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PRESENT STATUS OF SMALL-SCALE HYDROPOWER DEVELOPMENT *

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Present Status of Small-scale Hydropower Development

Introduction

This paper focuses on small-scale hydropower in the developing countries. It is concerned with an overview of the present situation and how it is likely to develop, rather than a detailed statistical survey on a country-by-country basis. Some detailed information is given relating to small-scale hydropower in selected developing countries, but this is of an illustrative nature.

Although a review of the history and current situation of small-scale hydropower development is interesting, the major concern must be to the future and how the developing countries can pursue small-scale hydropower developments as a tool in their overall economic and industrial development. It goes without saying that small-scale hydropower cannot be viewed in isolation, but must form an integral part of any country's total energy plan.

In reviewing small-scale hydropower developments that have already taken place, attention has been directed to the basic policy considerations which lay behind such developments. It is these considerations which may give positive indications as to how small-scale hydropower developments could be initiated in those developing countries which have not yet undertaken such programmes, and the strengthening of future programmes in developing countries, which already have established small-scale hydropower programmes.

Small-scale hydropower development can be viewed as a total system containing a number of elements, all of which need to be examined,both separately and as a whole. Firstly, there is the planning of small-scale hydropower and the development of specific programmes with the end uses of the energy identified. Secondly, there is the technology involved. Thirdly, there is the acquisition or local manufacture of the various equipments and components of a small-scale hydropower plant. Fourthly, there is the construction of the plant and all the associated activities, and finally, there is the operation and maintenance of small-scale hydropower plants.

In carrying out this study, the industrial aspects of small-scale hydropower development, both as a source of decentralized energy for local industry and the local manufacture and construction of small-scale hydropower, receives attention. This, of course, is only a reflection of the interest and responsibilities of UNIDO.

Small-scale hydropower is a potential energy source for the majority of countries, both developed and developing. As a result, co-operation in all aspects of small-scale hydropower at the subregional, regional and international levels have developed. One interesting feature of this co-operation is the extent of co-operation among developing countries.

Historical Background and Re-emergence of Small Hydropower

The exploitation of hydropower is an old and mature technology. Waterwheels were used to provide energy in many early civilizations. Even today, waterpower in this form is widely used in the rural areas of many developing countries.

The utilization of rivers, streams, waterfalls etc., to generate electric power was well-developed in Europe and North America by the beginning of the 20th century. With the increasing use and reduction in price of coal and subsequently oil, electric power generation in the industrialized countries was largely fossil fuelled. Therefore, hydroelectric power tended to be limited to large-scale projects on major rivers, and remote areas away from the electric grid. This was the general pattern in the industrialized countries and to some extent, the developing countries, until the early 1970s, when two major factors emerged. Firstly, there was the major increase in world oil prices in 1973, and again in 1979, coupled with supply interruptions and a general concern for security of oil supplies. The second, partly based on the first, was the concern related to the depletion of the world's resources. This was directed in large measure to oil and other depletable energy resources. One expression of this concern was the general interest and promotion of new and renewable sources of energy, which culminated in the United Nations Conference on the subject held at Nairobi in August 1981.

Currently, the developing countries are having to import some 60 per cent of their commercial energy, the bulk of which is in the form of imported oil. This has an obvious and serious effect on the balance-of-payment situation in developing countries. It has been estimated that the oil import bill of the energy deficient developing countries was some US$ 50 billion (10^9), and could rise to over US$ 100 billion by 1990. The price of oil has not been the only problem for the developing countries, but disruptions of supply and shortages have also occurred whenever the world oil market was in a tight situation. This is obviously the result of the fact that, individually, developing countries represent small markets and more importantly, the oil companies who largely decide on allocations, are controlled by industrialized countries.

In recognition of the difficulties faced by the developing countries in the importing of oil, and in view of the finite supply of fossil fuels, the United Nations Conference on New and Renewable Sources of Energy adopted a programme of action for the development and utilization of new and renewable sources of energy.

Within the category of new and renewable sources of energy, the Nairobi Conference recognized the important role for hydropower and indicated 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. It was also noted that the hydropotential in the developing countries was immense and largely unused.

The major advantage of hydropower over other forms of new and renewable sources of energy is that it can be developed using known technology, whereas many of the other new forms of energy, such as biomass conversion, tidal and solar energy, are still at the research and development stage, at least in terms of large-scale application in the developing countries.

As a result of the above considerations, many developing countries have initiated or strengthened programmes aimed at increasing the utilization of their hydropower potential. This is not a short-term activity requiring hydrological resource assessments and detailed planning relating to specific sites, as well as the development of an institutional mechanism for the planning and implementation of small-scale hydro programmes.

The general desire for indigenous and secure supplies of energy is now common to all countries and is therefore a stimulus for small-scale hydropower. Although many developed countries are examining and introducing new and renewable forms of energy, the majority of these developed countries have well-established electric grid systems, and, therefore, the role of small-scale hydropower at relatively high unit cost is rather small. On the other hand, many developing countries require decentralized electric power and small-scale hydropower is an economic alternative to the high cost diesel generation that is currently used. It must be recognized, however, that many of the plans for small-scale hydropower in the developing countries are being delayed by the difficult financial situation facing the developing countries.

The re-emergence and renewed interest in small hydropower worldwide over the last 10 years or so has, of course, stimulated activity in all aspects of the subject. The trend has been to simplify, standardize and reduce costs of the component parts of a small hydropower project. The introduction and utilization of advanced technologies, such as microelectronics and new materials, have led to technical improvements and cost reduction. A very important aspect is the use of microprocessors for remote control removing the need for operators in small plants in very isolated areas. Alongside these developments has been the general move towards local involvements in small-scale hydropower development in the developing countries. This has taken a variety of forms, and in some cases developing countries are virtually self-sufficient in the development and implementation of small-scale hydropower projects with major benefits not only to their balance of payments, but also to their overall technological capacity.

Hydropower Resources

As with other estimates of energy resources, the data on hydropower resources must be viewed with extreme caution. This is the more so when dealing with data from developing countries, where the statistics have only just started to be compiled.

Various authorities have examined the question of hydropower potential based on the admittedly relatively scarce data. Hydropower potential is usually divided into three broad categories: theoretical, technical and economic. 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 according to a report by the Preparatory Committee for the United Nations Conference on New and Renewable Sources of Energy, to an annual electric power output of 44.3×10^{12} kWh. The technical hydropower potential takes account of the fact that certain areas of rivers cannot, for technical reasons, be used for power production. It is therefore estimated that the technical hydropower potential is about half the theoretical level, (19.39×10^{12} kWh). The economic potential relates to those hydropower resources which are technically suitable for utilization, and which are regarded as economic compared to alternative sources of electric power. It is obvious, that this is a very subjective estimate, and will vary overtime depending on technology and relative prices of energy sources. According to the 11th World Energy Conference, the economic potential of hydropower is at least 6.4×10^{12} kWh (includes potential operating, under construction, and planned).

The breakdown of hydropower potential by region is given in Table 1 below. This is taken from the report of the Technical Panel on Hydropower to the Preparatory Committee for the United Nations Conference on New and Renewable Sources of Energy.

Table 1

Annual Hydrological 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	0.383	0.342
America (Latin)	5.67	3.78	0.299	0.355	0.809
Asia (excluding USSR)*	16.486	5.34	0.465	0.088	0.368
Oceania	1.5	0.39	0.099	0.080	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.

Hydroelectric power during the early 1980s was providing about 23 per cent of the world's electricity (United Nations Energy Statistics). The total installed hydroelectric capacity was reported at the 11th World Energy Conference to be about 372,000 megawatts,with an annual production of 5.7 million terrajoules (1.6 million gigawatt hours). This is approximately 16 per cent of the total installed and installable capacity as reported in the World Energy Conference Survey of Energy Resources, which gave a figure of 34,921,000 terrajoules yearly production (2,200,000 MW generating capacity at 50 per cent capacity factor). The industrialized countries (OECD) have developed about 46 per cent of their capacity, while the developing countries have on average developed only about 7 per cent. Figure 1 below shows the world hydropower potential by region, and gives estimates of the operating, under construction, planned and remaining potential considered probable for development.

WORLD HYDRAULIC RESOURCES

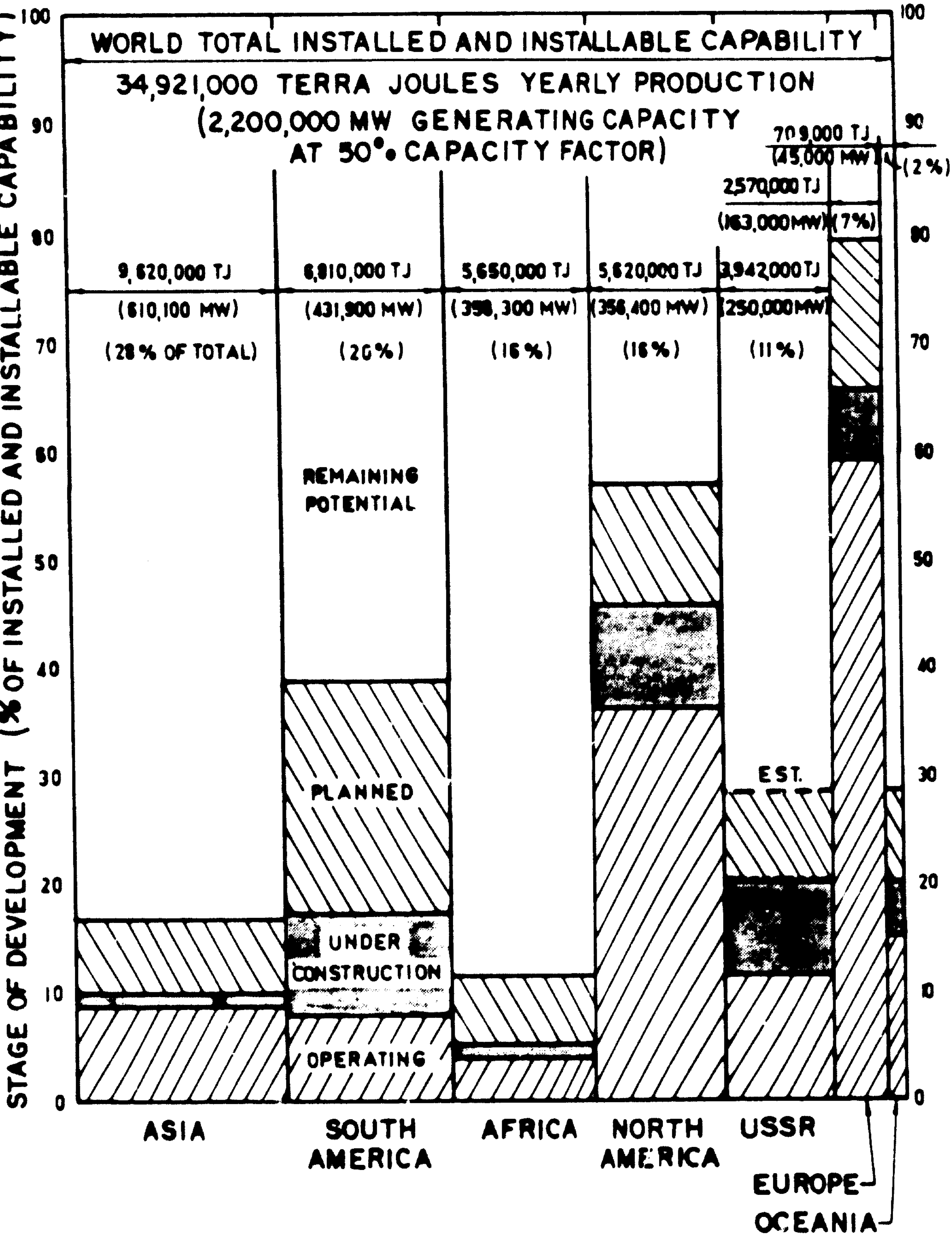

FIGURE 1

Source: Hydraulic Resources by Ellis L. Armstrong, World Energy Conference.

It is interesting to note from Figure 1 the relative share of total hydraulic resources by region - Asia having 28 per cent, South America 20 per cent and Africa 16 per cent. Not only is the developing country share some 64 per cent of the total resources, but their share of remaining potential is also very high.

Figure 2 shows the world hydraulic resources, broken down by developing, developed and centrally planned economies. The country groupings and names again are taken from the report to the World Energy Conference by Ellis L. Armstrong, and do not equate with the official names of countries used by the United Nations.

The breakdown used in Figures 1 and 2 relating to operating, under construction, and planned should not be given too much importance, as it concerns the situation as it was in 1976. But it is at least an indicator of the general situation in the regions of the world. From experience elsewhere, it is likely that the under construction and planned elements are probably overestimates, given the economic situation that most countries have been faced with in the last few years.

Based on the data contained in Figures 1 and 2, an estimate was made of the probable hydroelectric development to the year 2020. As this forecast was made in 1980, it should b treated with some reservation. This forecast is shown in Table 2 below, and even accepting the reservation noted above, the growth for the developing countries will be much higher than for the other two categories, representing some 41 per cent of the total world hydroelectric power.

It must be remembered that all these estimates of hydroelectric power capacities and their growth are based on comparisons with other energy sources for electric power production and any change in relative energy prices will have a major impact. Similarly, hydropower potential is sensitive to changes in technology, which again will have a direct impact on their relative competitiveness. Another point to consider is the financing of such large-scale capital investment projects usually associated with hydroelectric power resource development. It was estimated that the developing countries would have to spend some US$ 15 billion a year to the year 2020 to develop their hydroelectric installations. With the current economic and financial situation facing the developing countries

WORLD HYDRAULIC RESOURCES

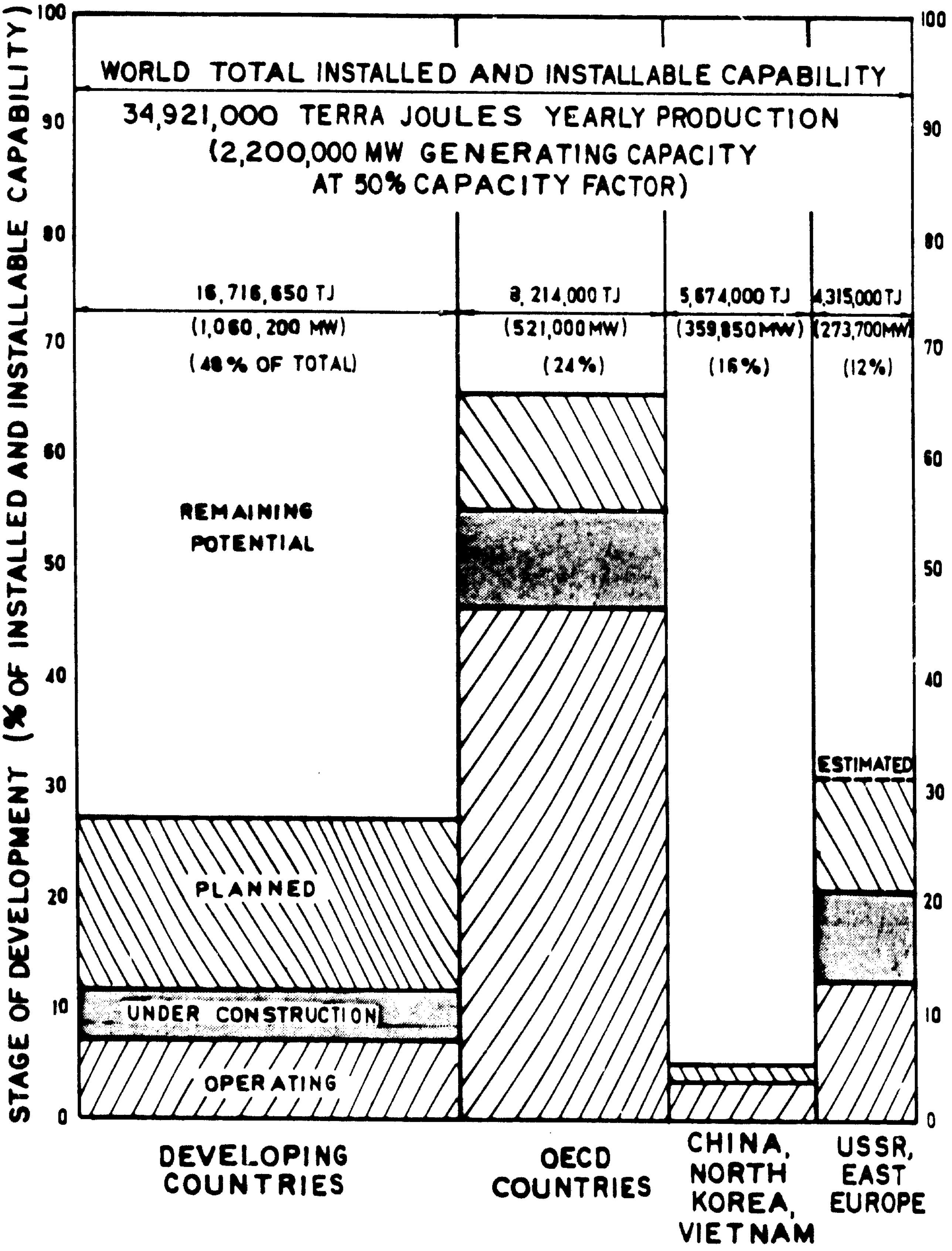

FIGURE 2

as a whole, some doubt must exist as to their ability to achieve this level of capital investment for hydropower development.

Table 2

Estimated Probable Hydroelectric Development

Divisions	Potential Energy in Thousands of Terajoules (TJ) Year 1976	Year 1985	Year 2000	Year 2020	Total Developable from 1976 WEC Survey
OECD Countries	3,776	4,493	5,369	7,800	8,214
Centrally Planned Economies	719	1,200	2,880	8,700	9,990
Developing Countries	1,172	1,973	4,490	11,800	16,717
World Total	5,667	7,666	12,739	28,300	34,921

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

All these estimates of hydropower resources are based on information provided by countries. In many cases it is clear that the data only relates to hydropower potential with power plants with capacities of more than 5 MW. Therefore, the resources in the categories small, mini and micro hydropower are usually excluded. This means that the resources of hydropower potential are underestimates and probably more so in the developing countries, where information on rivers etc., are less well defined. It is possible, however, to gauge the scale of the hydropower resources, both worldwide and in the developing countries, from the available statistics, because there should be a positive relationship between large-scale hydro resources and those relevant for small-scale development.

On a national basis estimates of hydropower resources, especially those for small scale, can only be obtained after fairly detailed site surveys on rivers and river basins. This is of course a time-consuming and costly operation, and should be considered as part of a total small-scale hydro development programme utitilizing, as far as possible, simplified assessment techniques.

Major Developments in Small-scale Hydropower in Developing Countries

Unfortunately, there is no comprehensive and unified information source on developments in small-scale hydropower in the developed or developing countries. This is partly due to the very large numbers of plants involved, and secondly to the fact that they are by their very nature small, decentralized and, in some cases, especially in the developed countries, outside the public system. As a result, the information and statistics available on small-scale hydropower development tend to be sketchy and in a non-standard form. Perhaps as the importance of this decentralized power source grows, there will be a better statistical base, upon which to draw general conclusions, and monitor the situation. Therefore, the information that has been obtained from the developing countries regarding their small-scale hydropower at the various UNIDO meetings on this subject, has been utilized. As mentioned earlier, this is illustrative of the situation in developing countries as a whole.

People's Republic of China

Without doubt, China has pride of place in regard to small hydropower. By the end of 1982, 86,000 small hydropower stations with a total installed capacity of over 8 million kW had been built in China. This provided an annual energy output of 16.3 billion kWh. The construction of SHP has been implemented in more than 1,300 counties, of which 744 obtained their power mainly from SHP stations.

In China, SHP plays an important role in solving the problems of rural power demand. It serves local industries, irrigation and drainage, and helps to raise the people's general standard of living. An example of the utilization of electric power from SHP for local industries is that of Yongchun county in the south Fujian province. Here 252 SHP stations with a total capacity of 23,000 kW have been built. Their annual energy output is 60 million kWh. These SHP stations provide cheap motive power for a whole range of small industrial production units, covering coal mining, cement, chemical fertilizer, machinery, textile, paper, porcelain and printing, timber, sugarprocessing, teaprocessing and winemaking. The annual output value of these county-run industries have increased more than four times since 1969, when the first SHP conference was held in that county.

China is rich in waterpower resources. The results of a general survey showed that the hydropower resources are 680 million kW, of which 380 million are considered exploitable. Within this category, some 70 million kW are considered suitable for the development of SHP. Table 3 below shows the SHP resources in China by areas.

Areas	Exploitable MW	%	Developed (MW)
Southwest	33.392	46.8	1,790
Northwest	9.361	13.1	470
Central and South	15.542	21.8	3,390
East	9.424	13.2	1,960
Northeast	1.953	2.7	180
North	1.641	2.3	220
TOTAL	71,313	100	8,010

The development of SHP in China can be divided into 3 phases. During the fifties, China was engaged in a co-operative transformation of agriculture. The national programme for agricultural development stipulated "any water conservancy project capable of generating electric power should carry out simultaneously the construction of medium and small size hydropower stations". By 1960, some 9,000 SHP stations with capacities totalling 238,000 kW had been set up. The SHP stations which were constructed were very small, with an average of only 2.6 kW. In addition, most of these were isolated stations and working under run-off conditions without any regulation, with inferior quality in construction and low reliability and efficiency of the generating units. In this period, the turbines and penstocks installed in several places were made of wood and bamboo respectively, and the electric power generated was used solely for illumination and simple processing of agricultural products.

In the sixties and seventies, the capacities of new SHP stations increased with an average of 44 kWs for each station. Some of these SHP stations were connected to the national grid and some others developed their own district power supply for local irrigation as well as for local industry. During this period, the necessary materials for construction of SHP components were assigned to various local factories. This measure gave great impetus to various provinces in their tasks of manufacturing mechanical/electrical equipment.

From the late seventies, SHP in China developed very quickly, with average annual increases in capacity from 5-600,000 kW. The SHP developments during this period showed the following important characteristics:

- key stations were increased, and reliability improved;
- the average capacity of SHP stations reached 99 kW;
- distribution districts of SHP were gradually increased, and independent local grids were set up within the range of a county;
- the quality and reliability of power supply was improved to render a more useful service to industrial and agricultural uses;
- surplus electric power began to be utilized to meet seasonal needs;
- a series of general and specific policies for the development of SHP was instituted.

All the equipment and components for SHP stations in China were manufactured locally. In addition, the construction of SHP plants was carried out by the local people, with the Government providing the techniques, equipment and necessary raw materials.

India

Small hydroelectric projects in India can be broken into two broad categories: small independent hydroelectric projects in the hills, mainly Himalayan, using medium/high heads, but with small discharge; and small installations in the plains, which utilize water regulated for other purposes, e.g. irrigation canals, and small dams. These are of low head with larger discharge.

India possesses a large conventional hydro potential, of which only about 10 per cent has been tapped so far. The small hydropower developments are receiving a great deal of attention, and at present some 88 schemes were in operation by 1980, and a further 93 were either under construction or investigation. The installed capacity of these schemes, if all are completed, would be 1.4×10^6 kW.

The future prospects for small hydropower in India appear very promising. The low head canal-type schemes are essentially secondary in nature and can only be developed as part of a major programme of irrigation, etc. On preliminary assessments, the potential of this type is likely to be of the order of 3 million kW. In the hilly regions, more topographical and hydrological information is needed to identify potential small hydropower sites. But a rough estimate is that some 2 million kW capacity could be installed.

The small hydropower schemes in the hilly regions are used locally for domestic and rural industries. The small hydropower developments in the plains, however, are connected to the grid system, as grid lines are available almost all over the plains.

The complete design and engineering for all Indian small-scale hydropower projects including feasibility reports, planning, construction and commissioning of civil, electrical and mechanical work is done by Indian engineers. In addition, the manufacture of the components of the generating units and auxiliary equipment is carried out in India.

Pakistan

In Pakistan the work on high head/low discharge near-perennial waterfalls has captured the attention of people living in remote areas. Some 40 small-scale hydropower units have been established by 1982. These had a total capacity of 340 kW, and provided light to over a 1,000 households and motive power to 39 small industrial units. After overcoming some initial skepticism, the demand for small-scale hydropower has now outpaced the supply. The provision of electric power to remote regions has brought some major social changes. The introduction of lighting, ceiling fans, heaters, radios and televisions, irons and sewing machines, represent a quantum jump in exposure to modern technology.

Sri Lanka

In Sri Lanka there are 12 conventional hydropower schemes in operation or construction. These range from 6 to 200 MW. As for minihydro plants, some hundreds were constructed during the 1930s and 1940s, in connection with the tea plantations. But since the 1950, and the introduction of large public sector hydropower schemes most of these mini plants were abandoned, which is now considered rather a short-sighted action. The Ceylon Electricity Board, although not undertaking the construction and operation of minihydropower plants, encourages other Government corporations and the private sector to develop such plants. The Ceylon Electricity Board offers consultancy services and has constructed a 35 kW plant as a demonstration project. The main concern at present for the Ceylon Electricity Board is the development of small hydropower schemes in the range of 1 to 20 MW. Some 30 to 40 schemes in this size range have been identified. One scheme is to be undertaken with Chinese Government support, and it is hoped that this will stimulate further small hydropower development.

The problem for minihydro plants in Sri Lanka is that they are generally run-of-the-river plants, and most streams in Sri Lanka have practically no flow for power generation in the dry season - 6 months of the year. In the wet season, there is a large excess capacity from conventional power stations. In remote villages, where the grid is not available, a stand-by diesel generator would have to be provided in addition to a mini hydropower plant, because of the problem during the dry season.

As to local manufacture and construction, there is ample civil engineering expertise in Sri Lanka to develop mini and small hydropower schemes, but management and finance are badly lacking. Demand for electromechanical equipment associated with mini and small hydropower schemes is not sufficient for local manufacture in Sri Lanka. It is expected that China and India could provide the necessary equipment at low cost.

Burma

Burma has a long-term hydropower development plan, the main objectives of which are as follows:

- to supplement hydropower to the existing power suppl';
- To provide more economical and reliable power supply and extend it to more rural areas to stimulate economic activity and spread social welfare to a larger cross-section of the population;
- to substitute the use of petroleum products, natural gas and fire wood with a renewable energy resource available in abundance locally for electric power generation; and
- to conserve kerosene and petroleum products used for lighting and other purposes in rural areas and remote locations.

Under the long-term plan, a few medium and mini hydropower projects are presently in various stages of construction and several new projects are being proposed. At present, seven mini hydropower plants are under construction, of which four are conventional run-of-the-river type, and the remaining three are bulb type for installation at existing irrigation outlets. The installed capacity ranges from 60 kW to 4,000 kW having a total installed capacity of 6,950 kW. Site surveys, investigations, design and construction are being undertaken locally, however, turbines, generators, switch gear and other electrical equipment are to be purchased from abroad.

Thailand

About 75 per cent of Thailand's energy supply is derived from imported oil. To reduce such heavy dependence and to diversify, the 5th National and Economic Social Development Plan for the period 1982-1986, called for the acceleration of the development of indigenous sources of energy. Hydropower was listed as one of the top priorities for development. The plan also calls for the acceleration of rural electrification programmes to cover over 50,000 villages, which means a doubling over the 1980 level of villages with electric power. However, the extension of the national grid to cover the villages nationwide is not economical, since the country is large and the villages are sparsely located. In this situation, the development of small-scale hydropower generation is appropriate.

The inventory of small-scale hydropower potential identified that out of 1,066 MW potential, 243 sites with a total capacity of 413 MW were technically feasible for development. 25 top-priority sites are to be implemented during the 5th National and Economic Social Development Plan. Their installed capacity will be some 50,000 kW, with an annual generation of about 215 GWh, which should save some 67,000 tons of oil per annum.

To reduce the investment cost of the small hydropower plants, the villagers are encouraged to participate in the development of the project to the maximum extent possible. In this way, the cost of the civil works can be reduced by as much as 40 per cent. For the generating equipment, at least for the smaller scale projects, locally manufactured parts have been utilized.

Nepal

Nepal has a theoretical hydropower potential of some 83,000 MW. Up to 1983 only 113 MW had been installed, i.e. 0.15 per cent of the available potential. The electric power production from these hydropower installations only contributes about 2 per cent of the total energy requirements of the country.

Small-scale hydropower plants are seen as a way of providing electric power to isolated areas of the country, which could not be connected to the central power supply system. For the purpose of planning and implementing small hydropower schemes, an autonomous Government Board was created in 1977. Currently, there are more than 30 projects spread throughout the country at various stages of completion. Another 10 to 15 projects are to be prepared within the next 2 to 3 years.

United Republic of Tanzania

Tanzania has abundant potential of hydropower resources spread throughout the country. In the early 1950s, the country started exploiting its hydropower potential, when 3 small hydropower plants were installed with a capacity of 3.8 MW. In the early 1970s, with the high cost of oil it was decided to meet increased power demand by hydropower generation. Feasibility studies of numerous potential sites were undertaken, and a site on the Great Ruaha River was selected as the most economic location for a 200 MW hydropower plant. It was not until 1980, that the Government of Tanzania decided to embark on a major mini hydropower development programme. Some 15 sites are being investigated. The long-term aim is to exploit all mini and large hydropower resources to gradually replace all existing diesel power plants throughout the country. The implementation of the mini hydropower plants will be decentralized in order to reduce costs and improve local participation.

Zambia

Zambia has 3 large hydropower stations which produce approx. 96 per cent of all electric energy generated in the country. The distribution is effected by means of a national interconnected grid. The development of hydropower in Zambia over the past 25 years has progressed to the point that a substantial export of electric power takes place from Zambia to neighbouring states, mainly Zimbabwe.

Even with these large hydropower plants, the Zambian Government has decided to replace the existing small diesel power stations with small hydropower in the rural Northwestern province and the rural areas of the rest of Zambia. The Northwestern province of Zambia is higher than other areas and has heavier rainfall. Although the rivers in this region allow for plant capacities of up to 20 or 30 MW, the sites that have been chosen have been adapted to local demands. Two sizes have been chosen, one 50 to 200 kW, and two 500 to 2,000 kW. In selecting the sites, special attention has been paid to their proximity to the load centres, in order to minimize transmission costs. Five sites have been selected for more detailed investigation. It is proposed to use standardized power house structures, so that they can be utilized with slight modifications at any other hydropower station site in the project area.

Dominica

Two hydroelectric power stations exist in Dominica, both located in the Roseau Valley. The first was commissioned in 1952 and has 3 pelton turbo generator sets, each rated at 320 kW. The second was commissioned in 1967 and has two units of 940 kW each. Plans are under way for the construction of a third hydroelectric station, which is expected to have a rated output of 750 kW. The Government of Dominica has been pursuing a programme to establish a number of small decentralized hydro schemes around the country in areas not served by the public electricity mains. This is considered the cheapest and quickest method of providing electric power to those population centres. There are now at least 4 such micro hydro schemes at various stages of development. A major problem, common to all of them, is finance. In this matter, the community self-help approach is being encouraged to help reduce overall costs.

Major Considerations related to Small Hydropower for Developing Countries

From the information on small-scale hydropower development in developing countries, some general factors emerge, which are briefly dealt with below.

One of the major incentives for the development of small-scale hydropower in the developing countries is the desire to reduce the level of oil imports. Small-scale hydropower is a very efficient substitute for diesel-fuelled generation. It must be noted, however, that for effective substitution the power supply should be continuous and not subject to long periods of non-operation due to water level conditions in the river. In addition to the cost of imported fuel, there is also the equally important factor of security of supply. The developing countries have often found themselves to be the first to suffer when there are shortages on the world oil market.

Small-scale hydropower utilizes a continually renewable energy form and is non-polluting compared with conventional energy sources. A major advantage of small hydropower schemes using run-of-the-river is that it does not affect the surrounding land use, which is not the case for large hydropower schemes with dams and flooded valleys for reservoirs.

All developing countries examining small-scale hydropower see the provision of relatively small quantities of energy to remote areas as a major advantage. Rural electrification is a long-term goal for many developing countries, but there is now widespread recognition of the need to bring electric power to isolated rural communities at the earliest possible opportunity. It is also possible for these small hydropower plants to be formed into or contribute to a grid system at national or regional level. For decentralized systems the high capital investment cost of small hydropower is not such a disadvantage, because the alternative, normally diesel-fuelled generation, is also very expensive.

The provision of even a minimum of electric power in remote rural villages has important socio-economic and cultural impacts. With electric light, productivity can be increased because working hours can be extended. With radio and television remote villages have direct access to outside information and they can be used as a valuable educational tool. In many cases, the provision of rural electric power through small hydropower schemes has encouraged and fostered the development of rural industries. This is a very important aspect in relation to the concept of rural or decentralized industrial development, which is now gaining momentum.

Hydroelectric power can be and often is an important part of multi-purpose utilization of water resources. Where canals for irrigation have been constructed, these have been used for small hydropower projects.

The technologies related to small hydropower are relatively simple and well-known. They are available from a variety of sources and for the developing countries only require adaptations either to meet site-specific conditions or reduce costs. With standardization and large-scale production the unit costs for small hydropower stations can be substantially reduced. As a result of the relatively simple technology involved, the major components of a small-scale hydropower plant can be manufactured by a growing number of the developing countries. A number of the larger developing countries are already completely self-sufficient in the manufacture of small-scale hydro equipment.

The civil construction in a small-scale hydro plant is an important element in the cost. The cost for this activity can be greatly reduced and the foreign exchange component eliminated by the utilization of local resources.

Although small-scale hydropower has high unit investment costs per installed kW, it has the advantage of being a self-contained and relatively low total capital investment, which can be completed in a reasonable period of time. This must be contrasted with the millions of dollars and 5-year plus construction period for large-scale electric power generation. In a period of capital shortage for the developing countries, this factor is very important.

Small hydropower in line with hydropower generally has very low operating costs, a long service life and is relatively cheap and simple to maintain. These are all characteristics which are of major advantage in a developing country environment.

International Co-operation in Small-scale Hydropower Development

The principle possibilities for international co-operation in the small-scale hydropower field lie in the areas of technology transfer and development, joint research and development, training, manufacture of equipment, and civil construction.

International co-operation extends to all types of international relations, which are designed to pursue the mutual advantages of the co-operating parties. It is based on the principles of: respect for the sovereignty of the parties, equality of rights for all parties, the voluntary participation of all parties, mutual assistance and reciprocal benefits. This set of general principles applies to co-operation on small-scale hydropower development which is today carried out at all levels - global, regional, subregional and bilateral. An important aspect of international co-operation in small-scale hydropower is the increasing role of economic and technical co-operation among developing countries, which should be taken as supplementary and complementary to traditional

North-South co-operation, i.e. between industrialized and developing countries. The importance of such international co-operation has been recognized at the first UNIDO/ESCAP/RCTT Joint Seminar Workshop on the Exchange of Experiences and Technology Transfer on Mini Hydro Electric Generation Units, in Kathmandu, Nepal, which adopted the Kathmandu Declaration for international co-operation in SHP, which reads:

"The Seminar-Workshop on the Exchange of Experiences and Technology Transfer on Mini Hydro Electric Generation Units organized by UNIDO/ESCAP-RCTT in co-operation with the NCST and the RECAST of Nepal from 10-14 September 1979 in Kathmandu has demonstrated the interest in and the importance of this subject.

Exchange of information, knowledge and experience is felt to be of basic importance for promotion of this technology, not only between developed and developing countries, but also among the developing countries themselves.

In this respect, parties carrying out activities in this field: governments and official and private institutions, as well as UN agencies and other international and bilateral organizations are invited to increase their supporting efforts to accelerate the electrification of rural areas by means of small-scale power production including micro and mini hydro generation within the framework of rural development plans.

The participants of the Seminar-Workshop therefore decide to underline the need for the strengthening of international co-oepration in a systematic, efficient and effective manner, and wants this to be referred to as the Kathmandu Declaration."

This spirit of co-operation was further enhanced at the second Seminar-Workshop in China and the Philippines, which adopted the Hangzhou/Manila Declaration on SHP co-operation.

"The developing nations of the world are called on to initiate and accelerate MHG progammes encouraging local involvement to assure that such programmes will not remain dependent on other countries. The developed countries, international financial institutions and technical assistance groups are enjoined to assist the developing nations in this effort by providing technical and financial assistance in establishing a range of demonstration on MHG plants as well as local manufacturers of MHG equipment and machinery.

Although there is an existing technology of MHG, that technology is not widely available. The establishment of a means whereby ready access to this technology would be possible is encouraged. Perhaps the existing UNIDO INTIB programme could undertake the dissemination of basic technological information.

Finally, the delegates believe that continued information exchanges of country experiences in initiating MHG programmes would be valuable in the effective implementation of their programmes. UNIDO is requested to assist in ecouraging the continued exchange of these experiences.

The participants of the Second UNIDO Seminar/Workshop/Study Tour on Mini-Hydro Power Generation (MHG) decide to underline the urgency of the needs to implement programmes for supplying cheap, reliable and renewable energy sources for the rural people particularly of the developing world, and wish this to be referred to as the Hangzhou-Manila Declaration on Mini Hydropower Generation (MHG)."

In fact, this was the basis for the establishment of the regional network for SHP in the ESCAP region, which has since been established by UNIDO as an official instrument and is undertaking practical and realistic activities in all fields of SHP as mentioned before.

In organizing the regional co-operation, the work of OLADE on this subject has been used as a model for an effective and realistic mechanism which can really benefit the member countries. OLADE, the organization in Latin America for the development of energy, is an intergovernmental institution which has been conducting a borad range of regional programmes in mini hydro, as well as other traditional and renewable sources of energy.

At the Third Workshop of SHP organized by RCTT/UNIDO/REDP in Malaysia in 1983, four participants from Africa recognized the significance and benefits of such a regional mechanism and urged UNIDO to initiate steps towards formulating a similar network in Africa. Following the principle of avoiding the establishment of a large bureaucratic institution, UNIDO is presently engaged in promoting the concept of RN-SHP in Africa by involving selected countries who are actively pursuing a small-scale hydropower development programme and who have expressed interest to participate in this activity.

Within the UN family, a number of organizations are jointly and/or independently pursuing the promotion of SHP within the context of their respective areas of responsibility and mandates. It is our hope that these activities could be pulled together in order that the assistance available from the UN as a whole could be conducted in a co-ordinated manner for the benefit of the recipient developing countries.

Similarly, during recent years, an increasing number of industrialized countries have included the field of SHP in their general programmes of assistance. It is felt that some form of co-operation and co-ordination might be useful. However, the best solution is that the developing countries acquire and build up their own capabilities to take their own decisions regarding which outside assistance would be of greatest benefit.

In conclusion, it is our strong belief that the SHP programmes can bring a positive impact in a broad area of economic and social development, helping with the energy problem, building up rural development and the introduction of rural industries, initiating and strengthening the mechanical and electrical engineering capabilities of the developing countries. To ensure this, more effort should be paid to the promotion of international co-operation and co-ordination to bring the maximum positive impact to the developing countries, and we in UNIDO are determined to continue to undertake the leading role and to try and serve the needs of the developing countries.

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