed

** WIP is a Munich based project developer*
Source: WindStats Newsletter [4]; Suppliers, 2/2003

Table 22: New MW wind turbines

5 Key requirements for Offshore Wind Development

The most important prerequisite for offshore development is that an adequate legal and administrative framework exists. That is already the case for Ireland, where the necessary legal framework for offshore development is well established and easy to apply for the developers.
It seems relatively simple - as described in section 2.2.2 - to obtain permission to build wind farms offshore. The conditions and cost for getting a lease for investigation of the site and subsequently a license to build on the site and a license to generate and supply power to the grid are well established.
Unlike the situation in Denmark, where the offshore areas for wind farms are restricted and determined centrally by the Danish Energy Authority, the Irish situation is a decentralized approach where the pick of areas is open for private initiative. The Danish investor does not have to cover the cost for the preliminary investigation carried out by the state, whereas in Ireland it seems to be up to the investor to carry the cost and take the risk that the site chosen is not suitable for a wind farm. But the Irish system gives a better opportunity to have a number of sites investigated in parallel and thus eventually will facilitate realization of set targets for wind power deployment.
A number of fields off the eastern coast are already reserved by different enterprises and are ready for exploitation of the wind resources once the infrastructure is fully developed and the economical conditions sufficiently attractive. The Arklow Bank wind farm erected end of 2003 is the first Irish offshore wind farm and experiences from that project will after a period of operation be valuable for the development of other projects to come. – As mentioned previously the track records with offshore wind farms are rather limited. But according to the Danish experience much will be learned from the first practical projects. It has to be born in mind that offshore wind application is still in the pioneering phase, and that there is a big economic risk that requires good financing, warranty and insurance. The total investment cost relative to the return of wind energy production will be significantly higher than for good sites on land. Thus the price paid for produced wind electricity from offshore wind farms also will have to be higher – maybe 30 % or so than wind electricity from inland wind farms. A stable and relatively high price for the electricity during a number of years will be a necessary incentive for realization of the necessary number of projects to meet the targets.
One of the big cost factors is the electric cable for connection to land. In Denmark that investment is regarded as part of the national grid and not included in the wind farm budget.
The planned 2x 500MW interconnection to Wales will be of great importance for development of wind power in Ireland and a prerequisite for meeting the targets set up in the present study. It is important, however, that the implementation can take place in 2006 as scheduled and not be delayed by problems with ownership and financing.

When only considering the target for offshore wind energy production it may be most advantageous to take small steps until the most pioneering work has been done elsewhere and then take larger steps after the technology has improved and cost been reduced. However, if the strategy at the same time is to develop a local industry it will be better not to hesitate in the beginning to be sure to get on the wagon before it is too late.

6 Industrial Development

This chapter will assess the opportunities for the Irish Industry. The methodology used is the following:

1. Identification of market volume - This reports scenarios until 2010 and 2020 respectively. The volume of offshore development in Ireland and in the region (including UK) is particularly assessed for the period 2004 through 2010

2. Identification and quantification of the value chain for offshore wind power

3. Description of likely requirement to competences within each sector of the value chain

4. Review of existing competences within the Irish Industry

5. Assessment of the most favourable niches for Irish players and quantifying of likely market shares over time, subject to supportive action put in force for facilitation of the establishment of an Irish Wind Power Industry.

6.1 The value chain for offshore wind power

There are already experiences from several offshore projects about the cost distribution of the turn- key price:

6.1.1 Project preparation

In general the preparative cost are relatively high for offshore projects. The reason for that is that many of the activities are new and have never been carried out for land based turbines. It is among others: offshore wind resource assessments, wild life assessments (fish & birds), assessment of soil condition on the seabed, special assessment of impact on sea traffic, commercial fishing etc. A total EIA (Environmental Impact Assessment) is a requirement for all future offshore projects. Along with all these physical conditions, a visual impact study has to be accomplished. Offshore wind farms with "state of the art" turbines will be visible up to + 20 km offshore, and most projects so far are situated within 10 - 15 km offshore.

Studies and experiences from Denmark and Germany indicates that preparative cost including the design and documentation for the whole projects comes up to about 10 % of the turn key price for a project.

6.1.2 Foundation

The cost of foundation is sensitive to the water depth on the chosen site. The large projects implemented in Denmark are built on relative shallow waters. From 5 - 10 m, except some part of the latest Horns Rev Project (160 MW), where a few turbines are on 10 - 15 m depth. Horns Rev used monopiles vibrated down in the soil, where most of the other projects have gravity foundation (in concrete and filled up with gravel/stone). The latter type of foundation is feasible for water depths until 7-8 m. For deeper waters the monopiles are desired for economic reasons. When water depths exceed 20 m, the tripod foundations seems to be the favourable solution, but there is no practical experience with that type so far.

For these reasons the foundation cost can vary a lot depending on the actual parameters. So, the 18% of total cost from the Nysted project (See section 4.2, Table 20) may be in the low end. For future Irish offshore Wind farms 20-25 % is more likely.

6.1.3 Wind turbines for offshore wind farms

The turbines itself is still the most expensive part of the element in the offshore wind farm. From the latest Danish "Nysted Offshore Wind Farm" equipped with 2.3 MW Bonus turbines, the cost of turbines makes up 49 % of the total. It is a little high, mainly due to the fact that the sea cable connection to the shore and the related transformer station (130 kV) is not included in the project, as the cost for this infrastructure is covered by the system operator, Elkraft System, and transferred to all consumers' bills!). If those infrastructure cost were included the turbines share of the project cost would consequently be lower. However all in all around 45-50 % for the turbines is a qualified guess. For on-land installations, the turbines weight of total cost is typically 70 - 75 %.

6.1.4 Electric connection - sea cable & transformer station

With distances offshore as at Nysted it will typically account for 15- 20 % of the total turn key cost. For Horns rev, the sea cable and offshore transformer (130 kV) was 15 % of the total cost. Based on above experience figures it is suggested that an electric connection of an Irish offshore Wind Farm will amount to at least 17 % of the total cost. The most sensitive factor for the electric connection is distance and number of turbines in the project. Small offshore, even near coast, becomes relatively expensive to connect to mainland grid.

Another implication, not considered here, is the reinforcement of the grid on-land which might be necessary "upstreams" of the connection point. It depends on the structure and strength of the overall electric grid and system characteristics described in this reports chapter 2 section 2.3.4)

6.1.5 Improved control and on-line monitoring - SCADA

For the Nysted project these features counted for 4 % of the total cost. In our definition of major cost elements, we have decided that these cost are integrated in turbines cost and in electrical infrastructure cost in general. Also preventive maintenance for the subsequent operational phase calls for special monitoring of turbines and sub-systems of the machine.

6.1.6 Others

There can be other cost related to accessibility of the turbines, fender/platforms, special boat approach equipment, helicopter access port etc. Such expenses depend on the location and the cho-

sen strategy for the subsequent service & maintenance set up. The "width of the weather window" is decisive for these features and for final design of the wind farm.

Based on the above remarks and experiences from projects already commissioned, the value chain is defined and the cost share of each element is chosen, taking into consideration the likely conditions for an average Irish offshore wind farm. And the same key figures are used for the calculation of content of volume of the UK offshore projects.

It is obvious, that the preparative cost will be lower after the first projects have been accomplished, as some general assessments does not have to be repeated, when extending a wind farm in the same area. But most of the projects to be installed until 2010 will be first phase projects in virgin areas, and therefore they will have to bear relatively high costs for preparative investigations.

Different from the two large projects in Denmark, the grid connection of the wind farm, meaning sea cable and offshore transformer, is included in the projected turnkey cost and is estimated to account for around 17 % of the total cost.

6.1.7 Share of cost within the value chain (% of total cost)

The elements that constitute the "value chain" of an offshore wind energy project are given in an overview in Table 23 together with the relative share of estimated cost for each element.

In Table 25 are shown the volume for the total offshore wind power market in the region (including UK). The figures originate from Table 18 in chapter 3.5 and constitute the estimated offshore investment in Ireland (according to Target 2) and in UK. The total cumulative investment 2004 through 2010: **EUR mill 5,604.5.**

Estimated cost of offshore development in Ireland 2004 - 2010 (see Table 16 in 3.5)

For this calculation the figures derived from Target 2: 20 % penetration by 2010 - has been used, and only the investments for offshore wind power development.

Cumulative investment 2004 through 2010: **EUR mill 578.9**

The investment potential in Irish offshore is suggested to be the platform for an emerging Irish industry within offshore wind power development.
There is also the investment potential in the onshore development, making up a cumulative investment of **EUR mill 836.4**. The value chain for on-shore development has not been assessed specifically, but it is different from the offshore situation. The development on-shore is seen as a continuation of the on-going development with participation of Irish companies.

6.1.8 Employment potentials

In Table 26 and Table 27 is shown an example of the benefit for Irish industry by assuming a relatively high - but realistic - market share for Irish companies in their domestic market. As a spin-off from participation in the Irish development, it is likely that the Irish industry will be able to gain a modest market share in the UK offshore market. It has to be underlined, that it is just an example with assumed market shares. The present study has not made it possible to justify a certain market share, as no in-depth interviews with candidate companies have been carried out. However, there is no doubt that the total Irish engagement in the offshore industry in the region, will increase significantly, even with very modest market shares in the UK market.
The total cumulative market, according to the estimated market shares is:

Cumulative share of turnover in Irish offshore 2004 to 2010:	**EUR mill 156.6**
Cumulative share of turnover in the UK Offshore 2004 - 2010:	**EUR mill 249.3**
Total for Irish Industry (2004-2010)	**EUR mill 405.9**

Employment derived from the development:
By assuming 1 (one) man-year per 100,000 EUR of turnover in the industry, the total corresponds to 4,059 man-year over the 8 year period (2004-2010).
This corresponds to a current work force of some 500 jobs in the period.

For the UK offshore market with assumed 10% share of the market, within 3 of the element in the value chain, and 5 % on sea-cable connection

6.2 Players and competences required

Following is listed the most important competences required for materialisation of the targets for offshore wind power development in Ireland and in the UK. Along with that the typical players present in the field to day are identified. The challenge is that large scale offshore is still a new area, which open opportunities for new players. Also experiences/skills gained from other offshore industries (Marine construction in general and Oil & Gas exploitation in the North Sea) is a platform for entrance in the specific Wind Power offshore business.

6.2.1 Project preparation

All skills regarding how to cope with the offshore climatic environment is required. Wind resource assessments and physical monitoring on-site is a must. In-depth knowledge on operational conditions (loads, dynamics, electric interaction with grid) of wind turbines is required enabling the project team to optimise the lay-out for an offshore wind farm. The design of a wind farm is based on high- level discussion of requirements between owner/design team and the wind turbine supplier as well as the grid operator, who manage the grid where the project feeds in its electricity.

For projects implemented until now it is normally the customer/owner who hires the advisory companies and consultants covering several areas as: offshore construction, wind resource assessment and related tools, measuring on-site, and design of the whole electric infrastructure. Along with the technical related assessments, skills on environmental impact studies for ending up with an acceptable environmental impact statement for the project, is required.

All these assessments, wind farm lay-out, production estimates creates the basic documentation for bankers and insurance companies and paves the way for getting the investment financed. Decision makers in the financial sector, uses often other consultants for control/verification of the consultant reports/statements they have got from the owner and his project design team.

Project preparation requires almost all sort of high level consultant assistance on wind power, wind assessment, offshore construction, special marine conditions, electric design of power plants and their interaction with the electric grid, the environmental impact and risk analysis.

6.2.2 Foundations

Building of foundation for wind turbines situated offshore requires a mix of experiences gained from on-shore wind turbines and from other areas of offshore construction (harbours, piers, oil & gas exploitation etc.). Geological investigations of the soil is a must. Specific requirements depend on choice of foundation concept or the other way around, the geology might be determining for the choice of foundation. Erosion of sea-bed, scour etc. must be investigated before choice of foundation design. These are all skills covered by traditional offshore entrepreneurs and specialised consultancies. Next to deciding for a foundation design there is a huge logistic task for how to implement the foundation on the intended site - hereunder considerations about processes to be done on-site or on-land (in workshops or docks). That involves barges, tugs, crane facilities, hydraulic vibrators, diver-assistance etc. Often the climatic -window is narrow and calls for a very detailed planning of the implementation phase.

Building foundations requires skilled offshore construction companies and special consultants in the field of offshore design and companies specialised in the logistics offshore and all sort of equipment applied for the task.

6.2.3 Offshore wind turbines

Special designed wind turbines for offshore applications, is offered by leading companies in the wind power industry. All turbines designed for and used in offshore wind farms comes from companies with long term track record as supplier to the land based development of wind power. With only around 500 MW offshore wind power in operation in the world and only two projects larger than 100 MW, it is a new area for these turbine manufacturers. There is no doubt that the leading companies to-day will be the future suppliers of wind turbines for offshore wind power plants. The companies with experiences from building offshore turbines are: BONUS Energy, VESTAS Wind Systems and GE- Wind. Other companies also work with offshore turbines to be seen in near future (see Table 22 in chapter 4). It is likely that an offshore wind turbine supplier will out-source some parts of the WTG to local companies near by the actual sites - heavy steel parts for the machinery/towers and all sorts of accessories for access to the turbines. Until now the large turbines - up to 2.5 MW - are pre manufactured in suppliers workshop factories. Whether more manufacturing will be let out to local sub-suppliers when the turbines grow to 5 MW size is still a question. Among other things it will depend on the complexity of transportation and logistic, which increases by size of the turbines.

The competences of building wind turbines for offshore installation is in hands of leading WTG suppliers on the world market, and it is not likely that we will see small new enterprises as suppliers. They will not be able to gain the required competences. It is however a possibility that local companies in steel industry and electric equipment industry can be sub-suppliers to the WTG manufacturer particularly on project specific requirements to the WTGs.

6.2.4 Electric connection - sea cable and transformers

The electric infrastructure for an offshore wind farm requires experiences from similar work for utilities and power plants. In the case of offshore requirements to construction, work in sea-bed is a must. In almost all areas of Europe, such competences exist on local level. From task to task some special equipment must be hired from specialists abroad. It can be special "cable-laying" vessels. Transformer stations for transforming from low voltage level to a higher before connection to land via 10 - 20 km sea-cable, is normally sourced among a few suppliers on the international scene. The related construction work for placing the transformers can be sourced locally. In future HVDC connections and inverters may be required for offshore wind farms far from the shoreline.

The competences in the design and implementation of electrical infrastructure can be found among companies normally providing that type of services for the utilities. Particularly for offshore wind power it is required to cooperate with companies that possess the special competences of offshore cable lying.

6.2.5 Control systems for operation of offshore wind farms

Due to the remote installation in an offshore environment, the control and monitoring of operation will be an even more important feature to secure a reliable operation and a high availability of the offshore plant. So-called SCADA (Supervision Control and Data Acquisition) systems will be developed specifically for the operation of offshore wind farms. The competences may be found among electronic Soft-& Hardware Companies with experiences from similar task from other complex systems where on-line control is required. For the subsequent operational phase such systems have to be optimised in way of supporting reliability, preventive service and maintenance and securing of the optimal interaction with the electricity system on land.

The required competences for design and implementation of SCADA-system applied for offshore wind power plants can be found in Electronic and software Companies working with systems of similar complexity. A tight cooperation with the turbine manufacturer and the utility (System operator) is needed to secure the optimal operation of the power plant.

6.3 Profile of Irish Industry's competences

A number of Irish companies which posses some of the above mentioned competences that are in the wind energy business are listed in annex 1. The list of the companies has been provided by Enterprise Ireland and by the Maritime Institute respectively. Only a few of the companies has actually done work for the wind industry so far, but many of them will quite easily be able to transform their services to cover several of the needs mentioned, if the market develops to a sufficient size.

Particularly in the areas of sub- delivery and in the high tech and software services the competences are good. In the field of heavy steel manufacturing the competences are low.

Following the above- mentioned phases of wind energy project development comments are given as to how the existing competences in Ireland fit the needs described in 6.2. It should be noticed that the statements are subjective and qualitative, based on impressions obtained from the interviewed stakeholders and the list of companies. No detailed or quantitative investigation has been performed under the study.

6.3.1 Project preparation

The Irish developers already are experienced in managing wind energy projects both on land and offshore. All the necessary skills and competences are present in Ireland for consultancy assistance, measurements of wind and ocean climate, marine data and infrastructure planning.

6.3.2 Foundations

Irish companies can carry out all planning and preparatory work. Some of the skills necessary for building offshore foundations will be similar to what is needed for ocean engineering in connection with wave energy development. The manufacturing of the foundations can also be made in Ireland. However, it is a question of competitiveness, whether it should be done elsewhere. (The foundations for the Nysted wind farm in Denmark were built in Poland, although the competences were present in Denmark.)

6.3.3 Wind Turbine Manufacturing

Ireland has no tradition for building wind turbines. It will be very much up-hill if competences in this area should be established in Ireland at this stage. Should a sufficient market develop in Ireland the focus should be on supplying components to the wind turbine manufacturers. Electric equipment is an area where Irish competences can come to hand.

6.3.4 Electric connection – sea cable and transformers

The necessary skills and competences are similar to activities related to the utilities and are present in Ireland.

Manufacturing of transformers and switch gears is an area where the necessary competence might be easily obtained. ABB, which is a major manufacturer of transformers and generators already has a transformer factory in Ireland.

6.3.5 Control systems and maintenance

Ireland has a top competence in development of software solutions that might be used in connection with the design of surveillance equipment and systems for preventive control of the state of operating wind turbines. Development of advanced SCADA systems is probably an area where Irish companies can benefit from their experiences in other similar fields. The best opening for development of a business in the wind energy field would probably be a close cooperation with the developers or owners of the wind farms.
Also in the area of physical service and maintenance of the wind turbines the necessary competences exist. But it must be kept in mind that close cooperation with the wind turbine manufacturers is important for development of the detailed skills.

6.4 Barriers and opportunities

The general impression from several stakeholders interviewed in the study is that it is too late to start wind turbine production in Ireland as the wind power industry has reached a mature level with a few big international players with a long history and track records of experience, that are operating and competing on the global marked.
Manufacturing in Ireland will – according to stated Irish policy - only be of interest if it has a value-added dimension and is intended for the world market.

On the sub-supply side however there are certain areas where Irish companies have good potentials. That could be in software and consultancy and special niche products that can be used to improve the quality and increase the value of the products and services.

Concerning the major, heavy elements like tower, gearbox, transmission chain and rotor blades the potentials for indigenous production seems very limited as it stands to day except for the cases mentioned below.

Apparently there is a need for increasing tower-manufacturing capacity on the UK/Irish market. Two major Irish manufacturers of steel structures have previously tried to convince wind turbine manufacturers about their ability to produce towers for wind turbines. However, their prices turned out to be much too high to be able to deliver towers at prices close to what can be offered by the highly specialized tower manufacturing facilities already available in Scotland and Wales.
In order to be competitive the efficiency has to be improved considerably, which will require huge investments.
The skills and qualifications are present. But as long as the local industry does not know the wind development plan in Ireland and the local market, the investment in more specialized production facilities is too risky, and financing impossible.

ABB produces transformers in Ireland. And the plant is, according to more of the interviewed stakeholders, ranked as the most efficient of all ABB productions in the world. There might be a possibility to apply those skills also for production of transformers to wind turbines.

Rotor blade manufacturing is another of the main components where the necessary knowledge about composite materials and production of test blades already exists in Ireland (Galway). However, for the very large blades of above 50 meters length that are used for offshore wind turbines, it will be necessary to invest in new production facilities that - similar to the case of tower manufacturing - has to be competitive with highly efficient production plants elsewhere. Also it has to be considered that the major wind turbine manufacturers have chosen to in-source manufacturing of the blades, because the knowledge and skills in that respect is an important competition parameter.

The only way of establishing a modern rotor blade manufacturing facility in Ireland will probably be that a major wind turbine manufacturer finds it attractive to do so. The precondition for that will be a stable Irish/UK market of at least 100 MW wind turbines per year.

In a commercial sense the wind energy technology is now mature and international so a local industry will only be able to survive if it is compatible on a commercial basis with possible incomers from abroad.

The following activities will have the best opportunities for local work:

- preparation and planning
- transportation and erection work
- installation and cabling
- operation and maintenance

The main effort should be put into the strong competences that already exist in the software area in Ireland.

A major barrier to overcome if a local industry should evolve is – as it was expressed by one of the stakeholders - that: “the contract between supplier and developer will often rule out local participation because they will have difficulty in fulfilling the standards and criteria in the contract”.
It should also be kept in mind that the name and track record of a sub-supplier is paramount for a bank that will look at liability to lend money at a reasonable price.

6.4.1 Knowledge barriers

The interviews carried out in the study revealed that the knowledge about the Irish wind energy plans and the wind energy technology itself in general is rather limited among Irish companies. Representatives from the industry participating in an interview at Enterprise Ireland felt that they needed more information about the plans and time frame for the development so that they would be better suited to make decisions about their strategies. They needed also more information about the market and the demands they are up against.
There is a big question mark about the implementation of the official government targets: “Will the market be big enough and the incentives attractive for the individual companies to take the risk to invest in a new area of knowledge and more efficient production facilities?”

Only sporadic meetings have been held so far between the big international wind turbine manufacturers, Irish developers and Irish companies about the perspectives for supply of goods and services from Irish companies.

It is believed that there is a need for information material and education about wind energy technology and the market in general. Better knowledge about the different stages in the wind energy deployment process would help Irish companies getting a realistic view on their potentials.

Moreover the relevant companies often are quit small and isolated and could benefit from an Irish network building. The Maritime Institute mentioned a similar problem in relation to establishing an industry sector for ocean energy.

Enterprise Ireland and the Irish Development Agency both mentioned that there had been no targeted information activity about wind energy technology from them so far. But they both expressed their willingness in helping to arrange relevant meetings and workshops as soon as the long-term targets for wind energy deployment are confirmed. IDA would also like to have data about the statistics and prospects for the world market.

It was suggested that the major wind turbine manufacturers and developers meet with potential stakeholders. A seminar could be arranged by Enterprise Ireland where local production and services can be identified and the conditions described.

Also set-up of "work-shops" to produce specialized items of something that can go into a wind turbine delivery might be considered.

6.4.2 R&D and education

It has been argued that although there is a good fundamental basis for research and development in most of the relevant areas for wind energy development there is a very poor organization of the cooperation between industry and R&D. Thus there seems to be a huge gap between basic and applied research. Also the integration between different disciplines like mechanical and electrical engineering is poor.

IDA has good contacts with technical colleges and universities in Ireland and can help industry sectors to have people educated and trained to obtain the necessary skills. IDA with about 300 persons – half in Ireland, half world wide – is a strong body in helping foreign companies to invest in Ireland, and the cooperation with Enterprise Ireland constitute a strong partnership in the business development of the Irish society.

Innovative projects in the field of ocean engineering and offshore wind energy should be supported in order to develop both engineering skills and testing of new ideas that can turn out to be an asset in the long run. One example is an already patented system by Sure Engineering for a floating platform that might be applicable for offshore wind farms in the future in water depth above 60 meters.

It is difficult to get an overview of small innovative companies that are normally thrived by one or a few persons, as Enterprise Ireland in general does not take care of such small companies. The Maritime Institute has been gathering data for the purpose of registering companies that might be interesting for development of a future wave energy industry. Some of those may also be interested in offshore wind energy development.
There is a need for networking of small companies who might benefit from each other in the development of a business. The first step should be a database or register of companies. That could be established by Enterprise Ireland, which also could be the initiator and serve as hub for such networking.

6.5 Key requirements for industry development

In summary the key requirements for development of an Irish wind industry are as follows:

1. Clear and consistent signals to the industry about targets and operational conditions for Irish wind energy deployment.
2. Infrastructure (grid) and planning conditions in place.
3. Focus on the total Ireland/UK market when developing the industry.

4. Focus on products and services that can supply and improve already existing technology.
5. Cooperate with major international wind turbine manufacturers to decide on development of value-added services.
6. Public funding of information, education and R&D.
7. Facilitate net-working between small companies.

Table 23: The value chain in offshore Wind Power

Elements of value adding until commis-sioning date.	**Project preparation & design of wind farm**	**Foundation**	**Internal ca-bles/ trans-form.**	**Wind Turbines Erection of tur-bines**	**Transformers & Sea cables**	**Others**
Sub- activities	Wind Resource Assessment Wind Monitoring Submersible investigations Drill samples of soil Wild life, birds & fishes Marine Archaeological investigation Visual impact assessments EIA , Environmental Impact Assessment Park optimization - micro-siting Lay-out of internal grid Issues regarding financing, insurance and legal aspects Project certification Traffic- sea and air - marking lights , buoys etc.	Pre-manufacturing of elements. Transportation to site Placement on site Drill./vibrating. Preventive measures on surrounding sea-bed area Features for boat access	Connecting of cables be-tween WTG's and Transformer or assembly points. Protection of cable-trenches in soil. Linking of SCADA system	WTG manufactur-ing. Transportation to shore and to off-shore site. On-site assembly Connection to grid infrastructure Control system connection to SCADA system Commissioning test of turbines	Offshore Trans-former station col-lecting electricity from the Wind Farm O&M center im-plemented Heli-port (evt.) Excavating trenches for the sea cable connec-tion to land In special cases : on-land con-verter/inverter HVDC - AC	Insurance in construction pe-riod Other financial cost Special precau-tions related to construction
Share of turn key cost (%)	10%	20%	6%	46%	17%	1%

Table 24: Actual value by element referring to Table 15, Target 2 (Offshore in Ireland - 2004- 2010)

Element of ...	Project preparation	Foundation	Internal cables/ transformers	Wind Turbines	Transformers Sea cables for land connection	Others
Share of total value in EUR mill	**57.9**	**115.8**	**34.7**	**266.3**	**98.4**	**5.8**

Table 25: Estimated value by element on the UK/Ireland market. Total for 2004 to 2010.

Element of ...	Project preparation	Foundation	Internal cables/ transformers	Wind Turbines	Transformer sea cable - for land connection	Others
Share of total value in EUR mill	**560.5**	**1,120.9**	**336.3**	**2,578.1**	**952.8**	**56.0**

Table 26: Likely market share for a successful Irish offshore Wind Power Industry

The value chain volume and market share (%)	Project Preparation	Foundation	Internal Cables/ transformers	Wind Turbines	Transformer - sea cable connection to land	Others	Total in EUR mill Weighted share %
Turnover EUR mill	57.6	115.8	34.7	266.3	98.4	5.8	578.6
Likely Share, Irish Industry %	50%	50%	75 %	5%	25 %	100%	27%
Share in EUR mill	**29**	**57.9**	**26**	**13.3**	**24.6**	**5.8**	**156.6**

Table 27: Likely market shares (example) for Irish companies in the UK offshore Wind Power Industry

The value chain volume and market share (%)	Project Preparation	Foundation	Internal Cables/ transformer	Wind Turbines	Transformer - sea cable connection to land	Others	Total in EUR mill Weighted share %
Turnover EUR mill	560.4	1120.9	336.3	2578	952.8	56	5604.4
Likely Share, Irish Industry %	10 %	10%	10%	0	5%	0	4.4%
Share in EUR mill	**56**	**112.1**	**33.6**	**0**	**47.6**	**0**	**249.3**

7 Policy Options

Support Schemes for Wind Power in a Liberalised Market

7.1 How can Wind Power be supported?

How wind power and other renewables are to be integrated into the competitive electricity market is still an open question within the EU. At present, most renewable energy technologies are not economically competitive to conventional power producing plants. Thus, it can be expected that if renewables have to compete on pure market conditions, this will halt the development of new renewable capacity. Moreover, the intermittency in production, which characterises some renewable technologies, such as wind power and photovoltaics, requires a close interplay with power systems and regulators.

Different models for generating additional payments to renewable technologies exist at national level, which will make it possible for these technologies to be partly economically compensated for the environmental benefits that they generate compared to conventional power production. Some of the more obvious possibilities are mentioned below:

- The feed-in tariff scheme (FIT), where renewables are paid a fixed tariff for all their power production. Normally, a FIT-system is accompanied by a prioritised dispatch agreement, i.e., the transmission system operators (TSO's) are obliged to purchase all production from renewables at the fixed price and correspondingly to handle the balancing of power;
- An environmental adder scheme, where the starting point is the spot market price (or equivalent power price) to be paid for all renewable power production and an environmental premium per energy unit produced is added on top of that. Different versions exist of adder schemes, including maximum limits for the total price and eventually prioritised dispatch agreements;
- The green certificate system is a system whereby all renewable technologies are certified. The owners of renewables will thereafter receive a certificate per produced energy unit (per Mwh). The energy authorities specify a quota for the development of renewable power production and in order to fulfil this quota, producers or consumers have to purchase certificates. Non-fulfilment of this will result in a fine to be paid;
- The tendering system, where a specified volume of renewable capacity is requested by the authorities to be developed at the lowest possible costs. The authorities give specific conditions for the tender and competition among the bidders is expected to ensure the most efficient development.

The above-mentioned schemes have been used in a variety of EU member states. In the following, the experiences gained by using some of these schemes in Denmark will shortly be summarised.

7.2 Feed-in Tariff

The feed-in tariff has proven to give excellent results for wind power with regard to deployment as seen in Germany, Spain and, previously, Denmark, although the capabilities of the FIT-system to reduce the production costs of renewable power are not seen to be quite as convincing.

In Denmark, the FIT-scheme was used from the end of the 1970's until the late 1990's, when a Tradable Green Certificate Scheme was supposed to be introduced in Denmark. From a Danish point of view, the pros et cons of this scheme were:

- *Effectiveness.* The FIT-scheme proved to be very successful in implementing on-land wind power in Denmark. This was partly due to the stability of the scheme and politicians agreeing on a continuous development of wind power until the end of the 1990's.
- *Economic efficiency.* The price paid to wind turbine owners was kept almost constant at approximately 8 c€/kWh from the late 1970's until the scheme was changed. Due to the technological development of the turbines, wind power became highly profitable in the 1990's and the development boomed. Thus, the tariff should have been lowered in the mid-1990's, but it was not so. Instead, a growing opposition against the growing profitability of turbines made an abrupt change necessary in 1999.
- *Trustworthy.* As mentioned, the political climate was for a continuation of wind power and, therefore, investors perceived high confidence in the FIT-scheme as a basis for investments in wind power. Thus, it seemed that investors in most of the Danish development of wind power required an appropriate risk premium, although profitability became too high in the late 1990's.

In general, it seems that if a FIT-scheme were combined with a benchmarking gradually lowering the tariff for each new vintage of turbines, this could prove to work, not only effectively, but also economic efficiently.

7.3 Tradable Green Certificate Scheme

A number of EU member states, Holland, Belgium, the UK, Italy and Sweden, already have or are presently aiming at introducing tradable green certificate systems (TGC's). Though, these TGC-systems appear to be quite different, For example, Holland has a voluntary scheme, Italy places the obligation on the power producers, while Sweden sets the quota on electricity consumers. Thus, no common EU TGC-system seems to be underway within the next year.

Denmark intended to introduce a TGC-scheme in the late 1990's as the predecessor of the in terms of implementation all too successful FIT-scheme. Thus, the aim was to establish a scheme with annual quotas of renewable produced power, where the quotas were coupled to domestic power consumption. Thus, the target was in 2005 to achieve 20% of power consumption covered by renewables. But quite a number of issues turned out to be barriers for the introduction of the TGC-system. The considerations were focused on the following issues:

- *Lacking investor confidence.* The Association of wind turbine owners and the Wind Power Industry was at large against the TGC-scheme, mainly because the price-determination of the certificates (in combination with the spot power market) was supposed to be lacking transparency, thereby, implying a higher risk premium by investors. Thus, the expected improvement in economic efficiency of the TGC-scheme compared with the FIT-system could be more or less reaped by a higher risk premium, eventually leading to even higher costs for society.
- *The market too small.* The intention was to establish solely a Danish TGC-market, but in which case, the volume of certificates at the market would expectedly be too low to become a well-functioning market, especially if technology trenches were to be introduced as well to prevent technology lockouts.
- *Offshore wind farms the dominant future development.* With regard to on-land wind power development, Denmark is close to becoming saturated. Any on-land capacity increase will most likely occur due to re-powering schemes. But large-scale offshore projects do not fit well into a TGC-system that comprises only a small market. These farms would more likely be the outcome of an extensive planning process and, therefore, be more compatible with a tendering procedure.

By now, the Danish TGC market is delayed at least until 2005, but nobody really believes that a national TGC scheme will be on the agenda again. Denmark is more likely to be a participant in a EU-wide scheme, if this should be adopted, although the problem of not being credited for any CO_2-reductions when buying certificates is still a major barrier.

7.4 Environmental Adder Scheme

Instead of a TGC-approach, Denmark, in terminating the FIT-scheme, adapted an environmental adder scheme, where a premium is placed on top of the spot power price. Thus, the existing Danish scheme is based on the spot market price of power plus a premium of 1.3 c€/kWh, although the total price paid per kWh must not exceed a cap of 4.8 c€/kWh. Finally, the Danish owners of new turbines are now responsible for balancing the power from the turbines and they are, therefore, reimbursed the average cost of balancing of approximately 0.3 c€/kWh10.

By now, the experiences of this scheme are the following:

- *Cap:* The cap of the scheme is strongly criticised because it gives the investors the downside risk without compensating them with the upside opportunities. Ongoing negotiations will probably lead to a removal of the cap;
- *Ineffective:* Besides the erection of an offshore wind farm (planned several years ago), 2003 witnessed almost a total halt in the Danish development of wind power. The prices paid were seen as too low, not giving investors any incentives to engage in new wind farm projects.

As mentioned, the Danish scheme will probably be changed on short notice, mostly because the existing scheme has proved not to bring about any investments in new wind power facilities.

7.5 Tendering System

The tendering system has most intensively been used in Ireland and the UK. The tendering schemes have presumably managed to reduce the production costs of wind power, whereas, especially in the UK, the success in the deployment of wind power has been limited.

While Denmark has no major experiences in using tendering schemes so far, it has been agreed as a part of a Danish energy policy agreement (dated 29 March 2004) that the concession holders for the next two offshore wind farms in Denmark each of 200 MW are to be selected by tendering.

The Danish tendering strategy is especially being characterised by the strong planning procedure behind those offshore areas found suitable for tendering. Specific areas are pre-screened and allotted for establishing offshore wind turbines. In this way, the risks of the investors are expectedly decreased, although only the chosen investor can undertake the final environmental impact assessment, because it is related to the specific project. The maximum capacity of the wind farm is predetermined in the tendering requirements, while the size of the turbines is to be chosen by the winning investor. Thus, technical improvements, for example, utilisation of larger turbines, can be fully exploited by the investor. A certain minimum expertise concerning the necessary technical and financial capacity of applicants is required.

For the existing offshore wind farms in Danish waters, the system operators have borne the costs of grid-connection from the farm to the shore and, in addition, any further costs associated with reinforcement of inland grids. This appears still to be the case in the coming tendering procedure. A tendering report published by the Government mentions two possibilities for the future distribution of grid-connection costs introducing at the same time competitive elements in the tendering procedure:

1. The investor will have to contribute to the costs of grid-connection to the shore. The applicant with the highest contribution will win the tender. The tariff paid to the turbine owners will consist of the spot market price of electricity plus an environmental premium, which is at present approximately 1.4 c€/kWh, and in total not more than a maximum of 4.8 c€/kWh. In addition to this is added 0.3 c€/kWh, because the owners are themselves financially responsible for balancing the power production. But, as stated above, these conditions will probably be changed in the ongoing discussions between the Government and the parliamentary political parties.

10 An extensive transition scheme exists for those turbines established before 2003.

2. The applicants will have to compete for the premium to be added on top of the spot market price. Thus, the one who requires the lowest premium will win the tender. The tariff will then be the spot market price plus the required premium and a reimbursed fixed balancing (0.3 c€/kWh). The costs of grid-connection will be borne by the system operators, as is the case today.

The first wind farm in the western part of Denmark will be selected by tendering according to principle two above. Balancing costs are to be borne by the operator. The location is near the existing Horns Rev wind farm and bids are due on 4. January 2005. For the second 200 MW offshore wind farm to be established by tendering the screening procedure is finalised and the political decision regarding the location pending.

8 References

[1] Department of Public Enterprise, *Green Paper on Sustainable Energy*, September 1999.

[2] Bolik, S., Grid requirements challenges for wind turbines. Proceedings Fourth International Workshop on Large-Scale Integration of Wind Power and Transmission Networks for Offshore Wind Farms, Billund (DK) October 2003.

[3] Garrad Hassan, The Impacts of increased levels of wind penetration on the electricity systems of the Republic of Ireland and Northern Ireland: Final Report, 11th February 2003,OFREG/CER.

[4] Consultation Document, Options for Future Renewable Energy Policy, Targets and Programmes by Department of Communications, Marine and Natural Resources, December 20 2003.

[5] Trotter, A. The challenge to the National Grid in coping with Renewable Power, in proceedings from the conference Before the Wells Run Dry, Ireland's Transition to Renewable Energy, Feasta, SEI and Tipperary Institute, 2002.

[6] Kristoffersen, J. R. & P. Christiansen. The wind farm main controller and the remote control system in the Horns Rev offshore wind farm. Offshore Wind Energy in Mediterranean and other European Seas, OWEMES 2003 Naples, Italy 10/4-12/4 2003.

[7] IEA Wind Energy Report 2003

[8] IEA Wind Energy Report 2002

[9] The 165 MW Nysted Offshore Wind Farm in Operation June 2003, On Schedule – On Budget, Per Voelund and Lars Woller, EWEC 2003

[10] Concepts of Offshore Wind Turbines Foundations Adapted to French Coastal Conditions, Jacques Ruer et al., EWEC 2003

[11] Rules for Design of Offshore Wind Turbine Structures, Peter Petersen et al., Det Norske Veritas, EWEC 2003.

[12] Technical Due Dilligence for Financing Large Wind Farm Projects, Lucy Craig et al, EWEC 2003

[13] Innovative Foundation Solutions, Lars Bo Ibsen, Work shop N104 at EWEC 2003

[14] Floating Offshore Wind Turbines for Shallow Waters, B.H. Bulder et al., EWEC 2003

[15] BTM Consult ApS, World Market Update 2003

[16] Photos and sketches for Horns Rev wind farm from Elsam A/S, www.hornsrev.dk

[17] Photos and data for Nysted wind farm from: www.nystedhavmoellepark.dk

[18] Photos and data for Middelgrunden wind farm from: www.middelgrund.com

[19] Energistyrelsen (The Danish Energy Authority): Betingelser for udbud efter forhandling ved havvindmøllekoncession ved Horns Rev (Conditions for tendering to obtain an offshore wind farm concession at Horns Reef); 29 October 2004.

Appendix 1. Brief Terms of Reference

Offshore Wind and Industrial Development Opportunities from Wind in Ireland

Objectives of the Study

To support the Government of Ireland and SEI in analysing and developing targets, programmes and policies in connection with implementation of wind energy in the Republic of Ireland.

The present study will examine:

- Task A: Key requirements to meet potential future targets for the deployment of offshore wind energy in Ireland.
- Task B: Potential opportunities for the development of an industry supplying the wind energy market in Ireland and overseas.

Task A: Key Requirements to meet Potential Future Targets for Offshore Wind

The study will aim at estimating the contribution from offshore wind in Ireland and the analysis will include the following issues:

- Key characteristics of policy to promote deployment
- Key characteristics of financial support options including levels of support
- Available technologies and reliability
- Operation and maintenance requirements
- Insurance requirements
- Marine support facilities
- Licensing and planning approval process
- Environmental impact assessment
- Guidelines and codes
- Grid connection
- Other critical issues

Task B: Development of an Industry Supplying the Wind Energy Market In Ireland

The study will aim at estimating the volume of services and goods from meeting the demand from the offshore and onshore wind energy markets in Ireland and the analysis will include the following issues:

- Wind turbines and supply of components including electrical and mechanical engineering and assembly
- Construction of wind farms and civil engineering
- Electricity networks within the wind farms
- Grid connections
- Consultancy services
- Financial services
- Operation and maintenance services

The study will estimate the existing industrial capacity in Ireland to supply the above needs and suggest opportunities where the industrial capacity in Ireland might be expanded.

The study might suggest policies and measures, together with estimates of the cost, to stimulate the development of the industrial capacity in Ireland.

Project Period*: November 2003 to May 2004*

Project Partners:

Risø National Laboratory (project coordination)
The Danish Energy Agency
BTM Consult Aps.

Appendix 2. Meetings with Stakeholders

Date	Time	Company	Contact	Contact Details / Meeting Location
1/12	14.00-16.00	VeeLite Lighting Ltd	Garry Kelly, Garret Kelly	086 2431900 Meeting to take place in SEI Glasnevin
2/12	10.00-12.00	SEI	Morgan Bazilian, John McCann	Address: Glasnevin Dublin 9 Ph: 8082067 Emer.craven@sei.ie
	12.00-13.30	University College Cork	Brian O'Gallachoir (Phone Meeting)	Address: Glasnevin Dublin 9 Ph: 8082067 Emer.craven@sei.ie
	14.30-16.30	Byrne O'Cleirigh	Liam P. O'Cleirigh	Ph: 01 6770733 LP.OCleirigh@boc.ie
3/12	9.00-11.00	ESBi	Pat McCullen	Address: 18-21 Stephen's Court, St Stephen's Green, Dublin 2 Ph: 7038297
	11.30-13.30	Airtricity	Brian Hurley Torben Anderson	Address: Block B, Ravenscourt Office Park Sandyford Dublin 18 Ph: 2130405 bhurley@airtricity.com
	14.30-16.30	Enterprise Ireland	Tom Talbot and Jennifer Good (EI) Michael Fenelon (Fenelon Engineering) Joe Hanley (Radley Engineering)	Address: Enterprise Ireland, Merrion Hall, Dublin 2 Ph: 8086391 Tom.Talbot@enterprise-Ireland.com
4/12	9.00-11.00	IDA Ireland	Dick Ryan, Brian Bastible	Address: Wilton Park House, Wilton Place, Dublin 2 Ph: 6024000
	11.30-13.30	Sure Engineering Europe	Thor Dan Hannevig Chris Hannevig	Address: 29 Lower Lesson Street, Dublin 2 Ph: 6622099 sureng@iol.ie
	15.00-17.00	Commission for Energy Regulation	Clare Beausang Siobhán Dinneen	Address: Plaza House, Belgard Road, Tallaght, Dublin 24 Ph: 4000800
5/12	9.30-10.30	DCMNR	Tom Burke	Address: Lesson Lane, Dublin 2 Ph: 6782000 Tom.Burke@dcmnr.gov.ie
	11.00-13.00	DCMNR	Eugene Dillion	Address: Setanta House, Nassau Street, Dublin 2, Ph: 6041061 Eugene.dillion@dcmnr.gov.ie
	14.30-16.30	Marine Institute	Eoin Sweeney	Address: 80 Harcourt Street, Dublin 2 Ph: 4766500 Eoin.Sweeney@marine.ie

Appendix 3. Policy Instruments AER

From www.Renewable-Energy-Policy.info

The objective of an AER competition is to compete for rights to generate electricity and to sell it to the ESB at agreed rates over a fifteen-year period. Prospective generators are invited to compete based on a price per unit of electricity.

AER I

Applied from - until:

1994

Targeted technology:

Wind, Hydro, Biomass/Waste, CHP

Objective:

To support renewable energy technologies that cannot yet compete with fossil fuel technologies in order to make them competitive in the future

Operational period:

A period of 15 years

Specification of the measure:

The first Alternative Energy Requirement competition started in 1994 with the objective of acquiring a total of 75 MW new generating capacity from wind, hydro, biomass/waste and Combined Heat and Power (CHP). An inevitable percentage of projects were calculated in advance to fail so contracts totalling 111 MW was awarded. By the end of 1997, some 76.5 MW new electricity generating capacity from renewables was on-line or under construction.

The feed-in tariffs offered under AER I were fixed in advance amounting to 6.1 - 6.6 p/kWh (7.8-8.4 ct/kWh) and 2.4 - 2.5 p/kWh (3.1-3.2 ct/kWh) for day hours (08:00 to 21:00, Monday to Friday) and night & weekend hours respectively - averaging 4 p/kWh (5.1 ct/kWh).

AER II

Applied from - until:

1995

Targeted technology:

Biomass/Waste

Objective:

To support renewable energy technologies that cannot yet compete with fossil fuel technologies in order to make them competitive in the future

Operational period:

A period of 15 years

Specification of the measure:

The second AER competition started in 1995. Finally, in February 1997 a consortium of Foster Wheeler Power Systems and ESB Power Generation was selected as the winner. It would set up a single biomass or waste fuelled electricity generating plant of up to 30 MW. But there were some problems with this project. First of all the European Commission refused to sanction ERDF support for the project because the proposed level of subsidy aid would not affect overall project economics. Besides this the project developers are awaiting a decision from 4 local authorities in the Dublin region as to whether they will supply the required waste. Planning permission and an integrated pollution control licence are also outstanding. In other words, the actual installed capacity is still zero.

The bids were capped at 3.6 p/kWh (4.6 ct/kWh). The successful developer bid in at 3.2 p/kWh (4.1 ct/kWh). In the first place the project was to be completed by the end of 1999 but now the project developers are still waiting for a decision from four local authorities for the supply of the required waste. Besides this, a planning permission and an integrated pollution control license are also outstanding.

AER III

Applied from - until:
1997

Targeted technology:
Wind, Hydro, Biomass/Waste, Wave (Pilot)

Objective:
To support renewable energy technologies that cannot yet compete with fossil fuel technologies in order to make them competitive in the future

Operational period:
A period of 15 years

Specification of the measure:
The third Alternative Energy Requirement was launched in April 1997, with a target of 100 MW (90 MW from wind, 7 MW from biomass and 3 MW from hydro). It this AER some 280 expression of interest were submitted and 92 proposals (a total of 640 MW) passed technical and commercial assessments. The technologies were treated separately in the competition with an additional small wind (< 5MW) category and a pilot wave energy plant included. The maximum size of wind farms was fixed at 15 MW, and no developer received contracts totalling more than 20 MW. In the end, 30 contracts were awarded, supporting almost 159 MW of electricity generating capacity (101 MW large wind, 36.5 MW small wind, 4.4 MW hydro, 14 MW waste to energy and 3 MW land-fill gas). Figuring ERDF-subsidy into tenders was compulsory. Afterwards the subsidy was not available for all successful projects. However, it is argued that not all-successful projects will proceed, so a reserve list has been created for projects currently without ERDF-subsidy. The projects had to be commissioned in 1999 but this was not done yet. The projects have progressed through planning permission.

The intense competitiveness together with the existence of subsidy support and tax relief was evident in bid prices as low as 2.8 ct/kWh among successful tenders. There was a cap price of 4.9 ct/kWh for wind, hydro, biomass/waste and a cap price of 6.3 ct/kWh for pilot wave energy plants. The successful bid prices ranged from 2.8 ct/kWh to 4.9 ct/kWh.

AER IV

Applied from - until:
1997

Targeted technology:
CHP (existing and new)

Objective:
To support renewable energy technologies that cannot yet compete with fossil fuel technologies in order to make them competitive in the future

Operational period:
A period of 15 years

Specification of the measure:
The fourth Alternative Energy Requirement competition was held in September 1997. This AER had to support the sale of surplus electricity from combined heat and power (CHP) installations: it aimed to support up to 25 MW generating capacity from new CHP plants and 10 MW generating capacity from existing installations. ERDF-subsidy was available for all projects and there was an installed cap price of 3.8 ct/kWh.

AER V

Applied from - until:
2001

Targeted technology:
Large wind (>3 MW), Small wind, Biomass/ Waste, Small hydro

Objective:
To support renewable energy technologies that cannot yet compete with fossil fuel technologies in order to make them competitive in the future

Operational period:
A period of 15 years

Specification of the measure:

The fifth AER from August 2001 took experiences from the previous rounds into account. An important experience was the fact that bids did not have planning permission to build and operate the proposed plant yet, which led to the fact that many projects were not installed. In this AER the bids therefore must have a planning permission. The total size of the tender is 255 MW and subdivided in technology bands, namely large wind (200 MW), small wind (40 MW), biomass/waste (10 MW) and small hydro (5 MW). The division between small and large wind projects is made to stimulate small community-based projects, which are deemed important for the longer-term sustainability of rural communities.
A list of successful applicants shows that the projects count up to 363 MW of renewable energy (318.3 MW large-scale wind, 35.8 MW small-scale wind, 8 MW biomass/waste, 0.9 MW small hydro), which is a significant step towards the government's target of 500 MW of additional renewables by 2005. The projects should be installed and operational by 31 December 2004.
The bids are capped at a maximum price per kWh depending on the technology. Twenty-five percent (25%) of the bid price is indexed to the Consumer Price Index to allow for inflation. The range for large wind is from 4.5 to 4.8 ct/kWh, for small wind from 4.72 to 5.3 ct/kWh, for biomass/waste from 3.8 to 5.9 ct/kWh and for small hydro there is a weighted average price of 6.4 ct/kWh.

AER VI

Applied from - until:

2003

Targeted technology:

Biomass (including CHP), hydropower, onshore and offshore wind

Objective:

To support renewable energy technologies that cannot yet compete with fossil fuel technologies in order to make them competitive in the future

Operational period:

A period of 15 years

Specification of the measure:

The sixth AER from February 2003. The total size of the tender is 578 MW and subdivided in technology bands, namely large wind (400 MW), small wind (85 MW), Wind Offshore (50 MW), biomass (8 MW), biomass CHP (28 MW), biomass-Anaerobic Digestion (AD, 2 MW) and small hydro (5 MW). The division between small and large wind projects is made to stimulate small community-based projects, which are deemed important for the longer-term sustainability of rural communities. Price caps in each category are:

- Large scale wind: 5.216 ct/kWh
- Small scale wind: 5.742 ct/kWh
- Offshore wind: 8.4 ct/kWh (indicative price cap)
- Hydro:7.018 ct/kWh
- Biomass 6.412 ct/kWh
- Biomass - AD 7 ct/kWh
- Biomass - CHP 7 ct/kWh

Appendix 4. Irish Companies with a potential in Wind Energy

Compiled by Enterprise Ireland represented by Jennifer Good.

Appendix 5. Irish Companies within Marine Business

Compiled by the Marine Institute represented by Eoin Sweeney

Bibliographic Data Sheet **Risø-I-2166 (EN)**

Title and authors

Offshore Wind Energy and Industrial Development in the Republic of Ireland

Niels-Erik Clausen, Egon Bjerregaard, Birger T. Madsen, Poul Erik Morthorst, Poul Sørensen

Department or group	Date
Wind Energy	October 2004 (final report)

Groups own reg. number(s)	Project/contract No(s)
1170 018 – 00	SEI no. RE/W/03/012

Sponsorship

Sustainable Energy Ireland

Pages	Tables	Illustrations	References
139	27	17	19

Abstract (max. 2000 characters)

As a part of the process of developing Irelands future policy and programmes on renewable energy Sustainable Energy Ireland has granted financial support to carry out the present study on offshore wind energy and industrial development. The study has analysed the key requirements for deployment of offshore wind energy and the industry development within wind The Republic of Ireland.

SUSTAINABLE ENERGY IRELAND

Glasnevin
Dublin 9
Ireland

t +353 1 836 9080
f +353 1 837 2848
e info@sei.ie
w www.sei.ie

Sustainable Energy Ireland is funded by the Irish Government under the National Development Plan 2000-2006 with programmes part financed by the European Union

NATIONAL DEVELOPMENT PLAN

DESIGNED AND PRODUCED BY BEGLEY HUTTON, DUBLIN WWW.BEGLEYHUTTON.COM