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"Wind Energy: National Programs and International Perspectives"

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These are preliminary lecture notes, intended only for distribution to participants.

Title -WIND ENERGY: NATIONAL PROGRAMS AND INTERNATIONAL PERSPECTIVES
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INTRODUCTION

The first wind energy programs started around 1975 after the oil crisis of 1973 . After 20 years of studies, research, development and demostration wind power technology has reached a good standard of quality and prices .
Really just now it is evident the availability of a large potential of wind power in the world not only at acceptable low kWh prices (7 cent USD now, target 5 cents , 1995), but useful to alleviate the effect of pollution (Global warming, acid rains, ..).
Developed countries have in general relevant wind power programs for technological advance and resources assessment . Emerging countries in cooperation with the developed partners are more and more involved in similar programs with own capitals and international financial aid . Developing countries , even with high wind potential , do not have technology, resource assessment capability, and financial power; then they are depending on the aid of international and national programs with poor results up to now.
In the following paragraphs a very summarized overview of national and international programs is given for continental areas to have a more compact panorama of the wind energy in the world. Only few specific countries have been reported as representative for each continental area to have an acceptable size of the paper.
Some information are given on the international programs and at the end the prespectives of wind energy in the world are summarized.
In the introduction considerations are reported on the wind energy resources in the world. In Appendices some contries are reported in texts taken by the literature, in general Wind Power , Wind Directions, IEA News.

WORLD WIND ENERGY

Two percent of the total solar flux, with an average value of 350 watts per square meter of the earth's surface , is transformed in the atmosphere kinetic energy ; it results about 106 000 Quads per year (1 Quad = 10 EXP15 BTU or 2 9 3 Wh).
Near surface wind energy amounts to 38% of the above value , 40 000 Quads per year; assuming a global energy extraction fraction by tha wind turbines of the order of 10%, the final wind power limit is 4 000 Quads per year.
In Table 1(Eldridge,1981) the power extraction limits of renewable energies are compared , excluding the direct solar; wind has the potential higher than hydro, geothermal, and tidal power. Moreover the power demand in many countries of the world has similar values for the wind power potential, as reported for the U.S. .
Of course in the reality , to get more practical values , the above extraction limit should be reduced by a factor of order of 100 *to take account of wind regimes, of the land use, of the environmental problems, of grid connection possibilities.
The distribution of wind energy on the Earth's surface is reported on wind maps in many ways. In general iso curves rappresent the annual mean wind speesd or the kWh per kW of installed machine and year at 10 or 50 m height . Fig. 1a , b (US Congress, 1984) show the windy continental regions and islands or coasts of the world with some lack of information on Siberia and China.
The annual mean wind speed of the siting area is only a preliminary parameter to be used for site selection and initial evaluation ; for the machine design and performance it is necessary to consider other parameters (Fig. 2-Hardy and Watson, 1977) such as max wind speed , gust spectrum, turbulence.

*This value comes by the assumption of using only 2/1000 of the country surface (Land + sea+ lakes) and by the concentrating about 5 times (1800/8760 hours)the annual mean wind flux in the turbine working time (Approximat. 1800hours).

The total wind power in operation in the world in 1990 was about 2000 MW with 1525 MW in California and 480 MW in European Community . The electricity generation was more than 3.2 TWh with 80% in California and 17% in Europe (Fig. 2- Milborrow, 1991).
The total installed power in the world was about 3000MW at the end of 1992 with 1800 in USA, 850 MW in Europe, and 350 MW in the other countries.

INTERNATIONAL COOPERATIONS PROGRAMS

The have their own development programs and technology for the exploitation of the potential of wind energy in their territories . On the other hand emerging countries have reduced financial resources and incentives for using renewable energies , while developing countries lack of financial resourses and technology.
Then cooperation activites among developed, emerging and developing countries have been carried out on bylateral agreements or through specific programs of international organizations.
US-AID (USA Agency for International Development) is collaborating with many countries through the Office of Energy. In the past wind programs have been developed in the Mediterranean with Egypt, Tunisia, ex Jugoslavia; presently is supporting an irrigation project by small wind pumps in Indonesia together with the Wolrd Bank.
DANIDA , the Danish aid agency , has been very active in Capo Verde, China , India , and Somalia. In Fig 3 the results of the investment programs for wind energy in the above countries are compared.
El Dorado is a 5 years program set up by the German Federal Resarch Ministry (BMFT) to provide financial and technical assistance for 20MW of wind power plant to be installed in the developing countries having cooperation agreements with Germany. Concrete plans exist in Brazil, China, Egypt, and in the Martinique island.
Italy , Netherland, U.K. with other countries, the European Community have cooperation programs and are giving specific training courses on renewable energies for engineers and excecutives of developing countries.

The World Bank and the United Nations have started in 1991 the joint program GEF(Global Environmental Facility) to aid the environmentally benign developments in the Third World . GEF is promoting a large wind energy project in India for electricity generation (85 MW wind farm), in Costa Rica (20MW), and for irrigation in Indonesia.

NATIONAL PROGRAMS PER CONTINENTAL ARIAS

EUROPE

-European Community
During 1992 wind energy has been booming in Europe ; about 225 MW have installed compaired to the 10 MW of US (California). Germany and U.K. are the leading countries with respectively 100 and 50MW .
The total wind power installed in1991 in the European Community , that rapresents about 97% total European capacity, is shown in Fig. 4 , while fig. 5 reports the evolution in the last 11years
It appears in Fig. 6 that the rate of turbine installation has been evolving from a low mean value in 1980/84 (13 MW/year), to medium one in 1984/90(43 MW/year), and in 1989/92 up to the accelerating value 165 MW/year.
The total installed E.C. wind power in 1992 (Fig. 7) amounts to 785 MW with leading countries Denmark (450 MW), Nederland (100 MW), Germany (95 MW), Spain (45MW), and U.K. (30 MW); Greece (20 MW), Italy (15MW). Belgium, Ireland, Portugal , and France total 10MW together.
A forecast(Fig. 8) of the E.C. DG XVII-Energy (Novem,1992) shows a wind turbine capacity of 4050 MW in the year 2000 and of 10 100 MW in the member countries.

The ALTERNER program of EC has set a goal of 8000MW fo the year 2005. In the Plan for Action (EWEA, 1991) the European Wind Energy Association forecasts for E. C. an installed wind energy goal of 4000 MW for the year 2000 (Fig. 9)and 11500 MW for 2005. The European program for wind energy are:
-Joule I and II -DG XII Research
-Thermie -DG XVII Energy
-Alterner for dissemination and resources
-Other(framework, Pim, MED,..)
The rest of Europe (Finland, Norway, Sweden, Switzerland , Austria eastern countries, Russia and federated countries , Balcanic countries) has globally a good potential particularly in the North Europe. The installed wind power accounts for about 20 MW.

E. C. Member countries
-Denmark
The installed wind power is 450 MW .
The test Center of Riso has been very effective for testing many prototypes of small and large industry . The Meteorological Office of Riso is the leading team that has succeed in producing the European Community Wind Atlas in 1990.
The 650 kW stall controlled turbine Nibe A is operating with new cantilevered Wooden blades. Nibe B with pith controlled wooden blades has generated 7116 MWh (1991)in 25 699 hours since february 1984 . Nibe A and B are demonstraction plants for technology development.
The five 750 kW turbines installed in 1986 in Manesdo power station (coast of Zealand), were designed with experience of Nibe prototypes; four of them have accumualted 16 700 /18 000 hours operation untill 1992 ; the fifth unit damaged by a fire in 1987 is again in operation.
The 2MW Tjaereborg turbine, upscale version of Nibe and Manesdo units with a rotor diameter of 60 m , has accumulated 6779 hours(1991) and produced 444 MW.
By the end of 1991 the total wind capacity (private and utulities) was 418 MW with 740 GWh / year, corresponding to 2.3% of the Danish electricity consumption and at kWh cost of 0. O56 ECU .
The first Danish , and of the world, offshore 5 MW wind farm , installed in Vindeby (Wst of Lolland) in 1991 is operanting well with a cost of the kWh 50 % higher than the cost of the onshore site. The Wind farm contains 11, 750 kW Bonus turbined installed in a water depth ranging from 2 up to 6 m at a distance from shoreline between 1200 and 2400 m.

-Germany
The Meteorological Service has produced a new Wind Map of West Germany with extension to East Germany . The coasts of North Sea have the best winds (mean annual speed up to 6.9 m/s).The potential is very significant about 12 000MW (Jarass, 1981). In March 1993 the installed wind power was 180 MW (Fig. 10 -Knight, 1993).
Three 640 kW single-blade Mon 50 of MBB continues operation at the Wilhelmshaven . Another Mon 50 has been installed near Hamburg for a pumped storage plant.
The 1.2 MW WKA 60 , in operation in the island of Heligoland since march 1990 , has accumulated 9300 hours and 1900 MWh (october 1991) in the island grid fed by 2x2.7 MW diesel units.
The 3 MW Aeolus II , sister unit to the Swedish Nasudden turbine, has been installed in 1992 at Wilhelmshaven.
A new concept (no gear box- 4 pole generator) 450 kW prototype has been installed in the 1992 by Enercon at Hanswehrum (Lower Saxxony) for tests . Scaling up to a Mw size is considered.
Several other large and medium sized wind turbines have been developed , and are now in the market (Husum, Enercon , -Fig. 11).

A big support to the wind energy exploitation has been produced by the 250MW (50 MW reserved to East Germany) program of BMFT(Federal Research Ministry) started in 1989 planned to run up to 1996, monitoring project results up to 2006. Fig. 12 shows the annual targets: Fig 10 shows the the annual progress to february 1992.
Fig. 11 shows the maufactures of the installed turbines ; all are European with high percentage of German, Danish, Dutch wind industries . The categories of the developer are reported in Fig. 13. The 16 state subsidy levels are shown in fig . 14.
The 250 MW program has subsidised 117 MW , the total power of 719 turbines larger than 200kW, size non accepted for the best use of sites available.
The German booming market is considered due to three factors: first the 250 MW program, second the market stimulation programs by the the governments of the federal states, thirdly by the electricity price law of 1991(payment of kwh fed to the grid).

-Netherland
The technical potential is 9000 MW , but ambience perturbation(Noise, visual intrusion , ..) by wind turbines might reduce it to 2000 MW.
Government through the IPW (Integral Wind Energy Program) 1991-1995 has goal of 1000 MW for the year 2000 and 2000MW in the 2010 (Fig. 15-Novem, 1992). The installed power at the end of 1990 was 75 MW, in 1992 about 100 MW
In 1995 the IPW target is 400 MW to be reached at a rate of 60 MW/year. The utilities have ancounced plans to invest in wind capacity of 250MW untill 1995.
The TWIN (Support of Wind Energy in Nederland) program 1991-1995 , based on the results of the previuos research program NOW (1986-1990) will be annualy agreed with Novem (Ned. Agengy for Energy and Environ.) for technology development.
More infomation in App. A

-U.K. (see Appendix B)
-Spain "
-Italy "
-Greece "

Other European Countries
-Norway (See Appendix B)

-Czech Republic
Czech territory is in a moderate wind area , where significant applications can be done. The lack of wind data prevents a good evaluation a the wind potential. The Praga 's Hydrometeorological Institute is working for the wind energy assessment of the country.
The Vitkovice steel works in Ostrava has a wind branch : Vitkovice -Mostarna Frydek Mistek(VFM) , that is developing 75 KW and 315 KW turbines starting by the german technology (Tacke). A similar 315KW turbine is now produced by Energovars , a company set up by some people who left VFM. A first 315 kW Energivars prototype will be installed in 1993 by the utility CEZ in Krusne Hory an hilly part of Erzgebirge , a border area with Germany devasted by the lignite mining. CEZ also is planning the installation of four Danish 320kW turbine at Bozi Dar.
Two Vitkovoice 75 kW units are installed : one near Karlovy Vary by a private investor and another one at Bozi Dar a village on the Krusne Hory hills.
A Danish Wind Power 175 KW was installed in 1990 at Hruba Vrboka near Slovak border for the electric needs of a cooperative, and another 30 kW unit is in operation at Banov , South East Moldavia.
Aero Praha (Praga) is producing a 400 kW turbine in Co-operation with CKD Praha and the Italian West (Taranto)of the giant Alenia group.
Small size turbines are manufactured by Bohemia Electric Bese (7.5 kW), Delvet (3 and 7 kW), AVE Moravia (500w)
A wind farm project of 5 Danish Vestas, 500 kW turbines is planned near

Ranzovkesedlo, North Moravian hills, by a consortium of local people and municipality authority.

-Sweden (See Appendix B)

-Ukraine
A large project , worth USD 500 millions , is starting the installation of a 500MW wind farm with 5000, USW 56-100 units in Grimea by Windenergo . This Company has been set up by Californian U.S. Windpower , the Crimea electric utility Krimenergo and PHB Ukraine , a subsidiary of an American and British consultants Putnam, Hayes and Bartlett, already working for the Ministry of Energy and Elecritification.The Ukraine wind farm project on the Crimea peninsula (Black Sea) will produce one -eihgth of the power supplied by the three nuclear reactors surviving to the 1986 accident at Chernobyl. Windenergo will manufacture and sell the USW56-100 turbines , production is starting 1993. The first 250 wind turbines should be in operation in summer 1993.

NORTH AMERICA
-Usa
The wind energy potential mainly for electricity production in the grid is 80 TWh/year. A recent study of Pacific Northwest Laboratory has found significant wind resources in the most areas of United States to be exploited at convenient conditions. Another study by the UCS (1992) reports the wind potential for12 states (Fig. 16) for a total of 18.6 TWh. The evolution of wind power installed in California in the last 10 years is shown in Fig. 17. The total installed wind power in U. S. in 1992 is 1800 MW , of which up to 1700 MW in California, 25 MW in Hawai, the remaining 75 MW in the other States.
From the successful Wind Power Conference 1992 in Seattle (Washington State) , with more than 500 partecipants from utilities, industries and federal Agencies , many qualified speakers predicted about 4000 MW installed by the year 2000 or 5000 MW by 2001 and about 20 000 MW (50 0000 turbines of 400 kW) by 2005 with a production of 50 TWh/year , 64% of the nation's wind potential.
The American utilities are planning 1000MW wind power within the year 2000 .
The Northwest States will install 25 MW by 1994 and 100 -290MW by 1997. Wisconsin , Texas , New England are starting evaluation and planning of wind farms for the coming years.
The Rocky Flats Test Center is going to be renewed by NREL(National Renewable Energy Laboratory) for testing 20 turbines , to ensure delivery of wind turbines capable of producing power for $ 0.05/kWh by 1994-1995 in 6m/s winds.
The Advanced Wind turbine Program (AWP) of DOE (Dpt. of Energy) will support in the1992 /93 the development of unit size between 250 and 750 kW with energy cost of 4 cent/kWh (USD), compaired the today value of 7 Cent/kWh.
DOE and EPRI (Electri Power Research Institute) have set up a n Utility Wind Interest Group to incourage and give expertise to the regional utilities on wind energy.

-Canada (See Appendix B)

CENTRAL AMERICA
The most part of the Caribbean Islands have good wind regimes . Many cooperation programs with European and American countries are promoting wind energy .
In 1991 a 3 MW(12, 250 kW Nedwind) wind farm wereplanned for installation in the island of Curacao by the local utility Kodela with partial funds of Netherland Government and the European Community.
Martinique is cooperatng with Gemany through the El Dorado program.
On the continental shore the GEF(Global Environmental Facility) of World Bank and U.N.

has plan to fund a 20 MW wind farm project in Costa Rica together with Inter-American development Bank and the Costa Rican Electric utilty. The chosen wind turbine is the new US Windpower33-MVS.

SOUTH AMERICA
The wind potential is significant. No strong effort have been done to date for power applications.
-Argentina
The potential in Patagonia (South) is enormous , with a population grouped in few cities. Programs for wind energy application have started in 1984 in cooperation with Germany, and lately (1989) with Italy for the production of medium sized wind turbines in Argentina, where there are manufacturers of turbines up to 1 kW. The most known is Kokai-Tecnia.
-Brazil
The country is in the region of trade winds , that are good in the North-East coastline. Wind pumping is considered of interest for farmers . Application to stand alone systems have been studied for cooling storage systems.
Cooperation with Germany , related to development of a 100 kW turbine Debra in 1984/86, is now continuing through the El Dorado Program.
In 1991 a cooperation program has started between the Danish Folkecenter for Renewable Energy and the Brazilian Eolica (Univ. of Recife) with the aim of promoting wind Energy in Brazil , depending 96% by the hydropower. As a result of the collaboration a 75 kW Danish wind turbine will be installed by the electricity company CELPE in the island of Fernando de Noronha (North East). Later on the turbine will be manufactured in Brazil.
-Chile
The Pacific coast is has a good potential similar to the coast of Perù and Patagonia in the South. Interest is growing for application at University level. There is a manufacturer for small wind pumps(Teckne).
-Perù
The pacific coast is windy and has potential for wind farm application . In the 1985/ 89 for a collaboration program with Italian Riva Calzoni 5 , 5kW wind turbines were installed to supply electricity to a fisherman village.
-Uruguay
The wind potential is of the order of 400 MW (Vinas , 1992) in the range of cost of 4 cent/kWh (USD). The government authorities are planning to promote utilites for wind energy exploitation due to the shortage of other sources in the future(hydro).

ASIA

-China
A large potential of wind energy, of the order of 474 000 MW, has been evaluated on the base of measured data of 750 meteo stations . The windiest provincies are the northwestern Gansu and Xinijang , where 9 areas are available with a yearly wind speed average of 6m/s. Other windy provinces are : Inner Mongolia and the coastal Liaoning, Shadong, Zhejiang, and Fujian (Fig. 18)
The wind power goal in the year 2000 is to installe 1000 MW mainly connected to large or local electric grids to supplement the thermal and the hydro generating capacity , that now is 141 000 MW .
For this the Minister of Energy has launched a program for building 12 medium size wind farms within 1995,with a total capacity of 200MW, to alleviate the shortage of electric power and bring electricity to scattered communities. The wind farms will be installed in the province of Xinjiang, Inner Mongolia, on the Liaonig and Shandon peninsulas(Bo Hai Sea, and in Zhoushan Archipelago .Present installed wind power is 27 MW (23 grid connected).

The most important wind energy demonstration Center is at Dabancheg -Xinijang (See fig. 19), where are in operation 8 new danish 300kw turbines (4 Bonus, 4 Nordtank) , 13 Bonus 150 Kw (of 1989) and other 5 smaller tubines for a total power of 4.5 Mw. The Center, the largest Wind Farm in China , feeds electricity to the grid of Urumqi , the capital of province , with a power deficit of about 300 MW. A future expansion of the Center is promoted up to 30 MW in 1995 and 100 MW in 2000.
The Danish oversea agency DANIDA has been sponsoring Dabacheng Center by technological support, personnel training and turbines installation(3 million USD).
Danish Nordtank has supplied also9, 300kw turbines for two projects in southern Guangdong.
Other five test stations(three on the islands /Haitan and Dachen islands in the East and Nan'ao in the South China Sea , one at Zhurihe (Inner Mongolia) and at Rongchen (Shandong Peninsula) have 44 additional wind turbines , most from Europe.
Germany is present in China by El Dorado Programme financing two wind farms projects(worth 4 million DEM) with 12 , 250 kW turbines of Husumer Schiffswerk, of which 8 in Zhurihe(Inner Mongolia), 4 in Chagxing (Dalian).
MAN has installed a 10 turbine wind farm with 30kW Aeroman on Sijiao island (close to Shangai).
Italy has to supply some 300 kW turbines through a cooperation program .
China is the largest producer of micro (20-40 w) wind turbines in the world with 38 manufacturers producing 35 000 units a year .and with an installed number of machines of about 120 000 (roufly 4 MW) , 90% of which are used in the Inner Mongolia province by farmers and herdsmen as bactery charger, for ligthing, water pumping, butter churning , television.
The Chinese wind turbine technology is anyway growing . The Fuhou Power Equipment Factory (Fujian)as made a 55 kW turbine , installed at Pingtan Test site (Haitan island), and Fujian Machinery Plant has made a 200 kW .
Cooperation on technology is growing With European and USA.

-Russia (Siberia)
Wind energy potential in Siberia is huge . The annual average wind speed is 5 to 6 m/s in the area of Khabarovsk, 6 to 7 m/s in Sachalin , and to10 to 12 m/s in Kamchatschka. The wind share is about 50 % of renewable energy (Solar , wind , hydro) potential, that can cover the entire needs of rural esastern regions , exploiting it in a periobd of 12 years. At moment the numerous remote settlments rely on diesel generators.
Vetroenergetika , a company set up in1992 by the Russian Dalreo Group and the Dutch LMW , is planning to exploit wind energy in the East Siberia by special commercial aggreements to overcome the lack of Western money. Using the money earned in the West from sales of Siberian salmon , Dutch wind turbines can be bought. Up to now LMW , through Vetroenergetika, has supplied 55 small wind turbines to East Siberia .

-India
India has a potential of 25 000 MW wind energy generating capacity (Mathews, June 1992). The windy areas are more in the coastal areas of Gujarat, Tamil Nadu, and other southern regions (Maharashtra, Kerala,.), and in the mountainous part of internal regions(Madhya Pradesh, Himacal Pradesh,..).
In four districts of Andra Pradesh (Anantpur, Nellore, Chittoor, Cuddapah) there is a potetial of 830 MW, and plans are in progress for 90 MW to be installed in 13 different sites. Work are in progress for the completion of the Interim Wind Climatology Reports for all the states.
A power target of 1000 MW is considered for the year 2000 by the Minister of Power.
The DNES (Department of Non conventional Sources) has a target of 400 MW within the the the period of 8th Plan for India , still not approuved in 1992.
Total 1992 installed wind power is 50 MW , of which 38.3 MW has been commissioned supplying 60 TWh in 9 mounths of 1991. Fig. 20 a,b reports the Indian wind farms and locations.

DNES is developing indian wind technology with the state owned BHEL(Bharat Heavy Electrical Ltd.). Two prototypes of 55, and 200 kW have been constructed with a good indian technological content. The 200 kW prototype is connected to the grid in kajatar in Tamil Nadu. A 200kW second unit is expected to be installed within 1992 at Lambda Gujarat.
85 MW for wind farms are proposed and partially funded by the GEF(Global Environmental Facility), the joint program of the World Bank and the United Nations. The total cost of the wind farm , estimated 125 millions USD, will be shared by GEF (13ml), IDA (International Development Associaton-15 ml), the Danish DANIDA and the Indian Gouvernment and other organizations(OECF of Japan, ..). The size of wind turbines will be 200 or 300 kW ; the supply of turbines will be after an International bid.
The sites of the wind farms will be in the states of Tamil Nadu, Andra Pradesh or Karnataka, where are proven resources.
A large manufacturing capacity is present in India for wind pumps . About 2800 units have been istalled during 1991 in 23 states with support of DNES.
Hundred wind bactery chargers were put in operation. Other small unit (5kW) have been installed in West Bengal, In Lakshadweep, and Ladakh.

AUSTRALIA
-Australia
The danish Nordex has supplied a 150 kW To the town of Coober Pedy (South) and is partially funded by government. About 500 MW of wind power integration can be obtained with the 500 to 1000 MW of Diesel electricty generators spread in remote areas of the continent.
-New Zeland
Wind Potential is good ; mean annual speed of 10 m/s can be found in many area of the islands. The best areas are in the North and in the South.
Electricorp Production , the New Zealand utility, is planning wind energy applications to the grid . A medium sized wind turbine will be tested close the cappital city , Wellington

AFRICA
-South Africa
Wind resourse is good. National grid applications are considered feasible . At moment preference is given to the integration of small grid with diesel generators to be fed by small wind farms. Costs look promising(Fig. 22).
Low cost wind charger 150 W for education TV or wind pumps for remote applications are designed and built in South Africa.There are many units in the country. A special 1 kW Savonius turbine has been developed by the South African Plant and Engineering for the above application.

-Somalia (See Appendix C)
-North African countries (Egypt, Libya, Tunisia, Algeria , Marocco)
(See Wind Energy in the Mediterranean)

PERSPECTIVES
On march 1993 it was held in Travemunde (Lubeck-Germany) EWEC 93 , the Wind Energy Conference organized by the two General Directions (XII Sciense,Research and Development and XVII Energy) of the European Communities.
EWEC 93 gives the most up to date picture of wind energy technology, economics, applications, market in Europe and generally in the World considering the partecipation of 600 delegats, rapresenting 30 countries. Following specific trends are given for technology,market and for national and international programs according this conference

and oher sources of informations.

-Technology

*Horizontal axis machines are the most used with metal tubular towers, up wind.

*The number of the blades is more frequently two for large , two/three fo medium sized turbines, even if monoblades are available for both sizes.

* The trend for medium sized wind turbines is the range 400-750 KW/ unit with rotor diameter 35- 45 m

*The trend for large size wind turbines in the Europe and USA is now in the range 1-1.2 MW /unit with rotor diameter of 45-60m ; many protypes are under advanced phase of development.

The D.G.XII E. C. is promoting the development of the above large sized turbines trough the WEGA I and II program , considering this size more appropriate for the utilization of the available sites.

-Market

*The most commercial medium sized turbines are in the range of 30-45 m rotor diameter , 300- 600 kW.

Development of the annual sales of grid connected wind turbines with the actul sales up and including 1987 is shown in Fig. 23.

The international market is shared mainly by the Danish, Dutch and USA companies . In it is shown the Danish export 1991 1992 for a total of 930 turbines , over 100 power rating, with a total power of 215 MW.

Fig. 24

Curacao, Netherlands Antilles, the Caribbean.

3 NEWECS-45 near Medemblik (nr 13 on map), owned by PEN, the utility of the province of Noord-Holland.

Another NEWECS-25 unit was operated near Borssele by the utility of Zeeland. The machine was abandoned in 1989 because the operation and maintenance became too expensive as a result of regularly appearing failures.

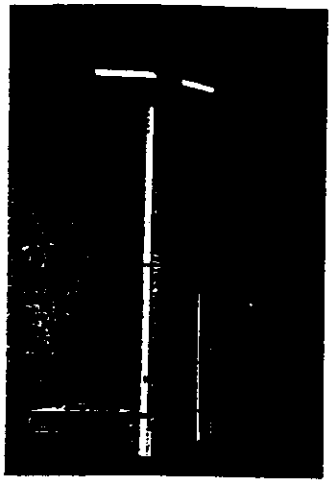
The brief specifications of the NEWECS-series are given in Table 7.

NEWECS-25 at Schiedam and Curacao.

These machines are in routine operation.

NEWECS-45 NEAR MEDEMBLIK

Since the comprehensive measuring programme (NOW and CEC DG XVII) had been concluded at the end of 1988, the turbine is in routine operation.



Three, 15.7 m diam, 75 kW Lagerway turbines at Zilpe.

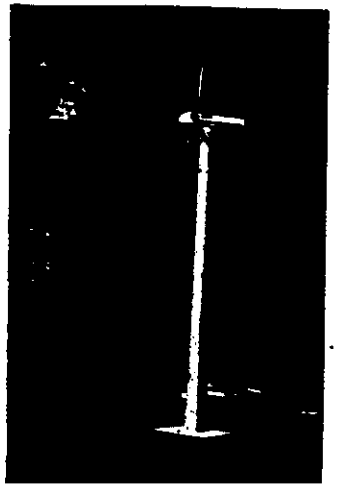


Table 7 – Specifications of NEWECS-25 and NEWECS-45

		NEWECS-25	NEWECS-45
Rated power	kW	300	1000
Rotor diameter	m	26,5	45
Hub height	m	22/35	60
Power control		full span blade pitch	full span blade pitch
Rotational speed	rpm	58 – 72	36 – 45
Optimum tip speed ratio		8	8
Blades : number		2	2
material		GRP	GRP
airfoil		NACA4412 to 4424	LS(1)-0417 to LS(1)-0421
weight	kg	600	2500
Masses: tower	ton	14/28	65
nacelle (incl rotor)	ton	13	35
Tower type		Tubular steel	Tubular steel
Conversion system		AC-DC-AC	AC-DC-AC

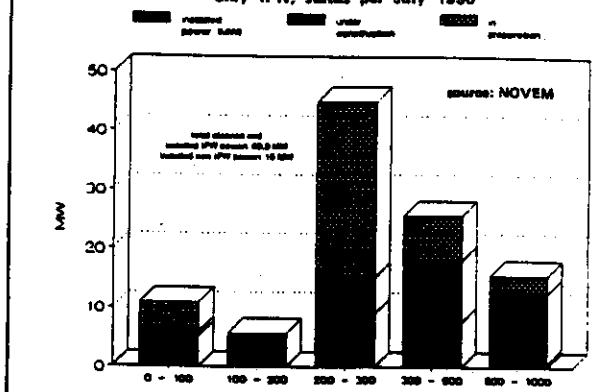


Figure 1 – Installed power per turbine (kW)

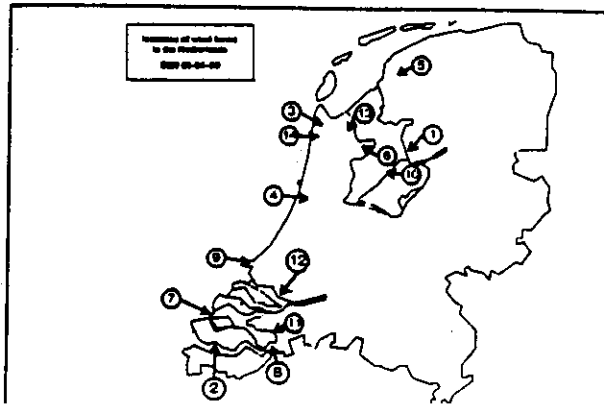


Table . Comparison of power demands and extraction limits. (Quads per year)

GLOBAL	
Power demand—1980	300
Extraction limits	
• Wind power	4,000
• Hydropower	120
• Geothermal power	6
• Tidal power	2
UNITED STATES (48 contiguous)	
Power demand—1980	60
Extraction limits	
• Wind power	60

Fig. 1

Lines of equal potential power output at various oceanic sites.

Developed by Sverre Petterssen, largely based on fifty years of United States Weather Bureau Records from ships at sea.

Outputs are stated in kilowatt-hours per kilowatt per year from a 1250-kilowatt turbine, 175 feet in diameter. The annual output of a turbine operated continuously at 100 percent capacity would be 8760 kilowatt-hours per kilowatt (24 hours per day for 365 days).

WINDY CONTINENTAL REGIONS

North America
- Labrador and Maritime Provinces of Canada
- New England States
- Great Lakes Area
- Great Plains Area
- Pacific Coast
- Alaska

South America
- Andes

Europe
- Alps of Central Europe
- Apennines of Italy
- Guadarramas of Spain
- Pyrenees of Spain and France
- Carpathians of Poland

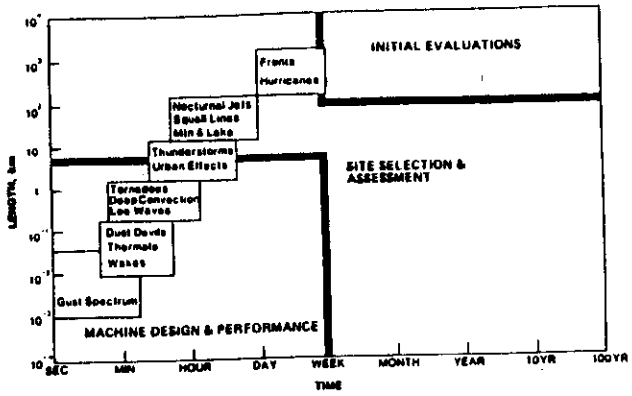
Asia
- Urals of Russia
- Himalayas of India and Tibet
- Deccan of India
- Kamchatka Peninsula of Russia

WINDY ISLANDS AND COASTS

Classified by Annual Output in Kilowatt-Hours per Kilowatt*

Region	Output in Kwh./Kw.								
	Over 6000	5000 to 6000	4500 to 5000	4000 to 4500	3500 to 4000	3000 to 3500	2500 to 3000	2000 to 2500	Less Than 2000
North Atlantic Ocean		Iceland	Faeroes Ireland Scotland Shetlands Norway	Azores Bermuda	Devonshire Wales	Cape Verde Island Martinique Porto Rico	Trinidad Aruba St. Martin	Cape Hatteras Madeira Nantucket Newfoundland Nova Scotia Santo Domingo	Bahamas Cuba Haiti Jamaica St. Martins Colon
South Atlantic	Sandwich Is. South Georgia	Falkland Is. Gough	Tristan da Cunha			Ascension St. Helena	Fern. de Noronha So. Africa	St. Paul	
North Pacific Ocean			Aleutians	Kamchatka Kuriles	Japanese Island	Formosa Palmyra		Hawaii Philippines	Guam
South Pacific Ocean	Auckland Campbell Macquarii	Bounty	Tasmania Ware-kauri	Chile New Zealand	Australia Lord Howe	Norfolk Ryukus	Kirmadec New Caledonia	Easter Fiji Gilberts Juan Fernández Luisiades Malden Marquesas Marshalls New Hebrides Pitcairn St. Felix Sala-y-Gomez Tonga	Samoa Society Is. Santa Cruz
Indian Ocean		St. Paul		Mauritius	Cocos		Madagascar	Ceylon Socotra	Andamans Seychelles Tachago

*Based on a 1250-kilowatt turbine, 175 feet in diameter. If a turbine operated continuously at 100 percent of capacity, the annual output would be 8760 kilowatt-hours per kilowatt (24 hours per day for 365 days).



The time and space scales important to wind energy development.

Source: Hardy and Walton, "Wind Energy Assessment," presented at Miami International Conference on Alternative Energy Sources, Dec. 1977.

Fig. 2

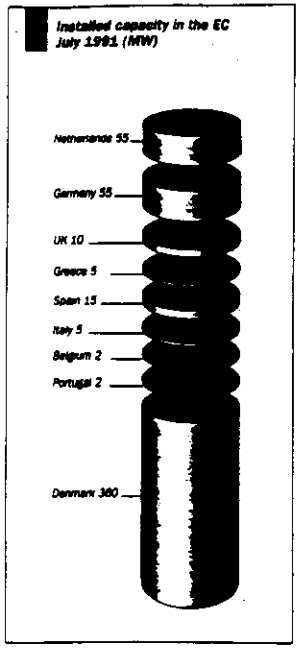


Fig. 4

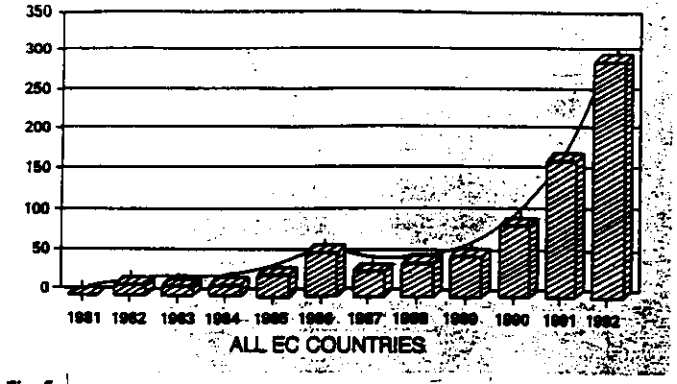


Fig. 5 *Trend of the EC wind energy market.*

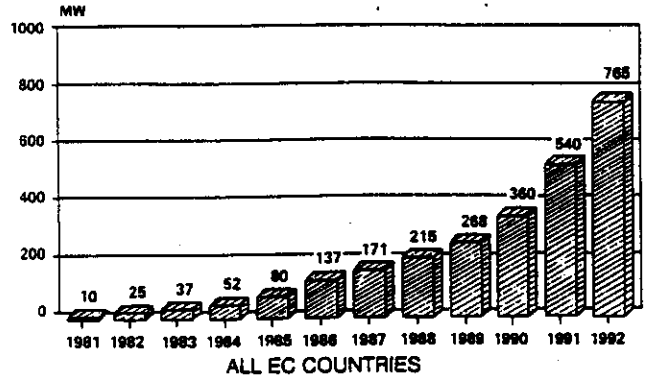


Fig. 6 *Evolution of the wind energy installed capacity in the EC Member States.*

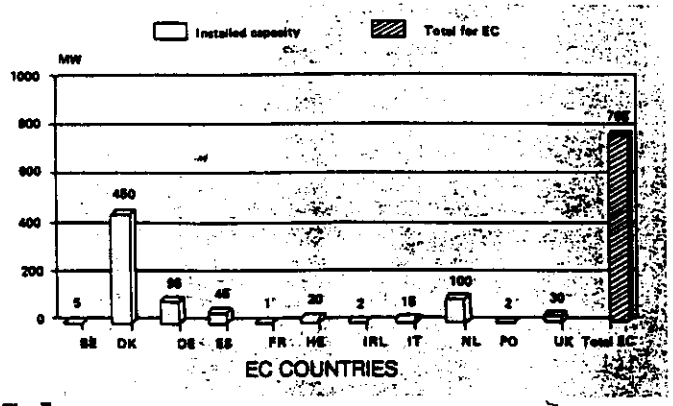


Fig. 7 *Wind energy installed capacity per EC country.*

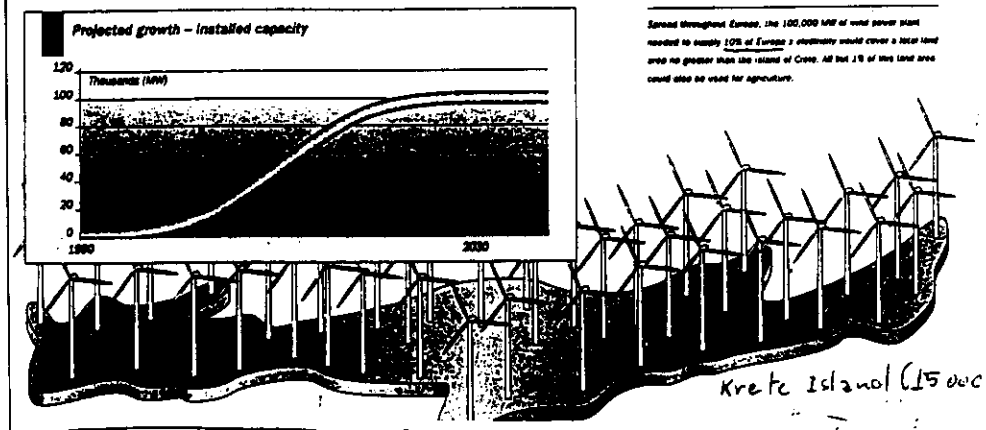
4,000 MW by the year 2000
11,500 MW by the year 2005
25,000 MW by the year 2010 and
100,000 MW by the year 2030.

The wind energy goal for 2030 establishes a long term scenario for the development of wind power in Europe, the timescale of which can be shortened if necessary.

Fig. 9

1 One Megawatt (MW) is the equivalent of 1,000 kilowatts (kW). A constant power output of 1 MW for two hours generates two Megawatt hours (MWh) of energy or 2,000 kilowatt hours (kWh). A household of four averagely uses 12 kWh in a 24 hour period.

Spread throughout Europe, the 100,000 MW of wind power plant needed to supply 10% of Europe's electricity would cover a total land area no greater than the island of Crete. All but 1% of this land area could also be used for agriculture.



Kreta Island (15 000 Km²)

	Capacity erected in 2000		Capacity erected in 2010
	1993		
België/Belgium	6	50	100
Denemarken/Denmark	520	1000	3000
Duitsland/Germany	220	500	1000
Groot Brittannië/Great Brittain	131	500	1000
Griekenland/Greece	26	400	1000
Italië/Italy	20	300	1000
Nederland/The Netherlands	120	1000	2000
Spanje/Spain	57	300	1000
Totaal/Total	1108	4050	10100

Fig. 8

Vooruitzichten ten aanzien van het geïnstalleerde windturbine vermogen in de Europese Gemeenschap. (CEG/DG XVII)

Forecast of erected wind turbine capacity in the European Community (CEG/DG XVII).

Progress to date
As of 1.2.93

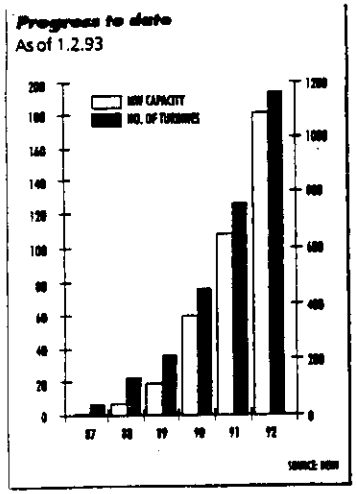


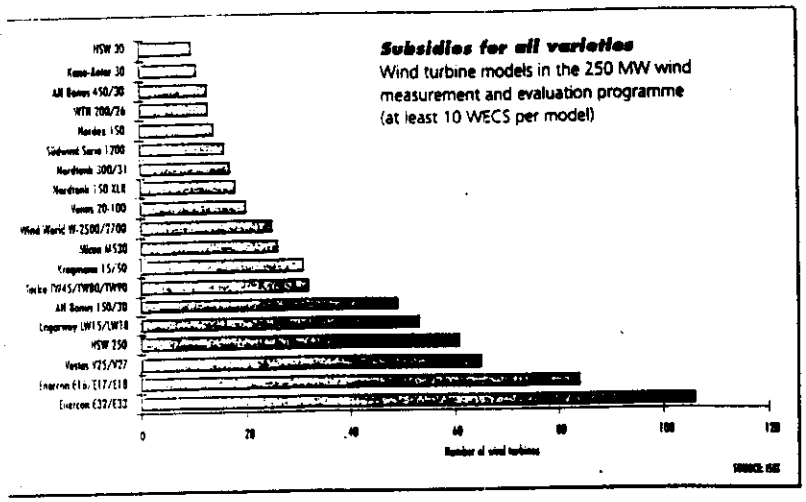
Fig.10

Planning ahead
Federal 250 MW programme

Year	MW*
1993	50MW
1994	20MW
1995	20 MW
1996	10 MW

*The annual MW targets are based on net generating capacity in winds of 10 m/s, the 250 MW on nameplate rating.

Fig. 12



Subsidies for all varieties
Wind turbine models in the 250 MW wind measurement and evaluation programme (at least 10 WECS per model)

Fig. 11

Behind it all
Categories of developer

Private persons	43.3%
Small companies	30.4%
Farmers	22.2%
District councils	3.5%
Other	0.7%

Fig. 13

State by state guide

No. of turbines and subsidy levels

STATE	NO. OF TURBINES	CAPITAL SUBSIDY*
Schleswig Holstein	504	14-17%
Lower Saxony	374	14-17%
North Rhine-Westphalia	188	0**
Mecklenburg-Vorpommern	40	20%
Rhineland-Palatinate	24	25%
Bavaria	15	30-50%
Hesse	14	50%
Sachsen-Anhalt	11	30
Baden Wuerttemberg	10	individual
Bremen	10	25%
Hamburg	7	30%
Saxony	7	30%
Berlin	4	0
Brandenburg	3	30-50
Saarland	0	20%
Thüringen	0	20
Total	1211	

Included in 250 MW programme

STATE	NO. OF TURBINES	INSTALLED CAPACITY
Schleswig Holstein	276	57.20
Lower Saxony	241	38.95
North Rhine-Westphalia	126	10.52
Mecklenburg-Vorpommern	30	5.55
Rhineland-Palatinate	16	1.80
Bavaria	6	0.16
Hesse	11	1.55
Sachsen-Anhalt	7	0.56
Baden Wuerttemberg	2	0.38
Bremen	3	0.75
Hamburg	4	0.36
Saxony	7	1.16
Brandenburg	1	0.30
Total	729	119.24

*Subsidies are often conditional—see text. **Until this year 25%.
(See map on survey cover for total capacity per state. Combined total 183 MW on 16.2.93)

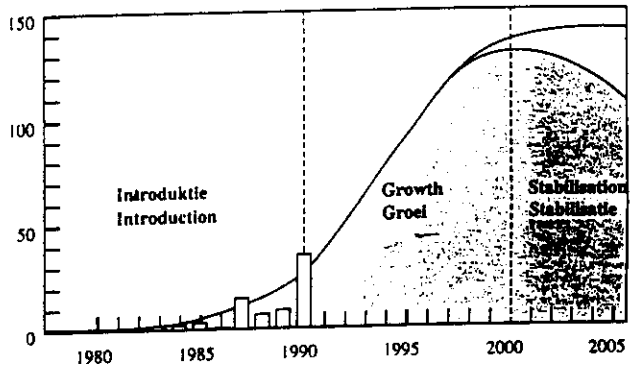
Fig. 14

Windenergie in Nederland

Wind energy in the Netherlands

Gewenst tempo voor het op te stellen windvermogen met het oog op de verschillende implementatiedoelstellingen.

Windturbine-afzet in MW per jaar/Wind turbines to be placed MW/year



☐ Gewenste nieuwbouw/Desired new construction
☐ Inclusief vervanging/Inclusive replacement
☐ Gerealiseerd/Realization

Fig. 15

Desired rate of wind power development with an eye to the various implementation objectives:
- 400 MW in 1995
- 1000 MW in 2000
-2000 MW in 2010

WIND ENERGY POTENTIAL –
With environmental and urban exclusions

	Class 3			Class 4-6		
	Thousand Megawatts	Billion kWh	Multiple of State Demand	Thousand Megawatts	Billion kWh	Multiple of State Demand
Illinois	25	60	0.45	0	0	0.00
Indiana	5	11	0.11	0	1	0.01
Iowa	579	1,374	44.87	245	713	23.27
Kansas	914	2,171	59.33	436	1,278	34.93
Michigan	149	353	3.71	6	18	0.19
Minnesota	395	938	21.26	461	1,337	30.32
Missouri	139	330	5.63	0	1	0.02
Nebraska	902	2,143	95.22	205	606	26.90
North Dakota	334	793	26.30	934	2,739	90.86
Ohio	72	170	1.36	2	4	0.04
South Dakota	753	1,789	217.94	517	1,524	185.68
Wisconsin	139	329	6.75	1	3	0.07
Midwest	4,405	10,461	14.32	2,807	8,225	11.26

Union of Concerned Scientists, Powering the Midwest: Renewable Electricity for the Economy and the Environment, 1993.

Fig. 16

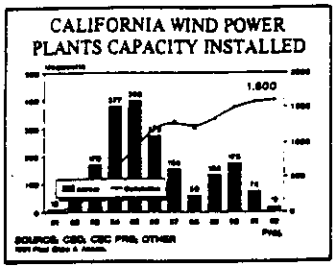
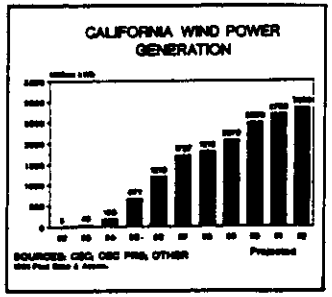
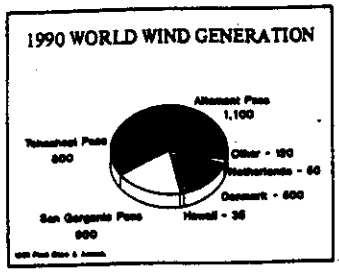


Fig. 17





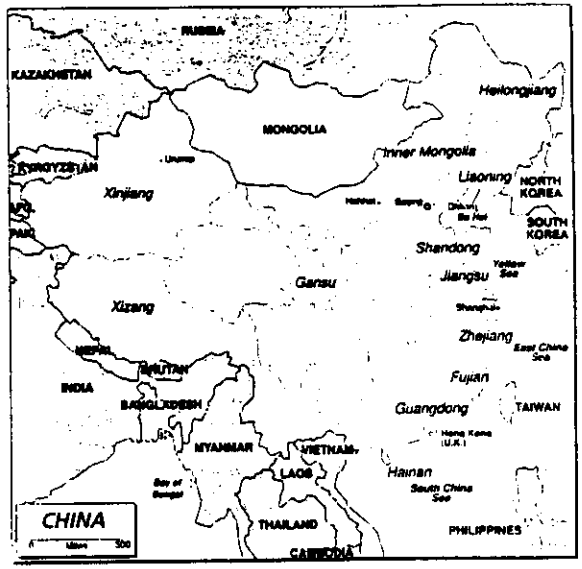
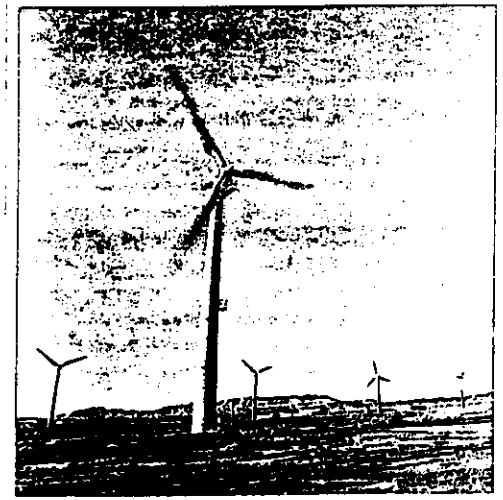


Fig. 18



Flagship projects Part of the Dabancheng wind farm of Bonus (above) and Nordtank turbines near Urumqi, capital of Xinjiang.

Fig. 19

WIND FARMS : Vital Statistics

Location	Aggregate Capacity (MW)	Number of Units x Size (kW)	Status
Mandvi Gujarat	1.10	2 x 110 3 x 22 14 x 55 1 x 15	Operational January 1988
	0.60	2 x 250	Commissioned Aug 1989
Tuticorin Tamil Nadu	1.10	10 x 55 6 x 55 4 x 55	Operational January 1988 November 1988 January 1989
Okha Gujarat	0.55 0.55	10 x 55 10 x 55	Operational March 1988 To be commissioned
Dangarh Maharashtra	0.55 0.55	10 x 55 10 x 55	Operational May 1988 Operational Dec. 1988
Puri Orissa	1.10	10 x 55 5 x 55 2 x 55	Operational May 1988 January 1988 March 1988
Kayathar Tamil Nadu	1.35 0.40 1.00 6.00	15 x 90 2 x 200 5 x 200 30 x 200	Operational April 1988 Operational June 1989 Commissioned 1988 Commissioned April 1988
Okha-Madhi Gujarat	1.80 1.80	12 x 150 5 x 300	Commissioned Aug. 1988 To be commissioned
Tirumala Andhra Pradesh	0.55 0.55	5 x 110 5 x 110	Operational June 1989 Under installation
Tuticorin Kayathar	0.55	5 x 110	Operational January 1989
Kharda Madhya Pradesh	0.90	9 x 100	Operation 1990
Lamba Gujarat	10.00	50 x 200	Operational April 1990
Tuna Gujarat	0.6600	11 x 55 1 x 50	Under installation
Muppandal Tamil Nadu	4.00	20 x 200	Operational April 1990
Muppandal (Private Industry) Tamil Nadu	1.80	5 x 300	Operational April 1990
	41.4655 MW		

Fig. 20

WINDFARM PROJECTS OF GUJARAT

Location	Year of installation	Installed Capacity	No. of Machines	Size of Machines	Total generation *(KWH)
Okha	March '88	0.55 MW	10	55 KW	4321784
Chhaniyadhi	August '89 Jan. '92	1.8 MW 1.8	12 6	(120100 KW (61300 KW	4483291 411088
Lamba	April '90	10.00 MW	50	200 KW	24222080
Mandvi	Jan. '88	1.10 MW	14 2 2 2	55 KW 110 KW 15 KW 22 KW	10,088,802.00 (upto Apr. '92)
	Sept. '89	0.60 MW	2	250 KW	1,388,036.00 (upto Apr. '92)
Tuna	May '88 June '88 Dec. '91	0.05 MW 0.055 MW 0.55 MW	1 1 10	50 KW 55 KW 55 KW	447,488.00 (upto Apr. '92)

* Upto 31st May, 1992.

WINDFARM DEVELOPMENT IN INDIA

The first generation of wind turbines was installed in 1986 in the western most coastal areas of the State of Gujarat in India. A private entrepreneurial group, Western India Erectors, with financial assistance from Gujarat Industrial Investment Corporation, had installed these machines (made by Micon of Denmark) at Mandvi under the name of Gujarat Wind Farms Limited. Immediately after this, again in 1986, Gujarat Electricity Board also erected a windfarm comprising ten 55kW rated Vestas turbines.

A second generation of wind turbines with individual Micro processor based control systems and a central windfarm

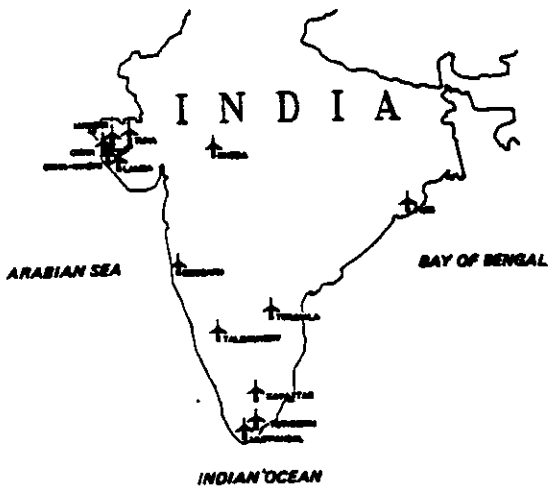


Fig. 21

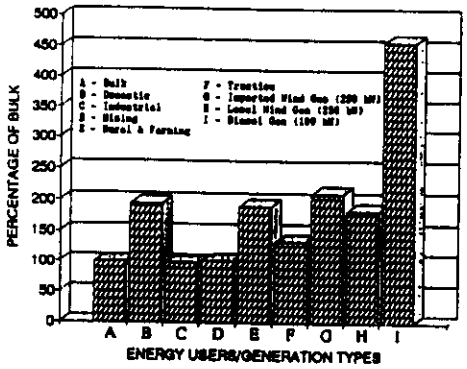
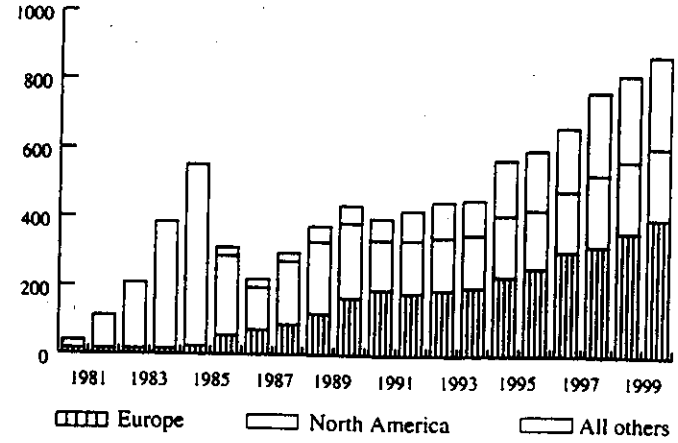


Fig.22

Figure 2 Bar graph showing a cost comparison of energy sources where the comparison is done as a percentage of t bulk generating costs. This is a mix of utility selling c and own generating costs eg. mining is utility and diesel wind is own.



Jaarlijks aantal verkochte windturbines tot en met 1987 en een "base case"-voorspelling tot aan 2000. (Jaras; Wind Energy 1988)

Annual wind turbine sales up to and including 1987 and a base case forecast up to the year 2000 (Jaras; Wind Energy 1988).

Fig. 23

Fabrikant/ Manufacturer	Land/ Country	Aantallen turbines (t/m 1989) Number of turbines (up to 1989)
US Windpower	US	3500
Mitsubishi	Japan	300 - 400
Vestas/DWT	DK	2800
Micon	DK	1600
Bonus	DK	1250
Nordtank	DK	1100
Danwin	DK	300
Windworld	DK	102
HMZ/Windmaster	B/NL	269
Nedwind-Bouma	NL	58
Nedwind-Newinco	NL	68
Lagerweij	NL	> 100
Holec	NL	19
MAN *	D	321
Enercon	D	35
Elektromat	D	15
WEG	GB	27

* Fabrikanten die hebben aangekondigd te zullen stoppen.

* Manufacturers that have announced to stop.

Overzicht van de belangrijkste windturbinefa-

Overview of the main wind turbine manufactu-

Radius R = 6378 km Surface S= 4πR = 510 million kmq
Total solar flux (annual average): 350 W/mq = 350 MW/ kmq
Solar flux transformed in wind power, 2% =7 MW/kmq

Total wind energy in a year: 7 MW/kmq x 510 ml kmq 8 760 h =
= 31. 27 ml TWh = 106 000 Quads

Extractable wind energy near Earth surface 0.38 x 106 000 = 40 000 Quac

Total wind energy available by wind turbines 0.1x40 000 = 4000 Quads
or about 1 million TWh per year

$1\ Quad = 10^{15}\ BTU = 293\ TWh$

Table 1 Comparison of power demands and extraction limits.
(Quads per year)

GLOBAL	
Power demand—1980	300
Extraction limits	
• Wind power	4,000
• Hydropower	120
• Geothermal power	6
• Tidal power	2
UNITED STATES (48 contiguous)	
Power demand—1980	60
Extraction limits	
• Wind power	60

Learning by their mistakes
Wise and unwise investments in aid

COUNTRY/ LOCATION	SIZE MW	NO., SIZE AND MAKE OF WIND TURBINES	START/ FINISH	DANIDA INVESTMENT	COST/ KWH	INTERNAL RATE OF RETURN (IRR)
India						
Lamba (Gujarat)	10	50 x 200 kW Vestas				
Kayathar	6	30 x 200 kW Micon	1986-1982	$27 million	$0.074	2.0-8.0%
Muppandal (Tamil Nadu)	4	20 x 200 KW Micon				
China						
Dabancheng	1.95	13 x 150 kW Bonus	1986-1981	$3 million	$0.08	0-2.0%
Cape Verde						
Praia	0.010	2 x 55 kW Vestas				
*Assomada	55/40	1 x 55 kW Bonus	1981-1989	$2.2 million	$0.14	0-2.0%
Somalia						
Mogadishu	0.22	4 x 55 kW Vestas	1984-1990	$3.1 million	$0.15	not given

Fig. 3

Country Reports

Canada

The Canadian annual budget for wind energy R&D is around 0.7 to 1.0 MCAD. Two test facilities are supported: the Atlantic Wind Test Station (AWTS) in Prince Edward Island and the Alberta Renewable Energy Test Site (ARETS) in Alberta.

Adecon Energy Systems is testing a 150 kW VAWT and is also assembling a 300 kW VAWT at their test site in Ontario. Hydro-Québec's research division, IREQ, is planning to set up a wind-diesel demonstration system at the AWTS, consisting of four 20 to 80 kW wind turbines and two 50 kW diesel generators.

The 500 kW Indal VAWT has completed several years of testing at the AWTS and has served its original R&D purpose. However, a recent problem in the lower bearing, and other intermittent maintenance requirements, may force a decision to dismantle the machine if continuing costs can not be balanced by revenues from the electricity generated into the Island grid.

In May 1991 a fatigue crack was discovered in one blade of the EOLE VAWT at Cap Chat, Quebec. The crack was repaired and the turbine was back in operation on 21 June. This large variable-speed turbine, nominally rated at 4 MW, was derated to approximately 2.5 MW after commissioning in March 1988 in order to avoid a structural resonance near full power. By the end of February 1992, 9140 MWh of electricity had been generated in somewhat more than 16.000 hours of generating time. Since beginning

automatic operation the overall availability has been about 93%.

Two windfarms are under construction in southwest Alberta: one at Cowley Ridge consisting of ten 100 kW and twenty 400 kW U.S. Windpower turbines, and the other at Pincher Creek, which will have ten 150 KW Adecon Adecon VAWTs. Both windfarms will sell electricity to a local utility for about 0.05 CAD/kWh. Another 10 MW windfarm has been approved for construction in 1993 in the same area of Alberta, and Saskatchewan is examining proposals for a 10 MW windfarm in that province.

Denmark

During the period 1980 - 1990, the total Danish government expenditure on wind energy was about 615 MDKK (about 95 MUSD or 78 MECU). About half of this was spent on subsidies, which were initially 30% of investment cost but have gradually been reduced to zero. Present annual allocation for R&D is about 10 MDKK.

The 650 kW stall-controlled Nibe A is being re-commissioned with new cantilevered wooden blades. Nibe B has had pitch-controlled wooden blades since February 1984 and has operated for about 25.699 hours and has generated 7116 MWh of energy. The five 750 kW ELKRAFT turbines, located near the Masnedø power station on the south coast of Zealand, have largely the same specification as Nibe B, and were installed late in 1986. Four of the five have each accumulated between about 16.700 and 18.000 hours. One was destroyed by fire in October 1987, but has been rebuilt and returned to service. The 2 MW Tjæreborg wind turbine is an upscaled version of Nibe B with 60 m rotor diameter and hub height. After a gearbox replacement, the machine is now operating well and had accumulated 6779 hours and produced 444 MWh of electricity by the end of 1991.

By the end of 1991, the total number of grid-connected small-scale wind turbines, privately or utility owned, was 3218, with a total installed capacity of 418 MW. The energy generated in 1991 was 740 GWh, corresponding to 2.3% of the Danish electricity consumption. The average cost of energy for eight wind farms in the ELSAM area of Jutland is equivalent to 0.0563 ECU/kWh assuming 20 years lifetime and 5% real interest rate, including O&M costs. The O&M costs are 0.0085 ECU/kWh, based on experience.

The first Danish offshore wind farm was commissioned in mid-1991 at Vindeby, north-west of Lolland. The wind farm has 11 turbines, each rated at 450 kW. The turbines are in two rows in water depth varying from 2 to 6 m, between 1200 and 2400 m from the shoreline. The cost of energy of 0.08 ECU/kWh is estimated to be 50% higher than for an average onshore site.

There is no sign of a decrease in Danish wind energy activity. Wind turbines are being sold to private owners at the same rate as previously, and the present 100 MW utility agreement will be followed by another 100 MW agreement to be implemented before the end of 1993.

Germany

As part of investigations into wind energy potential in Germany, a new wind map has been prepared by the German Meteorological Service. It displays annual mean wind speeds at 10 m height, averaged over a ten-year period of observations. The highest mean speeds, between 6.0 and 6.9 m/s, occur along the North Sea coast, but mean speeds up to about 5.9 m/s also occur along the northern coast of Eastern Germany.

The group of three 640 kW single-blade MON 50 at Wilhelmshaven continues operation and tests. A MON 50 is to be installed at Geesthacht near Hamburg to assist in supplying electricity for a pumped storage plant. First rotation is expected in late 1992.

By the end of October 1991 the 1.2 MW WKA-60 on Heligoland had operated for 9300 hours (grid-connected 4050 hours) since March 1990 and generated 1900 MWh. This turbine operates in parallel with the island's 2x1.7 MW diesel units. The sister unit at Cabo Villano, Spain (known as AWEC 60) required a period of service following a blade crack in May 1991. The WKA-60 II at Kaiser-Wilhelm-Koog had its first rotation on September 1991.

The tower for the 3 MW Aeolus II at Wilhelmshaven had been erected by November 1991, and the turbine is to be installed in Spring 1992. This is the sister unit to the Swedish Näsudden II machine, and is part of the PreussenElektra wind energy programme. Several other large and medium-sized turbines are being developed by German companies for installation in 1992.

The 250 MW programme, which was originally aimed at 100 MW, has been a great success: by the end of 1991, 2888 applications for subsidy have been filed, representing a normalized power of nearly

Windpark in Nord-Friesland, Germany as example of 250 MW Wind Programme.

600 MW since the beginning of the programme in 1989. Applications for 79 MW at 10 m/s wind speed (P_{10}) had been approved, of which 34 MW (P_{10}) are in operation. Meanwhile, by the end of March 1992, 93 MW (P_{10}) had been approved with 48 MW (P_{10}) in operation.

By the end of 1991, a total of more than 700 wind turbines were estimated to be operating in Germany with a total installed power of about 96 MW. Due to the success of the 250 MW programme, the total installed (rated) power exceeded 110 MW.

Italy

The main wind energy activities in Italy are carried out cooperatively between two state-owned organizations, ENEA (the Board for New Technologies, Energy and the Environment), ENEL (the National Electricity Board), and the Italian wind turbine manufacturers.

The main manufacturers are WEST and Riva Calzoni, who have developed three machine prototypes: the MEDIT (225 kW) and GAMMA 60 (1500 kW) by WEST, and the Riva Calzoni M 30 (200 kW). Riva Calzoni has also begun the design of the M 55 (800 kW) based on the M 30 concept. WEST has started production of the MEDIT 320 turbine, an industrial model based on the 225 kW prototype.

Since April 1991 at the Alta Nurra seaboard site, comparative tests have been carried out on a 300 kW MS-3 machine (Wind Energy Group, UK), a Windane 34 turbine (Vestas - DWT, Denmark), and the MEDIT and M 30 prototypes. At the end of 1991, a MEDIT 320 unit was also installed. In addition, the GAMMA 60 1.5 MW prototype was installed at Alta Nurra in April 1992. After some delays, construction contracts have been assigned for a new mountain-region test site at Acqua Spruzza in the Apennines, following approval of all building permits by local authorities. The construction phase is expected to be completed in the summer of 1993.

A first windfarm module of 1.5 MW, which includes four MEDIT 320 and three 30 kW AIT-03 units, has been put into operation by WEST in the Campania region near Naples. A study commissioned by ENEA to Riva Calzoni of a possible 10 MW plant in northern Italy has led to the pinpointing of ten possible sites where wind measurements are now being made in cooperation with ENEL. In ENEL's programme the first 10 MW windfarm will be located on Monte Arci, a mountain ridge near the coast of Sardinia. Construction should start in the second half of 1992. A second windfarm is planned for the Apennines, consisting of 32 MEDIT and M 30 units.

Japan

The New Energy and Industrial Technology Development Organization (NEDO) was established in 1980, supported by the Japanese government. In its early years it promoted projects such as development of a 100 kW-class pilot plant.

In 1991 NEDO started the conceptual design of a 500 kW-class wind turbine. Detailed design is scheduled to follow during 1992 - 1993, manufacture and installation in 1994 - 1995 and operation in 1995. The wind turbine is expected to be pitch-controlled with a 38 m diameter upwind three-bladed GRP rotor. The machine will have an induction generator and a 38 m monopole tower.

NEDO is also studying utilization technology for wind systems, aiming at developing control technology and

The FLEXHAT flexteeter.

obtaining operational data for wind farms. Two 250 kW and six smaller units will be built and operated on Miyako, Okinawa, during 1991 1995.

In another project of several years duration, NEDO is measuring and assessing wind wind conditions in order to find suitable sites for wind systems, and to estimate the amount of wind energy available in Japan.

NEDO's budget for the wind energy programme is equivalent to 6.5 MUSD for 1992.

In the area of basic research, studies have been carried out since 1978 at the Mechanical Engineering Laboratory (MEL), Tsuruba, on rotor aerodynamics, control systems, noise and vibration, and airfoil sections. Operational tests are performed on a small experimental wind turbine.

The Netherlands

Wind energy development in the Netherlands has accelerated rapidly since 1986 with the initiation of the 1986 - 1990 Integral Wind Energy Programme (IPW), which took into account the increasing concern for the environment. During this period, energy prices have risen less than expected, and although the cost of wind energy technology has been reduced, government support continues to be necessary for further application. Therefore, NOVEM (Management Office for Energy Research and the Environment) has been asked to develop a support program known as TWIN, which coordinates government-sponsored wind energy activities over the five-year period 1991 - 1995. The total costs of the programme, exclusive of subsidies for investments and feasibility studies, are estimated at more than 42 MNLG (≈23 MUSD). A large part of this is directed to industrial product and technology development (15 MNLG each), with lower amounts to implementation and market development (7.5), offshore applications (3.0) and technology transfer (1.8).

Market stimulation is achieved by subsidizing part of the commercial projects. The subsidy amounted to 37 MNLG for 1991 and 40 MNLG for 1992. There is some delay in the 250 MW plan for the utilities: 9 MNLG of the 1991 budget was not used. By the end of 1991 the installed power was 80 MW, with 20 MW under construction and 40 MW in the planning stage. The 1992 budget of MNLG 40 is allocated to 52 MW: 22 MW utilities and 30 MW private windfarms and single windturbines.

The Dutch industry now produces windturbines up to 500kW. A 750kW Windmaster prototype is currently in operation. The 1 MW Nedwind prototye will be in operation in 1993. The emphasis of the industrial R&D is on further development of existing turbines.

The FLEXHAT flexteeter research rotor has been succesfully tested at ECN's 25m HAWT. The use of flexible components can reduce the costs per kWh by 30%. The FLEXHAT programme is now being reviewed and development of a prototype should start by the end of this year.

Norway

The Norwegian wind energy programme is managed by the Norwegian Water Resources and Energy Administration (NVE). Its 1991 budget was 3.4 MNOK (0.5 MUSD) for the R&D Programme and 8.4 MNOK (1.3 MUSD) for the Introduction and Demonstration Programme.

Norway has a large wind energy potential along the coast, estimated to be about 12 TWh per annum in the cost range 0.35 - 0.65 NOK/kWh. Due to favourable regulation facilities of the Norwegian hydro power system, it can absorb a considerable amount of wind energy without serious problems. The near-term goal of the Introduction and Demonstration Programme is to develop wind power installed capacity of about 4 MW by the end of 1992.

The first Norwegian wind farm, consisting of three 400 kW units, started operation in early October 1991 at Vikna, north of Trondheim. The installed cost was 12.9 MNOK, 50% of which was funded by the government. Two more 400 kW units were installed in 1991 in the Vesterålen Islands, west and north of Narvik. Present installed capacity is 2.9 MW. For the time being, new hydro projects can provide energy at an average cost about half of the development cost of wind power integrated into the distribution system, indicating that the utilization of wind energy in Norway still needs subsidies to be economically attractive to the utilities.

Spain

The year 1991 was a breakthrough for the utilization of wind energy in Spain. The construction of three windfarms was initiated: the 3 MW farm at Cabo Villano in the northwest corner of the Iberian peninsula, the 20 MW PESUR and the 10 MW E.E.E. windfarms in the Tarifa aren near the Straits of Gibraltar. Two additional windfarms were approved and are now in the planning stage: the 10 MW Jandia windfarm at Fuerteventura, Canary Islands, and the 4 MW Tortosa windfarm at the mouth of the river Ebro. In summary, a total of 33 MW of wind power capacity is under construction and will be operational during 1992.

The national renewable energy plan, PER-89, for the period 1989 - 1995 foresees about 100 MW of wind power by 1995. The total investments are estimated at 13.600 MESP (≈130 MUSD), of which slightly less than half is expected to come from public funds.

The largest wind turbine in Spain is the AWEC-60 1.2 MW project, which was conceived in 1985 by a Spanish-German consortium. It is the sister unit of the WKA-60 turbines at Heligoland and Kaiser-Wilhelm-Koog in Germany. The first rotation was in October 1989. At the end of February 1992 more han 2400 grid-connected hours had been completed for a total energy output of more than 560 MWh. In May 1991, a crack in the main spar of one blade was discovered. After repair the machine was put back into operation in October 1991.

An ambitious alternative National Wind Energy Programme has been presented to the Parliament to promote the development of wind energy and, among other targets, to install 1000 MW of wind energy systems by the year 2000.

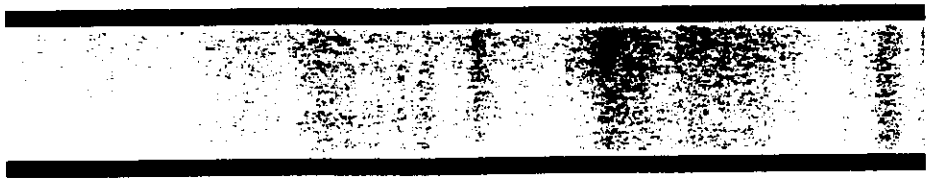
Wind energy R&D activities are continuing at public and private centres, the CIEMAT-IER being the main centre involved in various fields of research. Several projects are in progress, mainly in the areas of assessment of wind potential, blades and composite materials, environmental studies, wake effects and wind-diesel systems.

Sweden

A new demonstration programme for wind energy was launched in Sweden in July 1991. A new national agency, NUTEK, combining the activities of three former agencies including the National Energy Administration, is responsible for the programme, which allows for a 25% investment subsidy on certified installations of minimum 60 kW. 250 MSEK (40 MUSD) have been allocated for a five-year period ending 1996, corresponding to an installed capacity of about 100 MW. By April 1992, 6 MW had been approved by NUTEK, including a 7x225 kW wind farm near Varberg on the west coast. At present the total installed capacity in Sweden is over 11 MW not including Maglarp and Näsudden.

The 3 MW Maglarp turbine had logged 23.373 hours on-line by 7 April 1992 and had generated 30.566 MWh. The contract with the Sydkraft utility expired at the end of 1991, but the utility will continue operation without government support.

Wind energy research is mainly carried out at universities and national research institutes. The Aeronautical Research Institute (FFA) is performing studies in aerodynamics, structural mechanics and other aspects of machine design. Basic wind research is carried out at the University of Uppsala and electrical machinery is studied at the Chalmers University of Technology, which also operates the wind turbine



test station on the island of Hönö off the west coast of Sweden.

The Wind Energy Development Programme of Vattenfall (formerly the State Power Board) has several elements. The 3 MW Näsudden II turbine is expected to be delivered in late summer 1992, with blades to be delivered at the end of the summer. A design and development study of a third-generation 3 MW turbine is scheduled to start in Summer 1993 together with Kvaerner Industries. As a second development line, a 400 kW stall-controlled variable speed wind turbine, designed by Nordic Wind Power, will be installed at the end of 1992 near Lysekil on the Swedish west coast. For comparison, a standard three-bladed 450 kW machine will be erected at the same site during Summer 1992. A design study of a second-generation advanced wind turbine in the 500 - 1000 kW rated power range is scheduled to start in mid-1992.

The 220 kW wind turbine that was installed offshore at Nogersund in 1990 has produced about 400 MWh during its first year of operation. The Blekinge project for the study of a large offshore windfarm was completed in 1991. The cost of energy was estimated at 0.76 SEK/kWh (=0.13 USD/kWh), which is not competitive with presently predicted energy generation costs in Sweden.

United Kingdom

The significant stimulus towards commercial exploitation of wind energy in England and Wales has been the introduction of the Non-Fossil Fuel Obligation (NFFO), by which utilities are obliged to buy a proportion of the electricity they need from renewable energy sources, such as wind power. Regional electricity companies had entered into contracts with some 49 projects with a total rating of 192 MW, at a price of 0.11 GBP/kWh, to be paid until the end of 1998.

The Wind Energy R&D Programme budget for 1991/92 was 6.2 MGBP as compared to 4.5 MGBP in the previous year. Priorities include the support and monitoring of wind farms, work to identify the potential for advanced design concepts, and the validation of concepts through full-scale testing.

A new company, National Wind Power Ltd (NWP), has been formed jointly by National Power plc, British Aerospace plc, and Taylor Woodrow Holdings Ltd to develop commercial wind farms under the NFFO. There have been delays in the approval of several proposed windfarms owing to public concern about such issues as noise and visual impact, but progress is being made. Construction of WindElectric's 4 MW windfarm at Delabole, Cornwall was completed late in 1991. Planning approval has been given to NWP's windfarm at Caemmes, Wales and contract negotiations for the joint DEn/NWP windfarm of 21x300 kW units at Cold Northcott, Cornwall were nearing completion at the end of 1991.

The testing of several large wind turbines continues in the UK. The WEG 60 m 3 MW LS-1 machine on Burgar Hill, Orkney was returned to service in December 1991, following a decision to modify the main brake by providing a parking brake only, since safe braking is still obtained by the two independent fail-safe pitch control systems for the blade tips. By the end of March 1992 its total running time was 4758 hours with a cumulative output of 6375 MWh.

The medium-sized 250 and 300 kW turbines at Burgar Hill are both operating. The Howden 750 kW machine on Susetter Hill, Shetland, is out of service while repairs are being made to the blade tips, which were damaged during a severe storm in December 1991. The Howden 1 MW turbine at Richborough, Kent, has performed well and is the subject of a monitoring campaign funded by DEn and the CEC. The 500 kW vertical-axis VAWT at Carmarthen Bay, Wales was taken out of service due to a blade failure in February 1991. It was found that the failure was caused by fatigue related to design error, and that there was no inherent fault with the manufacture or operational loads.

United States

The U.S. Department of Energy (DOE) wind energy programme is expanding. The FY 1992 budget is 21.6 MUSD, nearly double that of FY 1991. During 1990 the installed capacity increased by 10% and electricity generation from wind by 20% to 2.8 billion kWh annually. Wind generating capacity interconnected with utilities at the end of 1991 totalled approximately 1600 MW. Today's windfarms produce power at costs of 0.07 to 0.10 USD/kWh (at 6 m/s annual wind speed at 10 m height), nearly one-third of those of ten years ago.

A recent study completed by Pacific Northwest Laboratory found that adequate wind resources for cost-effective energy production are found in most areas of the United States. Nevertheless, wind energy still faces widespread barriers to utility acceptance, including transmission issues, intermittency, utility reluctance to adopt unfamiliar technologies, and costs that are still not competitive in many situations. The US federal wind technology pro-gramme has set its goal to assist utilities and industry in market development and to develop advanced wind turbine technology to be economically competitive in the mid-term marketplace.

The largest expansion in the DOE budget is in the Advanced Wind Turbine (AWT) Program which has two components: the Near-Term Product Developmenmt Project and the Next-Generation Technology Project. The first project began in FY 1990 with the award of three contracts to study advanced technology, and turbines incorporating these advances will be field tested in 1992/93.

The second project will begin in 1992, and the next-generation innovative machines are scheduled to be built and tested three to four years later. They are expected to be in the 250 to 750 kW range, and the goal is to achieve a cost of energy of 4 cents/kWh or less.

In the area of cooperative programmes with utilities and industry, a Utility Wind Interest Group for information dissemination has been formed by DOE and the Electric Power Research Institute (EPRI). Cost-shared technology programmes are also being started, for example to solve problems in existing wind farms and to encourage regional diversification.

By the end of July 1991, the world's largest wind turbine, the 3.2 MW Mod-5B in Hawaii continued to operate with high average capacity factor in the persistent winds at the site, and had generated 25,344 MWh during a total of 19,253 hours.

APPENDIX C

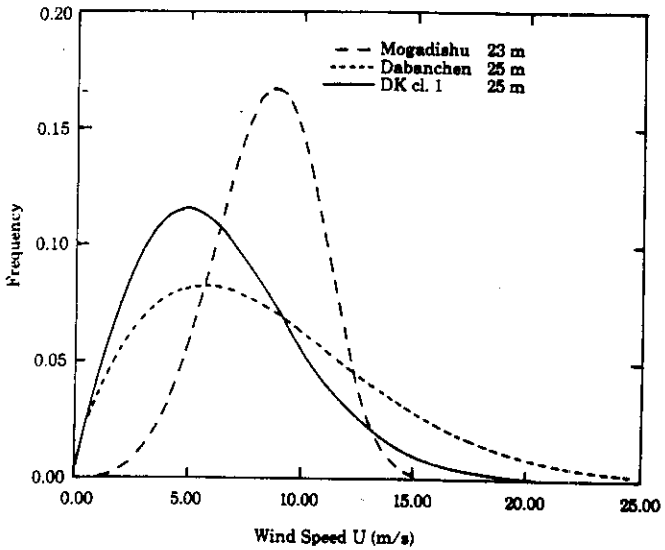


Figure 4. The wind speed probability density distribution at Mogadishu, Somalia, and Dabanchen, China, compared to the Danish roughness class 1.

1988 Totals		Mogadishu Wind Power Plant
kWh produced:	706,387	Installed capacity: 4×55 kW
		Date of installation: 27th August 1987
Runtime:	85.7%	
Capacity factor:	37%	
Overall eff.:	26%	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MWh	89.2	68.9	44.3	17.6	70.9	56.6	96.2	71.2	67.1	16.4	32.4	75.4
Time %	90.8	94.3	82.9	71.8	96.2	85.0	94.2	83.5	86.9	74.0	80.0	88.5

Table 2. Production statistics from Mogadishu Wind Power Plant, Somalia, 1988

Figure 5. Dabanchen Wind Farm,