UNITED NATIONS

GENERAL ASSEMBLY

Distr.
GENERAL

A/CONF.100/PC/24
10 December 1980

ORIGINAL: ENGLISH

PREPARATORY COMMITTEE FOR THE UNITED NATIONS CONFERENCE ON NEW AND RENEWABLE SOURCES OF ENERGY
Third session
30 March-17 April 1981
Item 2 of the provisional agenda

SUBSTANTIVE PREPARATIONS FOR THE CONFERENCE

Report of the Technical Panel on Wind Energy on its second session

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INTRODUCTION

A. Purpose of the report

1. The basic objective of the present report is to review the current status and describe the potential of wind energy and especially its relevance to developing countries. To this end, the Wind Energy Technical Panel of the United Nations Conference on New and Renewable Sources of Energy held two sessions, respectively from 12 to 16 November 1979 at Geneva and from 29 September to 3 October 1980, also at Geneva.

2. The Panel was composed of nine members appointed by the Secretary-General of the United Nations from among candidates nominated by Governments (see annex I below). Its mandate is defined in annex II to the report of the Secretary-General (A/34/585) and derives from General Assembly resolution 33/148 of 20 December 1978. The Second Session of the Preparatory Committee for the Conference held at Geneva from 14 to 25 July 1980, in its decision 5 (II) entitled "Reports of the Technical Panels and related resolution 2 (II) entitled "Ad hoc groups of experts", gave further precision to the form of the present report.

3. Documentation on which the present report is based, including the interim report of the Technical Panel on Wind Energy on its first session, is listed in annex II below.

4. A brief bibliography of key existing studies on wind energy, as requested by decision 5 (II), is listed as annex III to the present report.

5. The present report and those of the other seven Technical Panels together with the reports of the consultants on peat and on animal draught power will be used as source material for the six ad hoc expert groups, respectively on financing; information flows; research and development and transfer of technology; education and training; rural energy; and industrial issues. The reports of the Technical Panels and individual consultants will be used in the preparation of the synthesis document requested by decision 5 (II).

B. Basic characteristics of wind energy and the wind resources

6. The energy in the wind is derived from the differential heating of the atmosphere by the sun and the irregularities of the surface of the earth. While only a small proportion of the solar energy reaching the earth is converted into kinetic energy of the winds, the total quantity is extremely large. More importantly, nature concentrates this energy in certain regions, such that the average wind-energy flux or energy density in many locations can be equal to or greater than the average solar energy flux. For example, a site with 5.5 metre per seccnd (m/s) average wind has an average energy flux of about 200 watts per square metre (w/m^2) which is approximately equal to the daily average solar flux at a good sunny location.

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7. The power that can be achieved by a wind system is proportional to the cube of the wind speed; doubling the wind speed results in eight times the power. Site average wind speed (in fact, the actual wind distribution characteristic) is, therefore, an important factor in the economics of wind systems.

8. The wind-energy resource is quite variable in both time and location. The variability with time occurs during intervals of seconds (gusts), minutes (power variations), hours (diurnal cycles) and months (seasonal variations). This variability implies that wind energy is best utilized in three situations:

(a) Interconnected with other power plants, ranging from a small diesel to a large utility grid. The output of the windmill is then used to save conventional fuels; however, in utility applications some capacity credit is also achieved;

(b) Utilized in connexion with some form of energy storage such as batteries or pumped hydro-electric systems. In this case, firm power can be supplied, but the additional costs and losses associated with the storage system must be accommodated;

(c) Utilized in applications where the energy end use is relatively independent of time, has a time constant which can allow for the fluctuations in the wind or where an end product can be stored. Examples of these types of applications include some types of irrigation, pumping and desalination of water and heating, drying and cooling of agricultural products.

9. In addition, there are applications and localities where there is a potentially beneficial correlation or matching, on a statistical basis, of the availability of the wind and the need for the energy. In many localities, the winds tend to blow in the afternoons and evenings, which are also the most usual times of peak energy demands. Winter winds which may correlate with heating needs in cold climates or high spring and fall winds which may match low water reservoir levels are also examples of correlations which can increase the value of the energy from the wind. The ability to forecast the wind at any moment in time is, however, limited and this uncertainty must be allowed for in calculating economics, reserve margins and storage.

10. Relatively large variations in average wind speed can occur over relatively small geographical distances owing to the effects of terrain (mountains, valley funnelling effects, ground contours) and of uneven heating of the earth (coastlines, large lakes and forests). This variation over the terrain proves to be a major advantage, as well as posing a major challenge, for wind energy.

11. The advantage is that, by locating areas of good winds, sites with high energy densities can be utilized with a resultant significant increase in the energy captured and hence, the economics. Sites with 200-300 w/m^2 square metre at 10 m height are not uncommon and sites with 300-400 w/m^2 are not rare. Wind speed generally increases with height and thus hills, as well as tall towers, for the wind system, are desirable.

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12. The challenge is to locate the better wind sites and to determine the practically achievable wind resource of a particular area. Single measurement stations are not adequate and many, if not most, of the existing wind measuremen stations were not initially selected with wind power in mind (such as airport installations). Thus, wind resource assessment and wind "prospecting" for good locations are necessary.

13. A wind map for the world, developed for the present report, is presented in annex IV below. This provides a general idea of the windier regions of the world. Islands, coastlines, hills and areas near lakes represent higher potential winds. Large-scale maps cannot truly present, however, the possibilities for wind-energy siting or wind-system siting (there can generally be better sites in low wind regions and poor sites in high wind regions). The wind resource assessment must be performed on a geographic scale commensurate with the application and region under consideration, and a number of such assessments have been started in various countries.

14. While the need for a good wind sites is important for successful economics, it should not be overemphasized out of context with the particular application and competing alternatives. A high site wind speed (for example, 5-6 m/s) might be required to compete with electric generation near a large conventional power plant, whereas a low wind speed (for example, 3 m/s) could be adequate in a very remote area where the costs of transporting oil for a small diesel are high or few alternatives are available.

15. In converting the energy in the wind to energy in a useful form, several key characteristics should be stressed.

(a) Wind systems can be constructed in sizes ranging from a few watts up to 1 megawatts (MW) or more. For larger amounts of power, additional units can be added whether in "farms" or clusters or spread more randomly based on the terrain;

(b) Practical and effective wind systems can be constructed across a wide spectrum of materials and technological levels ranging from the individual craftsman or community level using local materials through the higher technology high speed systems manufactured in quantity. Across this spectrum however, advances in the understanding of the wind and the design of wind systems have increased their capability and practicality and the lack of thermodynamic losses means that relatively highly efficient systems, (up to 40 per cent) can be obtained. In addition, energy is captured over the rotor swept area (the "collector") with blades occupying only 10-60 per cent of the "collector" area. The materials requirement, compared to for example, solar collectors where the entire collector area must be filled, is correspondingly less, and the potential cost effectiveness is correspondingly enhanced;

(c) The shaft power from the wind turbine can be utilized for a wide variety of purposes, including electricity (ac and dc generation), direct pumping, direct mechanical work (grinding, sawing, extracting food oils) and direct heating (viscous "churns") although the design of the wind turbine may be different for different applications.

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16. Wind energy has been one of the few forms of renewable energy which traditionally has been cost-effective and practical during numerous previous eras. The question is whether the combination of improved knowledge of the wind and wind systems combined the rising cost and economic penalties associated with fossil fuels, can again lead to the wide-scale contribution of energy from the wind. Recent experiments and assessments lead to the probability that this can occur.

C. History of wind-energy use

17. The oldest known use of wind energy was to propel sailing ships and dates back to Pharaonic times in Egypt. This form of transport reached its zenith in the nineteenth century and then declined abruptly with the coming of steam engines. The use of windmills dates from at least the sixth century in Persia, and their early use in China is also recorded.

18. By the thirteenth century, four-bladed horizontal axis windmills, forerunners of the familiar "Dutch" windmill, were in use in many European countries. They were developed over the succeeding centuries and widely used for grinding grain, pumping water and operating a variety of machinery. They were also widely used in the Caribbean for crushing sugar-cane. At their peak, in the nineteenth century, it is estimated that in the Netherlands alone, there were about 10,000 such windmills, the largest giving power outputs up to about 50 kW. Their use then declined as steam engines became more economic.

19. In the later part of the nineteenth century, the small multi-bladed windmill was developed for pumping water. Some 6 million of these were manufactured in the United States of America alone between 1850 and 1940, and between 1920 and 1940, substantial numbers of small-wind-driven electric generators were also manufactured. These windmills were later largely displaced by rural electrification programmes.

20. Today these multi-bladed water pumping windmills are still being manufactured in in several countries, including especially Argentina, Australia and South Africa and about a million are still in use.

21. A particularly inexpensive form of windmill, made from wood and sail-cloth, has been used traditionally around the Mediterranean. On the island of Crete, many thousands of these sailmills were used for pumping water for irrigation earlier in this century, and many are still in use. A similar sailmill has also been used in Thailand for many years.

22. The water pumping windmills described above have a high solidity, that is, the area of blades or sails is a large fraction of the total swept area. This gives a high starting torque but a relatively low power co-efficient, which is a measure of the efficiency, ranging from about 20 to 30 per cent.

23. In the first half of this century, low-solidity wind turbines were developed, operating at a tip-speed ratio of four or more (that is, with blade-tip speeds more than four times the wind speed). Though these require good aerofoil section blades, they can achieve efficiencies of 40 per cent or more and are particularly suitable for low-cost electric power generation, where high starting torques are not required.

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Significant development of these machines ceased in the 1950s, as their output could not compete with cheap oil. However, increased oil prices have now made these machines economically more attractive (as will be discussed below).

D. Present status of wind-energy technologies

24. Since 1973, wind turbines have been the subject of intensive development; and the machines which are now emerging make use of the major technological developments that have taken place in recent years in the fields of structural design, materials and control and also take advantage of an improved understanding of wind loadings and rotor-aerodynamic performance.

25. Wind-energy systems are now seen to have major potential:

(a) For water pumping in rural areas, even with average wind speeds as low as 3 to 3.5 m/s;

(b) To supply electric power to homes and isolated communities, in combination with diesel back-up and/or energy storage systems;

(c) Integrated into large electric power grids, so reducing the consumption of fuel in power stations. Such large-scale applications generally require fairly good average wind speeds, usually in excess of 5 m/s, to be economic, but wind speeds of this magnitude are found in many countries.

The use of wind machines for other purposes, such as heating, cooling and water desalination is also feasible.

26. There are three principle dimensions to wind energy technology, namely:

(a) Type of machine, for example, horizontal axis, from sail and multi-bladed to fast-running propeller types and vertical axis from Savonius to fast-running Darrieus and variations;

(b) Purpose, for example, water pumping, water desalination, heating, cooling, autonomous electric power generation, power generation with grid connection;

(c) Size of machine, for example, small (less than 10 kW), medium (10-100 kW), medium-large (100-1000 kW), large (more than 1 MW).

27. Sailmills, multi-bladed mills and Savonius rotors are mostly rated at less than 10 kW. They have a high solidity and are not suitable for scaling up to larger sizes. They are mainly used for direct water pumping where there is a premium on considerations such as simple construction and a high starting torque. Low solidity wind turbines, horizontal axis and vertical axis, exist in all sizes and are used primarily for electric power generation.

I. WIND-ENERGY TECHNOLOGIES LIKELY TO BE SIGNIFICANT IN THE NEXT 10 TO 20 YEARS

A. Wind energy for water pumping in rural areas

28. The Panel foresees the possibility of wind energy playing a significant role in pumping water for household needs, animal husbandry, irrigation and drainage in rural areas, especially in developing countries. Larger irrigation and drainage systems requiring wind electrical conversion will be considered separately.

1. High-solidity water pumpers

(a) Technology of water pumping

29. A small windmill with direct mechanical drive to a water pump is a traditional technology, and commercial machines are still in extensive use in many parts of the world including Argentina, Australia and South Africa. In most cases, the water is pumped whenever the wind blows and is stored in a tank for use as needed. Careful matching of the windmill to the pump characteristic is important if the wind energy is to be used to maximum efficiency and the windmill, pump and storage must be treated as a system.

30. The conventional multibladed windmill is the type that has been widely used for this purpose in the past, as it has a good starting torque. It is now, however, widely used in developing countries, probably because:

(a) The conventional multibladed design is beyond the scope of local manufacture;

(b) Costs are too high for subsistence farmers, and financing has not generally been available;

(c) Maintenance and repair is a problem, despite the basic reliability of the machines, when local maintenance services have not been organized.

31. In the past few years, some new all-metal multibladed windmill designs have been developed by, for example, Intermediate Technology Development Growth (ITDG) in the United Kingdom of Great Britain and Northern Ireland and Steering Committee on Wind Energy for Developing Countries (SWD) and Working Group on Development Technology (WOT) in the Netherlands. Compared to the traditional multibladed windmills, they are considerably lighter in weight, more simple to construct and have a slightly higher over-all efficiency. These windmills, after adapting the design to locally available materials, can be manufactured in simply equipped workshops and are cheaper than commercially available mills by a factor of 2 to 4. The resulting savings in foreign currency expenditure are appreciable. A number of these windmills are operating in pilot projects, for example, in India, Kenya, Pakistan, Peru, Tunisia and Sri Lanka. Experience within these projects is showing that extensive field testing is essential and is resulting in a number of design modifications to ensure the reliability of the machines.

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32. Besides the design of all-metal windmills, improved types of sail windmills have been developed in Colombia, Ethiopia, India and the Netherlands, to try to meet the demands of the subsistence farmer. These mills, which can be fabricated in village workshops, are very much cheaper than commercial mills, even allowing for replacement of sails every two years. Such mills have been built in a number of places, but these activities do not seem to have resulted in dissemination of these technologies, possibly because of the lack of sufficient promotion and extension services.

(b) Economics of water pumping

33. Multi-bladed and sail windmills of improved design can be built locally in developing countries for around US \$50-\$150/m^2 of swept area (that is, less than half the cost of traditional imported models). Experience with these windmills indicates, as a conservative estimate, that they deliver an average hydraulic power of $0.1\bar{v}^3$ W/m^2 (where $\bar{v}$ is the average windspeed). This corresponds to about \$20-\$60 per average watt (pumping power) in a marginal average windspeed of 3 m/s and \$8-\$24 per average watt for a 4 m/s windspeed. A steady pumping power of 100 W, which is a typical requirement, for example, for irrigating 1 ha from a water table at a depth of 10 m, would correspond to a capital outlay of \$2,000-\$6,000 for the 3 m/s case and \$800-\$2,400 for 4 m/s. By comparison, the corresponding range for a small solar pump in conditions of good solar insolation is \$15,000-\$45,000.

34. The value of the pumped water depends on the incremental value of the crops resulting from the incremental water. In many cases, this incremental value is around \$0.03/m^3. One hundred watts corresponds to 1 litre/s from a depth of 10 m or 30,000m^3/y, assuming year-round pumping. If we assume fixed charges, consisting of combined depreciation, interest and maintenance charges, which amount to 20 per cent of the capital cost annually, the cost of the water in the above example would be \$0.013-0.04/m^3 for the 3 m/s régime and \$0.005-0.016 per m^3 for 4 m/s. These values correspond to a cost of \$0.45-1.35/kWh (hydraulic output) at 3 m/s and \$0.17-0.50/kWh at 4 m/s.

35. In practice, the cost would depend on the wind régime, pumping depth and seasonal irrigation practices, but irrigation costs by wind pumping appear to be economic even down to marginal wind speeds. Case studies in Indian conditions, taking account of the wind characteristic and seasonal water demands, confirm that even in marginal wind régimes, wind pumping is cheaper than the use of diesel or even of bullock power. In most cases, it is cheaper than grid-connected electric power if the real cost of rural power distribution is taken into account.

(c) Over-all assessment of water pumping

36. The use of small direct-drive water pumping windmills has been highly successful in the past in rural areas in many parts of the world. It continues to be so to this day in certain areas where they were never displaced by low-cost rural electrification or diesel pumps. From the large number of such pumps still in use (around 1 million), it may be inferred that the potential is very large indeed, perhaps running into many millions of pump-sets globally.

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37. Until recently, conditions have been less favourable in developing countries because:

(a) Subsistence farmers cannot afford the relatively expensive and usually imported multi-bladed windmills;

(b) There are no rural credit institutions and subsidies to assist farmers in buying windmills, while such facilities have been available for diesel and electric pumps;

(c) There are no rural extension services to help farmers install and maintain windmills;

(d) There has been a lack of awareness of the potentialities of wind energy, especially in developing countries.

38. There have now been developed multi-bladed and sailmill pump systems costing much less than conventional ones and capable of fabrication locally. These new designs appear to offer significant benefits for subsistence farmers in many areas of the world with low or moderated wind regimes. Rural extension services should promote programmes to introduce such machines. The feasibility of these programmes in any particular area must first be demonstrated by careful study of local conditions, followed up by demonstrations and extension services, ideally as part of an over-all rural development programme, which should include concessionary financing. Traditionally, windmills have been very reliable and new designs of windmills should be introduced only after field testing to ensure that these are equally reliable.

39. The further diffusion of these new technologies will require institutional and financial support programmes. This would include services to:

(a) Adapt the technologies to local conditions;

(b) Prove their reliability;

(c) Evaluate local wind regimes in relation to wind pump characteristics, water resources and cropping practices;

(d) Demonstrate the equipment;

(e) Train extension workers;

(f) Organize maintenance and repair;

(g) Provide financing on terms accessible to subsistence farmers.

2. Low-solidity wind electric water pumpers

40. For higher wind-speed régimes (annual average windspeeds in excess of 4 or 5 m/s), low-solidity wind turbines can be used with electric drive. This has a number of potential advantages:

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(a) Greater flexibility in siting the wind machine in relation to the well;

(b) Use of high capacity submersible or shaft-type turbine pumps instead of piston pumps;

(c) Wind turbines are becoming available for pumping powers up to 100 kW or more and can be used in large irrigation projects;

(d) They can be used in conjunction with a rural electricity grid so as to permit continuous pumping, but with reduced electricity consumption.

41. Low-solidity wind turbine electric pumps are already economically competitive with small diesel-driven pumps in many parts of the developing world. Relative costs depend on several factors, including the mean wind speed, the wind turbine's cost and the local price of diesel fuel. Absolute costs, per cubic metre of water pumped, also depend on the water depth and the cost of water storage. However, the comparison which follows does indicate some representative costs for both systems.

42. Small diesel generators cost around $1,500/kW ($4,500 for a 3 kW engine), and operate at very low over-all efficiencies of around 10 per cent, leading to specific fuel consumptions of around 1 litre/kWh of hydraulic output. If they operate at full capacity for eight hours per day (which is exceptional) and if the total annual fixed charge rate (including maintenance) is 30 per cent (which is very conservative for small diesel engines) then the fixed cost per kWh of hydraulic output is $0.30. With a fuel price of $0.60 per litre this gives a total cost of $0.90 per kWh hydraulic output.

43. The economics of providing diesel pumping improves rapidly, however, with increasing size, so that in the 25-100 kW range, capital costs fall to around $500/kW, efficiencies increase to as much as 25 per cent and maintenance costs are relatively lower. Costs are dominated by fuel costs and the relatively low utilization factors and are likely to range from $0.25-$0.50/kWh, corresponding to fuel costs in the range of $0.40 to $0.80 per litre.

44. Low-solidity wind electric pumps, by contrast, have capital costs of around $4,000/kW (electrical) at 3 kW rated sizes reducing to about $1,500/kW (electrical) in the 25-100/kW range (corresponding to a rated wind speed of 11 m/s). In a moderately good wind regime (5 m/s annual average wind speed), a capacity factor of about 20 to 25 per cent can be expected. Given a fixed charge rate of 20 per cent, which includes the cost of maintenance, and electrical to hydraulic conversion efficiency of 50 per cent, pumping energy costs will range from $0.70/kWh for small units to $0.25/kWh for the larger ones. They, therefore, offer a comparable or lower pumping cost than diesel pump sets over the whole range of interest, providing the wind regime is favourable. Wind speeds higher than 5 m/s would make the economics of wind electric water pumping even more favourable and it must also be recognized that over the next 10 to 20 years, developments in wind turbine technology will lead to further reductions in their cost, whereas the cost of diesel pumping will increase as fuel costs escalate further.

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B. Wind-generated electric power for isolated communities

45. The Panel expects to see wind energy playing a significant role in supplying electric power to isolated communities in good wind regimes, especially on islands and coastal areas and in mountain regions. This application involves meeting power demands of 10-1,000 kW from one or a few small-sized to medium-sized wind machines with diesel back-up and possibly some form of energy storage (such as pumped hydroelectric), so as to assure supply during periods of little wind. In the longer term, advanced energy storage systems may also be economic and eliminate the need for diesel back-up.

1. Technology of autonomous power supply (10-1,000 kW)

46. A number of low-solidity wind turbines, horizontal axis and vertical axis, are now becoming available in this power range, at the same time as fuel is becoming more costly for the diesel generator sets now commonly used in this application. While the variability of wind, even in relatively favourable locations, requires that the diesel engine be retained as a back-up, wind turbines promise to be economic as fuel savers and to reduce dependence on imported fuel.

47. In the United States, the horizontal axis, 200 kW rated, modOA wind turbine has been operating since 1977 in Clayton, New Mexico, supplying power to the local 3 MW-capacity diesel engine-powered municipal-utility system. Similar machines are now in operation in several other locations in the United States. In Canada, an experimental 230 kW Darrieus wind turbine has been operating in conjunction with the Magdalene Island grid system, and in China, an experimental horizontal axis, 40 kW, wind turbine is under test in a similar island application. A 550 kW wind turbine system, using two 250 kW machines and five 10 kW machines, is planned for installation in Malta. This last scheme also includes 7 mWh of pumped storage capacity.

2. Economics of autonomous wind power (10-1,000 kW)

48. Wind turbines in the range 10-1,000 kW are now becoming available commercially at capital costs of around $1,000-$2,000/kW, corresponding to about $400-$800/m^2 of swept area. These machines are in a size range suitable for supplying power to small islands, isolated communities, irrigation schemes and so on, without forming part of a large grid.

49. These markets are currently served, most often, by diesel generators. Because of variations in demand (leading to inefficient operation of the diesel), costs of supplying diesel fuel and maintenance problems, power generated is expensive, ranging in cost from $0.15-$0.50/kWh.

50. Although a wind turbine needs some form of back-up, such as a diesel engine or pumped storage, its energy costs are already competitive in many locations. A mean wind speed of about 6 m/s will give a load factor of 25-30 per cent corresponding to the capital costs of $1,000-$2,000/kW quoted above. With a capital charge rate of 20 per cent, this gives an energy cost in the range of $0.10-$0.20/kWh. Improvements in wind turbine technology over the next 10-20 years are expected to increase the economic attractions of using wind energy to save expensive fossil fuel and extend the range of viable applications to locations with lower mean wind speeds.

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3. Over-all assessment of autonomous wind power (10-1,000 kW)

51. Autonomous wind power systems in the range 10-1,000 kW, with diesel back-up and possibly hydroelectric storage, is already an economic alternative to conventional diesel generation for isolated communities in good wind regimes. With existing 1980 technology, the wind turbine cannot replace the diesel but can be used to give significant fuel savings.

52. The development of advanced, low-cost, energy-storage systems could eliminate the need for a diesel generator, and such developments may be anticipated over the next 20 years.

C. Large-scale electric power generation from the wind

53. The Panel sees a major potential for large-scale wind-generated electric power as part of a grid power supply, with power from conventional thermal power stations to provide the necessary reliability of supply during periods of low wind.

1. Technology of large-scale wind power

54. Low solidity, high-tip-speed ratio machines are used in essentially all applications over 10 kW. Currently, both horizontal axis and vertical axis turbines are being built or are under consideration in diameters up to about 100 m and with ratings up to about 4 MW (see table I below). It is likely that rather than design much larger machines, requirements for large blocks of power will be met by building arrays of turbines or wind farms. Preliminary studies indicate that in such arrays, separation of about 10-rotor diameters is required to avoid excessive aerodynamic interference.

55. The large modern turbines listed in the table achieve efficiencies for extracting power from the wind of up to about 40 per cent. As there is a theoretical limit of 59 per cent (the Betz limit) for such conversion (at least for conventional horizontal-axis wind turbines and vertical-axis wind turbines), there is only limited scope for further improvements in conversion efficiency. For this reason, most current effort is devoted to improving the over-all cost effectiveness (see para. 62).

56. The load factor is the ratio of the average power generated over the year to the rated power. It can be shown that the optimum-rated wind speed should be in the range from about 1.5 to 2 times the average annual wind speed at the site, and in these cases, the load factor is in the range from 40 to 30 per cent respectively.

57. Preliminary analyses by utilities in Denmark, the United Kingdom of Great Britain and Northern Ireland and the United States of America indicate that existing large-scale grid systems could accept 10 to 30 per cent of their energy from wind systems, though the value of the fuel saved diminishes as the penetration increases.

Table I. Medium-large and large wind turbines

Turbine	Location	Diameter	Rated power	Rated wind speed (m/s)	Status/remarks[c] (as of October 1980)
Mod 0	Ohio, United States	38 m	100 kW	6.5[b] a/	Research tests
Mod 0A-1	New Mexico, United States	38 m	200 kW	7.7[b]	Utility test - 8,000 hrs.
-2	Puerto Rico, United States	38 m	200 kW	7.7[b]	Utility test
-3	Rhode Island, United States	38 m	200 kW	7.7[b]	Utility test
-4	Hawaii, United States	38 m	200 kW	7.7[b]	Utility test - 1,500 hrs.
Mod 1	North Carolina, United States	61 m	2.0 MW	11.5[b]	Utility test
Mod 2	Washington, United States	91.5 m	2.5 MW	8.9[b]	Tests start 11/80 2 additional units 6/81
Mod 5-A/B	-	-100 m	-4 MW	-10[b]	Starting design 2 types
Mod 6-H/V	-	-40-60 m	-0.4-0.8 MW	-10[b]	Starting design 2 types[d]
Alcoa	Pennsylvania, United States	38 m	300 kW	-	On test - vertical axis
NRC/Hydro-Quebec	Magdalene Island, Canada	36 m	230 kW	13.5[a]	Utility test - vertical axis
Nibe A	Nibe, Denmark	40 m	630 kW	13[a]	In operation
Nibe B	Nibe, Denmark	40 m	630 kW	13[a]	On test
Tvind	Tvind, Denmark	54 m	2 MW	-12[a]	In operation
KMW	Goteland, Sweden	75 m	2.5 MW	13[a]	In fabrication
Karlskronavarvet	Maglarp, Sweden	78 m	3 MW	13[a]	In fabrication
McAlpine/Musgrove	United Kingdom of Great Britain and Northern Ireland	25 m	130 kW	11[a]	In design - vertical axis
Taylor-Woodrow	United Kingdom of Great Britain and Northern Ireland	60 m	3.7 MW	22[a]	Design completed
Growian I	Kaiser Wilhelm kog, Federal Republic of Germany	100 m	3.0 MW	11.8[a]	In fabrication
Growian II	-	145 m	5.0 MW	11.3[a]	In study
Voith	-	52 m	265 kW	8.7[b]	In fabrication
Growian II preprototype	-	48 m	-265 kW	-	In fabrication
25 m HAT	Petten, Netherlands	25 m	300 kW	13[a]	Tests starting 1/81

a/ a denotes at hub height; b denotes at 10 m; c horizontal axis unless otherwise stated; d one vertical axis.

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58. The combination of wind-power systems and hydroelectric systems is considered of particularly high potential. In many locations, the hydroelectric system is limited by the amount of rainfall and water. The combination allows the wind power to save water, which is then utilized during low-wind periods. In some cases, additional generating capacity, usually relatively inexpensive, must be added to the hydroelectric system. Studies in Denmark and in the United States have shown that this technique can provide both base and peaking power. Studies in the Netherlands are under way to investigate a combination of enclosed artificial lakes (polders) and wind power in a similar manner. The Bonneville Power Administration of the United States Department of Energy will commence testing three 2.5 MW, Mod-2 wind turbines interconnected with their hydroelectric system in 1981. A similar test project is being undertaken by the United States Department of the Interior which will commence testing one, and possibly two, 2-MW wind turbines in the Upper Missouri Valley hydroelectric system in early 1982.

59. Offshore winds are usually stronger than winds on land, and acceptable onshore sites are limited in many otherwise suitable regions. A number of countries have, therefore, undertaken studies on the technical and economic feasibility of siting large arrays of wind turbines on offshore platforms. The technology would, in many ways, parallel that of offshore oil and gas drilling platforms and, at least for shallow water, serious technical difficulties are not anticipated.

2. Economics of large-scale wind power

60. Estimates of all-inclusive electric power costs from the few existing prototype large wind turbines vary widely in the range $0.15 to $0.50/kWh (based on a fixed charge rate of 18 per cent). However, the cost of electricity from second generation machines such as the United States Mod-2, which was completed in late 1980 and has a diameter of 91 m and a rated output of 2.5 MW, is significantly lower, as indicated in the table below. (For purposes of comparison, the table also indicates costs for smaller machines.)

61. Table II. Wind energy cost estimates and goals a/

	Replicate present prototypes	Present types if mass produced	Advance designs if mass produced
Large systems	$0.08 - 0.10/kWh	$0.05 - 0.06/kWh	$0.035 - 0.045/kWh
Medium-large	$0.10 - 0.25/kWh	$0.08 - 0.20/kWh	$0.05 - 0.10/kWh
Medium and small	$0.15 - 0.50/kWh	$0.10 - 0.20/kWh	$0.05 - 0.10/kWh

a/ Assumptions: Site mean wind speed 6.3 m/s; 18 per cent fixed charge rate; 20-year amortisation period. Quoted costs do not include the reduction possible with tax credits. Mass production implies the manufacture of 100 machines or more. Costs quoted are in 1980 dollars.

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62. For all the use of wind power in past eras, the technology of wind systems, especially large systems, has been changing rapidly in the last few years and is expected to continue so for the next few years. This is primarily because of the major advances over the last 30 years in materials, controls and electronics, helicopters and aviation, computers and analytical tools, which have not before been applied to the field of wind energy. Specific areas of present and expected advances include:

(a) Understanding of wind loading and blade stresses;

(b) Blade materials such as fiberglass and wood epoxy techniques;

(c) Microprocessor controls for operational optimization;

(d) Capability for vibration/fatigue analysis with the resulting "soft" (low stiffness) systems and significant reductions in machine weight and cost;

(e) Advanced rotor configurations such as the teetered hub, delta-3 hinge, tip control and free yaw concepts;

(f) Simpler and less costly electrical power and interface equipment;

(g) Advanced system configurations such as the Darrieus, variable geometry and variable pitch vertical axis systems;

(h) Development of speed, frequency and voltage regulation systems for small machines.

Many of these advances also apply to small systems and medium systems. Advances in the understanding of aerodynamic loads, vibration and aerodynamic performance can also assist the design and performance of small systems intended for local or community fabrication. Research is under way in a number of countries on highly innovative concepts such as "tip vanes", vortex generators and diffusors. Conceivable radical advances or "breakthroughs" from such concepts, being unpredictable, have not been incorporated in the estimates presented above.

63. It may be noted from table II that the cost of present large machines, when in quantity production, should be competitive in many locations. By comparison, the fuel cost alone, for electricity from large oil-fired power stations, is about $0.06/kWh with oil at $35/barrel.

64. Since large wind turbines will be installed as part of a grid, they will not only act as fuel savers but will also reduce the requirement for installed capacity in the system, that is, they will have some capacity credit. One recent Canadian study for Prince Edward Island showed that it would be cost effective to add some 10 MW of wind power to the existing 100 MW system and that some capacity credit was justified, in this case about 25 per cent of the 10 MW wind power rating. British, Netherlands and United States studies confirm this order of capacity credit, at least for low-wind penetrations. However, the value of this capacity credit is not decisive to the economics of large-scale wind power.

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65. Studies of offshore wind-power generation have been undertaken in the Netherlands, Sweden, the United Kingdom of Great Britain and Northern Ireland, the United States and by Eurocean. The United States study considered floating platforms 200 km offshore in 150 m of water, whereas the other studies assumed shallow water (10-30 m depth) fixed platforms typically only 20 km offshore.

66. The study done for the Central Electricity Generating Board of the United Kingdom is especially encouraging. Including costing of construction shipyards for the platforms and regular maintenance, including scheduled blade replacement every 10 years, this study foresees costs of $0.08/kWh for electricity delivered to the shore from arrays of 100 m wind turbines. Offshore wind energy systems are seen as an attractive longer term (1990-2000) option for harnessing wind energy, that may be of particular interest in regions of high population density and limited land availability.

3. Environmental aspects of large-scale wind power

67. Wind-energy systems generally appear to be environmentally benign. However, as in any large-scale power system, all possible effects must be considered. The primary potential effects and their anticipated magnitudes are as follows:

(a) Weather or microclimate effects. The slowing down of the wind by the wind turbine has been estimated as having about the same effect on the local climate as a group of trees and only minutely small changes are expected;

(b) Effect on wildlife. Bird strikes have been considered possible. However, both analyses and the experience of several machine-years of operation have shown the extremely low likelihood of such impacts. The low solidity (two to three slender blades) and their visibly "slow" rotation alert birds to the turbine's presence, and wind turbines represent a much smaller hazard than television or radio towers. Cattle and deer routinely graze and several water birds nest adjacent to existing machines;

(c) Noise. Aerodynamically well-designed machines produce little noise and are generally inaudible over background levels beyond 100-200 metres from the machine. Any particular design, large or small, can, however, produce significant noise if aero-accoustic problems arise. One widely reported case was the United States 2 MW Mod-1 which encountered a very low frequency blade-tower wake interaction which, combined with the focusing effect of the mountainous terrain, led to unacceptable noise levels in a dozen homes in certain valley "pockets". Changes in rpm (tip speed), tower details and blade design appear capable of ameliorating the problem on this machine; it also appears to be unlikely in upwind designs (the Mod-1 has the rotor behind the tower, as do the four relatively silent Mod-OAs).

(d) Radio and television interference. The blades of a wind turbine can reflect electromagnetic waves, the effect being proportional to blade area and other parameters. Interference with radio and navigational signals is unlikely except within metres of the machine. The video (picture) portion of television can be affected by the larger machines at distances out to a few hundred metres or, in

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the worst cases, to a kilometre or two. This principally occurs when the wind turbine is at a high elevation and the television receivers are normally receiving weak signals owing to distance or to terrain shielding from the television station. The relative positions of the station, receiver and wind turbine also have an effect. Low-solidity (slender) blades, fiberglass or wood (instead of metal) blades, good receiving antennas and care in siting, all reduce the potential for interference;

(e) Energy use. One of the advantageous aspects of wind turbines is that the energy equivalent of that required for producing the materials and constructing the wind turbine can be returned (that is, produced) by the wind turbine in only six to nine months' operation. This short energy "payback" time is an important point in a time of energy shortage and demand growth;

(f) Safety. As in any large, rotating structure, safety must be a major consideration. Tower-overturning in a major storm is not considered a serious or particularly dangerous problem. Throwing a blade, or fragment, is a potentially hazardous occurrence. The high-solidity, multibladed water pumpers present few problems since their slow tip speeds and external bracing preclude a major blade throw. The low-solidity, high rpm and high tip speed (up to 100 m/s) modern electric generation wind turbine can present a potential blade hazard which must be allowed for in both the design and siting of these machines. Careful load assessment, stress analysis and quality control during the design phase, combined with vibration and crack detection and automatic shutdown sensors during operation are believed to be capable of reducing the probability of an actual blade throw in a production wind turbine to an extremely low level. However, additional care and inspections are required in the first experiments. Regardless, it is generally considered wise to place a safety or restricted zone around the wind turbine of 200 metres. While not yet accurately known (nor are there yet international or national standards) a distance of 200 metres or perhaps slightly more appears to be the farthest range that a blade, fragment or accumulated ice is likely to be thrown. The probabilities are considered sufficiently low that this area could be used for agricultural, grazing, roads and equivalent purposes, but until more experience is built up, caution dictates that residences or dense population activities should not be within such a range. It should be noted that the possible range of a thrown blade is, to a first order, independent of the size of the wind turbine;

(g) Land use. The actual land used by a large-MW-scale wind turbine is relatively small, about 2,000 m^2, not including transmission lines or rights-of-way. About 12 hectares would be utilized by a safety zone, but this would not remove that land from agricultural use. For groups of machines, aerodynamic losses dictate a separation of about 7-10 diameters; that is, a kilometre apart for 100 metre machines. The land in between would remain essentially unaffected except for any necessary access roads and transmission lines;

(h) Aesthetics and public acceptance. The reaction of the general public to the visual aspects and mere presence of wind turbines is a highly unknown and probably highly variable situation. Research has been done in both Europe and the United States, but with inconclusive results. Reaction to the first experimental

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machines, has been highly positive. Townspeople feel that they are pioneering or contributing to helping resolve their dependence on imported energy. This initial situation, while favourable, cannot be extrapolated to the future or to the large numbers of machines necessary for supplying large blocks of power. However, it should be noted that, because of the spacing requirements, only a few machines would normally be obtrusive from any given point. Nevertheless, the nature of the terrain, the attitudes of the local people and the manner in which they are involved in the decision process, as well as the cost and environmental consequences of other energy sources, will all affect public reaction. All that can be stated at this time is that in rural and agricultural areas, given reasonable care in the siting process, there is probably not a serious problem. However, in highly scenic or historic areas or in semi-urban/urban areas, one can anticipate possible problems and limitations on the use or number of wind turbines. In general, this will be a locally specific issue, quite variable in extent from country to country and locale to locale.

4. Over-all assessment of large-scale wind power

68. Major progress in the wind-power programmes of a number of developed countries now seems to assure the economic viability of large-scale wind-power projects over the next few years. Wind power should be capable of making a significant contribution to the electric supply grids of a number of countries before the end of the century.

69. Developing countries with favourable wind régimes stand to benefit from this development. Island countries and countries with coastal population centres should, in many cases, be able to make significant wind-power contributions to their electric power grids by the end of the century.

70. Much of the technology of fabrication of large wind systems should be within the capabilities of the more industrialized developing countries themselves, given appropriate assistance in establishing the industry and acquiring the necessary know-how.

71. Research and development is currently taking place primarily in a few developed countries. Developing countries should endeavour to enter this field gradually through the establishment of demonstration and training centres. These could develop basic skills and then, as the technology begins to be applied, they could progressively formulate suitable research programmes geared to their domestic needs.

72. To participate in these developments (the remarks of the present paragraph apply to both small and large wind machines) countries will need to augment their cababilities in the following areas:

(a) Awareness on the part of energy planners and policy makers;

(b) Assessment of wind resources and of favourable regions for wind power;

(c) Wind data collection and interpretation and site prospecting;

(d) Wind-power system analysis and design;

(e) Wind-power system economics;

(f) Wind-power system management;

(g) Wind-power system operation and maintenance.

73. Since financing would normally be made through electricity-supply authorities, early projects are likely to suffer from the conservative approach of such authorities to new technologies, especially so since most of the lifetime system cost must be expended at the outset. International lending agencies should, therefore, be urged to financially support early demonstration projects.

D. Small wind-power systems (below 10 kW)

74. Wind turbines driving brushless DC generators for charging batteries have been used since the beginning of the century for supplying electric power to isolated farms, weather stations, navigation aids and similar applications in remote areas. The cost of battery storage restricts the use of such machines to rated power outputs up to about 3 kW. This corresponds to the power range within which simple and efficient permanent magnet generators can be used, which offers the prospect of substantial future cost reductions. However, at present a 2 kW horizontal axis wind turbine would cost in the range of $10,000 to $20,000, tower and battery storage for four days included. Future applications which can be expected are for homes and clinics in rural areas. The cost of power from such systems ranges from about $0.5 to $1.0/kWh.

75. Somewhat larger autonomous systems can be provided by using a wind generator with a small diesel engine for back-up, and some battery storage (which not only provides some storage for surplus wind energy, but also ensures that the diesel engine never operates inefficiently at low part-loadings). A recent study by the United Kingdom of Great Britain and Northern Ireland for such systems arrived at the conclusion that, with diesel fuel at $0.6/litre and with battery storage amounting to 10 hours of mean load, power costs would be around $0.30/kWh. This is about the same as the cost of conventional small-scale diesel generation, but with reduced diesel fuel consumption. Subsequent studies have shown that power costs can be further reduced, but they emphasize the need for careful system optimization.

76. Electricity generation by wind turbines at the 10 kW rating is already being effected by private owners, especially in Denmark and in the United States. The wind generator, equipped with an inexpensive asynchronous alternator is connected to the utility grid, which is then used as frequency control, storage and back-up. These systems have already been shown to be cost-effective, depending somewhat on the difference between the utility's "buy" and "sell" rates for electricity. Typical prices range from $400 to $1,000 per m^2 swept area of the wind rotor (for example, $30,000 for a 10-m diameter machine with 10 kW rating). It is expected that this application will expand considerably as technical improvements and increased production rates lead to substantial cost reductions.

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77. There is a need to supplement existing diesel-power supplies, with ratings up to about 50 kW, using wind turbines with individual ratings up to about 10 kW. Experience with such systems is not yet available and the development of hardware for control for these applications should be promoted.

78. Wind electric turbines in the range up to 10 kW are also used for water pumping (see para. 44), desalination (para. 80) and heating and cooling (para. 79).

E. Wind energy for heating and cooling

79. Where heat is required, it is possible to convert wind energy with high efficiency to thermal energy through the wind turbine by means of a mechanical, hydraulic or electrical converter. There is scope to make the wind turbine simpler and less costly by direct mechanical coupling. Principal applications are in rural residential heating, hot water production and in heating or drying agricultural products. In colder climates, the potential correlation between wind availability and heating needs leads to the possibility of good economics in this application. Wind systems can also be used for cooling, either through the intermediary of electricity or by direct coupling to a heat pump or compressor. Applications include preservation of medicines and food-stuffs in remote areas, as well as fish drying.

F. Desalination of brackish and sea water

80. A study in Indian conditions (coastal areas of Gujurat state) indicated that brackish water can be desalinated by reverse osmosis, using wind power for high-pressure pumps. Calculations using a 5 m/s average wind speed and presuming an annual 20 per cent fixed charge rate show the water costs to be about $2/m^3. These costs are about half those for solar distillation in the same arid area. Desalination of brackish water by electrodialysis, using wind-generated energy, is presently being done in the Union of Soviet Socialist Republics. Since most coastlines tend to have a high wind potential, there is also a potential use of wind power for desalination of sea water, either through reverse osmosis or electrodialysis.

G. Wind energy for sea transport

81. There is now considerable interest in reviving the use of wind energy in sea transport making use of modern materials and automated technology. The wind energy would be used in a fuel-saver mode in conjunction with more conventional propulsion machinery. A particularly important application in developing countries is the renewed interest in sail for coastal fishing boats. In Japan, a sail-assisted tanker, Shinaitoku Maru, is about to enter experimental service. It is a 1,600 deadweight ton ship of 66 m length, equipped with two rectangular sails of polyester canvas with steel frames, each 12 m high and 8 m wide, mounted on the centre line and forward of the bridge. The sails are each made in three vertical sections and can be unfurled, given optimum orientation to the wind, and furled automatically

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under computer control. There has been a recent study by the United Kingdom of Great Britain and Northern Ireland for a packet boat powered by vertical-axis wind turbines (with auxiliary diesel) for supplying remote islands. All of these developments deserve serious attention for the future.

II. CONSTRAINTS LIMITING THE DEVELOPMENT AND UTILIZATION OF WIND ENERGY AND POSSIBLE MEASURES TO OVERCOME THEM

82. The following is a list of various constraints limiting the development and utilization of wind energy plus suggestions of measures to overcome them:

	Constraints	Measures
A.	Infrastructure and institutional	
1.	Wind resource estimates may not be reliable.	Preliminary evaluation of wind resources can be based on existing meteorological data, the reliability and quality of which should be improved.
2.	Lack of an institutional framework for developing policies, strategies and programmes in wind energy.	Creation of focal points for wind-energy policy and planning units in relevant government department.
3.	Past activities in wind energy have been spasmodic and limited in scope.	Specific programmes and goals should be established for wind energy.
4.	Lack of rural infrastructure for promoting the development of wind pumping and of autonomous wind electric power.	Establish rural development programmes and include water pumping by wind and autonomous wind electric power where relevant.
5.	Lack of manufacturing, distribution and maintenance services.	Organize manufacturing, distribution and maintenance services.
6.	Concern by power authorities over operational problems of integrating wind power into existing grids.	Preliminary operational experience in several developed countries suggests there are no serious operational problems. However, this must be demonstrated to the power authorities in many more instances, owing to the diversity of situations in different countries.

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Constraints

B. Research and development and transfer of technology

1. Even after a decision has been made to proceed with a wind-energy programme in a country, the successful transfer of technology to the country and its subsequent diffusion is dependent on a number of factors which will be similar for small-scale rural technolgies and larger-scale power technologies, although each may require a different institutional setting. These factors include:

(a) Access to technical information concerning technologies available on the market;

(b) Access to equipment designs and manufacturing know-how;

(c) Access to experienced technical advice during the initial stages of the programme;

(d) Research and development facilities to adapt foreign equipment to local conditions and to local manufacturing possibilities;

(e) Test facilities to test imported and local equipment under realistic conditions;

(f) Performance standards for wind equipment and corresponding engineering services to assist local manufacturers in meeting these standards;

(g) Demonstration facilities to demonstrate suitable imported or domestic equipment;

Measures

(a) Most of these constraints may be overcome by the creation of an appropriate wind-energy centre in the country with services corresponding to the relevant items (a) to (i). Such centres might cover both rural wind pumping and wind electrical power, although in many cases there may be good institutional reasons for separating these functions;

(b) In certain instances there may be a case for an internationally-supported centre organized on a subregional basis.

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Constraints	Measures
(h) Consultant and advisory services to carry out wind surveys and to evaluate wind-energy prospects, for example, in relation to local water resources and cropping practices for rural wind pumping or to carry out system design and feasibility studies for wind electric power;	
(i) Training services for local wind-energy specialists.	
2. In many instances, university research may lack direction and priority, small industry may lack technological capability and both may lack sufficient understanding of local practical problems of the user.	As wind-energy programmes or centres are developed, they should be implemented in a manner to cause close ties and communications between these three groups.
C. Education and training	
1. Lack of advisory and consulting services for decision-makers.	International agencies, particularly those of the United Nations system, should provide advisory and consulting services.
2. Lack of rural extension workers with relevant knowledge and skills in wind pumping.	National training course in rural uses of wind energy for rural extension workers.
3. Lack of wind-energy specialists in: (a) Data collection and interpretation and site prospecting; (b) Systems design, engineering and management; (c) Systems analysis and economic feasibility; (d) Systems operations and maintenance.	(a) Establish national or regional training centres; (b) Introduce these subjects in the curricula of universities and technical training schools; (c) Provide practical training through fellowships.
4. Shortage of specialists qualified to train others.	Fellowships should be provided to, and training courses should be developed in, suitable advanced centres of wind-energy technology, in order to train the trainers.

	Constraints	Measures
5.	Absence of wind-energy courses in universities and technical schools.	To develop curricula and supporting textbooks and lecture notes for universities and technical schools.

D. Information flows

	Constraints	Measures
1.	Insufficient detailed wind-resource data.	(a) Meteorological services should be encouraged to augment their wind-measurement activities and to take account of the special needs of wind energy. (b) Carry out wind-resource surveys, prepare wind-energy maps, and prospect for suitable sites.
2.	Absence of information on wind energy.	There is a proliferation of information services in the world, but access of users, especially users in developing countries, to these services is not always adequate. Actions to strengthen user access to the existing services, for example, by the compilation and updating of directories and through the production of a wind-energy news-letter for developing countries are required. In particular, information should be made available on: (a) Availability and capability of analytic tools, handbooks and computer software; (b) Catalogues and equipment information; (c) Equipment-performance standards, tests methods and testing services; (d) Consulting and design services; (e) Training services; (f) Manufacturing processes, including blueprints, licences, patents and know-how.

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Constraints	Measures
E. Financial	
1. Lack of funds for financing institutions, technical services, and training in developing countries.	International technical assistance in wind energy.
2. Lack of funding of rural wind pumping and autonomous power where relevant under credit terms accessible to subsistence farmers.	National and international funding of rural development programmes to include concessional credit facilities for wind energy for subsistence farmers and isolated communities.
3. Even when wind-energy systems are expected to be cost-effective, they may have difficulty in attracting financing owing to high initial costs (compared to fossil fuel systems) and to lack of familiarity on the part of financing institutions.	Government measures to assure sensitivity of local financing institutions to the needs of wind-energy users.
4. Lack of financing of medium-scale and large-scale wind electric power.	International lending institutions to be urged to include financing of medium-scale and large-scale wind-power projects on their merits when financing electric-power projects.
5. It should be recognized that in many countries, various forms of energy are artificially priced and this penalizes wind energy even when it is cost effective.	Governments should ensure that wind-energy projects and equipment receive equitable treatment, in terms of subsidies, with other forms of energy.

III. RECOMMENDATIONS

1. Preliminary wind-resource assessment

83. A preliminary wind-resource inventory should be undertaken as soon as possible in all countries having some wind-energy prospects. This could normally be based on meteorological data, which should be improved as necessary and could be carried out by national staff assisted by the wind-energy technical note now under preparation by national staff assisted by the wind-energy technical note now under preparation by the World Meteorological Organization (WMO). If necessary, further international assistance could, in specific cases, be sought.

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2. National wind-energy focal points

84. Countries having some prospects for wind energy should designate a national focal point for wind-energy policy-making, planning and implementation, within an appropriate department of Government (planning, finance, energy or rural development) or an agency nominated by the Government.

3. Wind pumping for rural development

85. Socio-economic systems studies indicate that small wind-powered water-pumping systems are quite appropriate to irrigation in small farms, even in comparison with other renewable energy sources. The panel strongly recommends inclusion of wind-powered pumps in rural development programmes wherever local conditions are favourable. An important positive aspect of small windmills is the likelihood of creation of additional employment in rural areas.

4. Wind energy centres

86. Because of the importance of creating national (and in certain cases subregional) centres for wind-energy technology, it is strongly recommended that international assistance, through the United Nations system and other agencies active in the field, be given to countries wishing to establish such centres. They should be tailored to suit the needs of the individual countries, taking account of those areas discussed in detail in paragraph 82, part B above (Constraints in research and development and transfer of technology).

5. Training of trainers

87. Because of the shortage of wind-energy specialists all over the world, it is recommended that training courses be established on a permanent basis at one or more suitable advanced wind-energy centres or other appropriate institutions.

6. Wind-energy information programmes

88. In view of the present initial use of wind power and the anticipated potential for rapidly expanded use, national focal points, wind-energy centres and appropriate international organizations should develop active information programmes to provide prompt, accurate and useful information and related materials on developments, techniques and experiences to potential users, decision makers and other interested parties.

7. Financing

89. The panel noted that wind-energy conversion systems (and most other renewable energy-conversion systems) are capital intensive (compared to conventional ones), even though they are cost-effective over a period of time. It is essential to devise suitable financial packages, including low-interest loans and subsidies to accelerate the pace of utilization of this energy resource.

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8. Time scales

90. The panel takes note of the feasibility of using small windmills in large numbers in the rural areas of many developing countries and recommends that it is now time to make definite commitments backed up by adequate infrastructural facilities and financial support. Small-sized and medium-sized wind-powered electric-generation systems are expected to be economically viable on a significant scale within the next five years. In fact, many isolated communities can take advantage of this technology in the immediate future. The Panel also believes that supplying electric power from land-based wind turbines into power networks could become commercially viable in 5 to 10 years' time and from offshore systems by the turn of the century.

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Annex I

LIST OF PARTICIPANTS

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Annex II

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1. General Assembly resolution 33/148 of 1 March 1979 on the United Nations Conference on New and Renewable Sources of Energy

2. United Nations Conference on New and Renewable Sources of Energy: report of the Secretary-General (A/34/585)

3. Report of the Technical Panel on Wind Energy on its first session (A/CONF.100/PC/12)

4. Report of the Preparatory Committee for the United Nations Conference on New and Renewable Sources of Energy on its second session (A/35/43 (Part II)) a/

5. Issue paper on wind energy (UNERG/WP/1/2) prepared by Bent Sorensen

6. Report for the Technical Panel on Wind Energy (UNERG/WP/1/2/INF.1 and corrigenda) prepared by Ulrich Hütter.

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a/ To be issued as part of *Official Records of the General Assembly, Thirty-fifth Session, Supplement No. 43* (A/35/43/Rev.1).

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b/ Available from Risø National Laboratory, DK-4000, Roskilde, Denmark.

c/ Available from Multi-Science, The Old Mill, Dorset Place, London, E15, United Kingdom of Great Britain and Northern Ireland.

d/ Available from Superintendent of Documents, United States Government Printing Office, Washington, D.C. 20402.

e/ Available from World Meteorological Organization, P.O. Box 5, CH-1211, Geneva 20, Switzerland.