OFFSHORE WIND ENERGY IN EUROPE

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19. JULY 2005

World Wind Energy Association

Founded in July 2001 in Copenhagen, Denmark

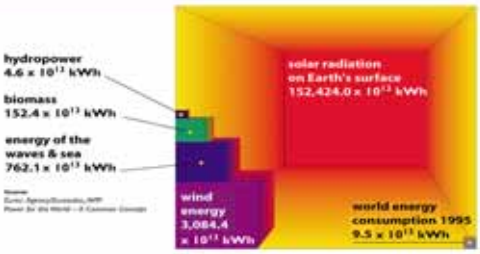
The Members:
National associations, scientific institutes, companies, public bodies and individuals from currently 70 countries on all continents, including many developing countries

The Aims:
Promoting the worldwide utilisation of wind energy by
- being a communication platform for all wind energy actors world-wide
- influencing national and international policies in favour of wind energy
- providing international technology transfer

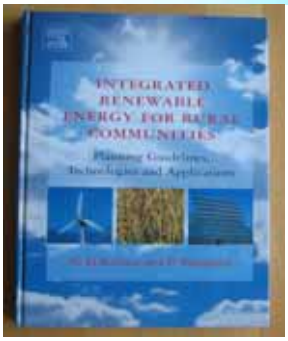
The Activities:
- World Wind Energy Conferences (WWEC 2005 in Melbourne/Australia)
- Several working groups (sustainability guidelines, repowering, hybrid)
- Advising governments, international organisations, etc.

Head office since July 2003 in Bonn, Germany

The Potential of Renewable Energies Worldwide

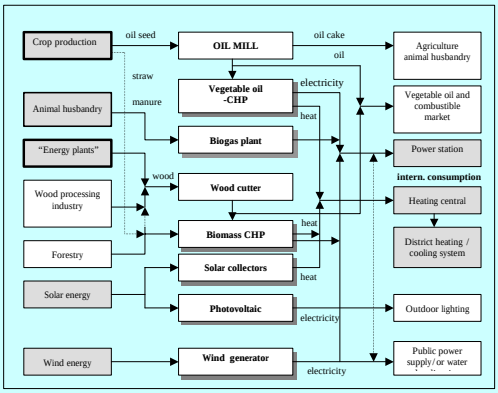


Integrated Renewable Energy



By

Nasir el Bassam & Preben Maegaard, ELSEVIER, Amsterdam and London, 2004



THE NEW TECHNICAL STANDARDS

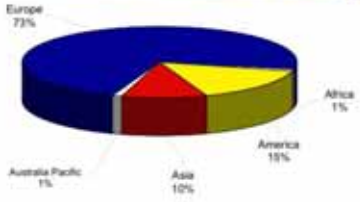
From 100 major fossil energy depots worldwide to millions of energy suppliers at farms with biomass; facades and building roofs with solar energy; **seas and plains with wind energy**.

From gigawatt- to kilowatt-size energy supply technologies.

From centralized power generation to on-site and distributed generation

From big scale supply technologies (oil refineries, natural gas networks, power stations) to mass-produced, small size renewable energy devices.

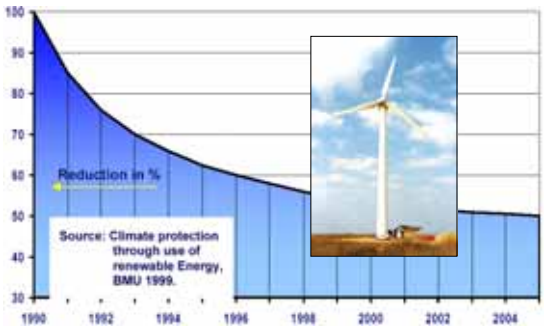
Grid-connected Wind Energy by Continent



	Installed Capacity 2004 (MW)	Installed Capacity 2003 (MW)	World market share in 2004 (%)	World market share in 2003 (%)
Africa	391.7	271.5	0.8	0.7
America	7.335.5	6.842.6	15.4	17.4
Asia	4.726.3	3.217.6	9.9	8.2
Australia/Pacific	346.3	233.5	0.7	0.6
Europe	34.816.4	28.730.2	73.1	73.1
World	47.616.4	39.295.3	100.0	100.0

Leading Wind Energy Markets 2004

Country	Additional Capacity	Rate of growth	Total capacity



Basic Legal Framework for Wind Energy

Conditions for Successful Implementation of Wind Energy

1. To allow connection of wind power to the public grid
2. Power purchase obligation of electricity from renewable energy installations
3. To pay a fair and guarantied price as a compensation to independent power producers

WINDMILL TECHNOLOGY – STATE OF THE ART

Large modern wind turbines involve....

Aerodynamics **(blades and structures);**

Mechanics **(machine elements, strength of materials, novel materials, testing);**

Electrical Engineering **(electrical machines, grid connection, load management);**

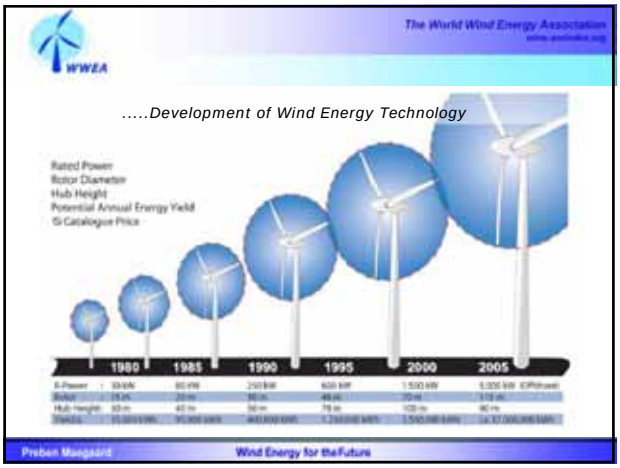
Electronics **(controls and power electronics);**

Controls **(control theory, hydraulics, pneumatics);**

Civil Engineering **(foundations, roads, power lines);**

Transport Logistics; Design; Architecture;

Economics; Project Planning & Management…


.....Development of Wind Energy Technology
Rated Power
Rotor Diameter
Hub Height
Potential Annual Energy Yield
Si Catalogue Price
1980
1985
1990
1995
2000
2005
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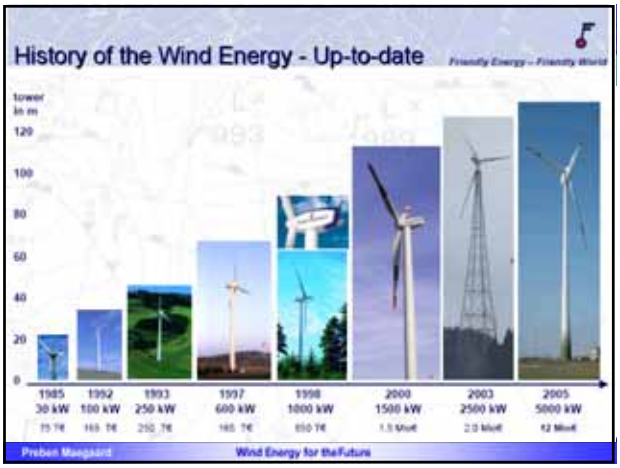
Wind Energy for the Future


History of the Wind Energy - Up-to-date
tower in m
120
100
80
60
40
20
0
1985 30 kW
1992 100 kW
1993 250 kW
1997 600 kW
1998 1000 kW
2000 1500 kW
2003 2500 kW
2005 5000 kW
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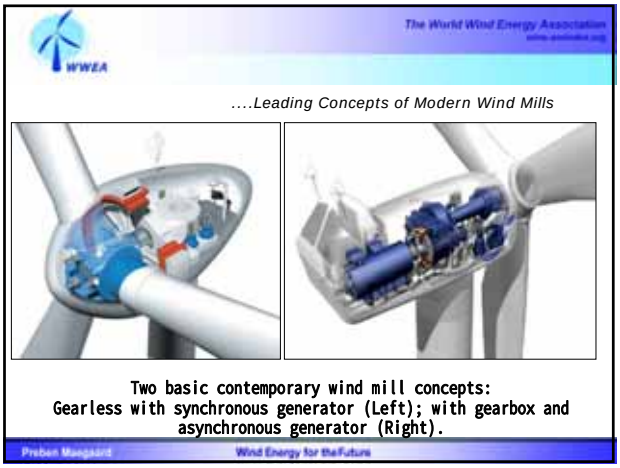
Wind Energy by Manufacturer
Manufacturers World Market Shares 2004
Ecotecnia 0.9%
Others 2.4%
Goldwind 0.5%
Repower 3.3%
Mitsubishi 2.0%
Nordex 2.2%
Fuhrländer 0.4%
Suzlon 3.8%
Siemens (Bonus) 8.2%
Vestas 33.0%
GE Wind 11.0%
Enercon 15.6%
Gamesa 18.9%


....Leading Concepts of Modern Wind Mills
Two basic contemporary wind mill concepts:
Gearless with synchronous generator (Left); with gearbox and asynchronous generator (Right).
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Manufacturing at LM of MW windmill blades
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.....60 meter LM blade
.....36 meter LM blade
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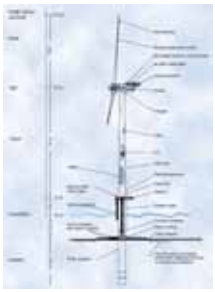
Advanced Windmill Technology for Offshore

Vestas 2 MW for Offshore



Source: Vestas

Source: Vestas

Turbine design and special offshore features

German MW Windmills for Offshore

- Average rated power onshore already in 2003 > 1.5 MW
- Prototypes 3.5 – 5 MW
- Largely driven by offshore wind in deep water (>25 m)

Rated Power: 4.5 MW Hub height: 112 m Rotor Diameter: 114 m Installed: 5

Enercon E112

Rated Power: 5 MW Hub height: 120 m Rotor Diameter: 126 m Installed: 1

Repower 5M

Rated Power: 5 MW Hub height: 102 m Rotor Diameter: 116 m Installed: 1

Multibrid M5000

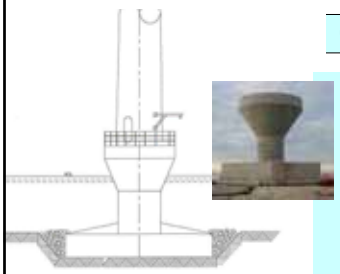
Offshore Wind Energy Technology Trends

The windmills used in current offshore projects were designed for land-use with modifications. With growing market windmills optimised for offshore will be developed. High reliability would suggest the use of well-proven technology. Modifications may include:

- larger windmills, up to 5 MW or 10 MW,
- faster rotational speeds than on land, where noise restrictions generally causes below optimum speed,
- larger generators for a specific rotor size to enable improved efficiency,
- high voltage generation, also possible in DC instead of AC,
- in the longer term, downwind machines, flexible blades or multiple rotors might become an option

TYPES OF OFFSHORE WINDMILL FOUNDATION.

TYPES OF FOUNDATION 1.



Concrete caisson

Advantages
- Well-known technology
  - Installation
  - Manufacturing
- Rigid tower base

Disadvantages
- Seabed preparation
- Size / Weight
- Decommissioning/removal

Variety of Offshore Foundations....

TYPES OF FOUNDATION 2.

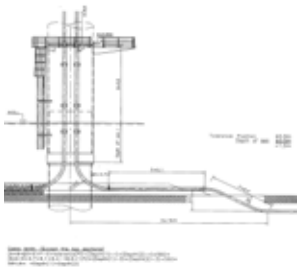
Tripod foundation

- Advantages
  - Applicable to deeper water
  - No or limited seabed preparations
- Disadvantages
  - Not applicable in shallow waters
  - Braces
    - Increases ice load
    - Makes boat access difficult

TYPES OF FOUNDATION 3.

Monopile foundation

- Advantages
  - No seabed preparation
  - Relatively simple to manufacture
- Disadvantages
  - Requires specialised installation equipment
  - Sensitive to solids when driven
  - Flexible at greater water depths



Horns Rev Foundation & Cable Attachment

Monopile is rammed into Sea Bottom

Source: Samsø

Installation of foundations

- Driving of monopile for windmill in the North Sea

The World Wind Energy Association

OFFSHORE WIND ENERGY IN EUROPE – STATUS AND PLANS

The World Wind Energy Association

Offshore projects in Europe end of 2004

	Realised	Projected	Total
Belgium	0	600	600
Denmark	409	400	809
France	0	60	60
Germany	5	70677	70682
Ireland	25	1255	1280
Netherlands	19	220	239
Spain	0	2563	2563
Sweden	23	2498	2522
UK	214	8699	8913
Total	**695**	**86973**	**87668**

[MW]

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OPERATIONAL OFFSHORE WINDFARMS IN EUROPE

Location	Country	Online	MW	No	Rating
Vindeby	Denmark	1991	4.95	11	Bonus 450kW
Lely (Ijsselmeer)	Holland	1994	2.0	4	NedWind 500kW
Tune Knob	Denmark	1995	5.0	10	Vestas 500kW
Dronten (Ijsselmeer)	Holland	1996	11.4	19	Nordtank 600kW
Gotland (Bockstigen)	Sweden	1997	2.5	5	Wind World 500kW
Blyth Offshore	UK	2000	3.8	2	Vestas 1.8MW
Middelgrunden, Copenhagen	Denmark	2001	40	20	Bonus 2MW
Utgrunden, Kalmar Sound	Sweden	2001	10.5	7	GE Wind 1.5MW
Yttre Stengrund	Sweden	2001	10	5	NEG Micon NM72
Horns Rev	Denmark	2002	160	80	Vestas 2MW
Frederikshavn	Denmark	2003	10.6	4	2 Vestas 1MW,1 Bonus 2.3MW and 1 Nordex 2.3MW
Samsø	Denmark	2003	23	10	Bonus 2.3 MW
North Hoyle	UK	2003	60	30	Vestas 2MW
Nysted	Denmark	2004	158	72	Bonus 2.3MW
Arklow Bank	Ireland	2004	25.2	7	GE 3.6 MW
Scroby Sands	UK	2004	60	30	Vestas 2 MW
Totals			587	316	

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Europe: Installed, approved and planned.

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Planned German Windfarms in the North Sea

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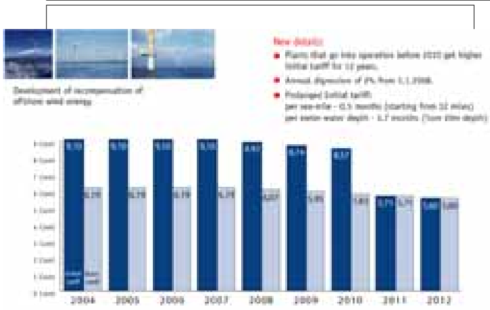
Planned German Wind Farms in the Baltic Sea

Germany: State Guaranteed Tariffs for 20 Years



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FIRST OFFSHORE WIND FARM IN GERMANY

- 14. July 2005: First German Offshore Wind Farm.
- The commercial banks hesitated to finance. The German Ministry for the Environment now supports the first German offshore windfarm with 5 million Euros. It will be operational in 2007 and situated in the North Sea outside the Island of Borkum.
- The windfarm will have a total capacity of almost 60 MW and consist of
- 4 x PROKON 5 MW
- 4 x REPOWER 5 MW
- 4 x ENERCON 4,5 MW
- The large power companies, Vattenfall, e.on and E.W.E. provides the cabeling.
- Source: Die Zeit

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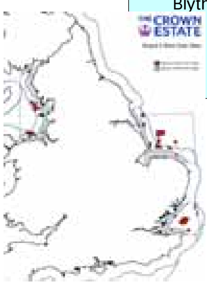
United Kingdom: Offshore Projects

Photos show 2 Vestas 2 MW windmills near Blyth Harbour



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Total technical Costs of European Wind Farms

Table 3.1 Published total technical capital costs for offshore wind farms

Project name	Rated power (MW)	Date installed	Capital cost (€M)	Specific capital cost (€M/MW)
Vindeby	4.95	1991	10.25	2.1
Lely (IJsselmeer)	2.00	1994	4.50	2.3
Tuno Knob	5.00	1995	10.35	2.1
Dronten/Irene Vorrink (IJsselmeer)	16.80	1996-97	20.50	1.2
Bockstigen	2.50	1997	4.70	1.9
Blyth	4.00	2000	6.32	1.6
Utgrunden (Öland)[1]	10.00	2000	13.90	1.4
Middelgrunden[2]	40.00	2000-01	51.30	1.3
Horns Rev[3]	160.00	2001-03[5]	300.00	1.9
Samsoe	23.00	2002-03	35.00	1.5
North Hoyle	60.00	2003[5]	105.70	1.8
Nysted	158.40	2003[5]	268.80	1.7
Scroby Sands	60.00	2003-04[5]	107.10	1.8

1. Confidential – figures shown are based on budget costs and possible rating of 10.5MW, not 10MW restriction.
2. Derived from figures published for half the project owned by Middelgrunden Cooperative, with estimate added for grid connection.
3. Verbally advised by Techwise July 2002, including grid connection. Vestas have announced that turbine supply contract price is DKK 1.8bn (€ 24M).
4. Based on exchange rates: €1 = $0.70 = DKK7.44.
5. Nominal contract price – not necessarily final costs.

Source: IEA

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European Offshore Windfarms in 2000 and 2004

Figure 1.1 Offshore wind farm projects developed up to 2000

Figure 1.2 Offshore wind farm projects developed up to 2004

Source: IEA

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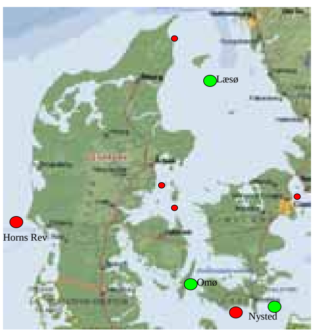
Offshore Wind Energy Policy in Denmark



- Reduce CO_2 emission with 50% before 2030
- 40% of electricity from Wind Energy (2005: 22%)
- Six demo projects:
  - Horns Rev 2002
  - Nysted 2004
  - Samsø 2003
  - Tunø 1996
  - Vindeby 1992
  - Middelgrunden 2001

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SUMMARY OF EUROPEAN OFFSHORE EXPERIENCES

Offshore is complicated!

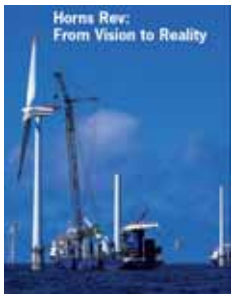
- Both measurements and modelling have a role.
- Specific site resource estimation still requires on-site measurements.
- Reliability of Technology still causes surprises.
- The **offshore** resource is as large as current EU electricity consumption, 320 TWh/y
- Overall estimate of 140 GW is much larger than the EU *White Paper* target of 10 GW in 2010

HORNS REV, DENMARK.

THE FIRST LARGE OFFSHORE WINDFARM

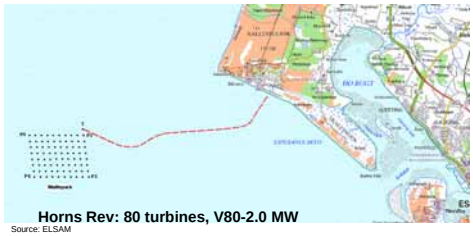
IN THE WORLD

Horns Rev Offshore Wind Farm



Installation during the summer months 2002 of 8o Vestas windmills at Horns Rev

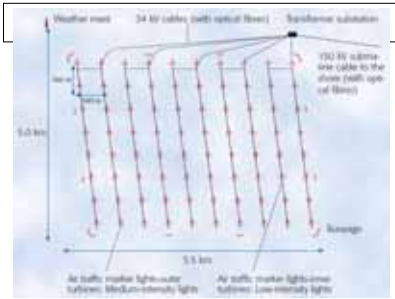
CABLE CONNECTION TO HORNS REV WIND FARM, NORTH SEA



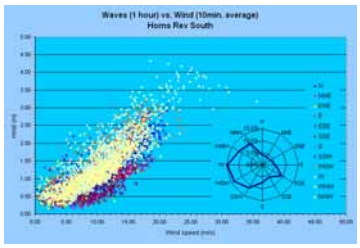
Horns Rev: 80 turbines, V80-2.0 MW

Source: ELSAM

Power interfacing at Horns Rev



Source: Elsam



Measure-ments of wind and waves at Horns Rev

FROM HORNS REV 1:

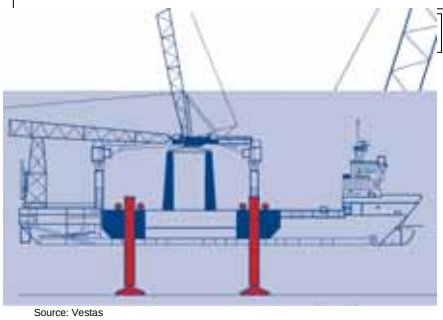
- **Almost 2 % of the total Danish electricity consumption**
- The total annual, Danish electricity consumption amounted to 34,913 GWh in 2001.
- The production from the Horns Rev wind farm is expected to reach 600 GWh

Loading Windmills in Esbjerg Harbour

Horns Rev: Purpose built Vessel

Source: Vestas

Ship Crane with Telescope Support to Sea Bottom



Source: Vestas

Horns Rev: Work in Progress 1

Source: Vestas

Specialized vessels in operation in the North Sea

Horns Rev: Work in Progress 2

Source: Vestas

Offshore construction

Offshore developments are more costly and more dependent on weather conditions during windmill erection. The wind farm at Horns Rev off the West coast of Denmark used modified crane vessels and optimized on-shore type windmills to reduce costs.

Heli-hoist platform

Source: Vestas

Horns Rev, Denmark

At Horns Rev in the North Sea, 30 kilometers off the Danish coast, 80 Vestas windmills, with a capacity each of 2 MW were installed in 2002. World's first large windfarm at Sea.

Horns Rev: 80 Windmills each 2 MW

Source: Vestas

BIRDS, FISHERY, COSTS AND INVESTMENTS CONCERNING OFFSHORE WIND ENERGY

OFFSHORE WIND ENERGY AND FISHING

Experiences reported from Middelgrunden, Copenhagen, Denmark, (2001):

- "Extensive netting takes place in the area, primarily for eel, cod and flatfish. Compensation was settled with the local fishermen, as fishing was prohibited during construction.
- Now fishing can resume as before, but no tool scraping the bottom may be used and it is prohibited to anchor within 200 meters from the sea cable. In the future the foundations are likely to serve as a reef and create a habitat for bottom animals and thus for more fish in the future".

OFFSHORE WIND ENERGY AND BIRDS

Reported from Blyth Harbour, England:

- "…appropriately positioned windfarms do not pose a significant hazard for birds."
- " For example, the 9 harbour-wall windmills at Blyth are in a busy bird area. Of the bird flights through the wind farm, only 1 in 10.000 have resulted in a collision. This translates to 1-2 collisions per year per windmill. To put the issue into perspective, every year more than 10 million birds are killed by cars in UK."
- Source: "The Royal Society for the Protection of Birds" and WWF

OFFSHORE WIND ENERGY IN ASIA

China to build wind farms offshore

(Agencies)
Updated: 2005-05-16 20:48

BEIJING, China -- China has unveiled plans to make offshore wind farms a key part of its renewable energy program within two or three decades.

The wind turbines, which would be built 50 kilometers (30 miles) out to sea, would be ideally situated to supply clean power to the populous and booming east coast area.

"Offshore wind sites are close to the main electricity load centers in eastern China, so offer great potential for future energy supply," Shi Pengfei, vice-chairman of the Chinese Wind Energy Association, told a conference this month.

DANISH FARMER INVESTED IN 2,3 MW OFFSHORE WINDMILL

- *"We estimate the pay-back time to be between ten and twelve years."*
- That is exactly what Jörgen Tranberg (48) has calculated for his own sake.
- Together with a partner, he bought windmill No. 8 of Samsoe Havvind and he reckons as follows: "*We estimate the output of one windmill at 8 million kilowatt-hours, for which a price of DKK 0,43 or € 0.058 is guaranteed. Yet, the market price in Denmark is DKK 0,33 or € 0,044. It is even possible to receive an additional DKK 0,17 or € 0,023 on top of the guaranteed price, if you bring in smaller and old windmills*"
- **"***Not that I do this for money*", he specifies. As a farmer with 110 dairy cows and annual quota of some 1 million liters of milk, his claim that he can make a living without having a windmill can easily be understood. He is a man with a sense for current trends.

MIDDELGRUNDEN -
DANISH COOPERATIVE OFFSHORE WINDFARM

Source: V. Kantor

Offshore windfarm at Middelgrunden, near Copenhagen, between Sweden and Denmark

Middelgrunden Windfarm, at Port of Copenhagen

20 Bonus windmills, each 2 MW

Bonus Windmills are shipped to the destination

Source:Samsø

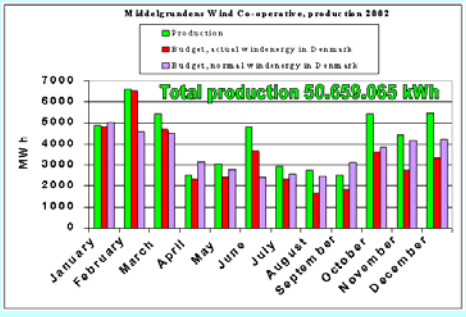
Installation of 2,2 MW Bonus Windmill

Middelgrunden Offshore Wind Farm

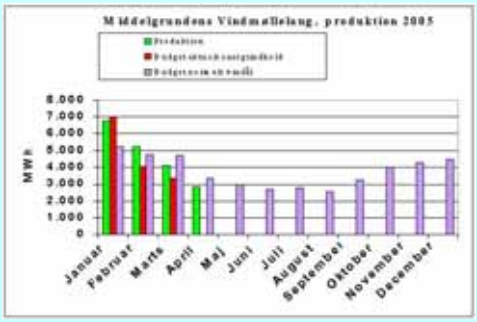
20 Bonus windmills of each 2 MW.

Joint venture of 8.500 local residents and the Copenhagen Utility

MIDDELGRUNDEN – 2002 PRODUCTION FIGURES



MIDDELGRUNDEN – 2005 PRODUCTION FIGURES



FOLKECENTER

ON-THE-NORTH SEA COAST PROJECT IN HANSTHOLM,
1992

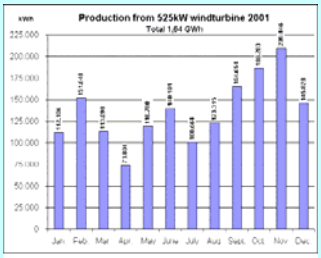
Folkecenter on-shore Pilot Project 1992

4 Folkecenter 525 KW windmills on the North Sea beach in Hanstholm, Denmark. The concrete foundations serve as coastal protection. In operation since 1992

525 kw Folkecenter Windmill at North Sea Coast

Joining hub and blade (left); Rotor is hoisted by cranes for assembly (middle); the rotor is joining the nacelle (right). Folkecenter, Hanstholm, 1992)

FOLKECENTER 525 KW ON-THE-COAST WINDMILL, FROM 1992.



PRODUCTION FIGURES per MONTH AND 2002 TOTAL: 1.640.000 kWh.

ANNUAL AVERAGE 1993-2002: 1.473.000 kWh

OTHER NEAR SHORE WINDMILL PROJECTS

ODDESUND NEAR-SHORE WINDFARM FROM 1985

20 Bonus 95 KW windmills in rough water near the North Sea. Is still in operation.

Lynetten Windfarm, Port of Copenhagen

Built and operated by local City Cooperative

Near Shore Wind Energy in Denmark

Offshore Windfarms in Denmark

6% of Denmark's electricity supply comes from offshore.

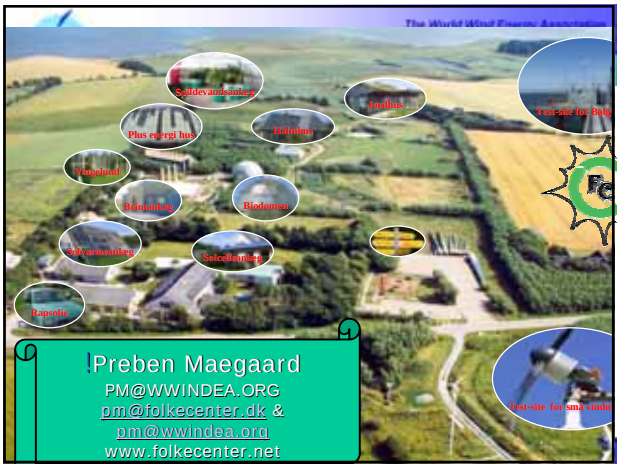
EXAMPLES OF NEAR-SHORE WIND ENERGY

- 1 MW BONUS windmills in Denmark
- 2 MW Scanwind windmill in Norway
- 4,5 MW Enercon windmill in Germany

Innovative and future offshore concepts

Floating Foundations and integrated maritime landscapes:
To be considered at deep sea waters depending on research, and experiences from existing offshore projects.


The World Wind Energy Association
4th World Wind Energy Conference 2005
See You in Melbourne, Australia
www.WWEC2005.com
Preben Maegaard
Wind Energy for the Future


Test site for Italy
Test site for small wind
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Thank You for
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