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SUBSTANTIVE PREPARATIONS FOR THE CONFERENCE

Report of the Technical Panel on Hydropower on its second session

* A/35/43 (Part II) and Corr.1, para. 67.

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INTRODUCTION

A. Background

1. The decision of the General Assembly (resolution 33/148 of 20 December 1978) to convene in 1981 a United Nations Conference on New and Renewable Sources of Energy is a reflection of the crucial role that energy plays in the over-all development of a country and the importance of developing new and renewable sources of energy, in order to meet energy requirements for continued economic and social development, particularly in the developing countries.

2. Consequently, within the framework of the preparatory process for the Conference, a Technical Panel on Hydropower composed of 12 experts from different countries (see annex I) held two sessions, from 18 to 22 February 1980 and from 24 to 28 November 1980, respectively.

3. Following the terms of reference of the Technical Panel on Hydropower 1/ and recommendations contained in the decisions taken by the Preparatory Committee for the Conference at its second session, 2/ the Panel has adopted the present report, prepared by the secretariat of the Conference, on the basis of contributions presented by members of the Panel, by the specialized agencies and other United Nations organizations dealing with energy problems, as well as information compiled by the secretariat.

4. The major purpose of the report is to provide information on the present state and trends of water power development with reference to applied technological, economic, social and environmental criteria; to determine major constraints faced by developing countries in water power utilization and measures to be taken to overcome those constraints.

B. General considerations

1. Principle of hydropower generation

5. Hydropower technology utilizes the difference of potential energy between different parts of a water body at a rate which is roughly proportional to the product of water level difference, commonly referred to as "head", and the discharge. Hence, hydropower planning and design is directed towards increasing these two quantities both by proper site selection and construction measures. With regard to the development of head and control of discharge different plant types can be distinguished: (1) river power plants where the head is created by weirs or dams; (2) diversion schemes which basically utilize naturally available heads; (3) run-of-river plants with little or no control of discharge; and (4) storage power plant with high dam and large reservoir for flow regulation. Since the amount and

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1/ See A/34/585, annex II.

2/ See A/35/43 (Part II) and Corr.1.

reliability of discharge, as well as the possibility of creating additional head by structural methods, depends entirely on the local hydrological and geomorphological conditions, respectively, hydropower planning and design does not result in standard solutions but rather in highly site-specific solutions. For this reason, discussion of design possibilities had to be kept relatively general in the present report.

2. Terminology and definitions

6. The Panel used for this report terminology and definitions developed by international professional organizations which are working in the field of water power technology and related subjects. These bodies, such as the World Energy Conference (WEC) and the International Electrotechnical Commission (IEC) keep up to date with technological developments, and publications are revised accordingly. The application of standards issued by IEC leads to lower investments and more uniform test methods if these standards are adhered to.

7. From the publications of IEC and WEC a few terms are listed to facilitate the reading of this report:

The term water power is used in the same sense as hydropower

Theoretical annual hydraulic energy potential can be calculated from the annual mass of precipitation runoff in a certain catchment area and from its height above sea level. The annual hydraulic potential can be expressed in kilowatt-hours (kWh) as:

theoretical potential;

technical usable potential;

operating potential;

potential under construction;

planned potential.

(See annex III, table 1, which is taken from the WEC Survey of Energy Resources, 1980.)

Hydro installation - an ordered arrangement of civil engineering structures, machines and equipment of various kinds designed chiefly to convert the gravitational potential energy of water into mechanical or electrical energy

Pumped storage - the operation whereby water is raised by means of pumps and stored for later use for the production of electricity

Tidal power station - a water power station which uses differences in water height due to the tides

Small-scale and large-scale water power development. The Panel is not aware of any classification adopted within the international community making a clear

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distinction between small-scale and large-scale development. In order to set a basis in this discussion the Panel recommends the following general size grouping of water power projects:

(a) Small-scale projects, plants or units: less than 10,000 kW;

(b) Micro-scale projects: less than 1,000 kW;

(c) Large-scale projects or plants or units: above 10,000 kW.

8. These limits may vary greatly from one country to another, depending also on the size and importance of the existing public utility network. It is also debatable whether the scale should refer to plant size or generating unit size. The Panel feels that until an international standardization body has answered this question the definitions refer to either plant or unit size.

9. The Panel notes that the Economic Commission for Europe has requested IEC to initiate the necessary actions to develop criteria for standardization of equipment for small-scale hydropower schemes.

3. References

10. Water power development has been going on for decades. Consequently, a vast amount of information is available on this subject. The continuous development of this technology is reported either at the national level in periodicals, or through international professional governmental and non-governmental organizations.

11. The Panel does not find it appropriate to present a list of bibliographic references, fearing that it would not be possible to select them in a way which would do justice to the technology achieved in this field in various countries.

12. Annex II contains a list of organizations providing publications in the field of water power, which may be governmental or non-governmental organizations. Also listed are some periodicals which carry significant hydropower information. Reference is also made to selected publications in which new technological achievements are presented, as well as to the publications used for the preparation of this report.

C. General prospects of hydropower

13. The importance of hydropower in the present-day fuel and power systems of practically all countries is due primarily to the fact that, of all the renewable sources of energy known today, hydropower is the most practical and effective in terms of utilization on an industrial scale. According to the Survey of energy resources, prepared for the eleventh World Energy Conference, held at Munich in September 1980, hydraulic energy currently provides about 23 per cent of the world's electric supply. WEC estimates that by the year 2020 about 80 per cent of the total developable hydroelectric resources will be used (see annex III, table 2). This explains the increased interest shown in technical and economic evaluations of the possible utilization of as yet untapped hydropower potential.

14. The evaluation of the economic potential of hydropower resources is determined by an economic comparison between the costs and benefits actually involved in possible hydroelectric power station construction and those of alternative thermal or nuclear power stations. Discounting techniques must be used to equate different benefit and cost streams over the economic life of all these types of electric power stations. The principal factors affecting the economics of various alternatives are changes in construction costs, in energy fuel costs and in environmental protection requirements.

15. Analysis of changes in the costs of power station construction over the past 15 to 20 years shows that cost reductions due to planning, construction technology, and power station equipment advances are counteracted by such factors as the rising cost of land, livestock and building materials, higher wages, and the spread of power station construction to remote areas where the geological and climatic conditions encountered by engineers are more difficult. Over all, there has been a steady growth in power station construction costs in all countries throughout the world. However, the cost-increase index in thermal and nuclear power station construction over the period in question has been somewhat higher than in hydroelectric power station construction. This can be ascribed to two factors: (1) scientific and technical progress has been most rapid in the organization and technology of construction methods, which, given the relative capital intensity of hydropower compared to steam-electric stations means that greater relative cost savings are achieved in the case of hydroelectric power stations; (2) conversely, the increased stringency of environmental protection regulations affects the cost of nuclear and coal power stations more than hydroelectric power stations.

16. The last-mentioned circumstance is due to the fact that the adverse effects of hydroelectric power station reservoirs on the environment have, in the majority of cases, always been reflected in the reported construction costs of those stations as compensation paid for flooded land, protecting the most valuable land with dikes, reinforcing stream banks, restoring fisheries, etc. In the case of thermal and nuclear power stations, the increased stringency of environmental protection requirements has entailed rather heavy new expenditure for the control of air and water pollution and for radiation protection. The positive effect of hydropower reservoirs on the environment must also be taken into account. In many cases creation of regulating reservoirs has substantially improved the water supply for agriculture, industry and the population, eliminated the danger of catastrophic floods etc., and these advantages have, in the final analysis, partly or even fully outweighed their negative environmental effects.

17. Forecasts of the costs of power station construction over the next 15 to 20 years, allowing for nature conservancy requirements, show that the rate of increase in the cost of thermal and nuclear power stations may also be expected to outstrip that of hydroelectric power station construction. In other words, this factor will help to increase the competitiveness of new hydroelectric power stations in the period under consideration and improve the economic potential of hydropower resources.

18. Increases in energy fuel prices, which have been particularly marked during the past decade, and analyses of the factors which have brought about these increases indicate that the cost of fuel used for thermal and nuclear power stations will continue to rise in the coming years as well. Consequently, this factor, too, will contribute towards improving the relative economics of hydropower resources.

19. In many cases, the utilization of river discharge for energy purposes will also be stimulated by the need for integrated utilization of water resources for the development of agriculture, industry and water transport. The regulation of river discharge by reservoirs for these purposes, as well as for preventing catastrophic floods, will facilitate the economic development of the surrounding areas and a more rational utilization of water resources.

20. The construction of hydroelectric power stations will also be encouraged in the short term by such factors as the high degree of operational flexibility and reliability of hydroelectric power station equipment. This is particularly important in view of the increasing share of large thermal and nuclear power stations with very limited flexibility in the over-all structure of power-generating networks.

21. The long service life of hydroelectric installations and the low manpower input required for their operation and maintenance also enhance the economics of hydropower, especially under inflationary conditions. The possibility of making extensive use of local materials and local manpower resources in hydroelectric power station construction is another factor of considerable importance for developing countries.

22. The above advantages of hydropower development support a conclusion that the utilization of hydropower resources will play a significant role in the development of fuel and power systems in all countries until at least the end of this century. This can only be achieved, however, if everything is done to disseminate existing experience in planning, constructing and operating hydroelectric power stations, especially in developing countries, and, at the same time, to refine existing techniques of utilization of hydropower resources with a view to greater economy.

D. Hydropower potential

23. Annex III contains the most recent (1980) WEC figures for global hydraulic energy resources in various areas of the world and the amounts that are already developed.

24. In world practice, hydropower potential is commonly divided into three categories: theoretical, technical and economic. According to available estimates the theoretical world hydropower potential, calculated as the total energy potential of river discharge in relation to sea-level or to the base level of erosion for closed basins, amounts to an annual electric power output of about 44.3×10^{12} kWh. For technical reasons, certain river reaches, mainly those near estuaries, cannot be used for power production, so that the technical useable hydropower potential is substantially below the theoretical potential; according to present-day estimates,

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it corresponds to about one half of the latter. The economic potential, that is, those hydropower resources which are technically suitable for utilization and which are today regarded as economic compared to alternative sources of electric power, is still lower. According to data quoted at the eleventh World Energy Conference, the economic potential of hydropower amounts is at least 6.4×10^{12} kWh (potential operating, under construction, and planned).

25. It should be stressed that the above estimates of all categories of hydropower potential are only tentative. Their tentative nature is due, above all, to the absence of sufficiently precise hydrological and topographical data for many rivers, especially in developing countries, to differences in methods used to calculate potential in various countries, and to scientific and technical progress in the technology of power station construction and generating equipment. Besides this, the amount of small-scale hydropower potential may not be reflected in these data. It is assumed that the vast majority of the above estimate of hydropower potential involves construction of power plants with a capacity of more than 5 megawatts (MW). World-wide interest in small-scale applications of hydropower has only recently emerged. Consequently measures of small-scale resource capability are not available. For all those reasons, estimates of hydropower potential have to be revised from time to time. The Panel therefore felt that practical measures taken to organize this work in all countries should be reflected in the recommendations included in this report. It is very likely that considerable hydraulic energy resources have not been investigated in some countries.

26. At the world level, the largest unexploited resources are located in Asia, Africa and Latin America. Although the estimates of hydraulic potential illustrated in annex III are subject to verification through site-by-site analysis of specific sites, in general, for many developing countries with distinctive topographic relief, there is considerable water power potential to meet electric generation needs now and in the near future.

27. For example, in theory Brazil's electric power requirement could be fully met at the close of the century by using its hydraulic potential, estimated at 209,000 MW, only 14 per cent of which is in use so far. According to a very well-established government programme that will probably continue for the next 15 years, hydroelectric production is being increased at an average rate of 11.3 per cent per year in that country.

I. PRESENT TECHNOLOGICAL "STATE-OF-THE-ART" AND TRENDS LIKELY TO BE SIGNIFICANT IN THE NEXT 10-20 YEARS

A. Large-scale hydropower development

1. "State-of-the-art" and trends

28. Large-scale water power development often occurs in conjunction with the construction of large dams below huge drainage areas and is usually associated with multiple-purpose (i.e. irrigation, flood control, navigation, water supply) project outputs. Such reservoirs are designed to control most if not all annual or seasonal flood flows.

29. At the present time a great deal of experience exists in both developed and developing countries in water power development under different climatic, engineering and/or geological conditions. Although in a number of countries, especially in Europe, most of the best large dam sites are already utilized for either multiple-purpose or, more rarely, single-purpose development, excellent sites still exist in many parts of the world. Moreover, the past seven years of rapidly escalating oil prices have signalled a fundamental change in world energy use and economics, which has led to reassessment and upward revision of the economic potential of water power resources and thus to establishing the feasibility of building new stations on sites formerly considered economically unfavourable.

30. Large-scale power plants associated with large-scale dams are usually preferred for development owing to the economies of scale and improved production reliability. This leads to a trend towards higher dams under challenging topographical and geological conditions.

31. Since 1969, a number of dams of more than 100 m in height have been and are being built in different parts of the world. The maximum height reached so far is 300 m (Nurek, USSR).

32. To reduce the cost of construction work, diverse construction materials have been used with more dams built of local materials such as rock, clay, sand etc. Rock and earth-fill dams with a clay core and pitched rock-fill embankments are the most commonly used. Rock-fill dams with asphalt core are a promising new design. Hydraulic-fill dams are still being built in some countries. There appears to be a promising future for the use of "reinforced" earth in the construction of dams from local materials with water flowing over them; such a project has been completed in France (Vailletan-de-Bime).

33. In addition, there are some large dams which were created by massive explosions; two dams already exist (54 and 58 m respectively) and one of 250 m is planned at Naryn, USSR.

34. Considerable technological progress has been made in recent years in the design and construction of concrete dams. For example, more than one third of high concrete dams now under construction are arch dams. Moreover, in recent years, arch dams have been built in increasingly awkward sites, as regards valley geometry, geological conditions and earthquake ratings.

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35. In concrete gravity dams, two different trends have emerged: light profile dams with a minimum volume of concrete but with buttresses, multiple arches, expansion joints etc.; and dams of simplified geometrical forms with more stringent mass-concrete requirements. Thorough investigation of the geological structure and geotechnical characteristics of the foundation, particularly its permeability and resistance to shear stresses, is of great importance for these types of dams.

36. It is difficult to say which of these trends are predominant. Light profile dams require more materials for shuttering and reinforcement, and involve more craft labour, whereas a simplified profile requires a greater volume of concrete. Besides this, simplification of forms is attractive because it lends itself to mechanization of work in situ. Relative price factors will certainly play an important part in prevailing trends shaping up in each country.

37. It is worth mentioning that a great deal of research has been done to improve methods of calculating static and dynamic stresses and to prevent excessive seepage through and around the dam (a main cause of dam failure). Careful and professional geotechnical investigations are essential to discover conditions that might lead to damage or failure during construction or operation of the plant. Generally the over-all dam and reservoir construction safety record over the years has been excellent.

38. In recent years, a number of non-traditional layouts or machine halls in water power plants have been used for passage of flood water through or over the top of the power house; consequently, a separate spillway is not required.

39. The construction of underground machine halls is widespread and often undertaken for economic and/or environmental reasons.

40. Many interesting new approaches have been proposed and used in the construction of intake pipes to the power house (steel-concrete; precase steel-concrete; steel pipes laid directly into the soil with no anchor support etc.). The Panel would also cite the use of an aircushion system instead of ordinary surge chambers combined with inclined pressure shafts. Similarly, one could mention the use of unlined as well as pressure shafts where the geology permits (see annex II, sect. C, documents Nos. 18 and 19).

2. Economics of hydropower development

41. The economics of a specific hydropower development can rationally be determined only in the context of long-range demand-supply studies with due consideration of all alternative supply technologies on the one hand and the expected future trends of demand and costs on the other. In this context a remark of caution is made against economic comparison based exclusively on specific cost indices such as fixed or variable product cost per unit of output.

42. For large-scale developments these economic analyses should be carried out in the framework of power system expansion studies, using the "system approach" rather than the conventional "alternative project approach". These studies should be

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conducted both in terms of national economic and corporate economics. Uncertainties of future trends should be handled by means of scenarios. This applies in particular to future demands and the interest rate of capital.

43. In spite of the fact that system aspects eventually determine the economics of hydropower, it is felt appropriate to indicate below some particular properties of this technology which are of economic relevance.

44. Unlike that of thermal plants, the output of hydropower plants, namely power and energy, is to some degree uncertain, since it depends on the uncertain properties of natural river flows. To distinguish between certain and uncertain outputs, i.e. firm and non-firm power and energy, extensive simulation of the expected plant operation is required.

45. Unlike that of thermal plants, the potential annual or seasonal energy production is, except for small installations, not limited by the possible operation times, but rather by the natural water inflow conditions and by the reservoir size, if any.

46. Unlike that of thermal plants, the variable operation cost, i.e. fuel costs, are negligible. On the other hand, because of higher construction costs and longer construction times, the investment costs are usually higher. This is in most cases also true for annualized capital cost in spite of the longer economic lifetimes of 50 to 60 years for hydropower installations as compared to 15 to 30 years for thermal power stations.

47. Economies of scale for construction costs versus installed capacity are distinctly pronounced. In particular for hydropower schemes with large reservoirs, the marginal cost of additional capacity tends to be very small.

48. With a total annual firm energy output limited for hydrological reasons and usually small marginal cost of capacity, it follows that at least in combined hydro-thermal systems, the most economic utilization of hydropower will be obtained for small ratios of annual energy (kWh) versus capacity (kWO) and for short operation durations (h) during high demand periods (peaking). Under such circumstances hydropower is competing with the least efficient steam-electric plants and with thermal peaking stations such as gas turbines and diesel generators.

49. In cases where the marginal costs of capacity are exceptionally high, i.e. for schemes with long penstocks or in predominantly hydro-oriented systems or in decentralized small systems, there is also economic scope for hydropower plants with long operation times, i.e. base load operations. In this case, hydropower is competing with base load plants on fossil or nuclear fuels or other base load hydro plants, most often in combination with so-called run-of-river plants with little or no storage reservoirs.

50. As regards the conditions for increasing the hydropower contribution within existing thermal or hydro-thermal power systems, there are principally three means:

(a) Increase of peaking power by installation of additional capacity in existing plants;

(b) Increase of total energy production by increase of total inflow through additional interriver diversions, by increase of storage volume through making higher or reconstructing existing dams; in projects with a low utilization rate at present, total energy may also be increased by increasing the installed capacity;

(c) Construction of new hydropower schemes with due consideration of later stage development according to (a) and/or (b).

51. The economics of action according to (a) are highly favoured by the generally low marginal cost of additional capacity as mentioned above. The economics of action according to (b) cannot be generalized since these measures are considered to be highly site-specific. The economics of new hydropower installations according to (c) are characterized by relatively high investment for the first stage, with subsequent lower marginal costs for power and energy and near-zero variable operation cost.

3. <u>Social acceptability</u>

52. Social acceptability of the use of any resource which is within the public domain is usually reflected in the policies and procedures of the political and institutional infrastructure. The flow of national streams and rivers is now almost universally accepted as a public resource and the development and use of river systems is usually controlled by governmental development and regulatory agencies. Over the past 10 to 20 years, water resource agencies, usually well schooled in the multiple-purpose aspects of river development, have experienced increasing conflict with other public and private institutions with water-related single-purpose or single-objective responsibilities, such as environmental quality of hydroelectric energy development. Even institutions with common single-purpose functions such as water supply sometimes clash when one entity is predominantly construction-oriented and the other focuses on regulatory approaches to problem solving.

53. The social effect of hydropower development may be advantageous to some users and disadvantageous to others, a point which must be borne in mind. Increased agricultural production resulting from irrigation, to mention just one example, can be an essential factor of economic and social change, which would not be brought about by single-purpose power generation.

54. Since human habitation has traditionally occurred at or close to rivers, the size of the population affected by reservoir development may be relatively large and because the prospective impacts are so eminent and visible, the affected groups' reaction to large-scale development schemes may be intense. Generalizations about the ability of societies to accommodate such impacts are difficult because the culture, mores, and political power of affected groups varies from country to country and from site to site within a nation. Generalizations about the acceptability of government response measures (such as mitigation of economic impacts) are also difficult because of variation in national mitigation capability and policy.

55. Mitigation frequently is the key to conflict resolution if the general public benefits are sufficient to cover local losses, and mechanisms are either in place

or can be implemented to achieve the necessary income transfer. Suffice it to say that with proper attention and care to social impacts in the planning of hydro projects, acceptable solutions can usually be devised. Some mitigation measures may be mentioned:

(a) Navigation locks can be provided to assure safe water transport past low-head dams;

(b) Fish protection devices include fish ladders or elevators for upstream migrants, and fish collection facilities and transportation pipes for downstream migrants;

(c) Water quality can be maintained through the use of multilevel ported intakes, submerged weirs upstream of powerhouse intakes, introduction of air into turbine draft tubes, and proper design of spillway structures;

(d) Silting resulting from construction activities can be controlled by the use of temporary settling basins;

(e) Reregulation reservoirs can be provided for peaking plants to level downstream flows.

56. Social attitudes toward energy development in general are likely to change as groups in all nations and at all levels of society develop a deeper sensitivity to and better understanding of the severity of the current energy crisis and the consequences of inaction. Attitudes toward hydropower development will also improve with realization that hydropower is one of the few and perhaps the only electric energy technology that combines the attributes of (1) renewable resource development and (2) use of indigenous development opportunities and (3) is commercially competitive with any other source of electric generation.

57. Emerging public attitudes toward nuclear development will also significantly affect the scope and pace of future large-scale hydropower development.

4. Environmental effects

58. All resource development projects have environmental consequences, and hydropower development is no exception. There are beneficial effects as well as negative ones. Some positive effects include:

(a) Swamp control;

(b) Landscape management, e.g. creation of lakes of recreational value;

(c) Flood control;

and the following negative effects are worth mentioning:

(a) The consequences of initial reservoir impoundment which can involve loss of productive agricultural lands in the reservoir area;

(b) Disruption of existing aquatic and terrestrial ecosystems;

(c) Loss of wild and scenic stretches on the river;

(d) Changes in water quality due to thermal stratification and oxygen depletion in the reservoir;

(e) Changes in scour and sedimentation patterns within and downstream of the reservoir and/or other perceived environmental dangers to human values and natural biological systems.

59. The environmental impacts of hydropower development are particularly severe where plant operation is seasonal, weekly and sometimes daily; this gives rise to fluctuation of reservoir levels and downstream flows which affect the ecosystem.

60. In general impacts on the environment can be related to physical effects (sedimentation, erosion of soil and water seepage, evaporation, hydrological regime and climate, water quality modifications, induced seismic activity etc.), to ecological effects (aquatic, terrestrial), to effects on human health (development and spread of disease) and to social and economic effects (resettlement problems, safety of downstream population, flood control, agriculture water supply, transportation etc.).

61. There are a number of competing concepts regarding the proper human use of natural river systems, which range from the wilderness vision which forbids any development (and occasionally) any use of a river to the "working river" concept which argues for optimal (or complete) development of the resource consistent with sound economic development and management principles. All of the world's river systems already lie somewhere on this development continuum, and proposals to begin or expand the development of any river can expect close scrutiny from environmental regulators and special interest groups alike.

62. There is no doubt that the net effects of the vast majority of water development projects around the world have been beneficial. Equally, however, there is no doubt that many of these development projects have produced (directly or indirectly) unanticipated adverse environmental side-effects, some of which could have been eliminated and others reduced in magnitude by appropriate planning.

63. Thus, the real question is not whether such developments will affect the environment, but how much change is acceptable to society as a whole, and what countermeasures should be taken to keep the adverse changes to a minimum at a reasonable economic cost.

5. Conclusion

64. In summing up, at present, hydroelectric power is very often an economically competitive substitute for thermal power production. As a synthesis of different aspects of hydropower developments it seems obvious that its over-all viability is clear and will be even more so in the future. Careful planning of mitigation measures can reduce social and environmental impacts. In the case of multi-purpose projects additional benefits accrue to the value of the energy provided.

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B. Small-scale hydropower development

1. Overview

65. The small water power development concept has found widespread acceptance in many parts of the world, primarily for providing electric power sources in remote areas not serviced by transmission from other generation centres.

66. Because of present high fuel costs and prospects of continued price escalation, small localized fossil-fuelled plants are becoming less attractive. Small hydropower plants where such sources are available may provide an economic alternative.

67. Prior to the 1930s, small-scale water power plants appeared in large numbers in many countries with water power resources and substantially contributed to the national energy needs. Improvements in design and construction methods resulted in larger plants being introduced and fitted into the system. The improved economy of larger plants compared to small plants gradually favoured large-scale development. This history of development has been experienced in most developed countries and may also be repeated in developing countries which have exploitable water power resources of different sizes and kinds.

68. Perhaps the greatest experience with small-scale hydropower development is in China, where 88,000 hydropower plants have been constructed during the last two decades. The average capacity of these plants is about 70 kW. In 1970 the average was 32 kW. In 1980 the average size of small-scale plants has reached 300 kW. In China the selling price of electricity from small-scale hydropower is about half the cost of electricity of small-scale steam plants. The highlight of the policy regarding rural electrification by means of small-scale water power development is that the benefits accrue to the community which builds and operates the supply system. Another feature of this policy is the financing of the plants by contribution of from one half to two thirds from the community itself.

69. At the same time, studies are being carried out in a number of industrially developed countries on the possibility of building small hydropower plants. In many cases this will involve equipping existing dams and reservoirs with small hydroturbines.

70. Many such dams and reservoirs have been constructed over the past 10 to 30 years without hydroelectric power plants because the energy which would be produced would have been more expensive than electricity generated using formerly inexpensive oil, gas and diesel fuel. But the situation has changed; many previously uneconomic sites can now produce electricity at competitive prices.

71. Existing dams and reservoirs have unique economic and environmental attributes in that such projects can be constructed at one half of the capital cost of a new site development and most of the environmental effects of reservoir construction have already been incurred. Since a large proportion of the economic, environmental and social constraints which usually inhibit hydro construction can be treated as "sunk costs", existing dam retrofit development opportunities are generally considered to be extremely attractive.

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72. In the United States of America, according to a study undertaken by the Army Corps of Engineers, there is about 26,000 MW capacity at existing dams previously built for flood control, irrigation and other non-power purposes. These sites could produce up to 5 MW each.

73. Although small-scale hydro is a sub-set of conventional hydropower and most of the technologies utilized for large-scale hydropower development are applicable to small-scale and/or low-head development to some degree, there are special development problems associated with the engineering and economic justification of small-scale hydro which merit special consideration.

74. Whereas extensive large-scale hydropower development can have significant impact on national energy budget and water development objectives, the construction of small-scale sites is unlikely to have a significant effect or impact beyond the locality or village where the resource is developed and used.

75. The search for economical small-scale sites is complicated by the large number of candidate sites in any river basin. Geological restrictions on sites are eased owing to lighter imposed loads, but underseeping in alluvial valleys (frequently sites for small-scale projects) becomes a relatively more expensive problem to resolve. Smaller design safety factors are allowable because the consequences of failure are typically less catastrophic. Outlets are simpler, frequently supplying unregulated river flows to the turbines on an "as available" basis. Spillways are sometimes incorporated into the dam itself, which then acts simply as an overflow weir during floods.

76. Because of the higher unit costs associated with small-scale or low-head sites, it is sometimes necessary to use standard package plants and remote operation for cost efficiency, with attendant engineering modifications incorporated into the design. There is therefore a trend towards standardization of equipment and towards "package-plant" approaches to reduce turbine production and installation costs albeit at the risk of some loss of plant efficiency and output. Usually hydro generating equipment is custom designed for the respective power stations. Therefore the cost of equipment is higher than that of standardized or mass-produced equipment. This trend is exemplified by recent initiatives by the water pump and electric motor industry (long ago standardized) to penetrate the hydroelectric market using pumps as turbines and motors as asynchronous generators.

2. Economics of small-scale hydropower development

77. To achieve a given level of electric generation capacity and output, small-scale hydropower development will be more expensive than large-scale development.

78. There may be mitigating circumstances which enable small-scale hydro to achieve economic parity with large-scale systems. For example, if electric demand centres are widely dispersed, the cost of constructing extensive transmission facilities to distribute the power generated by remote large-scale sites may exceed cost differences between small-scale and large-scale construction. In addition, since the use of standardized power plants and local materials and labour are more applicable to small-scale sites, the net cost savings achieved may be sufficient

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to justify a preference for small-scale development on both a national economic and regional economic basis, especially where the use of otherwise unemployed labour and materials can be credited to the project.

79. The most significant circumstance involves the over-all availability of capital and technical resources to construct, operate and maintain large-scale hydro and transmission systems. If a realistic assessment of site development opportunities shows that successful installation of major water resource development projects is not financially, socially or politically feasible, then the choice is reduced to small-scale hydro versus similar scale fossil-fuel based and renewable-fuel based technologies. While such an analysis is highly site-specific, it is generally accepted that on a life-cycle cost basis, small-scale hydro is economically competitive with small-scale fossil-fuel steam-electric plants, particularly if the hydro sites are located near electric demand centres (a likely prospect at villages and in rural agricultural areas).

3. Environmental effects

80. Small-scale hydro development is often considered to be more environmentally favourable than large-scale development, even when new small-scale dams must be constructed. This may not be generally true especially when considering the environmental impact per kW plant capacity or kWh output.

81. An assessment of small-scale versus large-scale effects on the environment in a specific area can only be achieved through site-specific or basin-specific analysis. Such an analysis must be broad enough to include the full range of environmental effects associated with all of the multiple purposes to be provided with each development plan, not just with hydroelectric production.

4. Social effects

82. Much of the impetus for development of indigenous resources stems from a societal desire to achieve self-sufficiency in energy production, to avoid continually rising energy prices, and to create new sources of energy to relieve the work burden on overtaxed human resources. Small-scale hydropower is particularly appropriate to meeting these societal desires.

83. The net social impact at the local level of such power plants may be significant, especially if small-scale hydro development serves as an economic and social catalyst for more extensive economic development. In situations where inflation-proof hydroelectricity can be used to back out oil-fired or diesel-powered generators through local initiative, the social sense of satisfaction and self-determination may be more than sufficient to overcome any short-term economic or financial disadvantage.

84. Additional national benefits may come out of rural electrification in cases where improvement of the economy in the rural areas favourably affects the over-all national economy, e.g. in preventing excessive migration to urban areas of the country. Rural development may be favourably supported by development of small-scale hydropower supply in such isolated areas.

C. Applications of micro-hydropower to rural development

85. In a number of developing countries micro-hydropower (less than 1,000 kW units) has a potential for making a contribution to rural development out of proportion to the absolute magnitude of the energy which can be delivered. Small hydroturbines may be used for direct mechanical drive for operating saw mills, grain mills, rice hullers or oil expellers etc. as well as for generating electric power, based on low-cost local manufacture. Simple turbines, usually of the cross-flow type, and with belt drive, adapted for fabrication in moderately equipped workshops, are now being made in a number of developing countries.

86. The regulation of hydraulic turbine generator sets, so that they run at constant rotational speed and deliver a constant voltage for alternating current at constant frequency regardless of water flow or load variation, is a serious problem in micro-units, which are most suitable for autonomous power supply to isolated communities. On the smallest units the problem may be solved through a brushless direct current generator charging a battery as in automotive systems. This is an expensive solution, however, which would rarely be justified.

87. More generally, a mechanical governor which regulates a valve to control the water flow is used. Simpler mechanical governors were used previously in some countries; such equipment should be reconsidered. Relatively inexpensive electronic load controllers have been developed; these sense voltage and frequency, and maintain a constant output in the face of a varying demand by diverting surplus power into a ballast load. The ballast load may be in the form of lift irrigation where this is an option.

88. Electric energy is often used for irrigation, for instance, when it is required to lift water to farms on hillsides. In such circumstances, the hydraulic ram may be in some cases a more economic solution. The ram is a relatively simple and inexpensive mechanical device, which is capable of converting, mechanically, the hydraulic energy of a larger flow of water to a smaller water flow lifted up to a higher head, which may be 15 to 20 times the initial head of water, and with an efficiency of 50 per cent. Hydraulic rams have proved successful in hilly regions of India and some other countries. Ordinary mechanical water pumps operating in reverse may be used for the same purpose. Simple equipment for the special purpose of lift irrigation, suitable for local manufacturing in the developing countries, is being developed.

D. Pumped storage

89. As at 1 January 1976, there were 200 operational pumped storage plants with an aggregate generation capacity of 37 million kW and 46 pumped storage plants with a 31 million kW capacity under construction in the world.

90. Since its introduction in the 1890s, pumped water energy storage has become widely adopted in electricity supply networks, for which it remains the only developed technology available for large-scale storage of electric energy. Striking technical advances have been made over the period: unit generating capacities have

increased from a few tens of kilowatts to approaching 400 MW, operating heads now extend to well over 1,000 m and over-all efficiencies have risen from around 40 per cent to better than 75 per cent. A variety of plant types is available and equally important developments have taken place in associated civil engineering works. Over-all the trend has been towards a reduction in real terms of the cost per kilowatt of pumped storage generating capacity. The range of operating roles of pumped storage plant has been steadily widened.

91. Existing pumped storage installations generally employ two surface reservoirs located at different levels. The lower reservoir is usually an existing reservoir or natural lake. Water is pumped up to a high reservoir using off-peak electricity generated by heat-powered plants or excess electricity from the hydro system and run down again in reverse mode to generate electricity when demand is high. Owing to pumping and recovery losses, approximately 4 kWh input is required for every 3 kWh reproduced. However, the advantages given by the redistribution of energy to high-load periods far outweigh the losses.

92. Pumped storage hydroelectric units have many unique characteristics which make them attractive additions to any modern system. They provide a speedy response to large changes in load which is equalled only by the conventional hydroelectric unit. Like conventional hydroelectric units, pumped storage units are highly reliable. They provide an excellent source of low-cost spinning-reserve capacity as an insurance against major system outages and for quick start-up of supply after system breakdown. Reversible pumped storage machines may be designed to operate successfully at light loads to provide the spinning-reserve capacity. Mention should also be made of operation of pump turbine generators for synchronous condenser operation.

93. Decisions to construct pumped storage capacity are primarily controlled by the need to provide for peak demand periods and the economical attributes of pumped storage versus other options to meet this need, including both supply and demand influencing alternatives. The technology is mature and the environmental consequences are negligible if sites are carefully selected. Opportunities to displace oil and gas-fired generation (where now in use to provide peak power capability) provide a strong impetus for development. Large-scale pumped storage projects are usually appropriate only where significant idle base-load capacity is available during off-peak hours and an extensive intertia/transmission system is already in place.

94. A new trend in the siting of pumped storage power plants has been the combination of pumped storage plants with nuclear or thermal power plants in integrated power generating systems, with joint use of the reservoirs for feedwater storage and cooling purposes (USSR, United States and other countries).

95. The next generation of pumped storage plants will probably use underground reservoirs, an idea being investigated intensively in Japan, the USSR, the United States and European countries.

96. Pumped storage projects may become increasingly desirable in the future as a means to accommodate the intermittance of solar, wind and tidal power energy generation.

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E. Tidal power

97. Tidal power resources are limited to a relatively few locales where tidal ranges are large and relatively narrow inlets to tidal estuaries can be found.

98. France and the USSR are the only countries that now have modern tidal power plants in operation. The 240,000 kW tidal power project at La Rance, and the 400 kW experimental tidal plant at Kislaya Guba Bay near Murmansk, are the most notable installations and have been widely publicized.

99. The major questions with tidal energy applications are economic in nature. It is essentially for economic reasons that none of the industrial-scale tidal power plant projects throughout the world, apart from La Rance, has been built to date. However, it is interesting to note that a reassessment completed in 1977 of two sites in the Bay of Fundy (Canada) show them to be economic and competitive in the utility system of the region.

100. Closely related to hydroelectric power generation, tidal power technology poses no serious technical problems. Environmental effects may, however, be more significant. The consequences of disrupting free entry and exit to ecologically fertile salt water marshes and aquatic breeding grounds can be profound and must be carefully assessed. The back-water effects caused by damming and controlling tidal flows can affect normal water levels in existing harbours and ports.

101. The technological progress both in design and manufacture of the running equipment and in the implementation of civil engineering works at sea, combined with spiralling oil prices, means that perhaps in the not too distant future tidal power schemes will become competitive at more sites.

F. Components in generation and distribution of electrical energy

1. Hydraulic turbines

102. The development of a wide variety of high efficiency hydraulic turbines has resulted in a considerable increase in the world hydropower capacity potential. Hydraulic turbines ranging from a few kW up to 700,000 kW are now in operation and their performance has been well demonstrated and proven.

103. Basically, the turbine technology for small-scale and large-scale development is the same. Available large-scale machine designs can be economically adapted to most small to micro hydro applications.

104. The costs of hydraulic turbines and generators are primarily a function of the available plant operating head. As the head decreases, considerably more water must be passed through the turbine to obtain the same power output. This condition results in a slower machine speed, and a physically larger turbine and generator, all of which contribute to higher equipment costs. It is apparent, therefore, that regardless of the type of turbine being considered, equipment costs for any low-head hydro project will be relatively higher.

105. The development of the adjustable blade (axial flow) Kaplan turbines provided a machine which assured high efficiency and satisfactory operation over a wide range of flows and heads. This was the first major effort to enhance the feasibility of low-head projects and resulted in numerous Kaplan turbine installations in hydropower stations with heads of up to 80 m.

106. Research carried out in recent years in a number of countries has shown that dual-regulation turbines are suitable for higher heads if use is made of diagonal turbines or Deriez in which the axis of rotation of the blades is at an acute angle to the axis of rotation of the runner (at an angle of about 40 to 60 degrees with respect to the unit axis). An important characteristic of such turbines is that they maintain their efficiency and operate at steady speeds despite considerable differences in head and flow. They are suitable for use in pumped storage projects where the available head is in the range of 10 to 100 m or more.

107. The largest units now being produced are Francis turbines (mixed flow). They are best for the intermediate head, ranging in current practice from 30 to 500 m, and are also used for operation at lower heads and small sizes.

108. The Grand Coulee-III hydroelectric station in the United States has three Francis turbines with a nominal capacity of 600 MW each for a design head of approximately 87 m and the next three units are each of 700 MW. The Sayano-Susenskaya hydroelectric station in the USSR has a Francis turbine which has a very high efficiency factor in the optimum zone (95.8 per cent) and a capacity of 650 MW for a design head of 194 m and 720 MW for a head of 202 m. At the Itaipu hydroelectric station (Brazil, Paraguay), it is intended to install 18 700 MW units, for a design head of 108 m.

109. Mixed flow types of runner wheels are widely used in reversible pump turbines. Considerable success has been achieved inxxmanufacturing these types of turbines in a number of countries. The basic trend in the development of reversible mixed flow machines is towards larger units and higher heads.

110. The Pelton turbines are best for high heads of more than 500 to 600 m. The maximum head achieved with such turbines is 1,800 m, in both Switzerland and Austria. At the Sy-Sima power station in Norway the 310 MW Pelton turbines are equipped with five jets each. Pelton turbines have found wide use in small hydropower stations where high heads combine with low flows.

111. For low-head hydropower plants up to 20 m tubular-type turbines (bulb and rim turbines) are manufactured by a number of companies world-wide.

112. Horizontal bulb turbines are now widely installed including the reversible-type bulb units at the 240 MW tidal power project at La Rance. Because of the axial flow and the well-adapted configuration of the flow chamber, horizontal turbines have a greater specific through-put than vertical turbines and their capacity is therefore approximately 20 to 25 per cent greater than a vertical turbine of the same size. Bulb turbines, while they have many advantages, nevertheless have low inertia which presents stability problems in lightly loaded isolated systems.

113. The efforts to reduce the cost of low-head turbines lead towards the design of an axial flow unit which reflects savings in the cost of civil works and machinery. The "straflo" turbine has the generator rotor mounted on the rim of the runner. Rim-generator turbine units are being proposed for heads up to 40 m and are available with variable-pitch runner blades suitable for reversible operation in pumped storage and tidal power applications, changing the sense of rotation.

114. The Ossberger cross-flow turbine is a low-speed unit suitable for both low-head and medium-head installations. Though Francis and propeller type turbines usually have higher peak efficiencies, the Ossberger divided guide vane section develops a flat efficiency curve over a wide range of flow and head conditions. Erosion of blades and other metal surfaces occurs only where there are appreciable amounts of silt or sand particles in the water.

115. The recently developed Schneider hydro-dynamic power generator operates on somewhat the same principles and presumably can be installed in canals, pipelines, rivers and tidal estuaries to develop power from heads as low as 1.5 m.

116. Finally, an analysis of experience acquired in hydropower turbine development shows that hydroelectric engineering trends in this field have shifted towards an increase in the speed of all types of hydraulic turbines and their use for higher heads; development of new, more advanced types of hydraulic turbines, including reversible, diagonal and horizontal machines; maximum increases in the unit capacity of turbines in giant hydropower stations; further improvement in manufacturing techniques, and greater reliability and durability of equipment.

2. Electrical equipment

117. The technology of generators and various other parts of the electrical subsystem is well advanced and proven and almost universally available.

118. The main trends in the development of hydroelectric generators are currently as follows:

(a) Improvement of the design and layout of hydroelectric generators;

(b) Use of water units with a capacity of up to 300 MW generally cooled by an indirect closed air-cooling system. Use of water cooling of the stator coils and the rotor makes it possible to reduce the dimensions of the equipment and to make savings on active materials;

(c) Development and construction of powerful generator-motors for pumped storage plants which are governed by the operating conditions;

(d) The need to operate, as generators, motor units and synchronous compensators; frequent start-ups and shut-downs; rapid increases and decreases of load, frequent change-overs in the course of each day;

(e) Improvement of insulation techniques has made it possible to go to higher generator voltage-up to 18 kV;

(f) Remote control operation which is primarily intended to reduce on-site manpower and operation costs.

119. The choice of generator, synchronous or induction, is a function of application. Selection should be based on a case-by-case analysis of the power grid in which the generator will operate.

120. When mini-hydro plants are to be connected to large established electrical grids, consideration should be given to the use of induction (asynchronous) generators. Induction generators are cheap because they are taken from series production programmes of ordinary asynchronous motors. Such generators eliminate the need for a speed-regulating governor and simplify the electrical controls. The system itself provides voltage and frequency control and excitation current. This simplified design means some reductions in equipment costs. Small generators are generally provided with brushless-type shaft-mounted exciters. The larger machines have static excitation equipment with solid state circuits and converters.

3. Electricity supply systems

121. Water power resources are site-specific. Transmission lines are, therefore, needed to bring the electrical energy to the consumption areas. Transmission system equipment is widely used. It is, however, worth mentioning that transmission sometimes represents a barrier to hydropower development in cases where hydropower sites are located very far from the consumption areas.

122. In remote areas of developing countries where the loads are quite low local small-scale plants may be economically justified compared to connexion to and supply from central systems. In large interconnected systems, the addition of a number of widely scattered small-scale hydro plants increases the reliability of supply for the local areas.

123. In connexion with the construction of huge hydropower plants remote from the consumption centre, technology has been developed for long distance transport of electrical energy with superhigh voltage - up to 800,000 volts and more - thus making development of remote large water power potentials more economically attractive.

124. Interties of systems such as the 1,300 km, 800,000 volt direct current line between the north-west power grid and that of southern California in the United States, or international interconnexions in Europe such as the 842 km, 750,000 volt direct current line connecting the electric power systems of the CMEA countries with that of the USSR, result in more economical and efficient use of electric generation capacity and in better utilization of hydropower as a part of a large interconnected system, by matching the peak-load time-tables and combining the reverse capacities of their power plants.

125. Electricity supply networks operate with alternating current at the frequency of either 50 or 60 hertz (Hz). When supply systems are designed, care should be taken at a critical stage to choose the frequency which is going to be the frequency for the country concerned.

G. Tariff structure in water power systems

126. Tariffs usually adopted in thermal-based electricity supply systems are not always appropriate in systems entirely or predominantly based on hydropower. Tariff structure should reflect the cost structure of the supply system, but it must also take into consideration the reaction of the consumer to the tariff. In interconnected hydro and thermal power systems with an increased contribution of hydropower the energy price component in the mixed energy-capacity tariff seen from the supply side may be set very low owing to the fact that the variable production cost of hydro is practically zero, but this may lead the consumer to draw energy out of the system to an extent beyond its capability to produce energy. However, pure hydropower systems, in particular in isolated small-scale developments with low utilization ratio of installed capacity versus potential energy, and introduction of pure capacity tariffs should be considered with the following advantages:

(a) No metering required; for power control simple cut-off devices if the consumers are sufficient;

(b) Promotion of the use of electricity for domestic and industrial use which is considered an important incentive for regional development;

(c) Avoids the unreasonable effect of an energy tariff where the price per unit energy increases when the consumer saves energy.

127. With sufficient water available at all times for maximum utilization of the installed capacity, the latter should be carefully considered to ensure that the consumers can make use of the available energy to the maximum extent.

H. Summary of section I

128. Summarizing section I of the report, the principal trends of hydropower development appear to be as follows:

(a) Reassessment and upward revision of the economic potential of hydropower resources and thereby establishing the feasibility of hydroelectric power stations on sites formerly considered economically unfavourable;

(b) Exploitation of the hydropower potential of small rivers to meet local energy demands in isolated communities or for specific consumer groups, both in developed and developing countries;

(c) Improvement of the competitive position of small-scale hydropower development by means of standardization of equipment and by a modular approach to power plant design;

(d) Development of pumped storage plants and other modification of existing river sites (combined hydroelectric and pumped storage schemes) to increase capacity for operation on mid and peak-load duty and to provide back-up storage for intermittent renewable energy systems;

(e) More efficient use of existing hydroelectric installations through expansion and/or replacement of obsolete equipment by modern equipment of greater efficiency and by retrofitting hydropower units at existing dams;

(f) Increase in the unit capacity of turbines, refinement in the design of the hydraulic turbines and improvement in manufacturing techniques, primarily to improve reliability and/or reduce cost;

(g) Multi-purpose utilization of water resources for power, irrigation, waterway, transport and water supplies which involve several users participating in the project;

(h) Growing attention to the environmental problems.

129. In conclusion, it is possible to emphasize that hydropower development is well rooted, with a record in the past, and will remain useful during an extended future; its technology for both small-scale and large-scale, pumped storage and tidal power is well known and ripe for immediate use.

130. Of all the various forms of renewable energy sources that are now being considered for exploitation, hydroelectric power is the only one with a fully developed technology and a proven record of reliable and economic service. It has already been exploited on such a massive scale that, until recently, hydropower accounted for over half of all electricity supply in several developed countries. The economic feasibility of hydropower is improving, compared to other energy sources which use finite fuels. The industrial infrastructure for the manufacture of hydraulic turbines, valves, gates, generators and associated electrical equipment is well established in many countries. Until such time as the newer energy sources are fully ready for commercialization, hydropower developments appear to offer the best short-term prospect for a national power supply system, assuming suitable sites are available.

II. CONSTRAINTS RELATED TO HYDROPOWER DEVELOPMENT AND MEASURES TO BE TAKEN

131. The constraints to hydroelectric development will be discussed primarily within the context of the problem faced by the developing countries, although many of the constraints also pertain to industrialized nations.

A. Lack of information

132. The information necessary to organize and conduct a hydroelectric development or expansion programme falls into three categories: (1) hydrological and other geophysical information; (2) multipurpose information and analysis; and (3) information with respect to alternative energy development analysis.

1. Hydrological and other geophysical information

133. As outlined under section D of the Introduction, entitled "Hydropower potential", it is not possible to design and implement an optimal water resource development project without substantial knowledge of variation in the flow of the river, particularly concerning extreme high or low flows.

134. A nation with an interest in hydropower development must immediately establish a carefully designed system of stream flow gauges, if not already in place, and concurrently collect historical evidence regarding the duration and volume of flows during past floods and drought. Some hydrologic simulation techniques are available which work with minimum data. However, a careful analysis of a particular river basin's topography and rainfall-runoff characteristics is required before a decision can be made to use simulation as a basis for project design.

135. In this connexion, the activity of international organizations such as the World Meteorological Organization (WMO) and the United Nations Educational, Scientific and Cultural Organization (UNESCO) in the field of hydrology should be considered as extremely important.

136. Basic hydrological data for small-scale projects are often not adequate since such projects are to be found on small streams or in remote areas. Extensive hydrological analysis for each site is not generally warranted because of the high cost relative to the over-all project cost. Yet flow analysis is essential to allow planning of such projects. Where flow data are insufficient, flows may be obtained by regression analysis with nearby locations where such data exist or with precipitation data. Small-scale developments can be used to train manpower and acquire hydro experience for subsequent large-scale projects.

137. The other information needed for hydro development decisions is routinely collected during site-specific feasibility studies. Subsurface conditions, the availability of construction materials, the economic costs and benefits of site development, and the associated environmental and social impacts of development can be determined using long-established and proven civil engineering and water

resources planning techniques. Because of site-specificity, such "front-end" data collection costs are high and there is no guarantee that the "best" sites initially determined through aerial surveys or map studies will prove to be the most economically or environmentally sound sites after a site-specific feasibility assessment is completed.

138. Adequate cartographic material is required for many purposes in infrastructural planning, but it is especially important for the assessment of hydraulic resources potential and hydropower development. Advances in aerial photography and space technology are opening up a whole range of quite new possibilities for the assessment of water resources, including hydroelectric potential, through the use of remote observation. Although the majority of techniques are still in a developmental stage it is quite possible that such techniques may become more cost-effective than conventional methods for reconnaissance and preliminary assessment by providing current information on topographical characteristics, surface water and flood maps, basin runoff, snow and ice monitoring and evapotranspiration.

2. Multipurpose information and analysis

139. Hydro resource development should not be conducted without an initial analysis of the economic opportunities associated with competitive use of reservoir storage and releases. Any good dam sites, particularly sites with large storage volumes, offer opportunities for generating many different types of beneficial use in addition to and in place of hydro. Thus information regarding present and future national water supply, irrigation, navigation, flood control, and other water resource needs should be economically analysed and the best mix of project outputs which can be achieved through integrated development of river basin resources should be selected. The most efficient approach to this type of analysis is to begin with an overview study of national water resource needs and development opportunities, and then proceed with successively refined studies to the river basin, sub-basin, and watershed level of analysis. This process can be performed in parallel to, and also as a guide for, the site-specific hydro data collection process.

140. In this connexion the organization of international seminars should be noted (see annex IV).

141. Information at the local, regional and global levels on aspects of water power technology is disseminated by several institutions and organizations (see annexes II and IV).

3. Alternative energy development analysis

142. Just as hydro development cannot ignore competitive water resource opportunities, hydro development analysis cannot ignore competitive modes of electric generation or the various trends which will affect future electric energy demand.

143. At this particular time (only a few years beyond the commencement of the

escalation of fossil fuel prices) uncertainty regarding the desired future mix of depletable and renewable-fuelled electric generation resources within a national energy system has in many instances slowed or frozen action to develop new resources. There are uncertainties connected to water power development, namely: (1) the economic lifetime of existing fossil fuel power plants is difficult to estimate; (2) the cost of implementing renewable technologies is uncertain; (3) the future demand for energy in various forms is uncertain; and (4) the organization of local, national and international organizations to deal with water power development has been slow.

144. Any hydroelectric expansion planning should be performed in a framework which compares the hydro project with other suitable electric generation alternatives. The economic analyses should be based on a system approach, whereby the effects of each alternative project on the long-term electrical system power costs are determined. In making these analyses, it is necessary to have sufficient information to make reasonable forecasts of the future availability and costs of fossil fuels and the extent of general inflationary trends which would affect both construction costs and annual plant operating costs. While it is desirable to achieve minimum system power costs, whenever possible, there are other basic objectives which also must be considered in the decision-making process. The latter include the conservation of non-renewable fuels, the effect on the total energy system, and the need to preserve the environment.

145. Analysis is necessary to characterize the specific uncertainties associated with near-term energy demand forecasts and the risks associated with investment in both relatively low and relatively high capital cost technologies. This analysis depends directly on assumptions regarding the availability and cost of future non-renewable fuel supplies and the future availability and cost of renewable resource technologies. The most direct approach is to treat this analysis from an "economics of investment only" perspective, where future fossil fuel prices are assumed to be totally responsive to accelerating demand and diminishing supply, inflation rates are totally related to the availability of investment capital, and discount rates are used as a key variable in choosing to invest in energy expansion projects. Since all of these factors can be interrelated through engineering economic methods, an analytical framework can be derived which compares the high capital cost, low fuel cost technologies, such as hydro, with relatively low capital cost, high fuel cost energy alternatives such as fossil fuel plants. Such an analysis also provides the necessary backdrop against which the environmental and social characteristics of alternative technologies can be incorporated and compared by costing out the mitigation measures necessary to alleviate the undesirable impacts associated with each of the candidate technologies.

B. Need for research and development

146. In general, as is the case with the state-of-the-art turbine technology, the state-of-the-art of the associated hydro engineering sciences is mature, with all technologies now being routinely used. With high mechanical efficiency and reliability already achieved, no engineering advance is needed to achieve wide

utilization of the hydro resource. However, successful research in the following fields would improve the economics and accelerate the pace of hydro development:

(a) More accurate and reliable methods of determining river hydrology using short periods of stream records;

(b) Less expensive aerial surveillance methods for identifying and evaluating potential dam sites;

(c) Quicker and cheaper subsurface exploration techniques;

(d) A more quantitative understanding of the economic trade-offs associated with standardized and package-plant designs for small-scale low-head hydropower applications;

(e) Less costly and/or more efficient methods of electricity transmission and distribution.

147. As a general rule, any major expansion of technology-oriented research and development beyond current efforts focusing on small-scale and low-head applications should be carefully considered before implementation, since the pay-off is likely to be marginal and the mere establishment of a technology research and development programme may create delays in hydro utilization until the results of the research are known. Similarly, multiple-purpose water resource assessment and development techniques are readily available and any long-term review of prevalent methods is likely to be counter-productive. Instead, research and development of improved techniques and measures to facilitate comprehensive national energy planning and decision making are urgently needed.

C. Need for local manufacturing capability

148. While the large majority of developing countries still import heavy electrical equipment, a few developing countries have started manufacturing such equipment. In some developing countries, public enterprises and/or domestic private firms are involved in the manufacturing process.

149. Where manufacturing of equipment in developing countries is carried out by subsidiaries of transnational enterprises, research and development tends to be centralized in the parent companies. If dependent firms were to be established in developing countries, research and development would be carried out locally, thus strengthening self-reliance. To achieve flourishing national industry a balanced combination of the above approaches seems advisable. Countries with rural populations and suitable hydrology should therefore examine the feasibility of developing hydropower resources through local manufacture of small-scale equipment.

150. Six main issues appear to be related to the strengthening of the local manufacturing capability of developing countries:

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(a) Adding manpower in the area of energy technology;

(b) Encouraging conditions for the transfer of energy technologies;

(c) Co-ordinating public utilities' purchasing policies;

(d) Promotion of research and development activities;

(e) Manufacture of energy capital goods;

(f) Use of internationally adopted codes, standards and specifications.

151. It is obvious that these measures are all interrelated and would effect change over a period of time. Such a set of policies would require the adoption of energy planning as an integral part of resource development planning. It is only through integrating the technology dimension into the whole concept of energy planning that an adequate policy framework can be established at the national level. Such a framework has not yet been established in most of the developing countries and it should therefore be an area of priority action for them.

D. Lack of trained manpower

152. Small-scale hydropower projects make maximum use of local construction materials and employ relatively simple technology, particularly when earth fill is used for construction of the dam. Any country with even limited experience and nominal civil engineering and utility engineering capability has the necessary skills to design, construct and operate small-scale hydropower facilities, particularly if package plants are used. Nevertheless, short specialization courses for engineers would be useful.

153. However, the construction of large-scale plants as well as their operation and maintenance involves more sophisticated engineering and project management capacity and skilled manpower. The Panel noted that provision of on-the-job training in the developing countries is of great value. Technician training for installation and maintenance work should not be neglected, as well as training of technician trainers.

154. The training of skilled manpower is an area which bears prospects for bilateral, regional and international co-operation with the help of appropriate international organizations.

E. Financial needs

155. As was discussed earlier, the hydropower potential of the developing countries represents about one half of the world total and only 9 per cent of this half has been exploited. The development of such huge potential requires the transfer of large amounts of capital.

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156. There are about 62 (non-OPEC) developing countries that have varying degrees of remaining hydropower potential. Financing assistance to the developing countries for the development of this potential will be required through bilateral and multilateral support from existing international organizations, perhaps through the implementation of new financing mechanisms.

157. In addition to investment capital, this assistance may include the following activities:

(a) Conducting a review of available data on hydro potential where thermal capacity is planned and economical hydro is available as an alternative;

(b) Arranging for appropriate programmes to improve the hydrological, meteorological and surface/subsurface mapping systems in the developing countries to assist future hydro development;

(c) Promoting the undertaking of large-scale and small-scale hydro surveys. This may require co-ordination with other countries. The mini-hydro survey should include studies of power market availability so as to determine: (i) how many sites could supply small systems requiring synchronous generators and governors; (ii) how many sites could be energy producers connected to major systems, requiring only asynchronous generators; and (iii) how many sites are remote from any power markets;

(d) Initiating a detailed study of the economic hydro cost ranges for use in assessing the future feasibility of developing hydro projects.

158. Water power developments generally require rather high capital investments. For developing countries, this would usually mean that external financing of such projects is essential. The intensive national and global programmes for developing hydraulic energy sources which are already in progress, or planned, will undoubtedly limit the availability of investment capital for further development. This factor suggests that very careful consideration should be given in every country to the selection of projects for external financing. Priority lists ought to be established for this purpose.

159. The financing terms offered for water power projects are often the same as for fossil-fuelled or nuclear power plants which have a much shorter economic life. The relatively high capital cost of hydropower projects creates a large debt burden during the early years of a hydropower plant and leads sometimes to the erroneous conclusion that an alternative, less capital-intensive energy project would be more economic. To overcome this problem, financing of water power projects should be brought more in harmony with the real economic life of such plants, which is normally considered to be at least 50 years.

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F. Institutional constraints

160. Regardless of its relative state of economic development, almost every country has several governmental authorities responsible for water resources development.

161. To resolve differences of view between such different entities, it is necessary to establish decision-making procedures allowing conflicts to be resolved satisfactorily. Such a procedure requires consultation between technicians, representatives of government departments, elected officials and energy users in a geographical unit which is not the normal framework for discussion and action, namely, the catchment area, with a view to arriving at a uniform perception and understanding of various problems and a common interpretation of information by people with different training and skills.

162. It is relatively simple to reach general agreement on projects which are beneficial merely to the community in which they are located. If benefits accrue merely to communities remote from the areas affected, local communities may often react more hesitantly. Thus, the community should, to the extent possible, be involved in the decision-making process and in the implementation of the project.

163. There is, therefore, a need for an organizational arrangement which simultaneously:

(a) Considers water resource development needs and opportunities in its entirety;

(b) Deals with the problem in the geographical framework of the catchment area;

(c) Promotes a decision framework with a common language, a common interpretation of information, and thus mutual comprehension;

(d) Includes an action organization responsible for promoting, constructing and operating works beyond the planning stage.

164. It is worth mentioning in this connexion the organizational arrangements adopted in some countries, which established a new basis for co-ordination in the use of water and include, *inter alia*, the following:

(a) An interministerial task force at the national level;

(b) Catchment area committees and finance agencies;

(c) Regional technical committees on water development (if one basin affects several regions).

165. The organizational arrangement which has been very briefly outlined above makes it possible to ensure the necessary consultations at all levels, to integrate

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individual projects into an over-all programme, to undertake in-depth studies, protect all interests involved, take full advantage of potentials, settle conflicts and, by providing for the involvement of interested parties in preliminary studies through the execution and operation of the works, create the motivation necessary for positive and coherent action.

166. Although this model arrangement is probably not directly transferable to different administrative, demographic, political, economic and cultural contexts, any other arrangement aimed at the same objective should recognize that hydropower development, irrespective of its size, must be regarded as an element of integrated water resources development.

167. To secure the public and private interests in water resources utilization, suitable legislation is required. Such legislation exists in many different countries which could serve as a model for other countries.

G. International institutional constraints

168. National or regional boundaries seldom conform to watershed boundaries, but may follow rivers (boundary rivers) or cross rivers (transboundary rivers) thus effectively dividing a basin. Where national boundaries divide a drainage basin, which is the usual physical unit for assessing hydropower potential, the countries sharing the resource must engage in negotiations with a view to co-operating in the development and use of the resource for the greatest benefit of all concerned.

169. According to the Register of International Rivers, prepared by the United Nations, more than 200 river basins straddle boundaries.

170. In these rivers, a major difficulty is arriving at an equitable division of the water and of costs, benefits, responsibilities, construction and operation activities, or whether or not a development provides adverse or beneficial effects to the downstream country.

171. A number of successful international developments have been worked out, such as those on the Columbia and St. Lawrence rivers involving Canada and the United States; the Irongate dam on the Danube river involving Romania and Yugoslavia, a number of rivers in Europe, such as the Rhine, and in Latin America, such as the Parana involving Brazil, Uruguay and Argentina.

172. The latest example in solving such problems is the Treaty for Amazonian Co-operation 3/ signed by Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname and Venezuela. Article V of this treaty proclaims that the contracting parties shall make efforts aimed at achieving rational utilization of hydropower resources.

173. Problems of hydropower development in international rivers are complex - technically, socially, politically and economically - and the most knowledgeable, balanced and objective evaluations and judgements are necessary.

3/ See A/35/580.

III. GENERAL SUMMARY AND RECOMMENDATIONS

A. General summary

174. Of all renewable sources of energy, hydropower is expected to make a significant contribution in the energy picture, in particular power systems of countries throughout the world during the next 20 to 25 years. Only a small portion of the economic potential of hydropower resources is utilized today. An immense unused hydropower potential is available in the developing countries.

175. Hydropower utilization technology is by now sufficiently well developed. Much experience has been amassed in the building and operating of hydroelectric power stations in various regions of the world and under different climatic, geological and geophysical conditions. The efficiency factor of hydroelectric power equipment now being manufactured in many countries is very high. The dissemination of accumulated experience in planning and building hydroelectric power stations to developing countries and the expansion of co-operation in the manufacture of hydroelectric equipment are essential conditions for a fuller utilization of hydropower potential.

176. The growing importance of hydropower in national economies and energy systems is reinforced by the fact that water resources are used in an integrated manner for the development of irrigation, water transport, and water supply to industry and population. It is also reinforced by the importance of flood control. The excellent flexibility of hydroelectric generating plant and its operational reliability mean that hydroelectric power plants can be used to regulate capacity in accordance with consumer requirements, thus creating favourable conditions for the operation of thermal and nuclear power plants.

177. Considerable successes in the utilization of water power provide the necessary conditions for the development of pumped storage and for the utilization of tidal energy. Better utilization of hydropower potential is achieved through re-use of water power with reversible generator sets and the construction of pumped storage plants on minor watercourses. Experience gained from the construction of the first tidal power stations has shown that it is technically feasible to use tidal energy. For the present, however, the development of such power stations in suitable locations is held back by the high construction cost of such plants.

178. The extensive use of hydropower is currently held back by the inadequacy of background hydrological, topographical, geological and economic data, especially in developing countries where most of the as yet unused hydropower potential is concentrated. Lack of skilled personnel and financial constraints in these countries also exercise a serious limiting effect. Considerable possibilities for hydropower development are available on international rivers, but their use for power generation is often rendered difficult by the absence of basic legal standards to govern the joint construction and operation of hydropower installations on such rivers. The above-mentioned constraints could, however, be largely eliminated in the near future by the adoption of appropriate measures.

B. Recommendations

179. Having in mind the current availability of the established and widespread use of hydropower technology for the exploitation of the water resources of a country, the Panel makes the following recommendations to elaborate and enhance the use and value of this renewable resource:

1. General

180. Special attention should be drawn to the international professional organizations working in the field of water resources, water power, electricity systems and supply technologies. They should be encouraged to extend further their efforts to embrace developing countries in their activities to the extent possible. Developing countries not yet participating in such organizations should take steps to do so.

181. The international electrotechnical vocabularies published by the International Electrotechnical Commission (IEC) in several languages, with definitions for the hydraulic and electrotechnical field industries, e.g. water power and electrical supply system technologies, should be made full use of.

182. International standards covering various aspects of hydraulic and electrotechnical material for generation of electrical energy are issued by IEC. Application of such standards is recommended. They should be adopted as national standards also in countries where standards are not yet established.

2. At the national level

183. Proper institutions should be organized on local, national and international levels as appropriate to deal with hydraulic energy resources investigations and planning, construction and operation of hydropower plants and electricity supply systems, and other hydraulic installations associated therewith, and similarly on financing and legal matters.

184. In each country, subregional or regional institutions should be established to provide cartographic materials which are required for hydropower planning.

185. Hydropower potential should be examined in the context of a national natural resource development policy and stream gauging and other hydrological networks should be established to provide an adequate data bank for hydropower development.

186. The potential for rural application of small and micro-hydropower development should be examined and countrywide programmes for its development should be prepared where appropriate.

187. Because of limited availability of funds for hydropower development both at national and international levels, a priority list of hydropower development schemes should be established. Financing terms of such projects should reflect the long economic life of hydropower plants.

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188. National research, development and demonstration programmes should be strengthened with appropriate bilateral assistance or through international organizations to make it possible to assess, select and adapt relevant hydropower technologies developed in the industrial countries.

189. Training programmes to meet trained manpower requirements and programmes of training of trainers should be established with appropriate bilateral and international assistance through either training centres or pilot projects in the field of planning, construction, maintenance and operation.

190. Special legislation on water rights should be established in countries where such legislation does not exist or is inadequate.

3. At the international level

191. Hydraulic resources of countries should be reviewed on a global basis. In this connexion the Panel draws attention to the work of the World Energy Conference (WEC) on such reviews and recommends that future United Nations activities and others in this field should be co-ordinated with those of WEC.

192. Standardization of hydropower equipment and of the "package plant" design of small-scale and even large hydropower plants should be accelerated through international collaboration.

193. A world-wide survey on the manufacturing of hydropower equipment, such as turbines, generators, regulators etc., should be undertaken with the help of appropriate international organizations. The information could form a basis for the promotion of international co-operation and local manufacturing of such equipment, particularly in developing countries.

194. Information systems should be strengthened with respect to manufacturers of hydropower equipment and types of equipment manufactured by them.

195. Programmes of technical assistance to developing countries should be intensified, through appropriate international organizations, in the field of development and utilization of their hydropower potential, especially for the purposes of industrial and agricultural development of these countries.

196. The design and production of hydropower equipment in developing countries should be an object of special technical and financial assistance so as to ensure development of their hydropower potential without complete dependence on imports.

197. Regional seminars and workshops should be organized to disseminate information related to development of hydropower resources.

198. A survey of experience of hydropower development in international rivers should be undertaken with the help of appropriate international organizations and a set of practical recommendations, designed to promote utilization of hydropower potential of such rivers, should be developed.

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199. Collaboration of developing countries in development of large-scale hydropower projects should be promoted. Such a multinational approach to hydropower development would be efficient in promotion of regional and interregional co-operation. Interconnexion of intranational and, where applicable, national electric transmission networks should be recommended.

Annex I

LIST OF PARTICIPANTS

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Annex II

LIST OF ORGANIZATIONS, PERIODICALS AND REFERENCES

A. Organizations in the field of hydropower development and electricity supply

1. Governmental organizations

United Nations organizations and specialized agencies

World Bank

Regional development banks

European Economic Community (EEC)

Council for Mutual Economic Assistance (CMEA)

International Energy Agency (IEA)

Latin American Energy Organization (OLADE)

2. Non-governmental organizations

World Energy Conference (WEC)

International Commission on Large Dams (ICOLD)

International Electrotechnical Commission (IEC)

International Standardization Organization (ISO)

Union internationale des producteurs et des distributeurs d'énergie électrique (UNIPEDE)

Conférence internationale des grands réseaux électriques (CIGRE)

Congrès international des réseaux électriques de distribution (CIRED)

Association in the power supply industry in Denmark, Finland, Iceland, Norway and Sweden. International (Inter-Nordic) Co-operation in the Production, Distribution and Consumption of Electric Energy (NORDEL)

Union pour la coordination de la production et du transport de l'électricité (UCPTE)

International Water Resources Association (IWRA)

Commission de integración electrica regional (CIER)

B. Periodicals

Water Power and Dam Construction

Water International

Energy International

Civil Engineering Magazine

Water Supply and Management

Water World

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C. Special references and publications

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Annex III

WORLD HYDRAULIC POTENTIAL

Table 1. Annual hydraulic potentials

Region	Theoretical potential 10^{12} kWh	Technical usable potential 10^{12} kWh	Operating potential 10^{12} kWh	Potential under construction 10^{12} kWh	Planned potential 10^{12} kWh
Africa	10.118	3.14	0.151	0.047	0.201
America (North)	6.15	3.12	1.129	0.303	0.342
America (Latin)	5.67	3.78	0.299	0.355	0.809
Asia (excluding USSR)*	16.486	5.34	0.465	0.080	0.368
Oceania	1.5	0.39	0.059	0.020	0.032
Europe	4.36	1.43	0.842	0.094	0.197
USSR	3.94	2.19	0.265	0.191	0.17 (estimated)
Total	44.28	19.39	3.207	1.090	2.12

Source: World Energy Conference, Survey of Energy Resources, 1980.

* The figures may not include data from China. According to information presented by Mr. Zhu, member of the Panel, the theoretical potential of that country is estimated at 6×10^{12} kWh, with technically usable potential of 1.9×10^{12} kWh. At the end of 1979 the total operating potential was 0.05×10^{12} kWh and potential under construction 0.0517×10^{12} kWh.

Table 2. Estimated probable hydroelectric development

Country groupings	Potential energy in exajoules ($1\ EJ = 10^{18}\ J$) 1976	1985	2000	2020
OECD countries	3.78	4.49	5.37	7.80
Centrally planned countries	0.72	1.20	2.88	8.70
Developing countries	1.17	1.97	4.49	11.80
World total	5.67	7.66	12.74	28.30

Source: World Energy Conference, Survey of Energy Resources, 1980.

Note: The figures shown are the probable annual energy from installed hydroelectric facilities for the year indicated.

Annex IV

RECENT INTERNATIONAL SEMINARS IN THE FIELD OF HYDROPOWER DEVELOPMENT

A. Symposium on the Prospects of Hydroelectric Schemes in the New Energy Situation and Related Problems, Athens, November 1979

1. The increasingly high cost of oil-based energy supplies has turned attention afresh to the potential of hydroelectric schemes. In many countries that wish to leave no stone unturned in combatting the energy crisis, the role of hydroelectricity is being re-examined.

2. As a way of promoting this re-evaluation the Committee on Electric Power of the Economic Commission for Europe (ECE) organized a symposium at Athens, from 5 to 9 November 1979, on the prospects of hydroelectric schemes in the new energy situation and related problems.

3. By 1973, when oil costs were sharply increased, the countries of the ECE region had already exploited their hydroelectric potential to a very high degree and hydroelectric schemes in general were receiving less attention from the most economically developed nations.

4. Since 1973, however, changed energy conditions have brought to light the need to exploit more conventional sources of primary energy. Many countries have begun to re-evaluate their hydroelectric potential and consider the principles and techniques applicable to the planning, design, construction and operation of water-powered schemes.

5. The Athens Symposium provided the opportunity to exchange experience and information among ECE member countries to determine the extent to which hydroelectricity can be developed further to meet the needs raised by the new energy conditions.

6. Five general rapporteurs prepared consolidated reports, based on the national papers submitted. Papers focused on five main groups of subjects with emphasis on the identification of problems areas in which international co-operation is desirable. The main themes included the potential of hydroelectric schemes for power and energy; the relationship of such schemes with environmental considerations; technical and engineering problems; the role of hydroelectric schemes in an integrated energy supply system which includes other kinds of energy resources; and the evaluation of various kinds of schemes and their financial implications.

7. The proceedings of this symposium will be published in the first half of 1981 by Pergamon Press.

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D. Seminar/Workshop on the Exchange of Experiences and Technology Transfer on Mini-Hydroelectric Generation Units, Kathmandu, Nepal, September 1973

8. Seminar/Workshop was jointly sponsored by UNIDO and ESCAP/RCTT and organized at Kathmandu, Nepal, in September 1979. The Seminar/Workshop focused, inter alia, on the technology, economics, policy and institutional aspects of the promotion of the application of mini-hydropower generation units in developing countries, particularly in the rural and remote areas.

9. The meeting proceeded into group discussions by dividing the participants into three working groups:

Group I. Technical aspects (in-depth discussions):

(a) Specific technical aspects of equipment involved in mini-hydro plants

(b) Research and development

(c) Information system

(d) Technology transfer and training

(e) Standardization

Group II. Economic aspects:

(a) Total cost breakdown of different mini-hydro generation systems

(b) Economic comparison of different systems of electricity generation

(c) Cost reduction scheme

(d) Socio-economic benefits

Group III. Policy and institutional aspects:

(a) Policy on mini-hydro generation

(b) Institutions related to electrification and mini-hydro generation

(c) Financing institutions/training institutions

(d) Development and transfer of technology

(e) Standards and norms

(f) International institutions

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10. The meeting recommended, inter alia, the publishing of a newsletter containing information on planning and programmes, R and D work, design and manufacture of equipment and other developments, as well as the preparation of a manual for mini-hydropower stations.

11. The Seminar/Workshop adopted the Kathmandu Declaration for International Co-operation in the Field of Mini-Hydroelectric Generation Technology, and the Need to Strengthen International Co-operation to Accelerate the Electrification of Rural Areas.

12. The meeting was attended by 41 representatives from 23 developing countries and 27 representatives from 10 developed countries. Sixty-six papers which were presented at the meeting are available from UNIDO. a/

C. Second Seminar/Workshop/Study Tour in the Development and Application of Technology for Mini-Hydropower Generation, Hangzhou, China, and Manila, October/November 1980

13. The Second Seminar/Workshop was organized by UNIDO with the aim of proceeding further beyond the Kathmandu Workshop, by focusing on the planning, construction and application of mini-hydropower generation units (MHG), particularly by making a comparative study of the methods of planning and programme implementation in China and the Philippines. It further considered various means and measures to support the efforts of developing countries in the application of mini-hydropower generation, with specific emphasis on:

(a) The systems approach to the establishment of MHG projects, including considerations on the socio-economic benefits;

(b) Local manufacture of equipment and construction of MHG stations;

(c) The interlinkage between MHG and rural industry development;

(d) Cost reduction schemes in MHG installations.

14. The meeting further recommended a number of other programmes, including the preparation of a manual for prefeasibility and feasibility of MHG projects; the preparation of a manual for Chinese experiences on MHG, promotion of local manufacture of MHG equipment in developing countries; establishment of regional/interregional research, development and training centres for MHG; compilation of a bibliography on MHG; etc.

15. The Second Seminar adopted the Hangzhou-Manila Declaration on Mini-Hydropower Generation, which underlines the urgency of the need to implement programmes for supplying cheap, reliable and renewable energy resources for the rural population,

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a/ ID/WG.305/1-66.

and *inter alia*, called on the developing nations to initiate and accelerate MHG programmes encouraging local involvement. It further requested the developed countries and international financial institutions to help developing nations by providing technical and financial assistance; to encourage ready access to information on MHG technology especially through the existing UNIDO Industrial and Technological Information Bank (INTIB); and to continue the exchanges of country experiences.

16. The meeting expressed the view that follow-up action was expected to be undertaken by UNIDO or, through the intervention of UNIDO, by other United Nations or international agencies or organizations as appropriate complying to their given mandates in order that the requirements of the developing countries could be attended to expeditiously.

17. The second MHG meeting was attended by 38 representatives from 24 developing countries. Forty papers presented at the meeting are also available from UNIDO. b/

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b/ ID/WG.329/1-40.