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WIND ENERGY IN EUROPE

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WIND ENERGY IN EUROPE

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1. INTRODUCTION

Interest in the wind as a supplementary source for the production of electricity has recently gained renewed momentum from the widespread concern about the environmental problems involved in the large-scale use of fossil fuels and nuclear energy. Moreover, recent political events in the Middle East have suddenly drawn the attention of the public to the importance of having energy sources that are both safe and freely available.

Despite that, the part the wind (and renewable energy in general) can play in meeting the increasing demand for clean electricity has not yet been fully appreciated either by utilities or by governments in the European Community member states. The technology for producing far-from-negligible amounts of clean power from the wind is already being developed to-day, but its implementation calls for government decisions to enable present policies on electricity generation to be adapted accordingly.

The European Wind Energy Association (EWEA) has been formed to bring together the large number of people working on wind energy throughout Europe. One of the main objectives of EWEA is to act as a strong voice for this area of activity by, among other things, developing useful co-operation between European countries, and organising wind energy conferences.

In October 1991, EWEA published a "strategy document" [1] aimed at providing the general public - but more especially decision-makers in the energy field - with a picture of the real possibilities offered by wind energy within the geographical, social, and economic context specific to Europe. Production of the document was also funded by DG XVII of the Commission of the European

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Communities, the energy ministries of Denmark, the Netherlands and the United Kingdom, and the British Wind Energy Association.

An overview of the more significant features to emerge from the EWEA document is provided hereunder.

2. WIND ENERGY TO-DAY

This section attempts to present a picture of the current state-of-the-art regarding wind energy, in respect of both available resources and machinery technology. The advantages of using this renewable source to produce electricity are also pointed out.

2.1 Available Resource

To estimate the wind energy resources in the world is difficult, but some calculations have been made. Ignoring financial aspects, it can be demonstrated that the wind could, in theory, meet all the world's electric energy needs. However, in practice, this calculation has little meaning, except to establish that the resources are there.

Indeed, the wind possesses some characteristics that make it more difficult to exploit than "conventional" sources: its low energy concentration, with the consequent need to use a large number of wind turbines of considerable size in relation to the amount of generating capacity installed; its high variability over a period of time; and its extremely random availability.

A useful broad-brush idea of where Europe's land-based wind energy potential lies can be drawn from the European Wind Atlas, published with the encouragement and support of Directorate General XII of the Commission of the European Communities [2]. In addition, an even higher potential seems to exist offshore, where there is the advantage of better wind speeds, but the disadvantage of more difficult access.

It may be interesting to estimate the way in which wind power generating capacity would be distributed among the various countries of the European Community. By way of an example [1], a calculation was made of the wind generating capacity that could be set up in each country, taking into account both available resources and the technical limits to penetration by wind-generated electricity of the existing power systems. The resulting distribution is shown in Fig.1. This picture changes considerably, however, if the European grid is considered as a whole rather than as individual national grids.

2.2 Wind Turbine Technology and Applications

The technology of the wind turbine generators currently in use is only fifteen years old, and investment in it has so far been rather modest, as compared with other energy sources. Despite these slow beginnings, the total wind

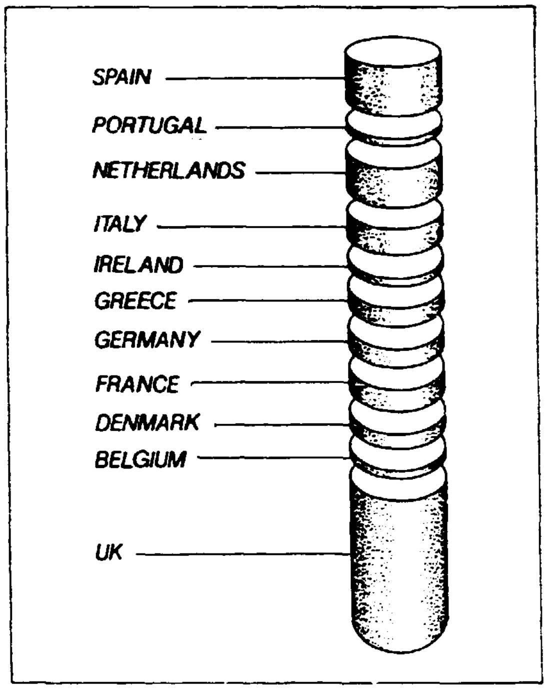


Figure 1. Possible distribution of wind generating capacity in the European Community, allowing for both resource and grid limitations.

generating capacity connected to the grid worldwide is now over 2,000 MW [1,3], not to mention the tens of thousands of very small machines used for water-pumping and battery-charging, especially in developing countries.

Nearly all the wind turbines manufactured by industry are of the horizontal-axis type, and most of them have a three-bladed rotor. As for the rotor, for some years now a number of manufacturers have been taking an interest in the two- and single-bladed type, to reduce costs and prolong the life of machines by making them lighter and more flexible, and, especially, by reducing the number of hi-tech components.

With regard to size of the machines, it may be said that the technology employed in the manufacture of wind turbine generators with a rotor of up to 25 m and an installed power of up to 250-300 kW has now become firmly established. These machines are mass-produced by many companies in the United States, Belgium, Denmark, and the Netherlands. More recently units with a rotor diameter of the order of 30-35 m, and power ranging from 300 to 500 kW, have also begun to be produced in small series of a few tens of units, and, in the meantime, companies from other countries, such as the United Kingdom, Japan, Germany, and Italy, have been joining in the wind energy market.

Two quite distinct approaches have been used to stimulate the industry: the market-led route, and the route of capital investment by governments in research and development. The market-led approach, promoted by the Americans and the Danes, produced an evolution of designs from small machines rated at around 20 kW up to 200-300 kW (Fig.2) [1]. The capital-intensive, research approach initially produced, both in America and in Europe, a number of giant machines, rated at 2-4 MW and up to 100 m in rotor diameter, which proved uneconomical. The two approaches have now met at rated capacities of 300-500 kW and diameters of 30-35 m, and look set to merge in a single technology that will gradually increase the size again.

It is worth mentioning that there has recently been, in Europe, renewed interest in large wind turbines, with the design and construction of a new generation of prototypes with rotor diameters between 50 and 60 m, and power of 1000-1500 kW. Some of these are particularly innovative from the technological point of view. In this connection mention should also be made of the results of a research project [4], promoted by DG XII of the Commission of the European Communities, whereby the unit cost of electricity produced by "light" wind turbines of advanced design would remain practically constant for rotor diameters within the 30-80 m range (Fig.3).

Major improvements in wind turbine efficiency and reliability have already been achieved. As shown in Fig.4 [1], the machines produced in the late eighties are approximately twice as effective as those produced early in the decade. Fig.5 [1] shows the gradual increase in the availabilty of the top-performing wind power stations (or "wind-farms") in California.

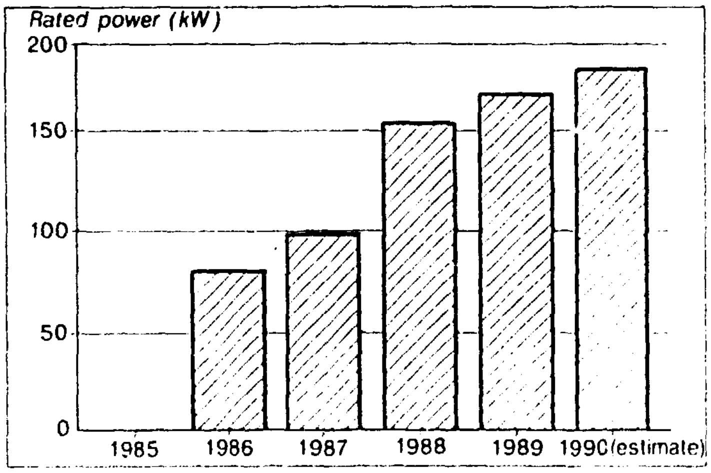


Figure 2. Average size of new wind turbines installed in the European Community.

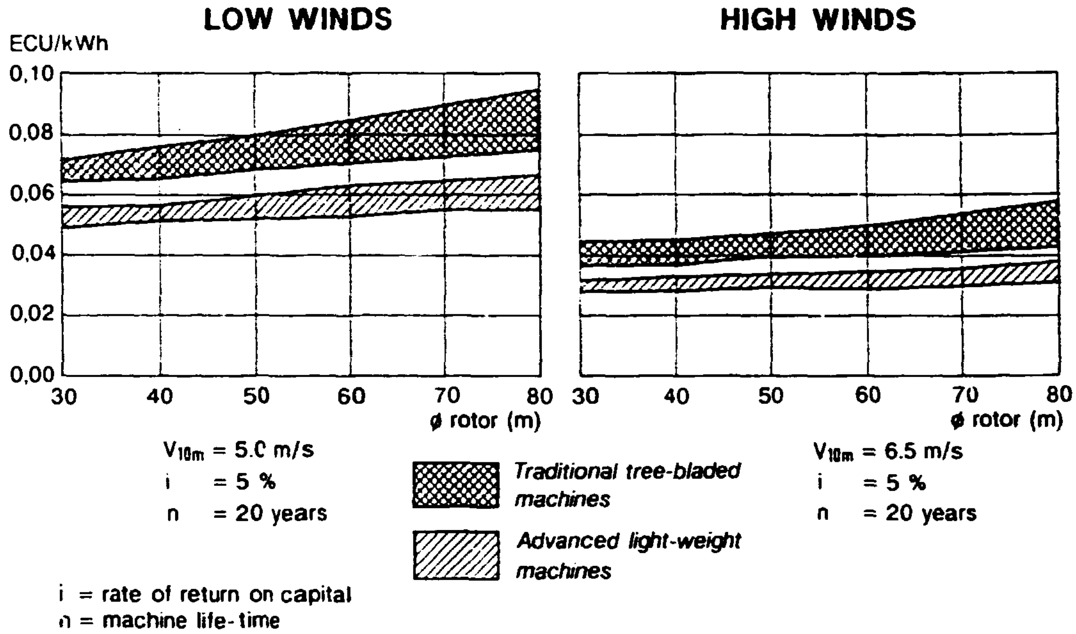


Figure 3. Unit costs of energy produced by wind turbines with rotor diameters ranging from 30 to 80 m (study by DG XII of the EC). The diagrams refer to sites with annual mean wind speeds of 5 and 6.5 m/s, respectively.

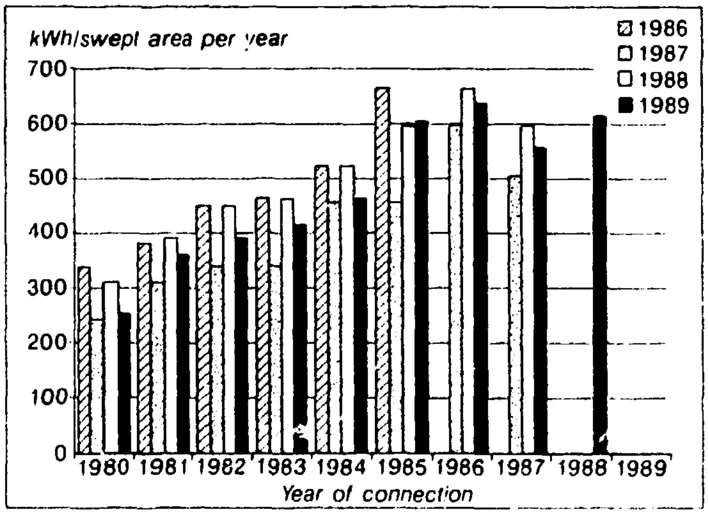


Figure 4. The growth in wind turbine energy output in the period 1980-1989.

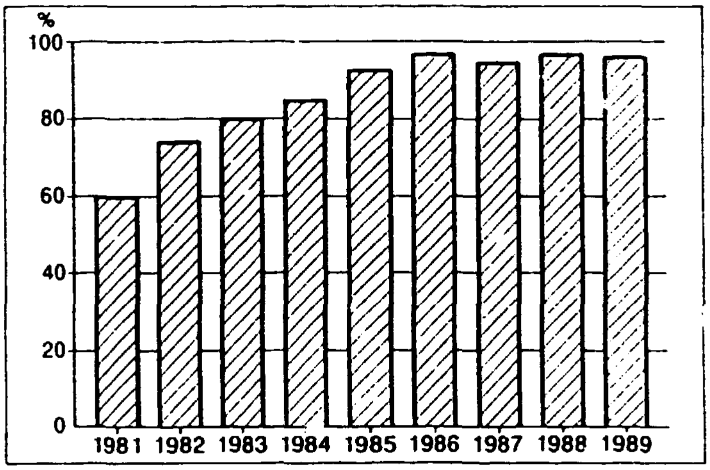


Figure 5. Increase in the availability of top-performing wind-farms in California.

2.3 Advantages of the Use of Wind Energy

Global warming is one of the major problems facing mankind. As a result of the evidence presented at the Toronto Conference in 1988, leading industrial countries agreed to reduce carbon dioxide emissions by 20% by the year 2005. An important contribution towards the achievement of this goal can be made by renewable sources, including wind energy.

In Europe, approximately one third of the CO_2 emissions comes from electricity generating plant, for which mainly fossil fuels are used. Bearing in mind the fact that, for every kilowatt-hour of electricity generated by renewable sources rather than coal, the emission of one kilogram of CO_2 is avoided, it follows that for every 1% of "conventional" generating capacity replaced by wind energy plant a 0.3% reduction in total CO_2 emission can be achieved. Wind energy can therefore be used to bridge the gap between CO_2 reduction targets and energy-saving programmes.

The reduction of sulphur and nitrous oxide emissions, which contribute to acid rains, is another important environmental benefit of wind energy; in addition, there is the saving of finite natural resources such as fossil fuels, which could be better used to produce other commodities rather than being burnt.

Wind energy can also make a far-from-negligible contribution to the diversification of power sources, thus boosting the reliability of electricity supplies. The recent Gulf War has brought this issue very sharply into focus once again, since the European Community still relies heavily on imports of oil from the Middle East.

Lastly, it is worth pointing out that, given a suitable site, a wind turbine can generate the energy consumed in its manufacture in less than one year [1]. Since the expected design life is 20 years, a well-sited wind turbine can have a net productive life of 19 years.

3. FACTORS CONDITIONING WIND ENERGY DEVELOPMENT

In industrialized countries, the production of significant amounts of electricity can only be envisaged with grid-connected wind-farms made up of a number of medium-sized or large units. The widespread use of such plants in the future is conditioned by a series of social, environmental, technical and economic factors, the more important of which are briefly recalled below.

3.1 Public Acceptance

People's attitude towards wind power is, in principle, very positive, but opposition may arise when a specific project is announced in a given place due to fears that the environment may be irretrievably damaged, or merely to fear of the unknown.

It has been found that such opposition largely subsides once the plant has been built. It is therefore warmly to be recommended that both planning authorities and local inhabitants be involved, from the very outset, in any decisions to be taken on a particular project.

3.2 Land Requirements

Apart from the large number needed, the wind turbines of a wind power plant have to be laid out according to certain patterns and properly spaced, so as to minimize the effects of aerodynamic interference. This means taking over vast areas of ground that have to be free of any kind of constraint that would prevent the installation of wind turbines. The power density that can be installed ranges, approximately, from 5 to 8 MW per square kilometre of land involved.

However, it should be noted that the structures of a wind-farm only actually occupy 1% of all the land concerned, unlike, for example, photovoltaic plants. Indeed, the actual wind turbines take up only 0.2% of the land, while the remaining 0.8% is accounted for by connecting roads and service areas. Ninety-nine per cent of the land in question can therefore continue in agricultural use (e.g. growing of crops, grazing), or remain a natural habitat.

3.3 Visual Impact

The visual impact of wind turbines on the countryside is the most contentious aspect of the siting of wind-farms. It depends not only on the shape, colour and layout of the wind turbines and on the landscape into which they have to fit, but also, to a far-from-negligible extent, on the subjective reactions of individual onlookers. The latter are in their turn influenced by their own attitude towards the plant. It is an unavoidable fact that the windiest places are often the most beautiful and show the least sign of human interference. Hence the importance of involving local members of the public in decisions affecting the compatibility of machines with their environment.

3.4 Audible Noise

Like visual impact, the noise issue has a strongly subjective aspect, since the level of noise acceptable to an individual will also depend on his general attitude towards the wind plant. The regulations governing noise vary a great deal within the European Community. However, noise is easily controlled if wind turbines are so designed as to limit the noise they make, particularly at lower frequencies.

A typical modern, 300-kW wind turbine operating at a wind speed of 8 m/s, produces, at a distance of about 200 m, a noise level of about 45 dB(A) - a level that is commonly considered acceptable, internationally, for rural dwellings (Fig.6) [1]. For a wind-farm with thirty 300-kW units, the typical noise level is 45 dB(A) at a distance of 500 metres from the nearest machine.

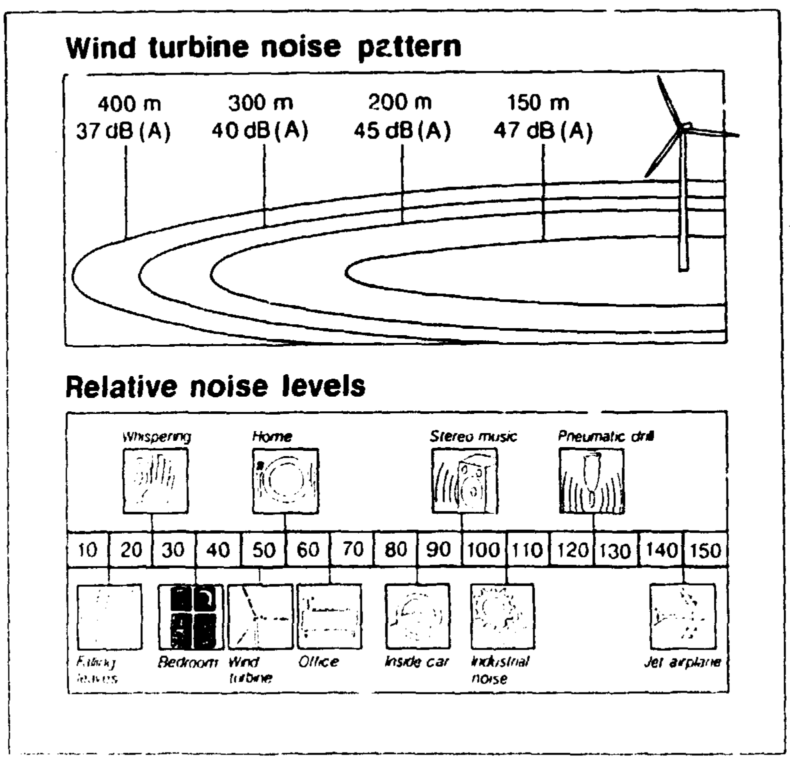


Figure 6. Wind turbine noise pattern, based on actual measurements.

3.5 Telecommunications Interference

Wind turbines may interfere with telecommunications. However, experience has so far shown that these effects are strictly local and limited to areas nearest the machines, and that they become entirely negligible when the rotor blades are made of materials other than metal.

Interference with TV reception should not, therefore, be considered an issue. As for radio links and other telecommunications, any problems can be easily overcome provided microwave routes are avoided and the installation of large machines is suitably limited around airports and other sensitive areas.

3.6 Impact on Natural Habitat and Wild Life

The possible effects of wind turbines on wild life and, especially, on birds, have been the subject of studies in several countries. A recent study [5] carried out at a Dutch wind power plant with twenty-five 300-kW units has shown that, from this point of view, a 1-km-long line of wind turbines is comparable to 1 km of motorway and, in some circumstances, could be only 10% as damaging as 1 km of high voltage line. Further studies are, however, in progress or planned, for the purpose of going deeper into possible effects on some aspects of bird life, such as migration, breeding, nesting and foraging.

3.7 Safety

Possible hazards to persons can have a serious bearing on the use of wind power plant, although it must be acknowledged that the safety record of wind energy technology has so far been very good. The few accidents involving human injury have been the result of poor management or lack of observance of safety regulations, rather than technical faults. Modern wind turbines are equipped with monitoring systems that give early warning of potential failures.

3.8 Acceptable Penetration of Electricity Systems

Inclusion in a power system of substantial amounts of wind generating capacity can lead to problems for the system itself, particularly as regards regulation of voltage and frequency, as a consequence of the variable and random nature of the source.

Special research is therefore called for, to look into the maximum acceptable levels of penetration by wind-generated power. In this connection, a Study on Wind Energy Penetration, promoted by DG XII of the Commission of the European Communities, is being conducted in co-operation with experts from some of the leading European utilities. The first part of this study has already shown that national systems in European countries can, without any need for major technical alterations, stand a degree of wind power penetration equal to 5% of their total electric energy production. Research is still proceeding, however, to ascertain the effect of higher degrees of penetration (10-15%).

3.9 Cost of Wind-Generated Electricity

The unit cost of the electric energy produced by grid-connected wind-farms depends on a number of factors, which are briefly dealt with hereunder.

The capital cost of a wind farm, of which wind turbines are a major, but not predominant part. Fig.7 shows the breakdown of plant costs for seven Danish wind-farms [6].

Since the energy produced by a wind turbine depends strongly on the wind speed at the site and the area swept by the rotor blades, a very useful parameter that fairly describes the cost effectiveness of a wind turbine is the cost per unit of swept area expressed in ECU/m^2, rather than the cost per kilowatt of rated power of the electric generator installed. For mass-produced, medium-sized wind turbines this cost (ex factory) is currently of the order of 300 ECU/m^2.

Additional costs, involved in the transportation and installation of wind turbines and electrical and civil-engineering infrastructures, vary considerably from country

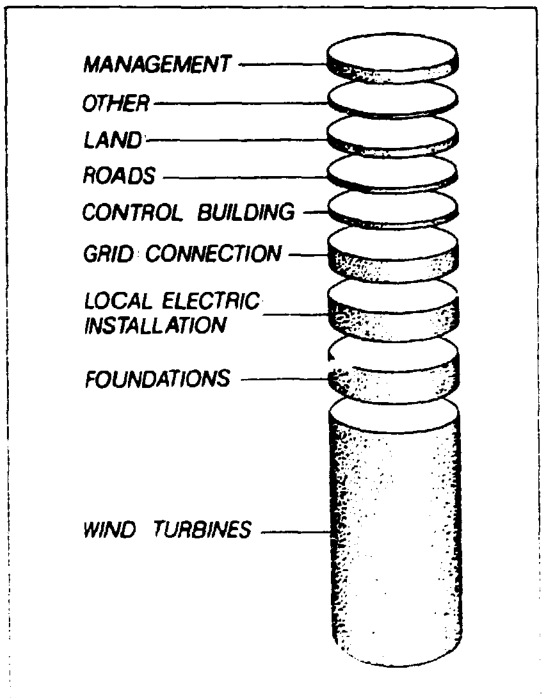


Figure 7. Balance of plant costs for seven Danish wind-farms.

to country and from site to site. The windiest sites are often the least accessible. These costs may equal between 50 and 100% of the ex-factory price of the machines.

The total plant cost may therefore be put at between 400 and 500 ECU per square metre of rotor area and per machine installed.

The rate of return required on the capital invested. The cost of energy therefore depends on the way the plant is financed, and this is the area that is particularly sensitive to political strategies. Typical power station projects in the public sector require a rate of 5% net of inflation. Higher rates may be applied to private ventures in the free market.

The useful lifetime of wind turbines, which decides the term of financial loans. Manufacturers usually state a lifetime of 20 years.

Annual operating and maintenance costs which, on an average, may be put at 2.5% of capital cost.

The wind conditions at the site, on which, obviously, the amount of energy produced annually depends. Good windy sites have annual mean wind speeds of at least 6.5 m/s, even though sites with lower wind speeds may be worth exploiting.

After conservative allowances have been made for availability (90%) and losses resulting from the wind shadow effect of machines sited in arrays (5%), by combining a number of likely values of the factors listed above, the cost of a wind-generated kilowatt-hour comes out at between 0.05 and 0.08 ECU/kWh [1].

3.10 Value of Wind-Generated Electricity

To estimate the financial profitability of the wind as a power source, the unit cost of energy has to be set against its value, which is the sum of the three factors dealt with hereunder.

The energy credit. The connection of wind power plants to an existing electric power system may result in a saving in annual operating costs, due in the main to reduced fuel purchases. This saving, divided by the number of kilowatt-hours that can be produced annually from wind energy, is called the "energy credit", and is basically the same as the marginal cost of the kilowatt-hour produced by "conventional" power stations.

The capacity credit. The connection of wind power plants may result in improved reliability of the electric power system or, should it be intended to expand that system, it may, given the same degree of reliability, make it possible to reduce the new amount of "conventional" capacity to be installed. The annual charge corresponding to any capital expenditure thus saved, divided by the kilowatt-hours producible annually from the wind, is called the "capacity credit".

It is nowadays commonly accepted that wind power plants may be allowed a certain capacity credit, though the computation of this parameter is anything but simple.

Analyses performed on this subject (for example, as part of the aforementioned Penetration Study promoted by DG XII of the Commission) have shown, among other things, that this capacity credit is not a constant value, but one that tends to diminish as the wind generating capacity installed in the electric power system increases.

The credit for avoided external costs. Producing electricity by "conventional" means, the public has to bear additional costs that are not yet calculated into electricity prices. These costs, called "external costs", are, for example, the costs of air pollution, damage to public health, military protection of fuel supplies, cleaning up after oil spillage, disposal of radioactive waste, etc.. The use of wind power makes it possible to avoid some of these costs. According to the results of a study published by O. Hohmeyer [7], wind-generated electricity may be allowed a credit in respect of avoided external costs of at least 0.04 ECU/kWh at 1990 rates. Similar figures have also been obtained, through a different approach, in another study conducted by A.J.M. van Wijk [8].

From the foregoing it can be inferred that wind-generated electricity is at present nearing competitiveness with more "conventional" sources. Moreover, if the vital issue of avoided external costs is taken into account, wind energy can be considered as fully competitive even to-day.

4. A STRATEGY FOR DEVELOPING THE WIND ENERGY MARKET

As compared with the large raw resource available, the present wind energy market is still relatively small. The size of the future market will be determined by the extent to which policies are adopted for encouraging the exploitation of renewable energy sources.

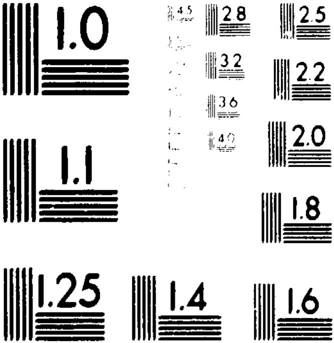
4.1 The Present Market

At present, the biggest factor in the world wind energy market is the supply of wind turbines for connecting up to large power systems. The situation by mid-1991, as regards grid-connected wind turbines, may be summed up as follows [1,3].

In the USA, installed power stood at about 1500 MW, with energy production, in 1990, of over 2500 GWh (i.e., millions of kWh), equivalent to about 3/4 of world production in the same year.

In the European Community, installed power was over 500 MW; of this, about 360 MW was in Denmark, 55 in the Netherlands, 55 in Germany, 15 in Spain, 10 in the United Kingdom, and the remainder in Greece, Belgium, Italy and Portugal. In 1990, 600 GWh was produced in Denmark alone, equivalent to 2% of that country's electricity needs.

At the present time, there are in the world about 30 wind turbine manufacturers of significant size, only two of which are outside Europe (1 in the USA and 1 in Japan). The European manufacturers are generally very small, and their



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number is on the decrease, given the tendency of companies in the same country to merge. These manufacturers, which are very well-known in their field, but virtually unknown in the world outside, especially among the major electricity utilities, are now being joined by companies of world renown that have acquired considerable expertise in mechanical and aerospace engineering (Alenia, British Aerospace, MAN, MBB, Riva Calzoni). The presence of these companies augurs particularly well for the development of new generations of wind turbines with advanced characteristics. On the other hand, the utilities, true to their traditions, expect to be able to count on manufacturing companies that are financially sound and in a position to guarantee continuity in the supply of machines and post-sales servicing.

4.2 The Potential World Market

The largest market is at present that of grid-connected wind turbines in industrialised countries. Until five years ago, this sector was dominated by the developments in California; but, more recently, the centre of activity has been shifting towards the European Community. Here, taking into account the programmes already approved by governments, machines representing about 2,000 MW of generating capacity should be installed by the year 2000. Provided the utilities play a significant part in this development, this amount might well rise to 4,000 MW. In the absence of any major political moves in the U.S.A., a moderate Californian market is, however, likely to continue for a few years at the rate of a few hundred megawatts per year, and then move to replace the rather poor machines that were erected in the early 'eighties. There is also incipient activity in Sweden, Canada, Israel and Australia. In Eastern Europe, pollution problems combined with power shortage also make these countries a very attractive market, at least in principle.

There is a large potential market for grid-connected plant in the developing world as well. Wind energy plants are easy to develop in gradual stages, which is particularly advantageous to countries unable to make substantial investments in new power stations. In India, 35 MW of wind turbines were already installed or under construction by the end of 1990, and a target of 500 MW of wind power has been set for the end the century. In Egypt, too, the target is for wind power to supply 5% of electricity by 2005 [1].

A potential market for wind pumps and "stand-alone" wind systems also exists all over the world. It may be worth recalling that tens of thousands of small machines are currently in use in China and Mongolia for pumping water and battery-charging. Wind energy is an important option for remote applications, and if a large part of the machines can be manufactured locally, this option will become still more attractive. Assistance from the industrialised world will however be necessary. Uses for stand-alone systems can nevertheless be found even in the developed world, wherever distance from the grid would normally make power very costly.

4.3 Action to develop the Wind Energy Market in Europe

For wind energy to make any significant contribution to world electricity requirements, its development should be stimulated by suitable strategies. In the specific case of Europe, installation of wind plant should now be accelerated by developing the market. There are several ways of achieving this, all of which play a vital role and should be promoted and co-ordinated by the European Community itself.

Research and development programmes. In Europe, Germany and the United Kingdom have invested most heavily in this area. Though the construction of large-sized prototypes in the U.K. and Germany has not resulted in the series production of units of the same size, the level of technology achieved in these programmes has been quite high, and the machines developed from it may become competitive with those resulting from stimulation of the market. The relationship between R&D and market stimulation needs to be constantly maintained; otherwise, even a repeat of some negative aspects of the early Californian experience may be expected.

The Commission of the European Communities is also supporting wind energy development through two of its Directorates General: the Directorate for Science, Research and Development (DG XII), which finances R&D within the framework of programmes such as JOULE, and the Directorate for Energy (DG XVII), which finances technology demonstration and dissemination within the THERMIE programme. It is desirable that the Commission should expand the respective spheres of action of DG XII and DG XVII.

Market stimulation. The wind energy market can be primed by: direct subsidization of installation costs; premium payments for the energy produced; and tax relief on wind plant investments.

Subsidizing installation costs may take the form of a percentage on the capital cost of plant, as formerly done in Denmark, or of a cash sum per kilowatt of installed capacity, as in the case of the Netherlands and California. Both systems may be open to abuse, however, and therefore require careful administration. To avoid such problems, subsidies are now calculated by more complicated formulas, based on rotor-swept area and generator capacity (the Netherlands) or hub height and rotor diameter (Germany).

The system of premium payments, on the other hand, is not open to abuse and can easily be justified. Two extra charges should be added to the price paid for a wind-generated kilowatt-hour: one that would take into account the social and environmental advantages of wind energy and would remain constant over the years; and a second charge, that would be in proportion to the difference in cost of wind as opposed to "conventional" sources, and would diminish with the passing of time until it eventually disappeared as the two sources became competitive. In a number of countries (the Netherlands, Denmark, Germany, Italy, and the U.K.) wind-generated power tariffs are going some way towards acknowledging these concepts

Tax relief, combined with other legislative measures, created the large wind power market in California. This development gave even European manufacturers, who exported machines worth 640 MECU during the Californian boom period, an enormous boost. In Denmark, an incentive in the form of tax relief still remains and is vital to continued development. Energy tax is refunded to renewable energy producers at the rate of 0.03 ECU/kWh, thus reflecting the costs spared by the public through the use of wind energy.

Introduction of wind turbine standards. At present, there are no internationally-agreed technical standards for the design, manufacture, installation and operation of wind turbines, although various European states have drafted their own requirements, which are used in testing, certification, and building licences. But this approach can lead to trade barriers, and is inhibiting the development of a free market.

In this area, an important contribution is at present being made, in co-operation with ISO, by the International Electrotechnical Commission (IEC) through its Technical Committee 88 "Wind Turbine Systems", which has been set up to prepare standards on safety, measurement techniques, and procedures for testing of wind turbines. Specifically, the preparation of an IEC standard on the safety of wind turbines is already at an advanced stage.

Physical planning guidelines. Physical planning authorities should take the initiative in establishing land areas suitable for siting wind plant, and issue planning guidelines on the matter. This would enable a realistic estimate to be made of a region's likely resources, give guidance to wind project planners, speed up the planning permit process, and prevent bad wind plant siting.

Involvement of electricity utilities. Utilities should no longer be expected to supply power at the lowest possible cash price, but at the lowest possible total cost to the public. Thus, they should be required to offer long-term power-purchase contracts to private wind plant operators; ensure development of a wind turbine market through investment programmes; allow access to the grid; stimulate development of technology; and co-operate with physical planning authorities.

Legislative measures. If physical planning authorities and electricity utilities do not take the above steps, then they should be required to do so by legislation. In California, the utilities were required to give renewable energies a fair deal by the Public Utilities Regulatory Policies Act (PURPA). PURPA-type regulations within the European Community would be an excellent means of stimulating a market for clean power production. Germany has already progressed some way in this direction, as has the U.K. with its Non Fossil Fuel Obligation. The Commission has issued a recommendation [9] that encourages utilities to co-operate in exploiting renewable energies. This recommendation has already been reflected in Italy's power sector regulations (Laws No.9 and No.10 passed in January 1991).

5. WIND ENERGY GOALS IN EUROPE

Denmark is already producing 2% of its present electricity requirement from the wind and is planning to generate 10% of it by the turn of the century. Based on available wind resources and inherent restrictions on its exploitation, the same 10% figure is, in principle, realistic as a long-term goal for Europe in, say, 40 years. This goal falls within the technical limitations involved in absorbing wind power into the existing grid.

The present annual gross electricity production of the European Community is approximately 1,700,000 GWh. By 2030, the annual yield from wind energy should therefore be 170,000 GWh. Assuming that the average load factor for wind turbines is 20%, the installed capacity required to achieve this target would be approximately 100,000 MW. This amount of wind energy might, however, well call for the use of offshore as well as land-based sites.

Taking into account the programmes already approved by governments, and assuming that the utilities play a significant part in this development, the following medium-term targets may be proposed:

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

These targets are based on a projected annual growth rate of 25-30%, and would allow for responsible and controlled growth of the wind turbine manufacturing industry (Fig.8) [1]. As installed capacity levels off around 2030, the manufacturing capacity will become constant, since the early machines will have reached the end of their projected life and will need replacing. Even if eventual installed capacity were actually limited to 100,000 MW - which it need not be - a constant volume of manufacturing output would remain.

Once the industry has reached mature mass production, this may be expected to provide ten jobs for each megawatt of wind turbines manufactured. By 2030, 50,000 people will be working in the European Community on wind turbine manufacture, according to the aforementioned scenario. In addition, new positions will be created in the operating and maintenance of machines, such jobs being expected to number about one per megawatt installed.

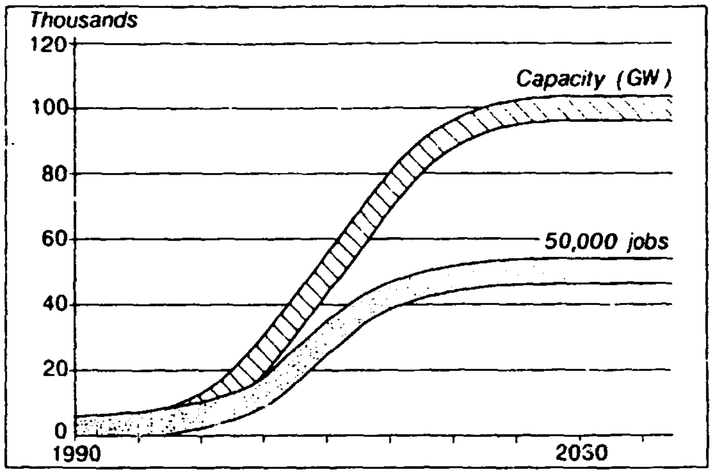

Figure 8. Projected growth of wind generating capacity and jobs in the wind turbine manufacturing industry.

6. CONCLUSIONS

The use of wind energy to generate electricity reduces dependence on imported fossil fuels and avoids far-from-negligible amounts of polluting emissions.

If fair accounting procedures are used for comparisons (e.g. taking into account avoided external costs), it now costs no more to generate electric power from the wind than from other "conventional" sources such as coal and nuclear energy.

With further investment and series production of turbines, wind energy is likely to become still more competitive.

The European wind energy industry has a leading role to play in the world. A buoyant home market would enable it to exploit a very large export market.

The widespread use of wind energy will only be achieved if policy objectives are clearly formulated and aimed at changing attitudes that have become rooted within utilities, planning authorities and national administrations.

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