Activities and Prospects

1 Introduction

This Work Package brings together current work from each of the member countries to help identify future strategies for adoption by the European Offshore Wind Industry.

With this objective, within this state of the art summary, the following issues are addressed:

- Recent and current research
- Recent and current projects and national plans
- Market developments
- Benefits to the environment
- Employment prospects for Europe
- Benefits for European Industry

Members of the Concerted Action have responded to questionnaires addressing these points. This document consolidates the responses and provides references for more detailed information.

Contents

The current activities in offshore wind energy are built on the experiences of two fields of engineering: those of wind energy and of offshore il and gas, with smaller but significant input from the field of coastal engineering. Wind energy has a history that stretches back about a thousand years, with one of the first records of windturbines being from the mid tenth century, a reference to vertical axis windturbines in Afghanistan; the horizontal axis type first appeared a couple of centuries later in Northern Europe and quickly became a common sight. The wind energy industry as we know it today, really began in the early Seventies, when the oil price shock caused many governments around the world set research programmes to investigate power generation technology from non-oil dependent sources, including wind energy. However, once the oil price stabilised, these research programmes were curtailed and no commercial plants were in fact built in this short period. The second oil price shock in the late seventies revitalised the efforts and led to commercial developments, such as the large fields of wind-turbines in California. This second boom drew in many established companies and encourage entrepreneurs to set up new enterprises, some of which persist as the big names of today. Many of the windturbines installed in the States in the mid-Eighties were manufactured in that country but Europe also supplied large number of them. When the supply of new projects in California dried up, most of these companies folded or closed their windenergy operations; the exception was in Denmark, where wind farm development persisted, albeit at a much lower pace, enabling a handful of Danish companies to survive and later thrive when the threat of environmental pollution and global-warming caused the current boom in wind energy.

The offshore Industry, which has grown up around the hydrocarbon reserves in the North Sea, is much more recent, with the first discovery in the British sector having been made in the Sixties. Since then, regular high prices for oil and incremental technological developments have allowed the Industry to exports ever deeper and more hostile waters, in fact significantly more hostile than the seas where the current offshore wind farms are being built.

The first ideas for generating electricity using wind in the offshore environment where in the late seventies and numerous feasibility studies where undertaken in the following decayed. It was only in the early nineties that the first prototype offshore wind farms were actually built: at Vindeby in Denmark in 1991 and a single turbine at Nogersund, Sweden in the same year. The performance of the wind farm at Vindeby has been heavily monitored and evaluated and much useful knowledge has been gained on the performance of windturbines offshore but also on the performance of wind turbine in general (specifically because of the low turbulence conditions). The windfarm consisted of 11 windturbines, rated at 450 kW, giving a total farm output off almost 5 MW; by way of illustration of the progress made in this industry, the largest single prototype wind-turbines currently being installed have the same rated power as that whole windfarm. Vindeby is located in a relatively protected part of the Baltic Sea, surrounded by islands but even there access has been a problem because of excessively high waves.

Vindeby was soon joined by a second wind farm in Denmark, at Tuno Knøb, and two further windfarms were built in the Dutch inland lake of IJsselmeer, at Lely / Medemblik and Dronten. These were built on monopiles, which is becoming the preferred support structure for offshore windturbines. In the latter half of the last decade, there was less activity, with a single windfarm being built at Bockstigen-Valor in

Sweden. The first years of this millennium have seen new windfarms constructed using large multi-megwatt windturbines; the largest is that Middelgrunden and is clearly visible from Copenhagen. It consists of 20 turbine each rated at 2 MW is located on concrete gravity bases; the wind farm at Blyth consists of only two turbine again each of 2 MW, however they are located in the harshest environment yet: the North East coast of England facing directly into the North Sea. Two wind farms have also been built in Swedish waters, at Utgrunden (in 2000) and Yttre Stengrund (in 2001) and now four wind turbine manufacturers have experience of building and operating large wind-turbines for offshore operation, which surely must give confidence for success of the projects over the coming years.

The construction of offshore wind farms has also been built on the activities of sympathetic politicians and civil servants, researchers and environmentalists. The field of tertiary education is now also becoming more active, with masters courses in wind energy or general renewable energy at universities in several European countries. The main body of this report attempts to give details of the more important of all these activities.

2 Recent and Current Research Activities

This section addresses recent and current research activities in offshore wind energy. A large number of national and international R&D projects on offshore wind energy have been undertaken over the last decades and the more recent and relevant are briefly described within this section. For convenience, they have been arranged in the following groups:

- Resource assessment,
- Windturbines (including support structures)
- Windfarm
- Installation
- O&M
- Integrated methodologies

Further information on European funded projects is available at the CORDIS and Agores databases and projects are generally reported at the appropriate European wind energy conferences:

- European Wind Energy Conferences [EWEC]
  - Copenhagen 2001,
  - Nice 1999,
  - Dublin 1997,
  - Gothenburg 1996.
- OWEMES Seminar (Offshore Wind Energy in Mediterranean and other European Seas):
  - Rome 1994,
  - La Maddalena 1997,
  - Siracusa 2000.

2.1 Resource assessment,

This section briefly describes research projects that have focused on defining the resource, for purposes such as estimating energy production, predicting the loads on the wind-turbine, optimising the wind farm layout and evaluating the extent of the total offshore resource available.

Predicting offshore wind energy resources [POWER]

This European funded project was undertaken jointly by CLRC\RAL (lead contractor), University of East Anglia, KEMA, Ecofys and Risø under the Fourth Framework JOULE Programme, reference JOR3980286 and was completed in the middle of 2001.

The objectives of the project were to assess offshore wind power potential in EU waters. The work involves determining the geostrophic wind from long-term pressure fields, transforming the wind to sea level, taking account of nearshore topography using WAsP and correcting for stability effects using a Coastal Discontinuity Model.

Wind Energy Mapping using Synthetic Aperture Radar [WEMSAR]

This European funded project is being undertaken jointly by Nansen (lead Contractor), ENEA, Risø, NEG Micon and Terra Orbit under the Fifth Framework Programme, Reference ERK6-1999-00017, and is due to be completed and in 2003.

The objective is to investigate, validate and demonstrate the potential of satellite-based synthetic aperture radar (SAR) to map wind energy in offshore and near coastal regions for potential wind-turbines siting.

Wind resources in the Baltic Sea

This European funded project was undertaken jointly by Risø it, University of Karlsruhe, the Finnish Meteorological Institute, University of Keele under the Third Framework Programme, reference JOU20325 and was completed in 1996.

The objective was to describe and map the wind resources of the Baltic Sea and the Gulf of Finland and to create and test tools for siting of windturbines in coastal areas.

Study of Offshore Wind Energy in the European Community

This European funded project was undertaken jointly by Germanischer Lloyd and Garrad Hassan under the Second Framework Programme, reference JOUR0072 and was completed in 1993.

The focus of the project was to undertake an exploratory study covering the following four tasks: the potential for offshore wind energy in Europe, experience in offshore engineering relevant to offshore wind farms, design guidelines and consideration of combined wind and wave loading.

The National Technical University of Athens is carrying out research into wave resource modelling [1], specifically for wave energy schemes but of relevance to offshore wind projects for determining the wave climate.

Research and design tools include:
The New WAsP The goal of the project is to develop the next generation of the WAsP computer program, which should be able to handle modelling in complex terrain as well as offshore in a better manner. Two tracks will be followed, one will try to take advantage of and implement the newest technologies within the flow-modelling field and the other will develop incremental improvements to the existing code. Once the new algorithms have been developed they will be implemented in the familiar WAsP GUI (Graphical User Interface) [7]-[11]

: Zukunftsinvestitionsprogramm (FuE/ZIP)
This project (in English ***Future Investment Programme)*** is being undertaken jointly by BMWi [Ministry for Economic Affairs] and BMU [Ministry of Environment Protection], is due to in 2001 and will cover:

- measurement platforms in the North Sea and Baltic Sea for wind resource assessment and ecological monitoring research:
- bird migration
- marine acoustics with respect to impact on sea mammals
- investigation on sea bed life
- investigation on impact on fish

2.2 Wind turbine

This section briefly describes research projects that have focused on modelling the wind-turbine and the support structure. Regarding the current status of design tools, these include:

- the prediction of offshore wind regimes by analytical techniques and the monitoring of existing wind farms
- refinement and development of integrated dynamic structural models of the entire turbine and foundation system
- reliability/availability
- prediction of rotor dynamics

Recommendations for Design of Offshore Wind Turbines [RECOFF]
This European funded project is being undertaken jointly by Risø (lead contractor), CRES, ECN, Garrad Hassan and Germanischer Lloyd, under the Fifth Framework Programme, reference ENK5-2000-00322 and is due to be completed at the end of 2003.
The project aims at the provision of recommendations for a standard design of offshore wind turbines. Readily available information will be utilised to the extent possible and where a need is identified, research and development will be performed. The recommendations will be addressed directly to the two standardisation bodies: the International Electrotechnical Commission (IEC) and the European CENELEC.
Design Methods for Offshore Wind Turbines at Exposed Sites [OWTES]

This European funded project is currently being undertaken jointly by Garrad Hassan (lead contractor), AMEC Borderwind, Germanischer Lloyd, PowerGen Renewables, TUDelft and Vestas under the Fourth Framework Programme, reference JOR3980284 and is due to be completed in 2002.
The aim of this project is to improve the design methods for wind-turbines located at exposed offshore sites and to facilitate the gradual, cost effective exploitation of the huge offshore wind energy resource available in European Union waters. As part of this project, a measurement system has been installed on one of the wind-turbines to enable design and certification methods to be verified.

Research into 'The Dynamic Response of Wind Turbine Structures in Waves' is underway by Prof. J M R Graham (Imperial College) et al, funded by the UK DTI Renewable and New Energy Programme, Engineering and Physical Sciences Research Council – Renewable and New Energy Technologies; EPSRC - RNET, [5]

A report has been produced in Finland on the response of OWEC's to pack ice [6]

'BLADED for Windows' and 'TURBLOAD' have been and are under development by Garrad Hassan. Validation and further development of existing aeroelastic models will be performed based on measurements at Blyth Harbour.

In the Netherlands, ECN have developed two wind-turbine models,

- the time-domain PHATAS-IV [14]
- the frequency-domain TURBU with the TURBU-OFFSHORE extension currently in preparation [13]

In Germany, wind turbine manufacturers, certifying bodies and universities are also cooperating in the development of their individual design tools [12]

In Belgium an integrated dynamic model of the complete system is currently under development using Finite Element (FE) analysis.

Proprietary computational fluid dynamics programs, for example by CFX, a division of AEA Technology, are used for the analysis of flow around and the behaviour of turbine blades.

Other Danish ongoing research focusses on:

- Aero-elasticity with special focus on offshore wind turbines.
- Design specifications for offshore wind farms

2.3 Windfarm

This section briefly describes research projects that have focused on the entire windfarm.

Cost Optimising of Large Scale Offshore Wind Farms

This European funded project was undertaken jointly by S K power (lead Contractor), National Wind Power, Risø, Nellemann, Nielsen & Rauschenberger, Rostock Stadwerk and the Polytechical University of Madrid, under the Fourth Framework Programme, reference JOR3950089 and was completed at the end of 1998.

This project investigated the technical and economic feasibility of a large scale offshore wind farm in the range of 200 to 500 MW in the Danish waters of the Baltic Sea and a Langeland Belt by examine the meteorological conditions and North

Efficient Development of Offshore Windfarms [ENDOW]

This European-funded project is being undertaken jointly by Risø (lead contractor), Garrad Hassan, Ecofys, Uppsala University, Robert Gordon University, NEG-Micon, SEAS, Oldenburg University, ECN and Elsamproject. under the Fifth Framework Programme , Reference ERK6-1999-00001, and is due to be completed in July 2003.

Using experience gained through the demonstration projects currently operating offshore, the major objectives are to evaluate wake models in offshore environments and to develop and enhance existing wake and boundary-layer models to produce a design tool to assist planners and developers in optimising offshore wind farms.

Measurement On and Modelling of Offshore Wind Farms

This European funded project was undertaken jointly by Risø, Bonus, Finnish Meteorological Institute and Madrid University under Third Framework Programme, reference JOU20350 and was completed in 1996. The main objectives of the project were to measure the nature of wind-turbine wakes at the Vindeby offshore wind farm, to investigate the structure of single and multiple wakes and to characterise the relationship between turbulence and wind-shear with wind-turbine separation.

Fyndfarm, a tool for optimisation of wind farm configurations, has been developed in the Netherlands.

2.4 O&M

Availability Model for Offshore Wind Farms.

This project is funded by the Danish Energy Agency (DEA) under the UVE Programme, reference ENS-51171-98.0033.

The project is managed by Riso, Department of System Analysis in co-operation with SEAS and is expected to be completed at the end of 2001. The aim of the project is the development of a general model for decision analysis for the optimisation of the availability of wind turbine farms offshore especially with respect to maintenance policy.. A determination of the balance between reliability of the turbines, their interconnections and tower access conditions will be carried out. The model will be constructed as an influence diagram, and relevant variables including those mentioned above will be taken into account. The variables will describe the farms geographical site, the turbines, including their main component reliabilities, the site climatic conditions, transport infrastructure, electrical connections, local as well as remote surveillance and control.

2.5 Integrated methodologies

Structural and Economic Optimisation of Bottom-Mounted Offshore Wind Energy Converters [Opti-OWECS]

This European funded project was undertaken jointly by TUDelft (lead contractor), University of Sunderland, Kvaerner Oil and Gas and Kvaerner Turbin under the Fourth Framework Programme, reference JOR3950087 and was completed at the end of 1997.

The overall objective of the study was to identify designs leading to a reduction of the cost per generated kilowatt hour of offshore wind energy by using an integrated approach in the design process.

Site Specific Design of Wind Turbines Based on Numerical Cost-Optimization.

This Danish project involves the direct use of site characteristics in the design process, when optimising wind turbines. Design loads are determined by use of detailed wind climate information for mountainous complex terrain, large offshore wind farms and very low or high annual wind speed. Benefits will be determined from the design of site-specific wind turbines and multi-site wind turbines. Design guidelines will be established for the adaption of existing designs to a specific site with only small adjustments and for the design of entirely new wind turbines. Numerical optimisation will be used to optimise wind turbines for the specific site characteristics. Existing design tools will be improved by development a complete direct design method that combines state-of-the-art aero elastic calculations, wind modelling, cost modelling and numerical optimisation. Two three-bladed wind turbines based on different concepts will be modelled and the design load cases will be found for six wind climates. The benefits from site-specific design and the possibility for multi-site design will be evaluated covering both re-design of existing wind turbines and design of new wind turbines

2.6 Environmental impact and Miscellaneous Aspects

In Denmark, a tool for LCA (life cycle assessment) of wind turbines is being developed, which will enable the environmental impact of wind turbines to be predicted.

Umweltforschungsplan des BMU (UFOPLAN): „Weiterer Ausbau der Windenergie im Hinblick auf den Klimaschutz“

This investigation was undertaken by BMU [Ministry of Environment Protection] and focused on the further development of wind energy use in Germany with respect to climate protection. It is an ongoing project and examines:

- Further Development of Wind Energy Use on Land and Offshore
- Wind energy pricing (EEG Renewable energy Law)
- Repowering onshore
- Workshops on Offshore Wind energy Use in (April/June 2000)
- Integration of conflicting environmental interest
- Grid integration
- Feasibility of remote offshore wind energy
- Operational aspects of offshore wind energy use and cost of offshore wind

UFOPLAN: „Untersuchungen zur Vermeidung und Verminderung von Belastungen der Meeresumwelt durch Offshore-Windparks im küstenfernen Bereich der Nord- und Ostsee“
This investigation was undertaken by UBA [Federal Office for Environmental Protection] and focused on the state of the art for avoidance and minimisation of environmental impact by offshore wind farms on marine environment. It is an ongoing project and examines:

- description of the state of the art with respect to environmental impacts on benthos, fish, birds, sea mammals
- development of IEA methodology
- risk analysis for ship collision
- formulation of measures to minimise impacts
- identification of knowledge deficits

Erfassung der Verbreitung, Häufigkeit und Wanderungen von See- und Wasservögeln in der deutschen Nordsee und Entwicklung eines Konzeptes zur Umsetzung internationaler Naturschutzziele (BOFFWATT)

This investigation was undertaken by BFN [Federal Office for Nature Preservation] and was completed in 1999; the report is available from BfN and covers:

- Investigation on sea bird populations in the German North Sea with respect to number of individuals and annual variations, feeding habits,
- development of a protection concept
- further need for research

See- und Wasservögel in der deutschen Ostsee und ihr Schutz im Rahmen internationaler Vereinbarungen
Additional ongoing study, also undertaken by BfN for the German Baltic Sea.

Erfassung und Bewertung ökologisch wertvoller Lebensräume in der Nordsee
Identification, investigation and determination of potential areas for marine nature preservation (with respect to FFH-protected areas) in the German North Sea. An ongoing project also undertaken by BfN.

Erfassung und Bewertung ökologisch wertvoller Lebensräume in der Ostsee

Identification, investigation and determination of potential areas for marine nature preservation (with respect to Baltic Sea Protected Areas (BSPAs)) in the German Baltic Sea. Completed in 1999 and a report is available from the authors, BfN.

3 Recent and Current Projects

This section describes recent and current demonstration and full-scale commercial offshore wind farm projects. Many of the earlier projects have been accompanied by extensive measurement and analysis programmes, which are also described here.

Most of the existing projects are demonstration projects, with the exception of Middelgrunden wind farm, a 40 MW development three kilometres off the coast of Copenhagen, Denmark. Most of the planned projects are fully commercial enterprises.

The following offshore windfarms are planned in Belgium:

- Vlakte van de Raan - 100 MW wind farm 12-15 km from the coast , developed by Electrabel and Ondernemingen Jan De Nul. This project includes a 20 MW pilot phase
- Wenduinebank - 100 MW (50x2MW) wind farm 5 – 8 km from the coast , developed by C-power (Interelectra, Dredging International, and Turbowinds)

Three offshore wind farms are already in operation in Denmark:

Name	**Number of Blades**	**Diameter**	**Turbine Capacity**	**Number of OWEC's**	**Type of Foundation**	**Installation Method**	**Marinisation**	**Maintenance Access**
Vindeby 2-6m WD 1.5-3km from shore	3	35m	450kW	11	RC Gravity	Modified transport ship (base) Jack-up (tower)	Offshore paint system, sealed, recycled cooling air, dehumidified. Standby heating, Nacelle-mounted hydraulic cranes	Special boat
Tuno Knob 3-5m WD 6km from shore	3	39m	500 kW	10	RC Box Caisson Ore Filled	Modified barges Floating crane	NA	Special boat
Middelgrund	3	76m	2MW	20	RC Gravity	Modified	Offshore paint system,	Special

Name	Number of Blades	Diameter	Turbine Capacity	Number of OWEC's	Type of Foundation	Installation Method	Marinisation	Maintenance Access
5-10m WD 2km from shore						transport ship (base) Jack-up (tower)	sealed, recycled cooling air, dehumidified, standby heating. nacelle-mounted hydraulic cranes	boat

In addition, there are several at various stages of planning:

- Horns Rev 160 MW (under construction)
- Roedsand 150MW (under construction)
- Gedser 150 MW
- Omoe 150 MW
- Laesoe 150 MW
- Samso 25 MW (EIA study issued)

Measurements are being taken at the Middelgrunden Wind Farm to assess wind spectra around the towers and power output in relation to the placement of individual turbines within the wind farm. Forces in the towers and foundations under environmental loading will also be measured.

In Finland, offshore wind farms are planned for:

- un-named on small nearshore rock islands
- un-named 10-30MW 5km offshore 6-10m water depth

Currently, there are no existing offshore wind farms in France, however several are planned or at various stages of development, including at:

- Breedt,
- Dunkerque

The largest number of planned offshore wind farms are in Germany. Locations where wind farm developers have stated their intention for developing offshore windfarms include:

- Butendiek 80 x 3MW
- Dan-Tysk 300 x 5MW
- Nordsee AWZ 100-200 x 5MW
- Helgoland I and II

- Borkum Riffgrund 200 x 3-5MW
- Borkum Riffgrund West 458 x 2.5MW
- Borkum III 12 x 4-5MW
- Pommersche Bucht 200 x 5MW
- Arkona-Becken 172 x 4-5MW
- Adlergrund 69 x 3-5MW
- Nordergrunde 76 x 2.5-5MW
- Offshore Helgoland 100 x 2MW
- Schleswig-Holsteinische Nordsee 100-200 x 5MW
- Wilhelmshaven 2 x 4.5MW
- Mecklengburg-Vorpommern 20 x 2MW
- Sky 2000 50 x 2MW

In Greece, following the deregulation of the energy market in 2000, petitions for 4 LSOWE-plants with total installed capacity of ~500 MW are currently under consideration at the Regulatory Authority for Energy of the Ministry of Development.

A number of offshore wind farms are also planned for Ireland, at [19], [24] & [25]:

- Kish Bank: 10km from shore, 200-250MW
- Bray Bank
- Arklow Bank: <10 m water depth, 10km from shore, 500+MW
- Blackwater Bank
- Codling Bank
- Greater Codling Bank

In Italy, there has been a feasibility study for out offshore wind farm at Ragusa.

In the Netherlands, there are two offshore wind farms located in the inland fresh water Ijsselmeer:

Name	**Number of Blades**	**Diameter**	**Turbine Capacity**	**Number of OWEC's**	**Type of Foundation**	**Installation Method**	**Marinisation**	**Maintenance Access**
Lely 5-10m WD 0.8km from A shore	2	40.8 m	500kW	4	3.7m monopile		No	

Name	Number of Blades	Diameter	Turbine Capacity	Number of OWEC's	Type of Foundation	Installation Method	Marinisation	Maintenance Access
Dronten 20m from shore		43.0 m	600kW	28	monopile		No	

In addition, two further windfarms of planned:

- Q7 Sector 100MW
- Egmont aan Zee 100MW

According to the Maritime Bureau, after exclusion of all restricted areas (birds, fishing, offshore exploitation), ca. 2 800 km^2 for development of offshore wind power is available in Poland, that is 8.5% of the Polish territorial waters. In the Gdansk Bay, the area where implementing wind turbines is possible is ca. 40 km long and on the open sea coast line (from Jastrzebia Gora to Swinoujscie) - it is ca. 200 km long, excluding costal banks at Wistula – and Szczecin Bays.

The Maritime Bureau in Gdynia has issued consents for two following offshore locations:
- 49-61 turbines of 2,0 MW near Bialogóra. Project led by Nowa Energi
- 50 x 2 MW near Karwia (Debki-Jastrzebia Góra). Project led by Wiatropol

At this moment there are two other pending applications at Slupsk Municipality, where Baltyckie Elektrownie Wiatrowe S.A. (Baltic Windpower S.A.) request for permission near Sarbinowo, however no information has been cleared yet.

It can be assumed that all the locations referred to have at least pre-feasibility studies made, but nothing has been disclosed yet.

Source: Maritime Institute, 2000

Fig. 1: Locations for potential offshore wind power development on Polish territorial waters.

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Three offshore wind farms are currently operational in Sweden:

Name	**Number of Blades**	**Diameter**	**Turbine Capacity**	**Number of OWEC's**	**Type of Foundation**	**Installation Method**	**Marinisation**	**Maintenance Access**
Nogersund 5m WD 0.5km from shore	3	27m	220kW	1	Steel tripod	Submersible barge		Boat & ladder
Bockstigen-Valar 6-8m WD 4 km from shore	3	37m	500kW	5	2.15m drilled and grouted	Jack-up		
Utgrunden								

In addition, further offshore wind farms are planned at:

- Orestad
- Klasardenproject

A demonstration of the commercialisation potential (Valar 2, 5 MW)

This European funded demonstration projects was undertaken by Vindkompaniet under the Fourth Framework Programme, THERMIE project reference WE/00057/96 in 1996 and 1997.
Research will also be performed at the Klasardenproject; a 42MW development in Sweden planned for 2002 installation.

There is one offshore wind farm in the United Kingdom off Blyth Harbour. Further information on this project can be obtained from www.blyth-offshore.co.uk: The Blyth offshore wind farm is a European-funded demonstration project undertaken by AMEC Border under the Fourth Framework Programme, THERMIE project reference WE/00208/95 between 1996 and 1999.

Name	**Number of Blades**	**Diameter**	**Turbine Capacity**	**Number of OWEC's**	**Type of Foundation**	**Installation Method**	**Marinisation**	**Maintenance Access**
Blythe Harbour, NE England5-11m WD 1km from shore	3	70m	2MW	2	3.7m drilled and grouted monopile	Jack-up		Boat & ladder

In addition, numerous offshore wind farms are planned, including for:

- Barrow
- Burbo
- Cromer
- Gunfleet Sands
- Inner Dowsing
- Kentish Flats
- Lynn
- North Hoyle
- Rhyl Flats
- Scarweather Sands
- Scroby Sands
- Shell Flat
- Southport
- Teesside

Construction of the 37.5 MW Scroby Sands offshore wind farm, East Anglia, England

This European funded demonstration project is currently being undertaken by PowerGen Renewables under the Fourth Framework Programme, THERMIE project reference WE/00218/97 and is scheduled to be completed in 2003.

4 National Plans

This section summarises the various national plans that have been put forward by countries across Europe.

Belgium's federal authorities have created a legal framework for granting concessions and authorisations for OWECS.

Today, wind turbines produce 15% of Danish electricity consumption. Denmark has a 2030 target of 4,000 MW produced by offshore wind. This, together with other renewables, will cover 50% of the total electricity consumption. The first milestone is the establishment of 800 MW offshore wind farms by 2008. Of this 45 MW is already established (Middelgrunden, Vindeby and Tunoe Knob). The 160 MW Horns Rev and 150 MW Roedsand are under construction. [34]-[36]

Finland

The national energy strategy from 1997 mentions renewable energy to have significant role and wind energy to have a recognised role by 2025. The Action Plan for Renewable Energy Sources elaborated this, while recognising the Kyoto protocol on the reduction of emissions of greenhouse gases of 1997 and the EU White Paper endorsed by the Commission in 1997 and the Council in 1998, into a targets for renewable energy deployment.

The target is to increase the use of renewable energy sources at least by 50% (3 Mtoe/a) by the year 2010 from the level of the year 1995. 90% of this increase is expected to originate from of bioenergy, 3% from wind power, 3% from hydropower, 4% from heat pumps and less than 0.5% from solar power.

The share of renewable energy sources in power production would increase by 8.3 TWh (2010 MW) from the level in 1995. The major part, 75 %, would be generated from biofuels. Achieving the targets would reduce greenhouse gas emissions by about 7.7 million tonnes of CO2 equivalent. The vision for 2025 is an addition of 100% (6 Mtoe) of renewable energy from the level in 1995, with biomass still dominating but already several per cents of the total electricity generated by wind.

The target for wind energy deployment is set to 500 MW in 2010 and a vision to 2000 MW in 2025. Thus wind energy production would reach 5 TWh/a in 2025, which is about 5% of the projected gross power consumption.
http://www.vtt.fi/ene/results/renewable.htm

Action plan for Renewable energy resources in Finland, English translation, Ministry of Trade and Industry, Reports 1/2000.
See also http://www.vtt.fi/ene/tuloksia/uusiutuvat/actionp.pdf

France has a target of 5,000MW to be generated by wind power in 2010.

In Germany there is no national plan in terms of installation figures, however the contribution of offshore wind energy use in the context of CO2-reduction and sustainable energy supply policy are investigated in a national study on the "Further Use of Wind Energy with Respect to Climate Protection" [31]. Governmental objectives are set to cover 5-6% of the national net electricity consumption with wind generated electricity by 2010 and to reach a 50% renewable energy share of the national electricity demand by 2050 [17]. Germany's Renewable Energy Sources Act (EEG – Erneuerbare Energien Gesetz) [3] continues the reimbursement at a fixed feed-in tariff. In the reformed EEG a specially raised tariff is foreseen during the first nine years of operation of an offshore wind farm. This regulation is limited to projects coming online before the end of 2006.

The Greek government's policy is in line with EU energy policy regarding the penetration of RES in the energy market. [16] and [17]. The government is encouraging the large-scale installation of RES plants by means of subvention of capital investment, loan interest subsidies and tax-exemptions. The legislation also applies to offshore wind energy.

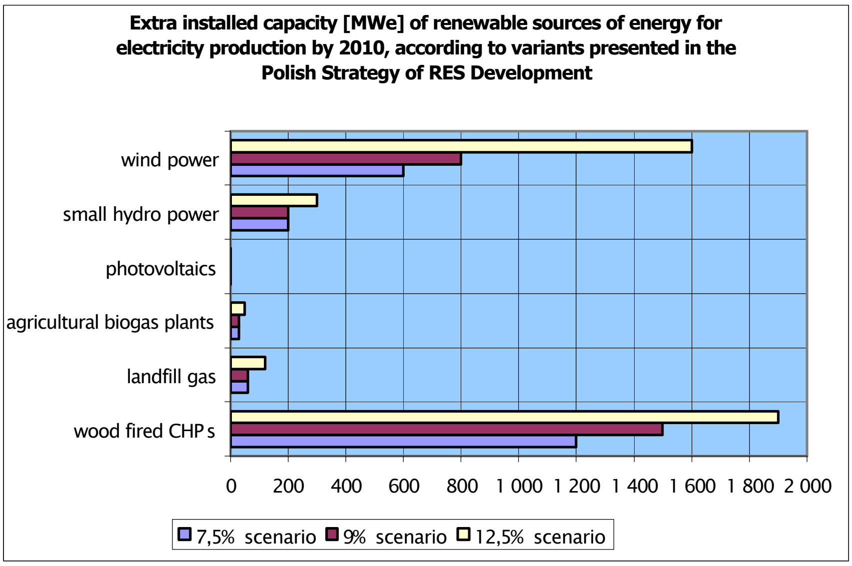
Ireland has no specific targets or detailed national plans for offshore wind energy, but it is the main focus of policy targets for both maximising offshore resources and promoting renewable energy. 7 foreshore licenses have been awarded for site investigation and procedures for foreshore leases are in place. [18]-[24]

Italy has produced a 'White Paper for the valorisation of Renewable Energy Sources', which forecasts 2500MW of electricity produced from wind by 2008-12. However, it envisages that this would be mainly onshore. There is an initiative by the Ministry of Environment with Assomineraria to produce an agreement document for national waters. The Province of Ragusa, Sicily has issued a Call for Proposal and Assignment document. (in Italian)

Officially, the Netherlands target (Duurzame Energie in Opmars; Ministerie van Economische Zaken 1997) is 20% renewables by 2020, equivalent to 2759MW, of which 1250MW is from offshore wind, [25]. The government is expected to increase this targeted power quantity in the near future.

Poland has a strategy for Renewable Energy Development of 7.5% by 2010, [15] Strategy aims to increase RES share in the total energy balance from the present 2,4% to 7,5% in the year 2010 and 14% by the year 2020. The document presents three scenarios of RES increase by the year 2010:

- 7,5% scenario,
- 9% scenario,
- 12,5% scenario.



Source: EC BREC

Extra RES installed capacity according to the Polish Strategy of RES development

Spain has no national plans and has no specific incentives for OWECS.

Sweden has no fixed target for offshore wind power, but it has been identified as a source of electricity generation that could replace nuclear, coal and oil. The state budget earmarks money for research and demonstrations in the field of offshore wind power. Many political and other groups are lobbying for offshore wind power and propose changing laws and regulations in favour of it. Some of the groups are developers and manufacturers with vested interests in promoting OWECS and some claims for future growth are considered unrealistic.

The UK has now ended the Non-Fossil Fuel Obligation but is still providing support (between £60m - £80m this year) and has issued a consultation document on renewables [26]. The primary market is likely to be licensed UK electricity suppliers fulfilling their Renewable Energy Obligation commitments. Current estimates are for net revenue of around £0.05p per kWh. The national objective is to reduce greenhouse gas emissions by 12.5% from 1990 levels by 2010, to reduce CO_2 emissions by 20%, 5% of UK electricity from renewables by 2003 and 10% by 2010, with 2600MW offshore by 2010, [27] & [28]. The Crown Estate has pre-qualified and allocated Agreements for Lease for the first round of offshore sites to 18 developers for 13 sites [30].

5 National Activities

5.1 National Organisations

Organisations that promote offshore wind energy are listed below by country.

Belgium

There are no national organisations that currently actively promote offshore wind energy in Belgium.

Denmark

- Dansk Vindmoelleforening (Association of Turbine owners in Denmark); www.dkvind.dk
- Vindmoelleindustrien (Danish Wind Turbine Manufactures Association); www.windpover.dk
- Energistyrelsen (Danish Energy Agency); http://www.ens.dk; Includes all official hearing papers like EIA Studies for new projects
- Energioplysningen (The National Danish Energy Information Centre); http://www.energioplysningen.dk
- Organisationen for Vedvarende Energi, OVE (Danish Organization for Renewable Energy); http://www.orgve.dk
- Forum for Energi- og Udvikling, FEU (Forum for Energy and Development, FED); www.energiudvikling.dk
- INFORCE (International Network for Sustainable Energy) ; http://www.inforse.dk

Finland

- There is no specific organisation that support offshore wind energy but general information about wind energy is produced and distributed by
- Finnish Wind Energy Association; http://www.tuulivoimayhdistys.fi
- Vindkraftföreningen (Wind energy association of Swedish speakiong minority in Finland); http://www.vindkraftforeningen.fi
- Motiva, the Energy Information Centre for Energy Efficiency and Renewable Energy Sources. http://www.motiva.fi/english/index.html

France

- Syndicat des Energies Renouvalables
- L'Agence de l'Environnement et de la Maitrise de l'Energie, ADEME
- Conseil Regional Nord pas de Calais

Germany

- Greenpeace, Germany
- German Wind Energy Association, BWE
- German Association of Mechanical Engineering and Terotechnology (Manufacturer)

Greece

- CRES, Center for Renewable Energy Sources
- NTUA, National Technical University of Athens
- ? ? ? -? ? ? ? ; Division for RES of the Greek PPC.
- ELETAEN; Greek Association for the promotion of wind energy
- ELFORES; Greek association for the promotion of RES
- Greek Association of Investors in Wind Energy and RE

Ireland

- Irish Wind Energy Association recently set up a committee on offshore wind energy (‘In the Wind’)
- Irish Energy Centre has a Renewable Energy Information Office which provides info and advice on all forms of renewable energy. (‘Energy Update Letter’)

Italy

- Ministry of Environ.
- Univ. of Bologna, Genova
- ATENA, ISES Italy, ANIV, A

Netherlands

- NEWIN,Nederlandsewindenergievereniging http://www.newin.tmfweb.nl/

Poland

- Wind Power Association
- Baltic Energy Conservation Agency (ewach@bape.ima.pl)
- EC BREC, (http://www.ibmer.waw.pl/ecbrec/)
- Elektrownie Wiatrowe S.A., (http://www.elektrownie-wiatrowe.org.pl)

Spain

There are no national organisations that currently actively promote offshore wind energy in Spain.

Sweden

- SVIF The Swedish Windpowerassociation
- SERO The umbrella organisation for all small scale energy associations
- Fabrikantgruppen A new association for all OWEC manufacturers with a Swedish office.

UK

- EPSRC-OWEN
- BWEA (British Wind Energy Association)
- DTI/ETSU (Harwell)
- CADDETT/ETSU
- Greenpeace
- Parliamentary Renewable and Sustainable Energy Group
- CREA

Europe-wide

- EWEA (European Wind Energy Association)
- EREC (European Renewable Energy Council)

5.2 Media and Information

Sources of media and general information on offshore wind energy are listed below by country, followed by a section summarising the Europe-wide sources:

Belgium:

There are no major sources of information on offshore wind energy in Belgium.

Denmark

Conferences:

- Every year, a 2-day conference on the results of the Danish Wind RTD program (Danish Energy Agency). Proceedings only in Danish.
- *Wind Power in Denmark. Technology, Policies and Results* and can be found on the Internet at http://www.ens.dk/Publikationer/Wind_Power99.pdf
- The two leading journals in Danish are: *Naturlig Energi* www.naturlig-energi.dk and *Vindstyrke*: http://www.vindstyrke.dk/
- every year, the report: *The World Market Update* is published by BTM Consult www.btm.dk

Projects:

- Middelgrunden Wind Farm; www.middelgrunden.dk
- Off shore Wind Farms in the Eastern part of Demark (SEAS, E2); www.seas.dk follow link to *vindkraft*
- Off shore Wind Farms in the Western part of Demark (Elsam); www.elsam.com follow link to *havmoeller*
- Proevestationen Risoe (Risoe national Laboratory, Wind department); http://www.risoe.dk/vea
- Energi- og Miljoedata (EMD); http://www.emd.dk

Finland:

- Tuulensilmä, periodical published by Finish Wind Energy Association
- Vindögat, periodical published by Vindkraftföreningen

France

- French Wind Energy Conference (Narbonne December 2000)
- “Systemes Solaires”, a French magazine on renewables contains articles on wind power
- http://www.espace-eolien.fr/lille/Offshore/centrbreedt.htm

Germany

- DEWEK, German Wind Energy Conference 1998 & 2000
- Workshops on Offshore Windenergy Use within the national research project “Weiterer Ausbau der Windenergienutzung im Hinblick auf den Klimaschutz“, organised by Deutsches Windenergie-Institut, Wilhelmshaven,

Greece

- A number of national Conferences, symposia, seminars, exhibitions etc are organized each year by CRES and NTUA.

Ireland

- IWEA Autumn conference 2000 – Large scale wind development. Dealt with onshore and offshore wind energy. http://www.iwea.com/index.htm
- http://www.irish-energy.ie/reio.htm
- http://www.eirtricity.ie/eirtricity_ie/newsframeset.html
- http://www.powergenrenewables.com/harnessingoffshorewindpower.htm

Italy

- Ingegneria del Vento, SolarExpo -Verona
- ENEA reports, ISES Italy ,
- ENEA OWEMES conference proceedings

Netherlands

No national conferences but Dutch organisations tend to take full part in European conferences and activities.

- NEWIN organise regular seminars

Poland

- Annual meetings of Wind Power Association,
- International Seminar on Wind Power Onshore and Offshore, Sopot 15-17 December 2000
- National seminar on implementation of wind energy, Kolobrzeg , *March* 1999
- Wind Power; Energy, Power, Environment; Przeglad Komunalny, Rynek Instalacyjny bape@ima.pl

Spain:
There are no major sources of information on offshore wind energy in Spain.

Sweden
A two days wind power conference supported by state money is held every second year. The last "Vind 2000" was very much focused on offshore wind power.
There are several commercial websites constructed by developers. Two uncommercial sites are:

- Vindkraft. Nu: a site with lots of general information about the national wind power development and
- Windpowerphotos.com: images from OWES and also onshore-based with focus on the beauty of wind power in nature.

UK
Conferences and seminars

- BWEA Annual Conference
- BWEA Offshore Briefing meetings for members
- Occasional ETSU workshops
- ESPRC Offshore Wind Energy Network (OWEN) special topic meetings

Internet sites
www.blyth-offshore.co.uk
www.bwea.com

Europewide
Conferences / seminars / Trade Fairs

- World Renewable Energy Congress
- EWEA conferences
- Sustain trade- fair, held every two years at the RAI. Amsterdam, last one in 2001; promoted 'Campaign for Take Off', an initiative to promote all forms of renewable energy. One of its targets is 10000MW of electricity generated by wind power by 2003.

Journals and magazines

- WindDirections (monthly magazine of EWEA and BWEA)
- WindPower Monthly, www.wpm.co.nz
- WindStats Newsletter www.gridwise.com/windstats
- Renewable Energy World

5.3 Research and Education
Organisations active in research including offshore wind energy topics and opportunities for education in the subject are listed below by country.

Belgium
There is limited academic research and education about wind energy and none on off-shore wind energy specifically.

Denmark
The main research organisation is
- Proevestationen Risoe (Risoe National Laboratory, Wind Department); http://www.risoe.dk/vea;
  - EWEC 2001 Course - From Wind to Power takes place at the end of June 2001.
- Wind research activities are included in the overall research activities at the Technical Universities and Engineering Colleges.
- No special offshore wind energy courses have been established until now but wind education courses are included in the different courses at:
  - Technical Universities in Copenhagen
  - Aalborg
  - other Engineering Colleges.

M.Sc. and Ph.D. degrees can be obtained in accordance with the general Danish education system: You have to find a specific scientific subject, an RTD institution or Company who is working within or close to the specific subject and supporting your specific proposal. There after you have to ask for approval at the institution and apply for a grant if needed

Finland
- VTT Energy; R&D:
- Finnish Met. Inst.; R&D:
- Helsinki University of Technology; master's course – not offshore specific

France
There is a research group in Nord pas de Calais
University studies on the impact on the seabed, Institut Francais de Recherche pour l'Exploitation de la Mer, IFREMER

Germany
46 institutions are concerned with use of wind energy; details can be found in the "Directory of German Wind Energy 1998"
Short Courses are organised by:
- Deutsches Windenergie Institut GmbH
- BWE

And workshops, including by:
- **BfN:**
  - Workshop "Technische Eingriffe in marine Lebensräume

- Workshop "Technical Impacts in Marine Habitats", State of the art summary on environmental impacts of offshore wind energy use – held 1999 (report avaoilable from BfN)

Greece

Research conducted in Greek Universities and Research Institutes covers the entire field of RES (wind energy, solar energy, biomass, geothermal, wave energy etc). As regards wind energy-offshore wind energy research is mainly conducted at:

- CRES,
- NTUA
- and the University of Patras

Most Technical Universities, technical educational Institutions etc have integrated degree and postgraduate courses on RES in their programmes.

The Department for education of CRES is organizing annual educational courses and seminars on several fields of RES

Ireland

- University College Cork – wind energy forecasting, wind energy policy, market incentives, wind energy storage, energy trends. Recently developed renewable energy course materials with CREST (UK) and TUD (NL)
- University College Dublin – wind energy resource assessment

Italy

- University of Bologna,
- University of Genova ,
- University of Rome

Netherlands

- Technical University of Delft; wind energy research is spread across several faculties, and co-operate under the interfaculty group Duwind. A total of about 40 people work full or part time in wind energy . The members are:
  - Section Wind Energy
  - Offshore Technology
  - Wind Turbine Materials & Construction Group (all in Faculty of Civil Engineering and Geosciences)
  - Electrical Power Processing
  - Electrical Power Systems (both in the Faculty of Information Technology and Systems)
  - Production Engineering & Industrial Organisation
  - Systems & Control Group (both in the Faculty of Design, Engineering and Production)
  - Flight Mechanics and Propulsion (Faculty of Aerospace Engineering)

- Energieonderzoek Centrum Nederland (ECN); Wind energy research is undertaken in the section *Wind Energy Unit*, where about 45 people work full-time on wind energy research and commercial projects.

Students at TUDelft are able to take wind energy modules as part of their degree course. In addition, various external short-courses are offered by both TUDelft and ECN

Poland

- Akademia Górniczo-Hutnicza, Kraków

Spain

- Polytechnic University of Madrid.
- Departamento de Energética y Fluidomecánica

Sweden

- VKK
- Kortkurserna på Högskolan i Visby

UK

There are research groups active and educational opportunities in offshore wind energy at the following institutes:

- City University Wind Energy Research Group
- Oxford University Wind Energy Research Group
- CRES Loughborough University Wind Power Short Course; MSc Renewable Energy
- De Montfort University Wind Energy Training Course
- University of Reading Energy Group
- University of York
- Energy Studies Unit, Strathclyde

In addition, there are wind energy modules in many undergraduate courses

6 Market Developments

6.1 Demand for Electrical Power (All Sources)

Demand for electricity and ***generating capacity*** throughout Europe is variable and very much depends on the size of individual countries and the types of industry and commercial development:

Country	Demand *TWh/year*	Installed Capacity *GW*	Comments
Belgium	80	15	
Denmark			

Country	Demand *TWh/year*	Installed Capacity *GW*	Comments
Finland			
France			
Germany	477	109.2	
Greece			
Ireland	18.6	4.5	[37], [38] & [39]
Italy			
Netherlands			
Poland		33	
Spain			
Sweden			
UK	379.5	75.305 [40]	28% is from coal, 24.5% from nuclear, 38.5% from gas, 1.5% from oil, 4% is imported, 2.5% is from 'other fuels' (biofuel 81.1%, hydro 15.9%, wind 2.6%).

Growth ***trends*** vary throughout Europe, for example, Ireland observed a 48% increase in demand between 1990-1998, whereas the UK only had an 8% increase between 1995-1999

Ireland ***predicts*** a 24% increase between 1999-2005 and Germany predicts demand to be 532 TWh/year in 2010, with capacity projected to be 115.4 GW in 2010.

6.2 Demand for Power from Renewables

Green energy products can include electricity from the following renewable sources (depending on the definition):

- Photovoltaics
- Onshore wind power
- Offshore wind power
- Wave power
- Large scale hydro
- Small scale hydro
- Geothermal
- Biofuels:
    - Landfill gas
    - Sewage sludge digestion
    - Industrial wood combustion
    - Coppice
    - Straw combustion

- Waste combustion

Of the biofuels, waste combustion and use of landfill gas do not qualify under the UK Renewable Energy Obligation.
In Poland local municipalities must include a contribution from RES in energy plans. The theoretical potential output from renewable energy is given below:

	Source	Energy [PJ]	Remarks
1.	Biomass		
	a. straw	160	
	b. wood	110	35 PJ- forest 15 PJ- afforestation 30 PJ-wood industry 30 PJ- recycling
	c. biogas+waste	236	36 PJ- animal manure 100 PJ- waste 100 PJ- waste water treatment plants
	d. biofuels	44	
2.	Hydropower	40	
3.	**Wind energy**	**47**	**36 onshore + 11 offshore**
4.	Solar energy	370	
5.	Geothermal	200	main sources
	Total:	**1 207**	

Source: 1a,1b- own calculations, 1c, 1d, 3- EC BREC, offshore- TERES, 2,5- various sources, 4- Hauff

In Germany, due to liberalisation of the energy market, there are several green energy products available on the market.

6.3 Current Demand and Trends

The Flemish region of Belgium issued a decree in July 2000 which requires 3% of the total electricity sold to the distribution grid to be from renewable energy sources produced within the region by 2004. A penalty of 0.12 EURO per kWhr will be imposed for the missing green kWhr. It is likely that the Walloon region will follow suit. Over 50% should be from wind energy, of which 50% is likely to be offshore.

In Denmark, the power market is fully liberalized. Regarding offshore wind energy, *Energy 21*, the current energy action plan, presupposes that up to year 2030 development of offshore wind turbines with a total of

4000 MW will take place. The production of electricity from wind power in 2030 is expected to contribute 40-50% to Danish electricity consumption.

Regarding renewable energy in general, it is expected from year 2003 that each consumer has to buy 20% of his electricity based on renewable energy sources. The ratio will be declared some years ahead and is expected to be increased in the coming years.

A green certificate market is expected to start up 2003 to cope with the demand for green electricity and by that establish a kind of liberalized green electricity market.

…

In Finland, the power market is fully liberalised, and there will only be commercial wind farms. The demand for green power is a prerequisite for wind energy installation. There is currently a small demand for green power, but several products are available

There is a national target of 5000MW of wind power by 2010 in France. The REFIT, Renewable Energy Feed-In Tariff, price is to be defined and a decree is to be published in March 2001.

Germany …

In Greece since 1994 a number of laws and regulations (Laws 2244/94, 2601/98, 2647/98) have been instituted aiming at the exploitation of the vast RE resources in Greece, mainly sun, wind, large/small-scale hydro and biomass. Together with the broad use of natural gas, the penetration of "clean energy technologies" in the public, industrial, agricultural and commercial sectors has risen considerably in the past decade.

The deregulation of the energy market in 2000 (Law 2773/99) followed vivid interest from private investors for installation & operation of RE plants. The central points of the present legislative and environment for RES-installations are summarised as follows:

- Production and trading of electrical power from RES by independent producers
- Buy-off commitment of "green" energy by the PPC
- Attractive tariff policy for "green" energy production
- Long-term purchase agreements for "green" energy
- Financial incentives for RES-installations (subventions, tax exemptions etc)

Fig. 1 shows the approved RE plant installations per technology, petitioned after the deregulation of the energy market was placed into effect. The plants are implemented with the "build-own-operate" (BOO) scheme. A large part of the plants is meanwhile in operation, while the rest is nearing completion.

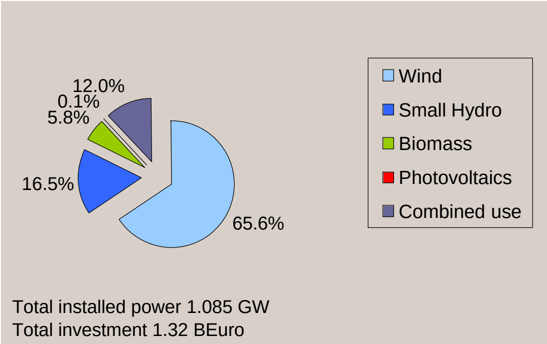


Fig. 1: Approved RES-plants after the deregulation of the energy market in Greece

Petitions are pending for farther plants, among which ~500 MW for offshore wind energy. The penetration of "green" technologies into the energy market is expected to reach the mark of 6% by 2008 (Fig. 2).

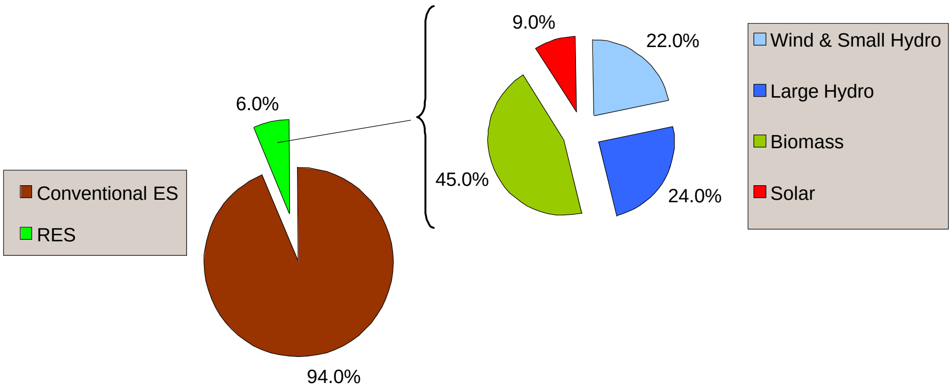


Fig. 2: Share of "green" power technologies in energy consumption by 2008

In February 2000, the electricity market in Ireland was partially liberalised. All large electricity consumers (>4GWh per annum) may choose their suppliers. In addition all customers (of any size) who wish to buy green electricity may choose their supplier. Green electricity suppliers are now targeting commercial customers who pay the highest tariff and are offering green electricity at 10% below what these customers pay the Public Electricity Supplier for brown electricity. To date, two windfarms (13 MW) have been built to sell directly to green commercial customers and a further 25MW of wind energy is imported from Northern Ireland to meet demand. It is uncertain what will happen to this market when the commercial customers can choose from brown electricity suppliers also in 2005 (probably at more competitive rates). The Government target for renewable energy is an additional 500MW by 2005, most of which is anticipated to come from wind energy

The Italian Government attributes strategic importance to renewable energy sources because of the contribution they can give to the guaranteeing of greater security of the energy supply system, the reduction of the relative environmental impact and the opportunities for protecting the territory and fostering social development. One aim of the Government in this sector, as stated in the Italian White Paper for the exploitation of renewable energies in August 1999, is to achieve the goal of doubling the contribution of renewables by 2010.

In 1999, for the whole electricity sector, Italy's overall electricity demand was nearly 286 TWh (including transmission and distribution losses). Of this, about 42 TWh was imported from neighbouring countries. The net electric energy produced in Italy was 253 TWh.
Italy's net production from renewable sources in 1999 including large and small hydro, geothermal, wind and photovoltaic plants, was as much as 22 % of total net production.
Installed net capacity totalled about 73.8 GW (of which 20.4 GW were hydro and 52.5 GW were thermal plants) as of the end of 1999.

Total wind power capacity in Italy at the end of august 2001 was 610 MW, with an average turbine size of 552 kW, whereas the total number of wind turbines was 1110.
National targets have been fixed for wind power capacity for three periods: 2002 = 700 MW, 2006 = 1,500 MW and 2008-2012 = 2,500 MW.
Given the growing rate of new wind installations registered in the last year, it is very likely that the first goal, 700 MW by 2002, will be exceeded.
As regards the likelihood of reaching the other targets after 2002, this will depend on the effect of the new legislative framework including the new market stimulation instruments for renewable energy sources.

Since the end of 1996, the CIP (Interministerial Committee for Prices) Provision no. 6/92 has shown itself to be the most successful instrument for the commercial implementation of wind energy in Italy. This system was based on buy-back prices mechanism.
Now, a new Legislative Decree (no. 79/99), which provides for the liberalization of the electricity market on the basis of the European Union Directive no. 96/92/EU, will change the system of stimulation and exploitation of renewable energy sources. This Decree was followed by a specific Decree regarding renewable energy sources, which introduces the new support system based on green certificate mechanism.

According to Article 11 of Decree 79/99, the transmission system operator (GRTN) must assure priority in dispatching to plants fed by renewable energy sources. In addition, starting from 1st January 2002 onwards, there is an obligation to introduce into the public electricity network, or to acquire fully or partially, a given percentage of electric energy from renewable sources, for all the subjects producing or importing electric energy from conventional sources.
The above percentage is initially fixed at 2% of the conventional energy that exceeds a quantity of 100 GWh per year and must be exclusively assured through new or repowered plants entered in operation after 1st April 1999 (as to repowered plants, only the energy produced by the added capacity can be taken into account).

Electricity produced by renewable energy sources is labelled with green certificates issued by the transmission system operator (GRTN) and having a value equal to or multiple of 100 MWh. Green certificates are tradable.
Another important aspect of green certificates concerns their compatibility with other incentives. In other words, for a green energy producer it will be possible to combine green certificates with any kind of subsidy, except the premium energy buy-back prices of CIP 6/92.

Regarding the economics, in 2000 the wind plant cost was around ITL 1.9 million per installed kilowatt; therefore in the same year the total invested capital on wind energy plants in Italy was about ITL 280 billion.
In regard to the energy cost, the selling price of electricity (net prices without taxes) varies, for typical domestic consumers, from ITL 100 to ITL 300/kWh, whilst, for industrial consumers, from ITL 100 to ITL 230/kWh.
For wind energy, in 2001 the buy-back prices fixed by CIP 6/92 are: ITL 239.6/kWh for the first eight years of the plant operation; and ITL 133.9/kWh for the remaining lifetime.
As already said above, in the next future, because of the new legislative framework, the support system will change through the introduction of the green certificate mechanism.

There are several green energy products available on the market in the Netherlands. Demand for green electricity has been significant and increased after the introduction of a green certificate scheme with imposed quota and penalties.

there are no green energy products are available on the market in Poland.

Policies for renewable energies in Spain are established in the “Plan de Fomento de las Energías Renovables” edited in December, 1999 by the Spanish Institute for the Energy Diversification and Saving (IDAE). This proposes a stable framework with direct price support for renewables, with a premium system similar to Germany’s.

Sweden currently produces 145 TWh/year. As the market is deregulated there are very different market prices depending on many parameters; precipation, winter temperature, long or short contracts etc. The present average price is about 0.15 SEK, about 0.018 EURO, which is very low in comparison with countries outside Scandinavia. More detailed information can be found on the website for Nordpool-the common Scandinavian powermarket..
Hydropower provides approximately half Sweden's electrical power, with the remainder mainly from nuclear. The Parliament has decided to close nuclear power stations and replace them with power from renewables. The process started with the closure of the first of twelve reactors, Barsebäck 1, in December 1999. Barsebäck 2 will be closed in 2003. There is currently no programme for closure of the remainder. Because of nuclear plant closures, more interconnection with grids in other European countries, and taxation on fossil fuels to incentivise reduction of greenhouse gases, there will be a gradual increase of prices.
Sweden has many more electricity heated houses than in other European countries and has a very low dependency on oil and coal for electrical power production
A large number of utilities in the deregulated market offer "green electricity" and some offer "extra green" from wind power. The price for wind generated electricity is about 5 – 10 % more expensive than the standard product.
Most customers are companies looking to strengthen their green image and obtain favourable publicity or to be environmentally certified.

There are several green energy products in the United Kingdom.

7 Benefits to the Environment

The benefits to the environment from using wind power are mainly by reducing atmospheric pollution. As well as a significant reduction in CO_2, other pollutants are also reduced; SO_2, NO_x, CO, Methane and Particulates.

The amount of CO_2 emitted by various types of power generation during all stages of a power generation plant's life cycle are listed below. The values given are subject to some local country by country variation, but wind power reduces emissions by orders of magnitude compared with conventional thermal power generation.

	CO_2 Emissions (Tonnes per GWh) [41]**,** [42] **&** [43]			
Technology	**Fuel Extraction**	**Construction**	**Operation**	**Total**
Coal-fired [1]	1	1	962	964
AFBC	1	1	961	963
IGCC	1	1	748	751
Oil-fired	-	-	726	726

Gas-fired	-	-	484	484
OTEC	N/A	4	300	304
Geothermal	<1	1	56	57
Small hydro	N/A	10	N/A	10
Nuclear [2]	~2	1	5	8
Wind	N/A	7	N/A	7
Photovoltaics	N/A	5	N/A	5
Large hydro	N/A	4	N/A	4
Solar thermal	N/A	3	N/A	3
Wood [3]	-1509	3	1346	-160

[1] Conventional plant [2] Boiling water reactor [3] Sustainable harvest

The actual saving in emissions depends to a large extent on the mix of types of power generation for an individual country or region and the type of plant replaced. It is apparent that any calculations on emissions savings must look realistically at the type of power generation likely to be replaced, and not just assume that the most polluting will be shut down.
As an example of this, it is interesting to note that the German energy mix including nuclear power is 0.6kg/kWh, whereas the mix excluding nuclear power is 0.89kg/kWh

8 Employment Prospects for Europe

Estimates for employment prospects are predominantly available for onshore wind or the generic wind industry. DWTMA [44] gives estimates of employment generated by wind energy in Denmark, broken down by sectors defined in Danish input-output tables and applying economic multipliers. EWEA, Cambridge Econometrics and ECOTEC [45], [46] & [47] use economic modelling techniques to estimate job creation for future energy mix scenarios. ESD for Friends of the Earth [48] surveys employment in the UK wind energy industry. [49]

Altener [50] provides estimates for both onshore and offshore broken down into construction & installation and operation & maintenance, for 1995 and scenarios up to 2020. ESD for Greenpeace [51] is dedicated to offshore estimates and uses input-output analysis to estimate job creation by industry sector as a result of installing some 10GW of offshore wind.

BorderWind for Greenpeace [52] is also dedicated to offshore wind and provides estimates of *direct* job creation by activity based on consultation with developers and operators. This estimate is reproduced below.

Estimate of direct employment to develop offshore wind farms.

		Full Time Jobs/MW

Project design and development	Marine/ground investigations	0.01
	Site development including permissions	0.1
	Design including structural, electrical and resource	0.02
	Finance	0.04
Component supply	Generators	0.15
	Gearboxes	0.9-0.4
	Rotor blades	0.5
	Brakes, hydraulics	0.04
	Electrical & control systems	0.04
	Towers	0.9
Assembly	Wind turbines	1
Installation	Foundation structure	0.3
	Electrical and connecting cables	0.05
	Wind turbines	0.3
	Project management & commissioning	0.11
Operation & maintenance	Management, routine and fault maintenance	0.06
TOTAL		4.52

Sweden has no wind power industry, however, even without turbine manufacturing in Sweden there will be an effect from the increasing wind industry upon the Swedish labour market. Steel manufacture and fabrication and electric equipment are standard Swedish export products.

Industry has started in Malmö and is planned in Kiruna and Luleå. The Swedish government has stated its intention to build wind power plants for 10 TWh annual production, of which more than half will be offshore.

It is predicted that in Germany, as a result of wind energy use, 25,000 to 30,000 jobs will be directly and indirectly created by the end of 2000 [53] & [54].

9 Benefits for European Industry

European industry at the forefront in providing consultancy services to wind energy, and this should continue for offshore. European offshore oil and gas sector experience of substructures, foundations and installation techniques is to some degree transferable to offshore wind. See Garrad Hassan and Partners: “Measures to Increase the UK-Manufactured Content of Wind Turbines”, ETSU W/45/00479/REP/1 1996 and “Offshore Wind Industry Capabilities in the UK”, ETSU W/35/00530/REP 1999.

The Netherlands has a large number of offshore engineering companies, who would be capable of manufacturing the offshore engineering components, however, the lack of a local market has handicapped the development of a flourishing wind turbine manufacturing industry.

Europe is a net exporter of services and equipment to the wind energy sector, thus securing more jobs and wider economic benefit in Europe than that supported by the domestic market alone. A mature European wind industry is in an excellent position to export to presently emerging or anticipated markets.
The technical advantage gained from European offshore wind farm development will be exportable to developing countries, which will provide new markets for wind energy industries & services. European developments will be a show-case for exports of consultancy services and equipment.

See [55] & [56].

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Activities and Prospects

1 Introduction

This Work Package brings together current work from each of the member countries to help identify future strategies for adoption by the European Offshore Wind Industry.

With this objective, within this state of the art summary, the following issues are addressed:

- Recent and current research
- Recent and current projects and national plans
- Market developments
- Benefits to the environment
- Employment prospects for Europe
- Benefits for European Industry

Members of the Concerted Action have responded to questionnaires addressing these points. This document consolidates the responses and provides references for more detailed information.

Contents

The current activities in offshore wind energy are built on the experiences of two fields of engineering: those of wind energy and of offshore il and gas, with smaller but significant input from the field of coastal engineering. Wind energy has a history that stretches back about a thousand years, with one of the first records of windturbines being from the mid tenth century, a reference to vertical axis windturbines in Afghanistan; the horizontal axis type first appeared a couple of centuries later in Northern Europe and quickly became a common sight. The wind energy industry as we know it today, really began in the early Seventies, when the oil price shock caused many governments around the world set research programmes to investigate power generation technology from non-oil dependent sources, including wind energy. However, once the oil price stabilised, these research programmes were curtailed and no commercial plants were in fact built in this short period. The second oil price shock in the late seventies revitalised the efforts and led to commercial developments, such as the large fields of wind-turbines in California. This second boom drew in many established companies and encourage entrepreneurs to set up new enterprises, some of which persist as the big names of today. Many of the windturbines installed in the States in the mid-Eighties were manufactured in that country but Europe also supplied large number of them. When the supply of new projects in California dried up, most of these companies folded or closed their windenergy operations; the exception was in Denmark, where wind farm development persisted, albeit at a much lower pace, enabling a handful of Danish companies to survive and later thrive when the threat of environmental pollution and global-warming caused the current boom in wind energy.

The offshore Industry, which has grown up around the hydrocarbon reserves in the North Sea, is much more recent, with the first discovery in the British sector having been made in the Sixties. Since then, regular high prices for oil and incremental technological developments have allowed the Industry to exports ever deeper and more hostile waters, in fact significantly more hostile than the seas where the current offshore wind farms are being built.

The first ideas for generating electricity using wind in the offshore environment where in the late seventies and numerous feasibility studies where undertaken in the following decayed. It was only in the early nineties that the first prototype offshore wind farms were actually built: at Vindeby in Denmark in 1991 and a single turbine at Nogersund, Sweden in the same year. The performance of the wind farm at Vindeby has been heavily monitored and evaluated and much useful knowledge has been gained on the performance of windturbines offshore but also on the performance of wind turbine in general (specifically because of the low turbulence conditions). The windfarm consisted of 11 windturbines, rated at 450 kW, giving a total farm output off almost 5 MW; by way of illustration of the progress made in this industry, the largest single prototype wind-turbines currently being installed have the same rated power as that whole windfarm. Vindeby is located in a relatively protected part of the Baltic Sea, surrounded by islands but even there access has been a problem because of excessively high waves.

Vindeby was soon joined by a second wind farm in Denmark, at Tuno Knøb, and two further windfarms were built in the Dutch inland lake of IJsselmeer, at Lely / Medemblik and Dronten. These were built on monopiles, which is becoming the preferred support structure for offshore windturbines. In the latter half of the last decade, there was less activity, with a single windfarm being built at Bockstigen-Valor in

Sweden. The first years of this millennium have seen new windfarms constructed using large multi-megwatt windturbines; the largest is that Middelgrunden and is clearly visible from Copenhagen. It consists of 20 turbine each rated at 2 MW is located on concrete gravity bases; the wind farm at Blyth consists of only two turbine again each of 2 MW, however they are located in the harshest environment yet: the North East coast of England facing directly into the North Sea. Two wind farms have also been built in Swedish waters, at Utgrunden (in 2000) and Yttre Stengrund (in 2001) and now four wind turbine manufacturers have experience of building and operating large wind-turbines for offshore operation, which surely must give confidence for success of the projects over the coming years.

The construction of offshore wind farms has also been built on the activities of sympathetic politicians and civil servants, researchers and environmentalists. The field of tertiary education is now also becoming more active, with masters courses in wind energy or general renewable energy at universities in several European countries. The main body of this report attempts to give details of the more important of all these activities.

2 Recent and Current Research Activities

This section addresses recent and current research activities in offshore wind energy. A large number of national and international R&D projects on offshore wind energy have been undertaken over the last decades and the more recent and relevant are briefly described within this section. For convenience, they have been arranged in the following groups:

- Resource assessment,
- Windturbines (including support structures)
- Windfarm
- Installation
- O&M
- Integrated methodologies

Further information on European funded projects is available at the CORDIS and Agores databases and projects are generally reported at the appropriate European wind energy conferences:

- European Wind Energy Conferences [EWEC]
  - Copenhagen 2001,
  - Nice 1999,
  - Dublin 1997,
  - Gothenburg 1996.
- OWEMES Seminar (Offshore Wind Energy in Mediterranean and other European Seas):
  - Rome 1994,
  - La Maddalena 1997,
  - Siracusa 2000.

2.1 Resource assessment,

This section briefly describes research projects that have focused on defining the resource, for purposes such as estimating energy production, predicting the loads on the wind-turbine, optimising the wind farm layout and evaluating the extent of the total offshore resource available.

Predicting offshore wind energy resources [POWER]

This European funded project was undertaken jointly by CLRC\RAL (lead contractor), University of East Anglia, KEMA, Ecofys and Risø under the Fourth Framework JOULE Programme, reference JOR3980286 and was completed in the middle of 2001.

The objectives of the project were to assess offshore wind power potential in EU waters. The work involves determining the geostrophic wind from long-term pressure fields, transforming the wind to sea level, taking account of nearshore topography using WAsP and correcting for stability effects using a Coastal Discontinuity Model.

Wind Energy Mapping using Synthetic Aperture Radar [WEMSAR]

This European funded project is being undertaken jointly by Nansen (lead Contractor), ENEA, Risø, NEG Micon and Terra Orbit under the Fifth Framework Programme, Reference ERK6-1999-00017, and is due to be completed and in 2003.

The objective is to investigate, validate and demonstrate the potential of satellite-based synthetic aperture radar (SAR) to map wind energy in offshore and near coastal regions for potential wind-turbines siting.

Wind resources in the Baltic Sea

This European funded project was undertaken jointly by Risø it, University of Karlsruhe, the Finnish Meteorological Institute, University of Keele under the Third Framework Programme, reference JOU20325 and was completed in 1996.

The objective was to describe and map the wind resources of the Baltic Sea and the Gulf of Finland and to create and test tools for siting of windturbines in coastal areas.

Study of Offshore Wind Energy in the European Community

This European funded project was undertaken jointly by Germanischer Lloyd and Garrad Hassan under the Second Framework Programme, reference JOUR0072 and was completed in 1993.

The focus of the project was to undertake an exploratory study covering the following four tasks: the potential for offshore wind energy in Europe, experience in offshore engineering relevant to offshore wind farms, design guidelines and consideration of combined wind and wave loading.

The National Technical University of Athens is carrying out research into wave resource modelling [1], specifically for wave energy schemes but of relevance to offshore wind projects for determining the wave climate.

Research and design tools include:
The New WAsP The goal of the project is to develop the next generation of the WAsP computer program, which should be able to handle modelling in complex terrain as well as offshore in a better manner. Two tracks will be followed, one will try to take advantage of and implement the newest technologies within the flow-modelling field and the other will develop incremental improvements to the existing code. Once the new algorithms have been developed they will be implemented in the familiar WAsP GUI (Graphical User Interface) [7]-[11]

: Zukunftsinvestitionsprogramm (FuE/ZIP)
This project (in English *Future Investment Programme)* is being undertaken jointly by BMWi [Ministry for Economic Affairs] and BMU [Ministry of Environment Protection], is due to in 2001 and will cover:

- measurement platforms in the North Sea and Baltic Sea for wind resource assessment and ecological monitoring research:
- bird migration
- marine acoustics with respect to impact on sea mammals
- investigation on sea bed life
- investigation on impact on fish

2.2 Wind turbine

This section briefly describes research projects that have focused on modelling the wind-turbine and the support structure. Regarding the current status of design tools, these include:

- the prediction of offshore wind regimes by analytical techniques and the monitoring of existing wind farms
- refinement and development of integrated dynamic structural models of the entire turbine and foundation system
- reliability/availability
- prediction of rotor dynamics

Recommendations for Design of Offshore Wind Turbines [RECOFF]
This European funded project is being undertaken jointly by Risø (lead contractor), CRES, ECN, Garrad Hassan and Germanischer Lloyd, under the Fifth Framework Programme, reference ENK5-2000-00322 and is due to be completed at the end of 2003.
The project aims at the provision of recommendations for a standard design of offshore wind turbines. Readily available information will be utilised to the extent possible and where a need is identified, research and development will be performed. The recommendations will be addressed directly to the two standardisation bodies: the International Electrotechnical Commission (IEC) and the European CENELEC.
Design Methods for Offshore Wind Turbines at Exposed Sites [OWTES]

This European funded project is currently being undertaken jointly by Garrad Hassan (lead contractor), AMEC Borderwind, Germanischer Lloyd, PowerGen Renewables, TUDelft and Vestas under the Fourth Framework Programme, reference JOR3980284 and is due to be completed in 2002.
The aim of this project is to improve the design methods for wind-turbines located at exposed offshore sites and to facilitate the gradual, cost effective exploitation of the huge offshore wind energy resource available in European Union waters. As part of this project, a measurement system has been installed on one of the wind-turbines to enable design and certification methods to be verified.

Research into 'The Dynamic Response of Wind Turbine Structures in Waves' is underway by Prof. J M R Graham (Imperial College) et al, funded by the UK DTI Renewable and New Energy Programme, Engineering and Physical Sciences Research Council – Renewable and New Energy Technologies; EPSRC - RNET, [5]

A report has been produced in Finland on the response of OWEC's to pack ice [6]

'BLADED for Windows' and 'TURBLOAD' have been and are under development by Garrad Hassan. Validation and further development of existing aeroelastic models will be performed based on measurements at Blyth Harbour.

In the Netherlands, ECN have developed two wind-turbine models,

- the time-domain PHATAS-IV [14]
- the frequency-domain TURBU with the TURBU-OFFSHORE extension currently in preparation [13]

In Germany, wind turbine manufacturers, certifying bodies and universities are also cooperating in the development of their individual design tools [12]

In Belgium an integrated dynamic model of the complete system is currently under development using Finite Element (FE) analysis.

Proprietary computational fluid dynamics programs, for example by CFX, a division of AEA Technology, are used for the analysis of flow around and the behaviour of turbine blades.

Other Danish ongoing research focusses on:

- Aero-elasticity with special focus on offshore wind turbines.
- Design specifications for offshore wind farms

2.3 Windfarm

This section briefly describes research projects that have focused on the entire windfarm.

Cost Optimising of Large Scale Offshore Wind Farms

This European funded project was undertaken jointly by S K power (lead Contractor), National Wind Power, Risø, Nellemann, Nielsen & Rauschenberger, Rostock Stadwerk and the Polytechical University of Madrid, under the Fourth Framework Programme, reference JOR3950089 and was completed at the end of 1998.

This project investigated the technical and economic feasibility of a large scale offshore wind farm in the range of 200 to 500 MW in the Danish waters of the Baltic Sea and a Langeland Belt by examine the meteorological conditions and North

Efficient Development of Offshore Windfarms [ENDOW]

This European-funded project is being undertaken jointly by Risø (lead contractor), Garrad Hassan, Ecofys, Uppsala University, Robert Gordon University, NEG-Micon, SEAS, Oldenburg University, ECN and Elsamproject. under the Fifth Framework Programme , Reference ERK6-1999-00001, and is due to be completed in July 2003.

Using experience gained through the demonstration projects currently operating offshore, the major objectives are to evaluate wake models in offshore environments and to develop and enhance existing wake and boundary-layer models to produce a design tool to assist planners and developers in optimising offshore wind farms.

Measurement On and Modelling of Offshore Wind Farms

This European funded project was undertaken jointly by Risø, Bonus, Finnish Meteorological Institute and Madrid University under Third Framework Programme, reference JOU20350 and was completed in 1996. The main objectives of the project were to measure the nature of wind-turbine wakes at the Vindeby offshore wind farm, to investigate the structure of single and multiple wakes and to characterise the relationship between turbulence and wind-shear with wind-turbine separation.

Fyndfarm, a tool for optimisation of wind farm configurations, has been developed in the Netherlands.

2.4 O&M

Availability Model for Offshore Wind Farms.

This project is funded by the Danish Energy Agency (DEA) under the UVE Programme, reference ENS-51171-98.0033.

The project is managed by Riso, Department of System Analysis in co-operation with SEAS and is expected to be completed at the end of 2001. The aim of the project is the development of a general model for decision analysis for the optimisation of the availability of wind turbine farms offshore especially with respect to maintenance policy.. A determination of the balance between reliability of the turbines, their interconnections and tower access conditions will be carried out. The model will be constructed as an influence diagram, and relevant variables including those mentioned above will be taken into account. The variables will describe the farms geographical site, the turbines, including their main component reliabilities, the site climatic conditions, transport infrastructure, electrical connections, local as well as remote surveillance and control.

2.5 Integrated methodologies

Structural and Economic Optimisation of Bottom-Mounted Offshore Wind Energy Converters [Opti-OWECS]

This European funded project was undertaken jointly by TUDelft (lead contractor), University of Sunderland, Kvaerner Oil and Gas and Kvaerner Turbin under the Fourth Framework Programme, reference JOR3950087 and was completed at the end of 1997.

The overall objective of the study was to identify designs leading to a reduction of the cost per generated kilowatt hour of offshore wind energy by using an integrated approach in the design process.

Site Specific Design of Wind Turbines Based on Numerical Cost-Optimization.

This Danish project involves the direct use of site characteristics in the design process, when optimising wind turbines. Design loads are determined by use of detailed wind climate information for mountainous complex terrain, large offshore wind farms and very low or high annual wind speed. Benefits will be determined from the design of site-specific wind turbines and multi-site wind turbines. Design guidelines will be established for the adaption of existing designs to a specific site with only small adjustments and for the design of entirely new wind turbines. Numerical optimisation will be used to optimise wind turbines for the specific site characteristics. Existing design tools will be improved by development a complete direct design method that combines state-of-the-art aero elastic calculations, wind modelling, cost modelling and numerical optimisation. Two three-bladed wind turbines based on different concepts will be modelled and the design load cases will be found for six wind climates. The benefits from site-specific design and the possibility for multi-site design will be evaluated covering both re-design of existing wind turbines and design of new wind turbines

2.6 Environmental impact and Miscellaneous Aspects

In Denmark, a tool for LCA (life cycle assessment) of wind turbines is being developed, which will enable the environmental impact of wind turbines to be predicted.

Umweltforschungsplan des BMU (UFOPLAN): „Weiterer Ausbau der Windenergie im Hinblick auf den Klimaschutz“

This investigation was undertaken by BMU [Ministry of Environment Protection] and focused on the further development of wind energy use in Germany with respect to climate protection. It is an ongoing project and examines:

- Further Development of Wind Energy Use on Land and Offshore
- Wind energy pricing (EEG Renewable energy Law)
- Repowering onshore
- Workshops on Offshore Wind energy Use in (April/June 2000)
- Integration of conflicting environmental interest
- Grid integration
- Feasibility of remote offshore wind energy
- Operational aspects of offshore wind energy use and cost of offshore wind

UFOPLAN: „Untersuchungen zur Vermeidung und Verminderung von Belastungen der Meeresumwelt durch Offshore-Windparks im küstenfernen Bereich der Nord- und Ostsee“
This investigation was undertaken by UBA [Federal Office for Environmental Protection] and focused on the state of the art for avoidance and minimisation of environmental impact by offshore wind farms on marine environment. It is an ongoing project and examines:

- description of the state of the art with respect to environmental impacts on benthos, fish, birds, sea mammals
- development of IEA methodology
- risk analysis for ship collision
- formulation of measures to minimise impacts
- identification of knowledge deficits

<u>Erfassung der Verbreitung, Häufigkeit und Wanderungen von See- und Wasservögeln in der deutschen Nordsee und Entwicklung eines Konzeptes zur Umsetzung internationaler Naturschutzziele (BOFFWATT)</u>

This investigation was undertaken by BFN [Federal Office for Nature Preservation] and was completed in 1999; the report is available from BfN and covers:

- Investigation on sea bird populations in the German North Sea with respect to number of individuals and annual variations, feeding habits,
- development of a protection concept
- further need for research

<u>See- und Wasservögel in der deutschen Ostsee und ihr Schutz im Rahmen internationaler Vereinbarungen</u>
Additional ongoing study, also undertaken by BfN for the German Baltic Sea.

<u>Erfassung und Bewertung ökologisch wertvoller Lebensräume in der Nordsee</u>
Identification, investigation and determination of potential areas for marine nature preservation (with respect to FFH-protected areas) in the German North Sea. An ongoing project also undertaken by BfN.

<u>Erfassung und Bewertung ökologisch wertvoller Lebensräume in der Ostsee</u>

Identification, investigation and determination of potential areas for marine nature preservation (with respect to Baltic Sea Protected Areas (BSPAs)) in the German Baltic Sea. Completed in 1999 and a report is available from the authors, BfN.

3 Recent and Current Projects

This section describes recent and current demonstration and full-scale commercial offshore wind farm projects. Many of the earlier projects have been accompanied by extensive measurement and analysis programmes, which are also described here.

Most of the existing projects are demonstration projects, with the exception of Middelgrunden wind farm, a 40 MW development three kilometres off the coast of Copenhagen, Denmark. Most of the planned projects are fully commercial enterprises.

The following offshore windfarms are planned in Belgium:

- Vlakte van de Raan - 100 MW wind farm 12-15 km from the coast , developed by Electrabel and Ondernemingen Jan De Nul. This project includes a 20 MW pilot phase
- Wenduinebank - 100 MW (50x2MW) wind farm 5 – 8 km from the coast , developed by C-power (Interelectra, Dredging International, and Turbowinds)

Three offshore wind farms are already in operation in Denmark:

Name	**Number of Blades**	**Diameter**	**Turbine Capacity**	**Number of OWEC's**	**Type of Foundation**	**Installation Method**	**Marinisation**	**Maintenance Access**
Vindeby 2-6m WD 1.5-3km from shore	3	35m	450kW	11	RC Gravity	Modified transport ship (base) Jack-up (tower)	Offshore paint system, sealed, recycled cooling air, dehumidified. Standby heating, Nacelle-mounted hydraulic cranes	Special boat
Tuno Knob 3-5m WD 6km from shore	3	39m	500 kW	10	RC Box Caisson Ore Filled	Modified barges Floating crane	NA	Special boat
Middelgrund	3	76m	2MW	20	RC Gravity	Modified	Offshore paint system,	Special

Name	Number of Blades	Diameter	Turbine Capacity	Number of OWEC's	Type of Foundation	Installation Method	Marinisation	Maintenance Access
5-10m WD 2km from shore						transport ship (base) Jack-up (tower)	sealed, recycled cooling air, dehumidified, standby heating. nacelle-mounted hydraulic cranes	boat

In addition, there are several at various stages of planning:

- Horns Rev 160 MW (under construction)
- Roedsand 150MW (under construction)
- Gedser 150 MW
- Omoe 150 MW
- Laesoe 150 MW
- Samso 25 MW (EIA study issued)

Measurements are being taken at the Middelgrunden Wind Farm to assess wind spectra around the towers and power output in relation to the placement of individual turbines within the wind farm. Forces in the towers and foundations under environmental loading will also be measured.

In Finland, offshore wind farms are planned for:

- un-named on small nearshore rock islands
- un-named 10-30MW 5km offshore 6-10m water depth

Currently, there are no existing offshore wind farms in France, however several are planned or at various stages of development, including at:

- Breedt,
- Dunkerque

The largest number of planned offshore wind farms are in Germany. Locations where wind farm developers have stated their intention for developing offshore windfarms include:

- Butendiek 80 x 3MW
- Dan-Tysk 300 x 5MW
- Nordsee AWZ 100-200 x 5MW
- Helgoland I and II

- Borkum Riffgrund 200 x 3-5MW
- Borkum Riffgrund West 458 x 2.5MW
- Borkum III 12 x 4-5MW
- Pommersche Bucht 200 x 5MW
- Arkona-Becken 172 x 4-5MW
- Adlergrund 69 x 3-5MW
- Nordergrunde 76 x 2.5-5MW
- Offshore Helgoland 100 x 2MW
- Schleswig-Holsteinische Nordsee 100-200 x 5MW
- Wilhelmshaven 2 x 4.5MW
- Mecklengburg-Vorpommern 20 x 2MW
- Sky 2000 50 x 2MW

In Greece, following the deregulation of the energy market in 2000, petitions for 4 LSOWE-plants with total installed capacity of ~500 MW are currently under consideration at the Regulatory Authority for Energy of the Ministry of Development.

A number of offshore wind farms are also planned for Ireland, at [19], [24] & [25]:

- Kish Bank: 10km from shore, 200-250MW
- Bray Bank
- Arklow Bank: <10 m water depth, 10km from shore, 500+MW
- Blackwater Bank
- Codling Bank
- Greater Codling Bank

In Italy, there has been a feasibility study for out offshore wind farm at Ragusa.

In the Netherlands, there are two offshore wind farms located in the inland fresh water Ijsselmeer:

Name	**Number of Blades**	**Diameter**	**Turbine Capacity**	**Number of OWEC's**	**Type of Foundation**	**Installation Method**	**Marinisation**	**Maintenance Access**
Lely 5-10m WD 0.8km from A shore	2	40.8 m	500kW	4	3.7m monopile		No	

Name	Number of Blades	Diameter	Turbine Capacity	Number of OWEC's	Type of Foundation	Installation Method	Marinisation	Maintenance Access
Dronten 20m from shore		43.0 m	600kW	28	monopile		No	

In addition, two further windfarms of planned:

- Q7 Sector 100MW
- Egmont aan Zee 100MW

According to the Maritime Bureau, after exclusion of all restricted areas (birds, fishing, offshore exploitation), ca. 2 800 km^2 for development of offshore wind power is available in Poland, that is 8.5% of the Polish territorial waters. In the Gdansk Bay, the area where implementing wind turbines is possible is ca. 40 km long and on the open sea coast line (from Jastrzebia Gora to Swinoujscie) - it is ca. 200 km long, excluding costal banks at Wistula – and Szczecin Bays.

The Maritime Bureau in Gdynia has issued consents for two following offshore locations:
- 49-61 turbines of 2,0 MW near Bialogóra. Project led by Nowa Energi
- 50 x 2 MW near Karwia (Debki-Jastrzebia Góra). Project led by Wiatropol

At this moment there are two other pending applications at Slupsk Municipality, where Baltyckie Elektrownie Wiatrowe S.A. (Baltic Windpower S.A.) request for permission near Sarbinowo, however no information has been cleared yet.

It can be assumed that all the locations referred to have at least pre-feasibility studies made, but nothing has been disclosed yet.

Source: Maritime Institute, 2000

Fig. 1: Locations for potential offshore wind power development on Polish territorial waters.

…

Three offshore wind farms are currently operational in Sweden:

Name	**Number of Blades**	**Diameter**	**Turbine Capacity**	**Number of OWEC's**	**Type of Foundation**	**Installation Method**	**Marinisation**	**Maintenance Access**
Nogersund 5m WD 0.5km from shore	3	27m	220kW	1	Steel tripod	Submersible barge		Boat & ladder
Bockstigen-Valar 6-8m WD 4 km from shore	3	37m	500kW	5	2.15m drilled and grouted	Jack-up		
Utgrunden								

In addition, further offshore wind farms are planned at:

- Orestad
- Klasardenproject

A demonstration of the commercialisation potential (Valar 2, 5 MW)

This European funded demonstration projects was undertaken by Vindkompaniet under the Fourth Framework Programme, THERMIE project reference WE/00057/96 in 1996 and 1997.
Research will also be performed at the Klasardenproject; a 42MW development in Sweden planned for 2002 installation.

There is one offshore wind farm in the United Kingdom off Blyth Harbour. Further information on this project can be obtained from www.blyth-offshore.co.uk: The Blyth offshore wind farm is a European-funded demonstration project undertaken by AMEC Border under the Fourth Framework Programme, THERMIE project reference WE/00208/95 between 1996 and 1999.

Name	**Number of Blades**	**Diameter**	**Turbine Capacity**	**Number of OWEC's**	**Type of Foundation**	**Installation Method**	**Marinisation**	**Maintenance Access**
Blythe Harbour, NE England5-11m WD 1km from shore	3	70m	2MW	2	3.7m drilled and grouted monopile	Jack-up		Boat & ladder

In addition, numerous offshore wind farms are planned, including for:

- Barrow
- Burbo
- Cromer
- Gunfleet Sands
- Inner Dowsing
- Kentish Flats
- Lynn
- North Hoyle
- Rhyl Flats
- Scarweather Sands
- Scroby Sands
- Shell Flat
- Southport
- Teesside

Construction of the 37.5 MW Scroby Sands offshore wind farm, East Anglia, England

This European funded demonstration project is currently being undertaken by PowerGen Renewables under the Fourth Framework Programme, THERMIE project reference WE/00218/97 and is scheduled to be completed in 2003.

4 National Plans

This section summarises the various national plans that have been put forward by countries across Europe.

Belgium's federal authorities have created a legal framework for granting concessions and authorisations for OWECS.

Today, wind turbines produce 15% of Danish electricity consumption. Denmark has a 2030 target of 4,000 MW produced by offshore wind. This, together with other renewables, will cover 50% of the total electricity consumption. The first milestone is the establishment of 800 MW offshore wind farms by 2008. Of this 45 MW is already established (Middelgrunden, Vindeby and Tunoe Knob). The 160 MW Horns Rev and 150 MW Roedsand are under construction. [34]-[36]

Finland

The national energy strategy from 1997 mentions renewable energy to have significant role and wind energy to have a recognised role by 2025. The Action Plan for Renewable Energy Sources elaborated this, while recognising the Kyoto protocol on the reduction of emissions of greenhouse gases of 1997 and the EU White Paper endorsed by the Commission in 1997 and the Council in 1998, into a targets for renewable energy deployment.

The target is to increase the use of renewable energy sources at least by 50% (3 Mtoe/a) by the year 2010 from the level of the year 1995. 90% of this increase is expected to originate from of bioenergy, 3% from wind power, 3% from hydropower, 4% from heat pumps and less than 0.5% from solar power.

The share of renewable energy sources in power production would increase by 8.3 TWh (2010 MW) from the level in 1995. The major part, 75 %, would be generated from biofuels. Achieving the targets would reduce greenhouse gas emissions by about 7.7 million tonnes of CO_2 equivalent. The vision for 2025 is an addition of 100% (6 Mtoe) of renewable energy from the level in 1995, with biomass still dominating but already several per cents of the total electricity generated by wind.

The target for wind energy deployment is set to 500 MW in 2010 and a vision to 2000 MW in 2025. Thus wind energy production would reach 5 TWh/a in 2025, which is about 5% of the projected gross power consumption.
http://www.vtt.fi/ene/results/renewable.htm

Action plan for Renewable energy resources in Finland, English translation, Ministry of Trade and Industry, Reports 1/2000.
See also http://www.vtt.fi/ene/tuloksia/uusiutuvat/actionp.pdf

France has a target of 5,000MW to be generated by wind power in 2010.

In Germany there is no national plan in terms of installation figures, however the contribution of offshore wind energy use in the context of CO2-reduction and sustainable energy supply policy are investigated in a national study on the "Further Use of Wind Energy with Respect to Climate Protection" [31]. Governmental objectives are set to cover 5-6% of the national net electricity consumption with wind generated electricity by 2010 and to reach a 50% renewable energy share of the national electricity demand by 2050 [17]. Germany's Renewable Energy Sources Act (EEG – Erneuerbare Energien Gesetz) [3] continues the reimbursement at a fixed feed-in tariff. In the reformed EEG a specially raised tariff is foreseen during the first nine years of operation of an offshore wind farm. This regulation is limited to projects coming online before the end of 2006.

The Greek government's policy is in line with EU energy policy regarding the penetration of RES in the energy market. [16] and [17]. The government is encouraging the large-scale installation of RES plants by means of subvention of capital investment, loan interest subsidies and tax-exemptions. The legislation also applies to offshore wind energy.

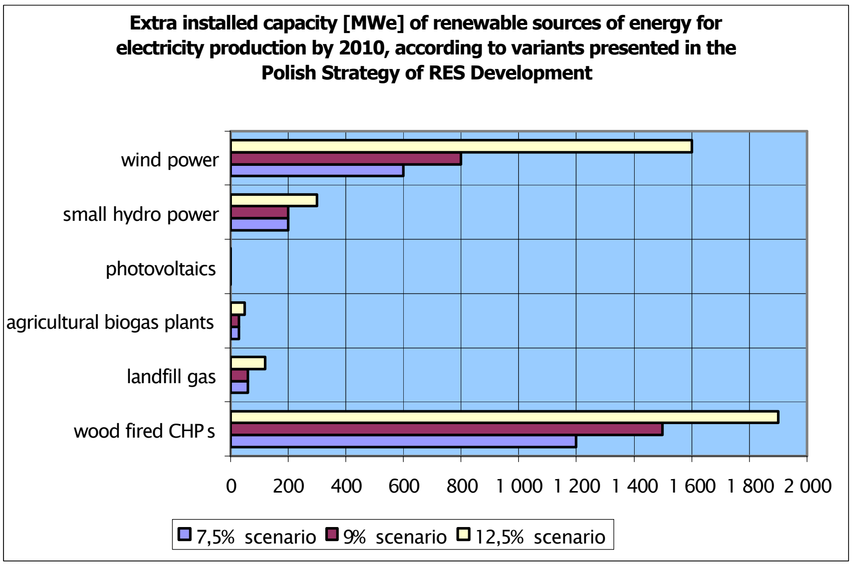
Ireland has no specific targets or detailed national plans for offshore wind energy, but it is the main focus of policy targets for both maximising offshore resources and promoting renewable energy. 7 foreshore licenses have been awarded for site investigation and procedures for foreshore leases are in place. [18]-[24]

Italy has produced a 'White Paper for the valorisation of Renewable Energy Sources', which forecasts 2500MW of electricity produced from wind by 2008-12. However, it envisages that this would be mainly onshore. There is an initiative by the Ministry of Environment with Assomineraria to produce an agreement document for national waters. The Province of Ragusa, Sicily has issued a Call for Proposal and Assignment document. (in Italian)

Officially, the Netherlands target (Duurzame Energie in Opmars; Ministerie van Economische Zaken 1997) is 20% renewables by 2020, equivalent to 2759MW, of which 1250MW is from offshore wind, [25]. The government is expected to increase this targeted power quantity in the near future.

Poland has a strategy for Renewable Energy Development of 7.5% by 2010, [15] Strategy aims to increase RES share in the total energy balance from the present 2,4% to 7,5% in the year 2010 and 14% by the year 2020. The document presents three scenarios of RES increase by the year 2010:

- 7,5% scenario,
- 9% scenario,
- 12,5% scenario.



Source: EC BREC

Extra RES installed capacity according to the Polish Strategy of RES development

Spain has no national plans and has no specific incentives for OWECS.

Sweden has no fixed target for offshore wind power, but it has been identified as a source of electricity generation that could replace nuclear, coal and oil. The state budget earmarks money for research and demonstrations in the field of offshore wind power. Many political and other groups are lobbying for offshore wind power and propose changing laws and regulations in favour of it. Some of the groups are developers and manufacturers with vested interests in promoting OWECS and some claims for future growth are considered unrealistic.

The UK has now ended the Non-Fossil Fuel Obligation but is still providing support (between £60m - £80m this year) and has issued a consultation document on renewables [26]. The primary market is likely to be licensed UK electricity suppliers fulfilling their Renewable Energy Obligation commitments. Current estimates are for net revenue of around £0.05p per kWh. The national objective is to reduce greenhouse gas emissions by 12.5% from 1990 levels by 2010, to reduce CO_2 emissions by 20%, 5% of UK electricity from renewables by 2003 and 10% by 2010, with 2600MW offshore by 2010, [27] & [28]. The Crown Estate has pre-qualified and allocated Agreements for Lease for the first round of offshore sites to 18 developers for 13 sites [30].

5 National Activities

5.1 National Organisations

Organisations that promote offshore wind energy are listed below by country.

Belgium

There are no national organisations that currently actively promote offshore wind energy in Belgium.

Denmark

- Dansk Vindmoelleforening (Association of Turbine owners in Denmark); www.dkvind.dk
- Vindmoelleindustrien (Danish Wind Turbine Manufactures Association); www.windpover.dk
- Energistyrelsen (Danish Energy Agency); http://www.ens.dk; Includes all official hearing papers like EIA Studies for new projects
- Energioplysningen (The National Danish Energy Information Centre); http://www.energioplysningen.dk
- Organisationen for Vedvarende Energi, OVE (Danish Organization for Renewable Energy); http://www.orgve.dk
- Forum for Energi- og Udvikling, FEU (Forum for Energy and Development, FED); www.energiudvikling.dk
- INFORCE (International Network for Sustainable Energy) ; http://www.inforse.dk

Finland

- There is no specific organisation that support offshore wind energy but general information about wind energy is produced and distributed by
- Finnish Wind Energy Association; http://www.tuulivoimayhdistys.fi
- Vindkraftföreningen (Wind energy association of Swedish speakiong minority in Finland); http://www.vindkraftforeningen.fi
- Motiva, the Energy Information Centre for Energy Efficiency and Renewable Energy Sources. http://www.motiva.fi/english/index.html

France

- Syndicat des Energies Renouvalables
- L'Agence de l'Environnement et de la Maitrise de l'Energie, ADEME
- Conseil Regional Nord pas de Calais

Germany

- Greenpeace, Germany
- German Wind Energy Association, BWE
- German Association of Mechanical Engineering and Terotechnology (Manufacturer)

Greece

- CRES, Center for Renewable Energy Sources
- NTUA, National Technical University of Athens
- ? ? ? -? ? ? ? ; Division for RES of the Greek PPC.
- ELETAEN; Greek Association for the promotion of wind energy
- ELFORES; Greek association for the promotion of RES
- Greek Association of Investors in Wind Energy and RE

Ireland

- Irish Wind Energy Association recently set up a committee on offshore wind energy ('In the Wind')
- Irish Energy Centre has a Renewable Energy Information Office which provides info and advice on all forms of renewable energy. ('Energy Update Letter')

Italy

- Ministry of Environ.
- Univ. of Bologna, Genova
- ATENA, ISES Italy, ANIV, A

Netherlands

- NEWIN,Nederlandsewindenergievereniging http://www.newin.tmfweb.nl/

Poland

- Wind Power Association
- Baltic Energy Conservation Agency (ewach@bape.ima.pl)
- EC BREC, (http://www.ibmer.waw.pl/ecbrec/)
- Elektrownie Wiatrowe S.A., (http://www.elektrownie-wiatrowe.org.pl)

Spain

There are no national organisations that currently actively promote offshore wind energy in Spain.

Sweden

- SVIF The Swedish Windpowerassociation
- SERO The umbrella organisation for all small scale energy associations
- Fabrikantgruppen A new association for all OWEC manufacturers with a Swedish office.

UK

- EPSRC-OWEN
- BWEA (British Wind Energy Association)
- DTI/ETSU (Harwell)
- CADDETT/ETSU
- Greenpeace
- Parliamentary Renewable and Sustainable Energy Group
- CREA

Europe-wide

- EWEA (European Wind Energy Association)
- EREC (European Renewable Energy Council)

5.2 Media and Information

Sources of media and general information on offshore wind energy are listed below by country, followed by a section summarising the Europe-wide sources:

Belgium:

There are no major sources of information on offshore wind energy in Belgium.

Denmark

Conferences:

- Every year, a 2-day conference on the results of the Danish Wind RTD program (Danish Energy Agency). Proceedings only in Danish.
- *Wind Power in Denmark. Technology, Policies and Results* and can be found on the Internet at http://www.ens.dk/Publikationer/Wind_Power99.pdf
- The two leading journals in Danish are: *Naturlig Energi* www.naturlig-energi.dk and *Vindstyrke*: http://www.vindstyrke.dk/
- every year, the report: *The World Market Update* is published by BTM Consult www.btm.dk

Projects:

- Middelgrunden Wind Farm; www.middelgrunden.dk
- Off shore Wind Farms in the Eastern part of Demark (SEAS, E2); www.seas.dk follow link to *vindkraft*
- Off shore Wind Farms in the Western part of Demark (Elsam); www.elsam.com follow link to *havmoeller*
- Proevestationen Risoe (Risoe national Laboratory, Wind department); http://www.risoe.dk/vea
- Energi- og Miljoedata (EMD); http://www.emd.dk

Finland:

- Tuulensilmä, periodical published by Finish Wind Energy Association
- Vindögat, periodical published by Vindkraftföreningen

France

- French Wind Energy Conference (Narbonne December 2000)
- “Systemes Solaires”, a French magazine on renewables contains articles on wind power
- http://www.espace-eolien.fr/lille/Offshore/centrbreedt.htm

Germany

- DEWEK, German Wind Energy Conference 1998 & 2000
- Workshops on Offshore Windenergy Use within the national research project “Weiterer Ausbau der Windenergienutzung im Hinblick auf den Klimaschutz“, organised by Deutsches Windenergie-Institut, Wilhelmshaven,

Greece

- A number of national Conferences, symposia, seminars, exhibitions etc are organized each year by CRES and NTUA.

Ireland

- IWEA Autumn conference 2000 – Large scale wind development. Dealt with onshore and offshore wind energy. http://www.iwea.com/index.htm
- http://www.irish-energy.ie/reio.htm
- http://www.eirtricity.ie/eirtricity_ie/newsframeset.html
- http://www.powergenrenewables.com/harnessingoffshorewindpower.htm

Italy

- Ingegneria del Vento, SolarExpo -Verona
- ENEA reports, ISES Italy ,
- ENEA OWEMES conference proceedings

Netherlands

No national conferences but Dutch organisations tend to take full part in European conferences and activities.

- NEWIN organise regular seminars

Poland

- Annual meetings of Wind Power Association,
- International Seminar on Wind Power Onshore and Offshore, Sopot 15-17 December 2000
- National seminar on implementation of wind energy, Kolobrzeg , *March* 1999
- Wind Power; Energy, Power, Environment; Przeglad Komunalny, Rynek Instalacyjny bape@ima.pl

Spain:

There are no major sources of information on offshore wind energy in Spain.

Sweden

A two days wind power conference supported by state money is held every second year. The last "Vind 2000" was very much focused on offshore wind power.

There are several commercial websites constructed by developers. Two uncommercial sites are:

- Vindkraft. Nu: a site with lots of general information about the national wind power development and
- Windpowerphotos.com: images from OWES and also onshore-based with focus on the beauty of wind power in nature.

UK

Conferences and seminars

- BWEA Annual Conference
- BWEA Offshore Briefing meetings for members
- Occasional ETSU workshops
- ESPRC Offshore Wind Energy Network (OWEN) special topic meetings

Internet sites

www.blyth-offshore.co.uk

www.bwea.com

Europewide

Conferences / seminars / Trade Fairs

- World Renewable Energy Congress
- EWEA conferences
- Sustain trade- fair, held every two years at the RAI. Amsterdam, last one in 2001; promoted 'Campaign for Take Off', an initiative to promote all forms of renewable energy. One of its targets is 10000MW of electricity generated by wind power by 2003.

Journals and magazines

- WindDirections (monthly magazine of EWEA and BWEA)
- WindPower Monthly, www.wpm.co.nz
- WindStats Newsletter www.gridwise.com/windstats
- Renewable Energy World

5.3 Research and Education

Organisations active in research including offshore wind energy topics and opportunities for education in the subject are listed below by country.

Belgium

There is limited academic research and education about wind energy and none on off-shore wind energy specifically.

Denmark

The main research organisation is

- Proevestationen Risoe (Risoe National Laboratory, Wind Department); http://www.risoe.dk/vea;
    - EWEC 2001 Course - From Wind to Power takes place at the end of June 2001.
- Wind research activities are included in the overall research activities at the Technical Universities and Engineering Colleges.
- No special offshore wind energy courses have been established until now but wind education courses are included in the different courses at:
    - Technical Universities in Copenhagen
    - Aalborg
    - other Engineering Colleges.

M.Sc. and Ph.D. degrees can be obtained in accordance with the general Danish education system: You have to find a specific scientific subject, an RTD institution or Company who is working within or close to the specific subject and supporting your specific proposal. There after you have to ask for approval at the institution and apply for a grant if needed

Finland

- VTT Energy; R&D:
- Finnish Met. Inst.; R&D:
- Helsinki University of Technology; master's course – not offshore specific

France

There is a research group in Nord pas de Calais

University studies on the impact on the seabed, Institut Francais de Recherche pour l'Exploitation de la Mer, IFREMER

Germany

46 institutions are concerned with use of wind energy; details can be found in the "Directory of German Wind Energy 1998"

Short Courses are organised by:

- Deutsches Windenergie Institut GmbH
- BWE

And workshops, including by:

- **BfN:**
    - Workshop "Technische Eingriffe in marine Lebensräume

- Workshop "Technical Impacts in Marine Habitats", State of the art summary on environmental impacts of offshore wind energy use – held 1999 (report avaoilable from BfN)

Greece

Research conducted in Greek Universities and Research Institutes covers the entire field of RES (wind energy, solar energy, biomass, geothermal, wave energy etc). As regards wind energy-offshore wind energy research is mainly conducted at:

- CRES,
- NTUA
- and the University of Patras

Most Technical Universities, technical educational Institutions etc have integrated degree and postgraduate courses on RES in their programmes.

The Department for education of CRES is organizing annual educational courses and seminars on several fields of RES

Ireland

- University College Cork – wind energy forecasting, wind energy policy, market incentives, wind energy storage, energy trends. Recently developed renewable energy course materials with CREST (UK) and TUD (NL)
- University College Dublin – wind energy resource assessment

Italy

- University of Bologna,
- University of Genova ,
- University of Rome

Netherlands

- Technical University of Delft; wind energy research is spread across several faculties, and co-operate under the interfaculty group Duwind. A total of about 40 people work full or part time in wind energy . The members are:
  - Section Wind Energy
  - Offshore Technology
  - Wind Turbine Materials & Construction Group (all in Faculty of Civil Engineering and Geosciences)
  - Electrical Power Processing
  - Electrical Power Systems (both in the Faculty of Information Technology and Systems)
  - Production Engineering & Industrial Organisation
  - Systems & Control Group (both in the Faculty of Design, Engineering and Production)
  - Flight Mechanics and Propulsion (Faculty of Aerospace Engineering)

- Energieonderzoek Centrum Nederland (ECN); Wind energy research is undertaken in the section *Wind Energy Unit*, where about 45 people work full-time on wind energy research and commercial projects.

Students at TUDelft are able to take wind energy modules as part of their degree course. In addition, various external short-courses are offered by both TUDelft and ECN

Poland

- Akademia Górniczo-Hutnicza, Kraków

Spain

- Polytechnic University of Madrid.
- Departamento de Energética y Fluidomecánica

Sweden

- VKK
- Kortkurserna på Högskolan i Visby

UK

There are research groups active and educational opportunities in offshore wind energy at the following institutes:

- City University Wind Energy Research Group
- Oxford University Wind Energy Research Group
- CRES Loughborough University Wind Power Short Course; MSc Renewable Energy
- De Montfort University Wind Energy Training Course
- University of Reading Energy Group
- University of York
- Energy Studies Unit, Strathclyde

In addition, there are wind energy modules in many undergraduate courses

6 Market Developments

6.1 Demand for Electrical Power (All Sources)

Demand for electricity and ***generating capacity*** throughout Europe is variable and very much depends on the size of individual countries and the types of industry and commercial development:

Country	Demand *TWh/year*	Installed Capacity *GW*	Comments
Belgium	80	15	
Denmark			

Country	Demand *TWh/year*	Installed Capacity *GW*	Comments
Finland			
France			
Germany	477	109.2	
Greece			
Ireland	18.6	4.5	[37], [38] & [39]
Italy			
Netherlands			
Poland		33	
Spain			
Sweden			
UK	379.5	75.305 [40]	28% is from coal, 24.5% from nuclear, 38.5% from gas, 1.5% from oil, 4% is imported, 2.5% is from 'other fuels' (biofuel 81.1%, hydro 15.9%, wind 2.6%).

Growth ***trends*** vary throughout Europe, for example, Ireland observed a 48% increase in demand between 1990-1998, whereas the UK only had an 8% increase between 1995-1999

Ireland ***predicts*** a 24% increase between 1999-2005 and Germany predicts demand to be 532 TWh/year in 2010, with capacity projected to be 115.4 GW in 2010.

6.2 Demand for Power from Renewables

Green energy products can include electricity from the following renewable sources (depending on the definition):

- Photovoltaics
- Onshore wind power
- Offshore wind power
- Wave power
- Large scale hydro
- Small scale hydro
- Geothermal
- Biofuels:
    - Landfill gas
    - Sewage sludge digestion
    - Industrial wood combustion
    - Coppice
    - Straw combustion

- Waste combustion

Of the biofuels, waste combustion and use of landfill gas do not qualify under the UK Renewable Energy Obligation.
In Poland local municipalities must include a contribution from RES in energy plans. The theoretical potential output from renewable energy is given below:

	Source	Energy [PJ]	Remarks
1.	Biomass		
	a. straw	160	
	b. wood	110	35 PJ- forest 15 PJ- afforestation 30 PJ-wood industry 30 PJ- recycling
	c. biogas+waste	236	36 PJ- animal manure 100 PJ- waste 100 PJ- waste water treatment plants
	d. biofuels	44	
2.	Hydropower	40	
3.	**Wind energy**	**47**	**36 onshore + 11 offshore**
4.	Solar energy	370	
5.	Geothermal	200	main sources
	Total:	**1 207**	

Source: 1a,1b- own calculations, 1c, 1d, 3- EC BREC, offshore- TERES, 2,5- various sources, 4- Hauff

In Germany, due to liberalisation of the energy market, there are several green energy products available on the market.

6.3 Current Demand and Trends

The Flemish region of Belgium issued a decree in July 2000 which requires 3% of the total electricity sold to the distribution grid to be from renewable energy sources produced within the region by 2004. A penalty of 0.12 EURO per kWhr will be imposed for the missing green kWhr. It is likely that the Walloon region will follow suit. Over 50% should be from wind energy, of which 50% is likely to be offshore.

In Denmark, the power market is fully liberalized. Regarding offshore wind energy, *Energy 21*, the current energy action plan, presupposes that up to year 2030 development of offshore wind turbines with a total of

4000 MW will take place. The production of electricity from wind power in 2030 is expected to contribute 40-50% to Danish electricity consumption.
Regarding renewable energy in general, it is expected from year 2003 that each consumer has to buy 20% of his electricity based on renewable energy sources. The ratio will be declared some years ahead and is expected to be increased in the coming years.
A green certificate market is expected to start up 2003 to cope with the demand for green electricity and by that establish a kind of liberalized green electricity market.

…

In Finland, the power market is fully liberalised, and there will only be commercial wind farms. The demand for green power is a prerequisite for wind energy installation. There is currently a small demand for green power, but several products are available

There is a national target of 5000MW of wind power by 2010 in France. The REFIT, Renewable Energy Feed-In Tariff, price is to be defined and a decree is to be published in March 2001.

Germany …

In Greece since 1994 a number of laws and regulations (Laws 2244/94, 2601/98, 2647/98) have been instituted aiming at the exploitation of the vast RE resources in Greece, mainly sun, wind, large/small-scale hydro and biomass. Together with the broad use of natural gas, the penetration of "clean energy technologies" in the public, industrial, agricultural and commercial sectors has risen considerably in the past decade.

The deregulation of the energy market in 2000 (Law 2773/99) followed vivid interest from private investors for installation & operation of RE plants. The central points of the present legislative and environment for RES-installations are summarised as follows:

- Production and trading of electrical power from RES by independent producers
- Buy-off commitment of "green" energy by the PPC
- Attractive tariff policy for "green" energy production
- Long-term purchase agreements for "green" energy
- Financial incentives for RES-installations (subventions, tax exemptions etc)

Fig. 1 shows the approved RE plant installations per technology, petitioned after the deregulation of the energy market was placed into effect. The plants are implemented with the "build-own-operate" (BOO) scheme. A large part of the plants is meanwhile in operation, while the rest is nearing completion.

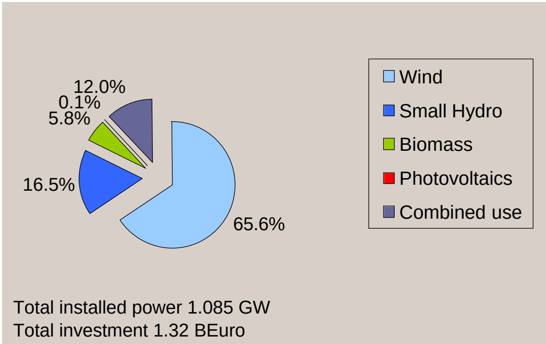


Fig. 1: Approved RES-plants after the deregulation of the energy market in Greece

Petitions are pending for farther plants, among which ~500 MW for offshore wind energy. The penetration of "green" technologies into the energy market is expected to reach the mark of 6% by 2008 (Fig. 2).

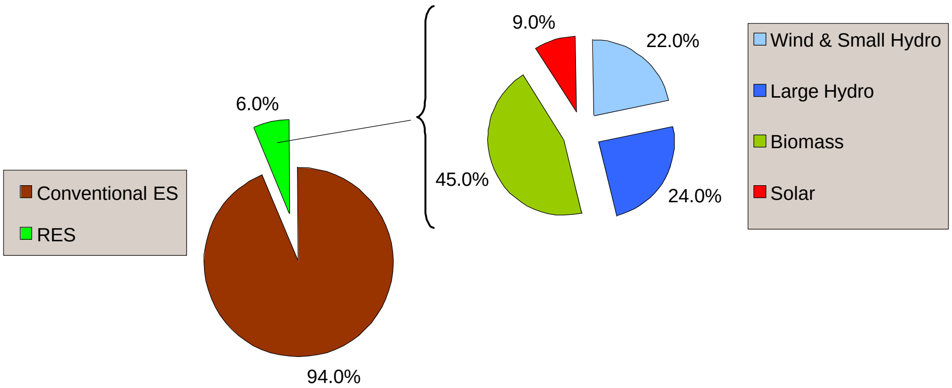


Fig. 2: Share of "green" power technologies in energy consumption by 2008

In February 2000, the electricity market in Ireland was partially liberalised. All large electricity consumers (>4GWh per annum) may choose their suppliers. In addition all customers (of any size) who wish to buy green electricity may choose their supplier. Green electricity suppliers are now targeting commercial customers who pay the highest tariff and are offering green electricity at 10% below what these customers pay the Public Electricity Supplier for brown electricity. To date, two windfarms (13 MW) have been built to sell directly to green commercial customers and a further 25MW of wind energy is imported from Northern Ireland to meet demand. It is uncertain what will happen to this market when the commercial customers can choose from brown electricity suppliers also in 2005 (probably at more competitive rates). The Government target for renewable energy is an additional 500MW by 2005, most of which is anticipated to come from wind energy

The Italian Government attributes strategic importance to renewable energy sources because of the contribution they can give to the guaranteeing of greater security of the energy supply system, the reduction of the relative environmental impact and the opportunities for protecting the territory and fostering social development. One aim of the Government in this sector, as stated in the Italian White Paper for the exploitation of renewable energies in August 1999, is to achieve the goal of doubling the contribution of renewables by 2010.

In 1999, for the whole electricity sector, Italy's overall electricity demand was nearly 286 TWh (including transmission and distribution losses). Of this, about 42 TWh was imported from neighbouring countries. The net electric energy produced in Italy was 253 TWh.
Italy's net production from renewable sources in 1999 including large and small hydro, geothermal, wind and photovoltaic plants, was as much as 22 % of total net production.
Installed net capacity totalled about 73.8 GW (of which 20.4 GW were hydro and 52.5 GW were thermal plants) as of the end of 1999.

Total wind power capacity in Italy at the end of august 2001 was 610 MW, with an average turbine size of 552 kW, whereas the total number of wind turbines was 1110.
National targets have been fixed for wind power capacity for three periods: 2002 = 700 MW, 2006 = 1,500 MW and 2008-2012 = 2,500 MW.
Given the growing rate of new wind installations registered in the last year, it is very likely that the first goal, 700 MW by 2002, will be exceeded.
As regards the likelihood of reaching the other targets after 2002, this will depend on the effect of the new legislative framework including the new market stimulation instruments for renewable energy sources.

Since the end of 1996, the CIP (Interministerial Committee for Prices) Provision no. 6/92 has shown itself to be the most successful instrument for the commercial implementation of wind energy in Italy. This system was based on buy-back prices mechanism.
Now, a new Legislative Decree (no. 79/99), which provides for the liberalization of the electricity market on the basis of the European Union Directive no. 96/92/EU, will change the system of stimulation and exploitation of renewable energy sources. This Decree was followed by a specific Decree regarding renewable energy sources, which introduces the new support system based on green certificate mechanism.

According to Article 11 of Decree 79/99, the transmission system operator (GRTN) must assure priority in dispatching to plants fed by renewable energy sources. In addition, starting from 1st January 2002 onwards, there is an obligation to introduce into the public electricity network, or to acquire fully or partially, a given percentage of electric energy from renewable sources, for all the subjects producing or importing electric energy from conventional sources.
The above percentage is initially fixed at 2% of the conventional energy that exceeds a quantity of 100 GWh per year and must be exclusively assured through new or repowered plants entered in operation after 1st April 1999 (as to repowered plants, only the energy produced by the added capacity can be taken into account).

Electricity produced by renewable energy sources is labelled with green certificates issued by the transmission system operator (GRTN) and having a value equal to or multiple of 100 MWh. Green certificates are tradable.
Another important aspect of green certificates concerns their compatibility with other incentives. In other words, for a green energy producer it will be possible to combine green certificates with any kind of subsidy, except the premium energy buy-back prices of CIP 6/92.

Regarding the economics, in 2000 the wind plant cost was around ITL 1.9 million per installed kilowatt; therefore in the same year the total invested capital on wind energy plants in Italy was about ITL 280 billion.
In regard to the energy cost, the selling price of electricity (net prices without taxes) varies, for typical domestic consumers, from ITL 100 to ITL 300/kWh, whilst, for industrial consumers, from ITL 100 to ITL 230/kWh.
For wind energy, in 2001 the buy-back prices fixed by CIP 6/92 are: ITL 239.6/kWh for the first eight years of the plant operation; and ITL 133.9/kWh for the remaining lifetime.
As already said above, in the next future, because of the new legislative framework, the support system will change through the introduction of the green certificate mechanism.

There are several green energy products available on the market in the Netherlands. Demand for green electricity has been significant and increased after the introduction of a green certificate scheme with imposed quota and penalties.

there are no green energy products are available on the market in Poland.

Policies for renewable energies in Spain are established in the “Plan de Fomento de las Energías Renovables” edited in December, 1999 by the Spanish Institute for the Energy Diversification and Saving (IDAE). This proposes a stable framework with direct price support for renewables, with a premium system similar to Germany’s.

Sweden currently produces 145 TWh/year. As the market is deregulated there are very different market prices depending on many parameters; precipation, winter temperature, long or short contracts etc. The present average price is about 0.15 SEK, about 0.018 EURO, which is very low in comparison with countries outside Scandinavia. More detailed information can be found on the website for Nordpool-the common Scandinavian powermarket..
Hydropower provides approximately half Sweden's electrical power, with the remainder mainly from nuclear. The Parliament has decided to close nuclear power stations and replace them with power from renewables. The process started with the closure of the first of twelve reactors, Barsebäck 1, in December 1999. Barsebäck 2 will be closed in 2003. There is currently no programme for closure of the remainder. Because of nuclear plant closures, more interconnection with grids in other European countries, and taxation on fossil fuels to incentivise reduction of greenhouse gases, there will be a gradual increase of prices.
Sweden has many more electricity heated houses than in other European countries and has a very low dependency on oil and coal for electrical power production
A large number of utilities in the deregulated market offer "green electricity" and some offer "extra green" from wind power. The price for wind generated electricity is about 5 – 10 % more expensive than the standard product.
Most customers are companies looking to strengthen their green image and obtain favourable publicity or to be environmentally certified.

There are several green energy products in the United Kingdom.

7 Benefits to the Environment

The benefits to the environment from using wind power are mainly by reducing atmospheric pollution. As well as a significant reduction in CO_2, other pollutants are also reduced; SO_2, NO_x, CO, Methane and Particulates.

The amount of CO_2 emitted by various types of power generation during all stages of a power generation plant's life cycle are listed below. The values given are subject to some local country by country variation, but wind power reduces emissions by orders of magnitude compared with conventional thermal power generation.

	CO_2 Emissions (Tonnes per GWh) [41]**,** [42] **&** [43]			
Technology	**Fuel Extraction**	**Construction**	**Operation**	**Total**
Coal-fired [1]	1	1	962	964
AFBC	1	1	961	963
IGCC	1	1	748	751
Oil-fired	-	-	726	726

Gas-fired	-	-	484	484
OTEC	N/A	4	300	304
Geothermal	<1	1	56	57
Small hydro	N/A	10	N/A	10
Nuclear [2]	~2	1	5	8
Wind	N/A	7	N/A	7
Photovoltaics	N/A	5	N/A	5
Large hydro	N/A	4	N/A	4
Solar thermal	N/A	3	N/A	3
Wood [3]	-1509	3	1346	-160

[1] Conventional plant [2] Boiling water reactor [3] Sustainable harvest

The actual saving in emissions depends to a large extent on the mix of types of power generation for an individual country or region and the type of plant replaced. It is apparent that any calculations on emissions savings must look realistically at the type of power generation likely to be replaced, and not just assume that the most polluting will be shut down.
As an example of this, it is interesting to note that the German energy mix including nuclear power is 0.6kg/kWh, whereas the mix excluding nuclear power is 0.89kg/kWh

8 Employment Prospects for Europe

Estimates for employment prospects are predominantly available for onshore wind or the generic wind industry. DWTMA [44] gives estimates of employment generated by wind energy in Denmark, broken down by sectors defined in Danish input-output tables and applying economic multipliers. EWEA, Cambridge Econometrics and ECOTEC [45], [46] & [47] use economic modelling techniques to estimate job creation for future energy mix scenarios. ESD for Friends of the Earth [48] surveys employment in the UK wind energy industry. [49]

Altener [50] provides estimates for both onshore and offshore broken down into construction & installation and operation & maintenance, for 1995 and scenarios up to 2020. ESD for Greenpeace [51] is dedicated to offshore estimates and uses input-output analysis to estimate job creation by industry sector as a result of installing some 10GW of offshore wind.

BorderWind for Greenpeace [52] is also dedicated to offshore wind and provides estimates of *direct* job creation by activity based on consultation with developers and operators. This estimate is reproduced below.

Estimate of direct employment to develop offshore wind farms.

		Full Time Jobs/MW

Project design and development	Marine/ground investigations Site development including permissions Design including structural, electrical and resource Finance	0.01 0.1 0.02 0.04
Component supply	Generators Gearboxes Rotor blades Brakes, hydraulics Electrical & control systems Towers	0.15 0.9-0.4 0.5 0.04 0.04 0.9
Assembly	Wind turbines	1
Installation	Foundation structure Electrical and connecting cables Wind turbines Project management & commissioning	0.3 0.05 0.3 0.11
Operation & maintenance	Management, routine and fault maintenance	0.06
TOTAL		4.52

Sweden has no wind power industry, however, even without turbine manufacturing in Sweden there will be an effect from the increasing wind industry upon the Swedish labour market. Steel manufacture and fabrication and electric equipment are standard Swedish export products.

Industry has started in Malmö and is planned in Kiruna and Luleå. The Swedish government has stated its intention to build wind power plants for 10 TWh annual production, of which more than half will be offshore.

It is predicted that in Germany, as a result of wind energy use, 25,000 to 30,000 jobs will be directly and indirectly created by the end of 2000 [53] & [54].

9 Benefits for European Industry

European industry at the forefront in providing consultancy services to wind energy, and this should continue for offshore. European offshore oil and gas sector experience of substructures, foundations and installation techniques is to some degree transferable to offshore wind. See Garrad Hassan and Partners: “Measures to Increase the UK-Manufactured Content of Wind Turbines”, ETSU W/45/00479/REP/1 1996 and “Offshore Wind Industry Capabilities in the UK”, ETSU W/35/00530/REP 1999.

The Netherlands has a large number of offshore engineering companies, who would be capable of manufacturing the offshore engineering components, however, the lack of a local market has handicapped the development of a flourishing wind turbine manufacturing industry.

Europe is a net exporter of services and equipment to the wind energy sector, thus securing more jobs and wider economic benefit in Europe than that supported by the domestic market alone. A mature European wind industry is in an excellent position to export to presently emerging or anticipated markets.
The technical advantage gained from European offshore wind farm development will be exportable to developing countries, which will provide new markets for wind energy industries & services. European developments will be a show-case for exports of consultancy services and equipment.

See [55] & [56].

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