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I. INTRODUCTION

The increasing population of the world, coupled with the rising expectations for a better life in the less developed countries and their desperate struggles for improvement, makes continuing economic development essential. This, in turn, requires adequate sources of energy. At present the world is dependent upon finite oil and natural gas resources for about three-fourths of its energy use. Oil provides about one-half of this use. While there are many uncertainties, the more reliable projections, such as those of the World Energy Conference Conservation Commission, indicate that the demand for oil will exceed the physical worldwide capability of production in about 10 years (see Figure 1). This makes the development and utilization of all other energy resources of paramount worldwide importance and requires immediate action. This is especially true of renewable energy resources such as hydropower.

As a continually renewable nonpolluting energy resource, with well developed and proven technology, hydropower is especially important in meeting energy needs in all areas of the world. It now provides approximately 23 percent of the electrical energy now being produced worldwide (see Figure 2). Studies indicate there is at least six times as much hydropower feasible for development as now being utilized. The studies indicate about 80 percent of this potential is likely to be developed by the year 2020. It has special importance and value in the less developed countries.

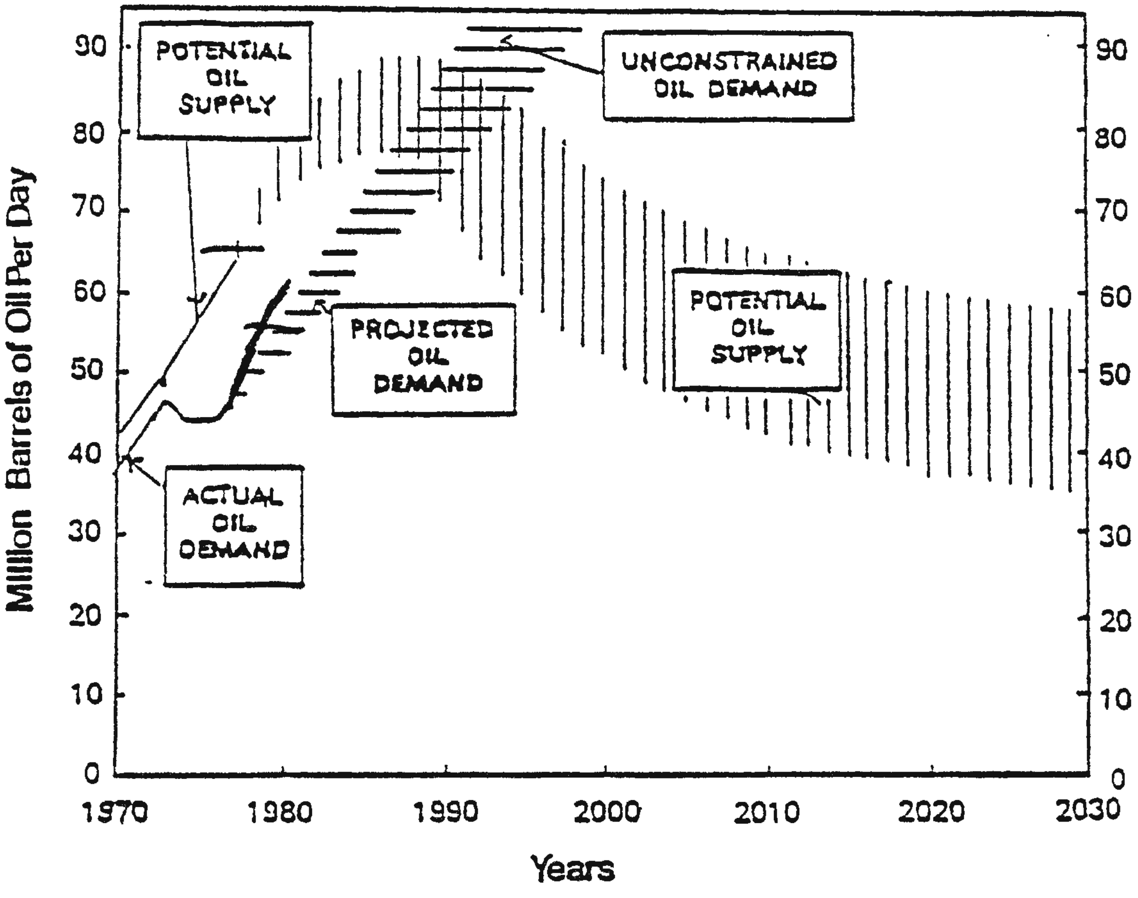


Figure 1. Potential Oil Production Compared to Demand - Worldwide - 1970-2030. (From data of World Energy Conference Conservation Commission studies. The potential oil supply is the estimated total worldwide physical capability of producing oil without political constraints. The demand curve is that considered most likely to occur, providing there is political stability; nuclear and coal-fired plants construction proceed as now planned; energy efficiency will be increased and conservation measures taken to the extent that the economy is not adversely affected; and other energy resources will be pushed. <u>Caution</u>: there are uncertainties and unknowns; note that the present demand is above the projection).

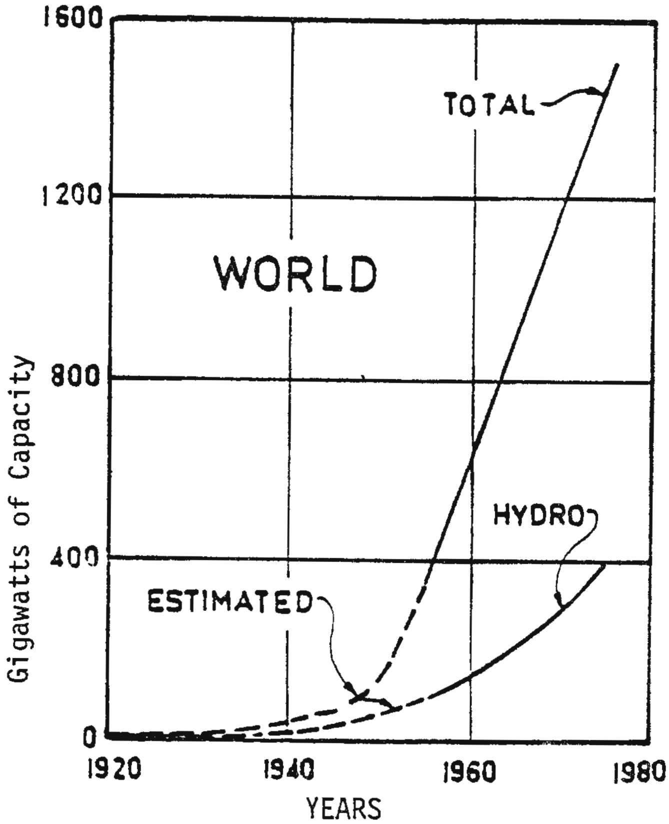


Figure 2. Worldwide Electricity Generating Capacity Showing the Amount Provided by Hydropower. (From Reference 2).

The issues, benefits, and problems are discussed in the following pages, along with suggested methodologies to expedite the full utilization of this important energy resource.

II. HYDROPOWER POTENTIAL

1. <u>History</u>. The mechanical utilization of hydropower appears to have developed about 1500 BC, primarily for rasing water to a higher level. A primitive waterwheel appeared about 200 BC as a supplement and replacement for the muscle power of man and animals. By 1000 AD water powered

grist mills were common; in 1086 AD it is recorded that there were 5,624 water mills, utilized primarily for grinding grain, serving 3,000 communities in southeastern England.

Water power use as the source of energy, other than muscle power and wind, brought about industrialization and the advance of civilization. It was not until the forepart of the 19th Century that the steam engine began to provide another source of energy. With the advent of electricity in the 1880's, the importance of hydropower increased, even though steam power had overtaken it in the amount of energy produced.

With development of efficient electric generation and improved technology of transmission, by 1910 the development of hydropower electric facilities was rapid and by 1925 provided 40 percent of the electricity produced with an installed capacity of 26,400 megawatts. By 1970 the amount of hydropower produced increased 15-fold over the 1925 production.

2. WEC Studies. The World Energy Conference, which now includes 76 nations, was organized in 1924 (initially called the World Power Conference), and has continually taken an active role in providing information on world energy resources and use. The first comprehensive study was published in 1929, entitled Power Resources of the World, Potential and Developed, and has been periodically updated and improved since.

In 1974, in preparation for the World Energy Conference Convocation in Detroit, Michigan, an extensive and intensive effort was made to reevaluate previous studies, and improve the information to make it as meaningful and useful as possible. It was a formidable task, but it provided the most comprehensive and complete analysis to date of the world's energy resources and use.[1] It was updated in 1976 and 1978 with some refinements, and preparation of the next comprehensive survey, World Energy Conference Survey of Energy Resources which is published every six years, is now underway and will be available for the World Energy Conference Convocation in Munich, Germany in September, 1980.

By agreement with the United Nations, since 1958 the World Energy Conference has become the primary source of information on world energy resources and the United Nations has continually provided data on world energy production, trade, and consumption.

Deeply concerned over the conflicting information, concepts, and data regarding energy, its use and the need for responsible programs for the future, the World Energy Conference formally launched its Conservation Commission Study in 1975. The charge was to determine the energy resources of the world as objectively and factually as possible, using the 1974 publication as a base with appropriate updating and refining; investigate ways improvements in development and utilization of these resources could be accomplished; assess possibilities of substituting other energy resources for oil; evaluate the probably extent conservation measures could reduce energy demands; and then to determine the most likely energy needs of the year 2020 and ways they could be met. The Conservation Commission, including the study reviewers, totaled 80 members, and in addition large task forces were formulated in the areas of oil, coal, natural gas, nuclear, hydraulic, and unconventional (such as solar, biomass, wind, geothermal) resources, and in conservation and energy demands. These various groups included experts considered the most knowledgeable in the world.

[1]Refer to list of references.

The studies have now been completed and the results published.[2,3,4] These studies provide the most fully comprehensive, objective, authoratative analysis of the world's energy resources and the demands for the next four decades. The author headed the study group on hydraulic resources. The following information and comments are based on these studies and the author's 40 years of involvement in various studies, planning, design, development, and utilization of hydropower energy resources.

3. Summaries of Potential. The Conservation Commission studies indicate there is a total potential from hydropower likely to be developed of 2.2 million megawatts of generating capacity with a potential annual energy production of 34.9 million terrajoules (9,700 million megawatt hours). These figures were determined from the capacities at the various sites on a river now installed and those which likely will be installed to utilize the energy. To produce this amount of energy would require the burning of an equivalent of about 40 million barrels of crude oil per day in an oil-fired thermal generating plant. This total potential is probably conservative; the increasing comparative economic and environmental advantages of hydropower are likely to increase the totals.

The present annual production of hydropower electricity is about 5.7 million terrajoules (1,550 million megawatt hours), which is approximately 16 percent of the Conservation Commission's estimated expected potential. To produce the same amount of electricity in an oil-fired plant as now being produced by hydropower, would require burning the equivalent of approximately 6.5 million barrels of crude oil per day.

Figure 3 illustrates the percentages of the world's total hydropower potential in the developing countries, in the Organization for Economic Cooperation & Development countries (Western Europe, North America, Japan, Australia and New Zealand) and for the centrally planned countries. It also shows the percentage of the potential in each of these areas that is now operating, that under construction, and the amount that has been programmed for construction. Figure 4 shows the same information broken down for Asia, South America, Africa, North America, USSR, Europe, and Oceania. These data are from the 1976 World Energy Conference survey of energy resources, and can be considered to fairly show the relative magnitude of hydropower resources in the various areas.

For convenient reference, detailed information from the World Energy Conference Survey of Energy Resources - 1974 are included in the Appendix. Page 1 of the Appendix is a summary of various areas of the world, and the following pages are details of each country, some broken down by river basins. The notes give details regarding the sources of the information in the tables.

The estimated amount of hydropower development from Reference 3 is as shown in Table I. Based on an estimated cost of 1,000 U.S. dollars per kilowatt installed, and with a capacity factor of 0.50, the capital investment required is indicated in Table II. It is evident that financing assistance to the developing nations will be required. Markets for the large potential in some of the developing countries may be slow in materializing, as they require large capital investments also. The increasing value of hydropower to the world economy may help alleviate these problems. For example, the 43,000 megawatts of hydropower potential in the lower Congo River in Africa may attract high energy intensive industry to locate plants where the low cost and available energy can be utilized.

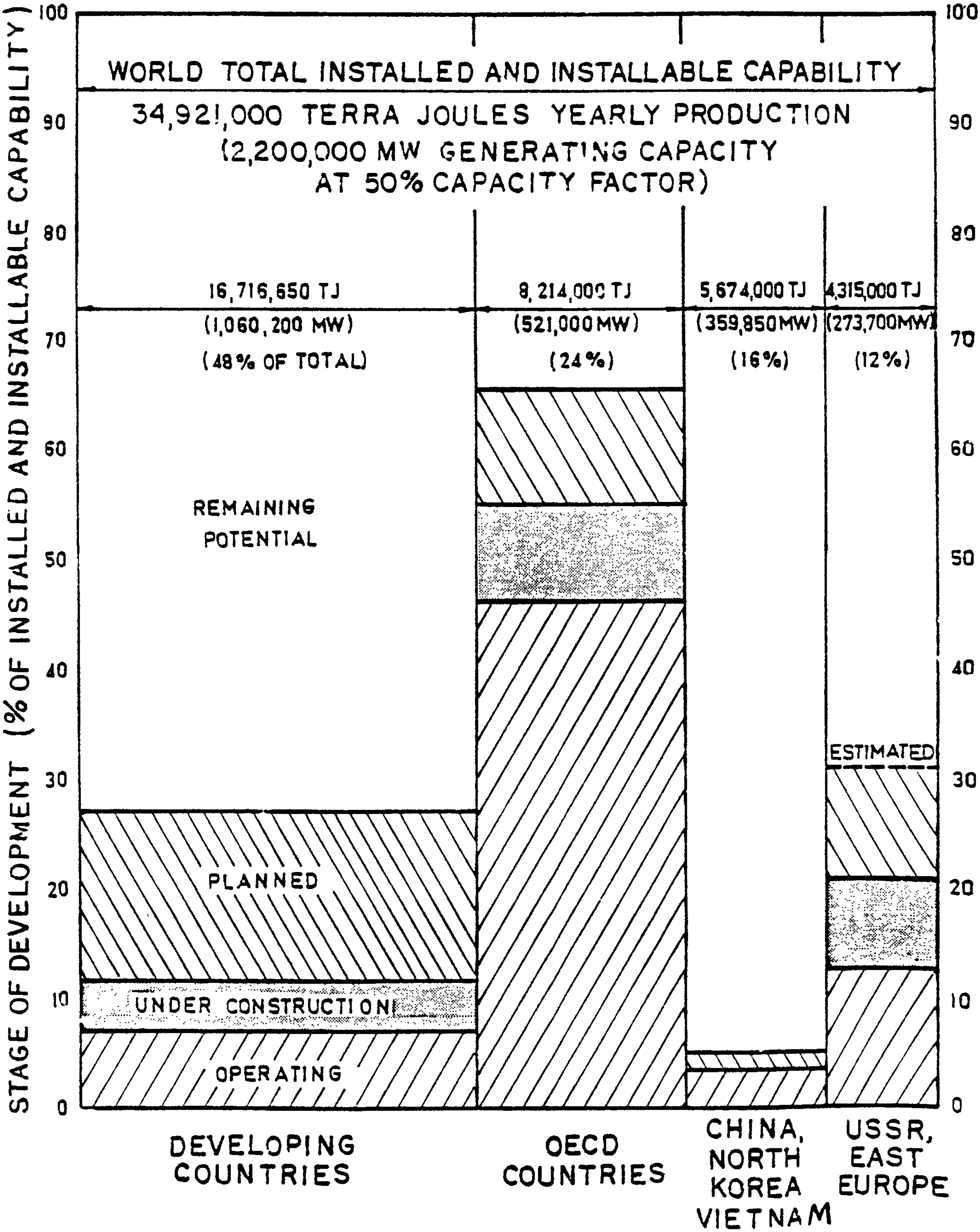


Figure 3. World Hydropower Resources (from Reference 3).

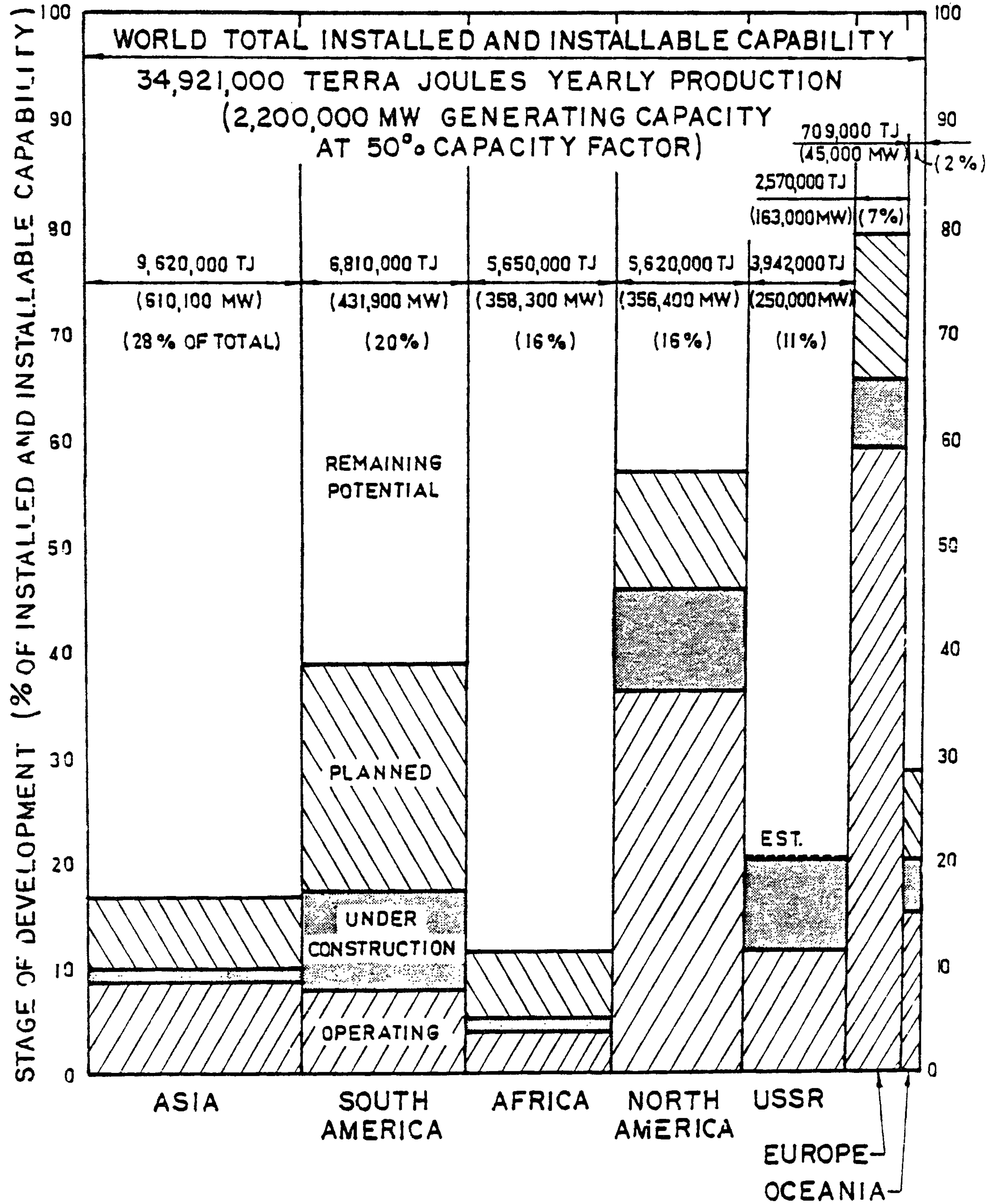


Figure 4. World Hydropower Resources (from Reference 3).

TABLE I

ESTIMATED PROBABLE HYDROELECTRIC DEVELOPMENT

Divisions	Potential Energy in Thousands of Terrajoules (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.

TABLE II

ESTIMATED CAPITAL COSTS OF HYDROELECTRIC INSTALLATIONS BASED ON TABLE I

Divisions	Average Annual Costs Between Years Shown -- 1976 U.S. Dollars in Billions 1976-1985	1985-2000	2000-2020	1976-2020
OECD Countries	5.05	3.70	7.71	5.80
Centrally Planned Economies	3.39	7.10	18.45	11.50
Developing Countries	5.64	10.64	23.17	15.31
World Total	14.08	21.44	49.33	32.61

4. Hydropower Advantages. While the amount of energy produced from hydropower and the potential are impressive, it is of greater relative importance, compared to other sources of energy, for the following reasons:

1. It is a non-consumptive generator of energy, utilizing a clean resource, continually renewable by the energy of the sun which creates and sustains the hydrological cycle.

2. It is essentially non-polluting and no heat is released.

3. The generation of hydropower requires some type of water control, ranging up to full control of the discharge from a watershed, thus it is an important part of the multipurpose utilization of water resources and reduces the potential of destruction from floods. Water out of control is mankinds most destructive force. With storage facilities, floodwaters are retained and better utilized for food production; for river regulation, improving navigation, fish and wildlife, and recreational potential; for municipal use and better control of wastewaters; and the destructive force of flood flows, as well as the energy of normal flows, is harnessed to provide electrical energy for man's use.

4. It is a reliable energy source within the hydrological limitations of the site. The relative simplicity of hydraulic machinery makes energy instantly available as needed. As no heat is involved, equipment has a long life, and malfunctioning is rare.

5. It can be made available in small installations at remote areas of developing countries with relatively simple technology, and can be a catalyst in developing other resources and creating opportunities for improving human conditions, as has been demonstrated in the past.

6. Its reliability and flexibility of operation, including fast startup and shutdown time in response to rapid changes in demand, makes it an especially valuable part of a large electrical system, increasing the overall economy, efficiency, and reliability of the entire system.

7. It has excellent peaking power capability, for the reasons outlined above. Storage of energy by pumped storage systems is the most economical and trouble-free method available to date for large scale use. While about four units of energy input is required for three units of output, the input is low-cost energy and the output is high value energy meeting peak loads. Even so, in a large electrical system, the alternative for peak loads may be the utilization of old and relatively inefficient thermal units; in these instances the use of pump storage can result in overall savings of energy. In flat topography areas, all-underground pumped storage facilities have potential.

8. Its technology is well developed and proven, with efficiencies of turbines now as high as 95%. Units ranging from a few kilowatts up to 700,000 kilowatts are in operation, and while the equipment must be adapted to the specific site for greatest efficiency, full reliance can be placed on performance expectations.

9. In the more developed countries, potential exists at present powerhouses and at dams without hydro installations for hydro production with minimum capital or energy costs. Also improvements in turbine and generator efficiency makes upgrading of many present equipment installations especially attractive. Changes in river basin hydrology also may create greater hydropower potential on existing structures.

10. Hydropower facilities have a long life; dams and control works will generally perform for a century or more with little maintenance required.

11. As no fuel is required, and heat is not involved, operating costs are low for hydropower. Because of this and the long life of the facilities, a hydropower installation is essentially inflation-proof.

12. Hydropower development makes maximum use of local materials and labor, compared to heat-power facilities, and thus usually is much more appropriate in developing country programs.

13. A vast quantity of hydropower remains to be utilized, especially in the developing countries, which on the average have developed less than 7% of their potential; in some countries it is less than 2%.

14. The economic feasibility of hydropower is improving, compared to other energy sources which use finite fuels. With more realistic methodology of economic evaluation, including full recognition of the value of non-use of depletable resources; of not being dependent upon fuel resources controlled by others; and of a non-polluting generator of energy; hydropower becomes increasingly attractive.

5. Issues. While the preceding information presents reliable generalized information, hydropower is a site specific energy resource. The physical potential in each instance will depend upon the topography to produce the head, whether by diversion and conveyance of the streamflow, or a dam to provide storage and head; and upon the volume of streamflow and its time occurrence. The geology of the site may preclude its utilization; it will affect the costs.

Economic viability will depend upon the costs and the availability of a market to use the energy, either existing or which will develop or can be made to develop. Social viability will involve the acceptance of the environmental effects, disruptions of existing social relationships, and of future impacts. The information supplied by the various countries, and developed from other sources, for the WEC survey represents that considered likely to be developed with the above considerations.

The data should provide a guide for determining where hydropower development efforts of the United Nations would be most effective, considering the energy needs in the various areas. However, the amount of small scale hydropower potential, which in each instance may be a relatively small quantity, but which may be very important in a local area, especially in the developing countries, may not be reflected in these data. These problems should be examined by the panel.

III. HYDROPOWER TECHNOLOGY STATUS

The technical factors determining developable hydropower involves hydrology, topography, and geology of the site, and technology of hydraulic control structures, hydraulic equipment, electrical equipment, and electrical transmission distribution facilities. The present status of the available technology and the present information available are discussed in the following paragraphs:

1. Hydrology. Generally adequate hydrology information is available worldwide for reconnaisance type studies, defined as the studies required to determine if feasibility studies to determine investment commitments are

justified. Sophisticated computer programs concerning precipitation, drainage area characteristics and runoff relationships have been developed so that shortcomings in streamflow data can be rectified. In most instances it is believed this can be the case for feasibility studies also. Methodologies for determining flow duration curves are well advanced. However, the Panel should review the adequacy of the existing stream gaging networks and data records, and the methodologies of formulating synthetic records to fill in gaps.

Procedures for utilizing basic hydrology data to determine the full range of information needed to determine hydropower development are well developed and documented. Computer programs for most of the procedures have been formulated. These include flood flow frequencies, storage and pondage requirements, and operational programs for entire river basins involving multipurpose uses of water.

2. Topography. With today's aerial mapping technology and widespread application, reconnaisance level studies at least can be adequately made from existing maps in most areas of the world. Detailed studies, especially those for design preparation, will generally require more detailed mapping. The Panel should determine whose mapping deficiencies exist, particularly in areas of the world where large hydropower potential remains to be developed.

3. Geology. Information concerning the foundation upon which required structures will be built is essential, as well as data concerning earth and rock materials available for building the structures. While a large amount of geological information is available concerning most areas of the world, site evaluations will usually require a site inspection, as a minimum, up to

detailed subsurface investigations for design purposes. Technology of subsurface investigations is well advanced, as is that of determining characteristics of earth and rock materials.

4. Hydraulic Control Structures. The design and construction of hydraulic control structures are well advanced and methodologies tested and proven. Many excellent reference textbooks and guide manuals are available. Several which the author considers especially valuable are included in the reference list.[5,6,7,8]

Attention must continually be given to maximizing the performance of the structures with assured safety and minimum costs. The Panel should examine areas where structures might be simplified for cost reduction, especially in the small scale developments. Potentials of standardized and prefabricated components of the structures should also be examined. Factors of safety applied to different size dams should be considered.

The size of the maximum flood the reservoir and the spillway should be designed to handle is a problem warranting continuing discussion. It is a function of the maximum possible flood which conceivably could occur, the probability of its occurrence, frequency of other floods, and the damage which could occur if the structures were overtopped.

Large hydraulic structures, such as spillway stilling basins, or large conduits where high velocities are involved, require extensive model testing to improve and check design studies.

5. Hydraulic Equipment. As was mentioned in the list of advantages of hydropower, equipment from a few kilowatts in size up to 700,000 kilowatts are in operation and their performance has been well demonstrated and proven.

In some instances, such as in developing countries with little technology support, mechanical utilization of hydropower may be desirable. Reevaluation of past technology of waterwheels and vertical axis river turbines need to be examined to determine whether or not they should be considered in these special instances as compared to more efficient turbines.

Figure 5 illustrates the common application ranges for use of conventional hydraulic turbines for best efficiency. Note that the impulse turbines (Pelton) is best for high heads; then the mixed flow scroll case impulse turbines (Francis) in the intermediate head range; the scroll case axial flow propeller in the lower range (the Kaplan is a propeller turbine with adjustable blades) and the straight axial flow units (tubular) in the lowest range. The small

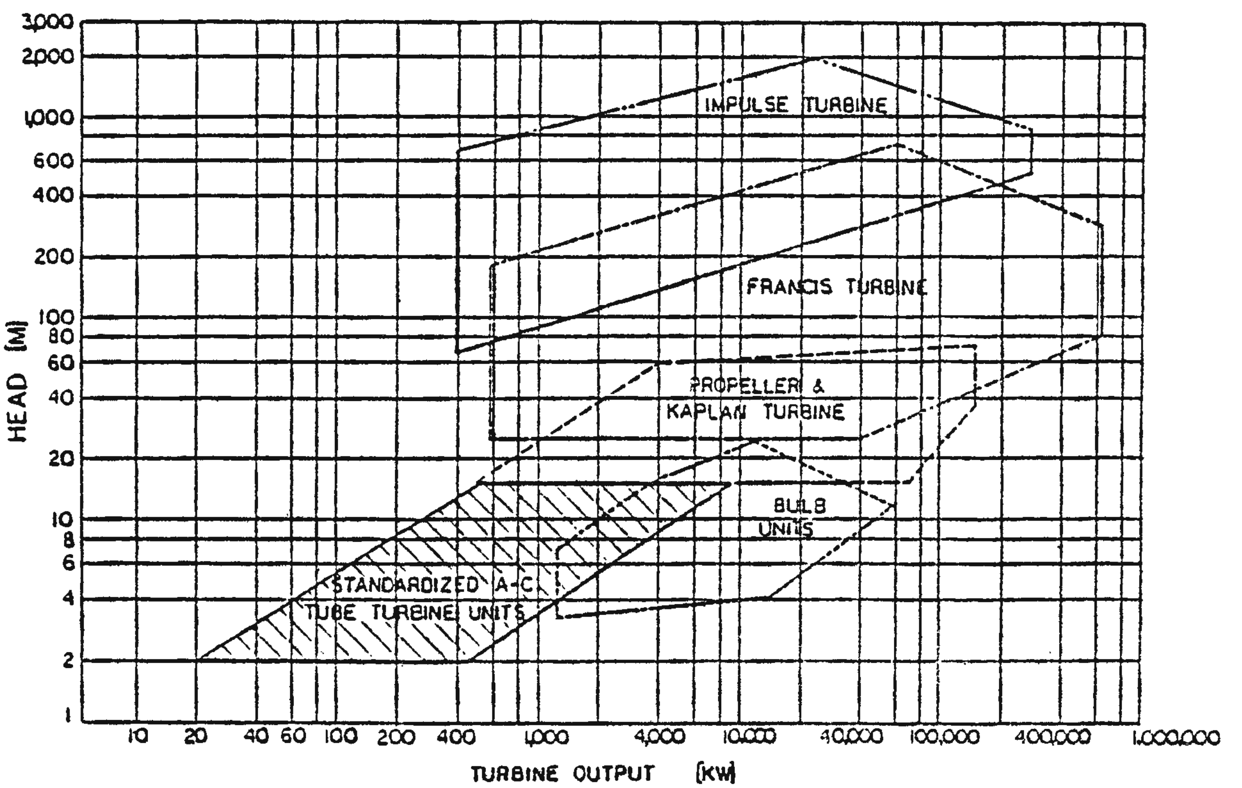


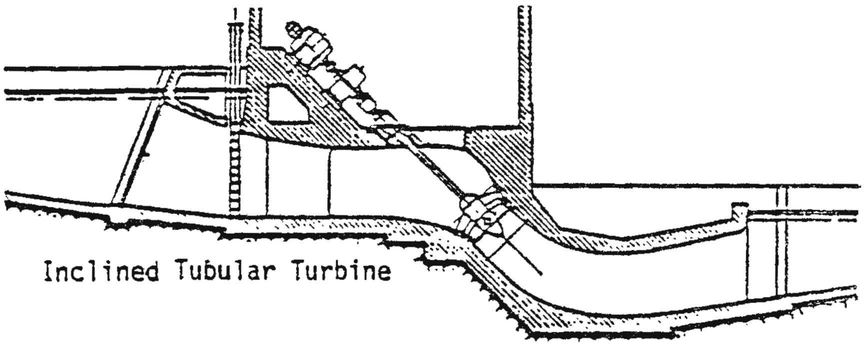
Figure 5. Common Application Ranges for Conventional Hydraulic Turbines

scale units lend themselves to standardized design and the range of the ten standard sized Allis-Chalmers units is also shown on the illustrations.

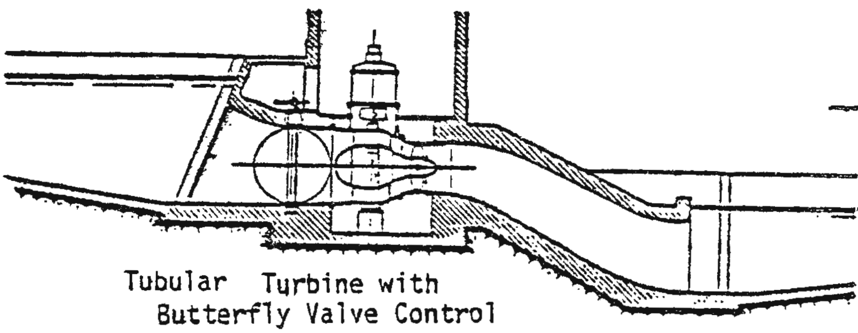
Figures 6 and 7 show various types of low head turbines and various types of configurations. Standardized equipment of various types has been developed in Europe, such as the units of Bofors-Nohob in Sweden, Escher Wyss in Switzerland and Neyrpic in France. Besides the standard Allis-Chalmers units, standardized package units of smaller size, 3 kilowatts and larger, are provided by Independent Power Developers, Northern Water Power Company, and James Leffel Company in the United States and Barker Hydraulic Turbine Ltd. in Canada.

Perhaps the greatest experience with low scale hydropower equipment is in China, where 88,000 hydroelectric plants have been constructed the last two decades with an average capacity of about 70 kilowatts. Figure 8 lists the characteristics of the 16 standardized turbine generator sets of capacities from 12 to 500 kilowatts, offered for export by the Chinese National Machinery and Equipment Export Corporation.

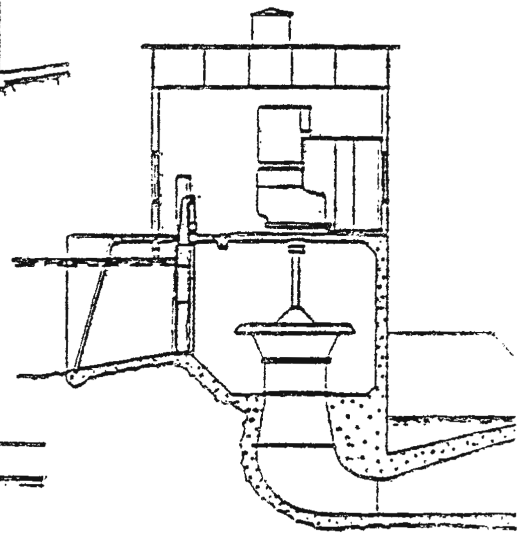
Detailed studies are required to determine the best type and size of turbine unit for the specific site. With small scale projects there is need to minimize initial costs, especially for micro units (less than 100 kilowatts). Various equipment performance and cost data are available from manufacturers but are widely scattered and there is a need for compilations and a centralized source of information. The Panel should consider preparing a compilation of the standardized units available along with their characteristics and the conditions to which they are best suited. Also studies should be made of ways



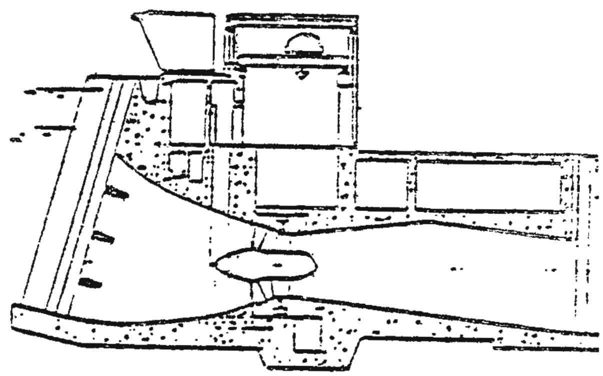
Inclined Tubular Turbine



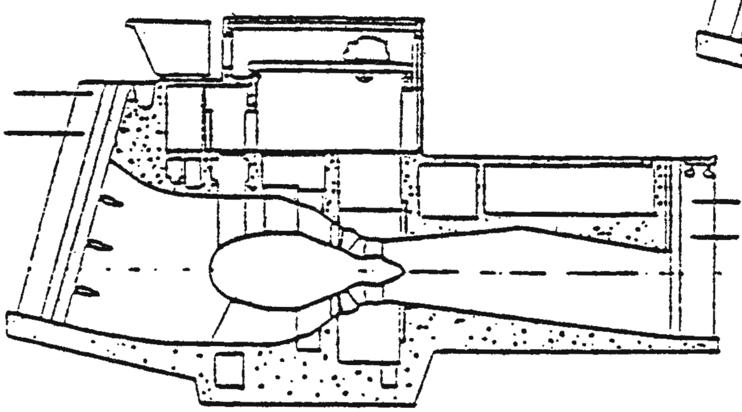
Tubular Turbine with
Butterfly Valve Control



Vertical Francis Turbine
Open Flume Arrangement

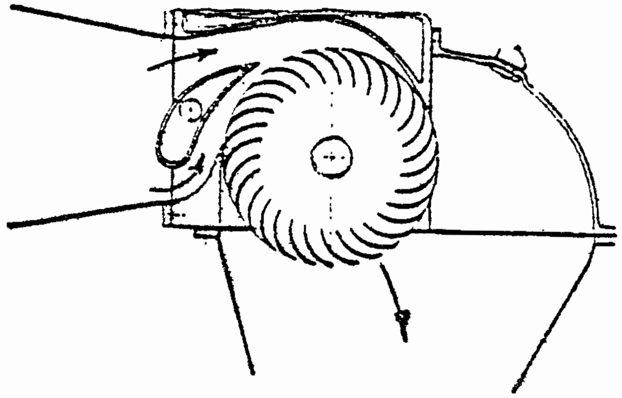


Rim Generator Turbine
(Straflo)

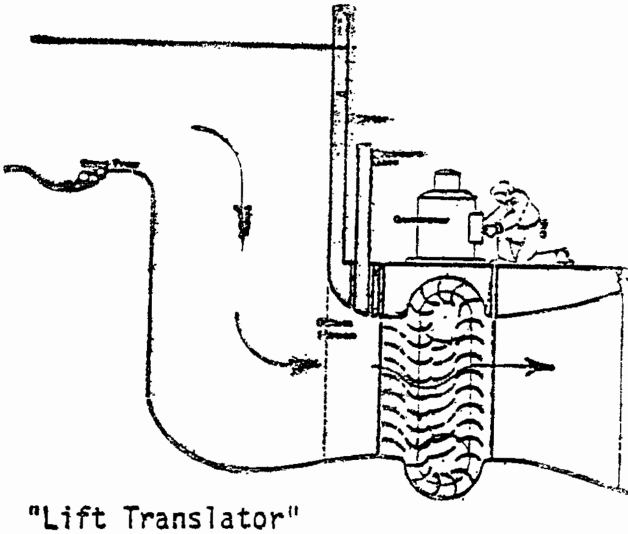


Bulb Turbine

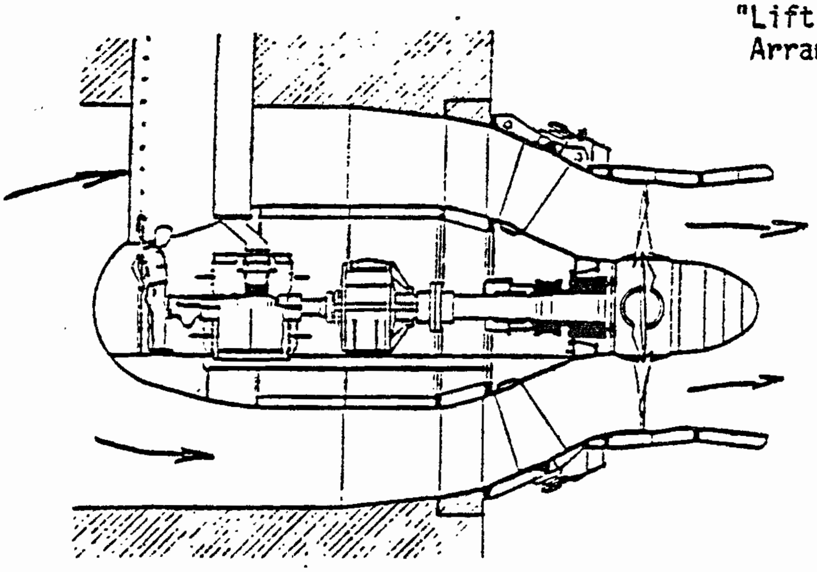
Figure 6. Various Low-Head Turbine and Generator Arrangements



Cross-flow Turbine
(Ossberger)



"Lift Translator"
Arrangement



Details of a Bulb Turbine

Figure 7. Details of Some Low-Head Turbines

Item №	Turbine				Generator				
	Type	Model	Head (M)	Flow (m^3/sec)	Capacity of Generator (kW)	Speed (rpm) 50Hz	Speed (rpm) 60Hz	Voltage (v) 50Hz	Voltage (v) 60Hz
1	Axial-flow reaction type	ZD760-LM-60	2~6	0.80~1.80	18, 30, 40, 55, 75	1000	1200	400	460
2		ZD760-LM-80	2~6	1.40~3.50	30, 40, 55	1000	1200	400	460
					75, 100, 125	750	900	400	460
3		GD560-WZ-60	8~14	0.90~2.20	40,55,75,100,125,160,200	750	720 (900)	400	460
4	Mixed-flow reaction type	HL210-WG-20	6~15	0.12~0.19	12, 18	1000	1200	400	460
5		HL310-WG-30	6~18	0.32~0.53	18, 30, 40, 55	1000	1200	400	460
6		HL260-WJ-35	10~25	0.50~0.80	55 ,75	750	900	400	460
					100, 125	1000	1200	400	460
7		HL260-WJ-42	8~25	0.65~1.15	75, 100, 125, 160	750	900	400	460
					200	1000	1200	400	460
8		HL110-WJ-42	30~80	0.36~0.59	100, 125	750	900	400	460
					160, 200, 250, 320	1000	1200	400	460
9		HL240-WJ-50	15~40	1.20~2.00	125, 160, 200	600	600	400	460
					250, 320, (400)	750	720	400 (6300)	460 (6300)
					500	1000	900	6300	6300
10		HL220-WJ-50	25~59	1.50~1.80	320, (400)	750	720	400 (6300)	460 (6300)
					500	1000	900	6300	6300
11		HL110-WJ-50	35~80	0.56~0.85	200, 250, 320	750	900	400	460
					400, (500)	1000	1200	400 (6300)	460 (6300)
12		HL110-WJ-60	30~70	0.70~1.10	160, 200	600	600	400	460
					250, 320, (400)	750	720	400 (6300)	460 (6300)
13		HL240-WJ-71	23~32	2.90	500	500	514	6300	6300
14	Impulse type	CJ-W-55/1×58	100~260	0.12~0.19	75, 100, 125, 160	750	720	400	460
					200, 250, 320, 400	1000	900	400	460
15		CJ-W-65/1×72	100~260	0.18~0.29	125, 160	600	600	400	460
					200, 250 320, (400)	750	720	400 (6300)	460 (6300)
					500	1000	900	6300	6300
16		CJ-W-92/1×11	138~145	0.50	500	500	514	6300	6300

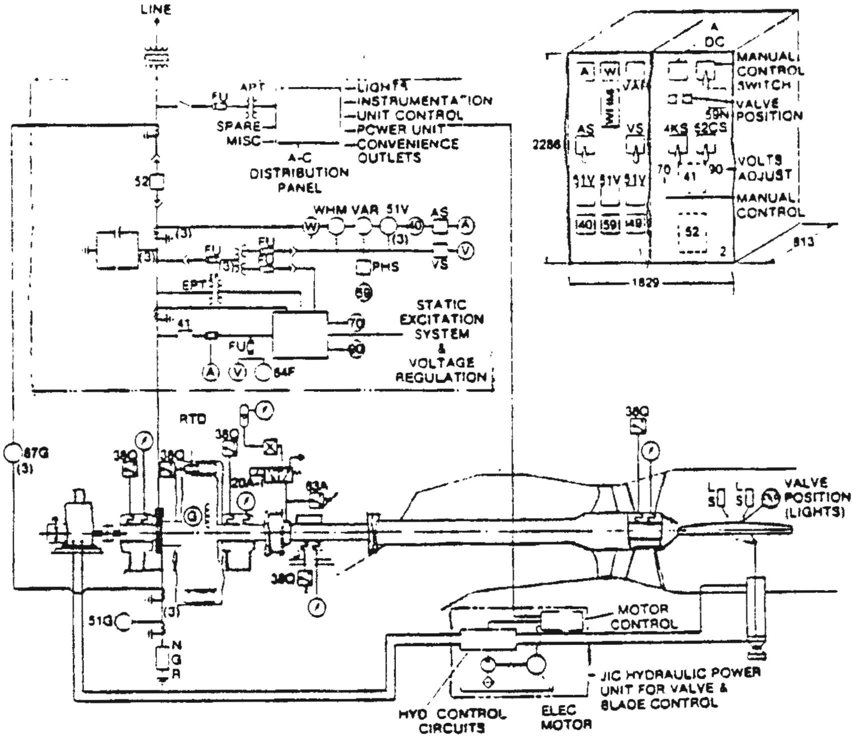
Figure 8. Characteristics of Standardized Turbine Generator Sets with Capacities from 12 to 500 Kilowatts, Offered by the China National Machinery and Equipment Export Corporation.

to reduce costs of these smaller units by new technology, such as the "lift translator" shown in Figure 7 which is now undergoing testing. Other innovative ideas should be explored.

6. Electrical Equipment. The technology of generators and various other electrical machinery is well advanced and proven, and almost universally available. However, the arrangements of machinery and controls to fit the production capability of a site with continually changing load demands, can vary widely. For instance, synchronous generators are required in an isolated plant, or at a location at the end of a line of a large system, and in all high capacity installations. Figure 9 lists those situations where synchronous generators are required, and those where less costly induction generators may be used. It also illustrates the electrical controls needed for each generator.

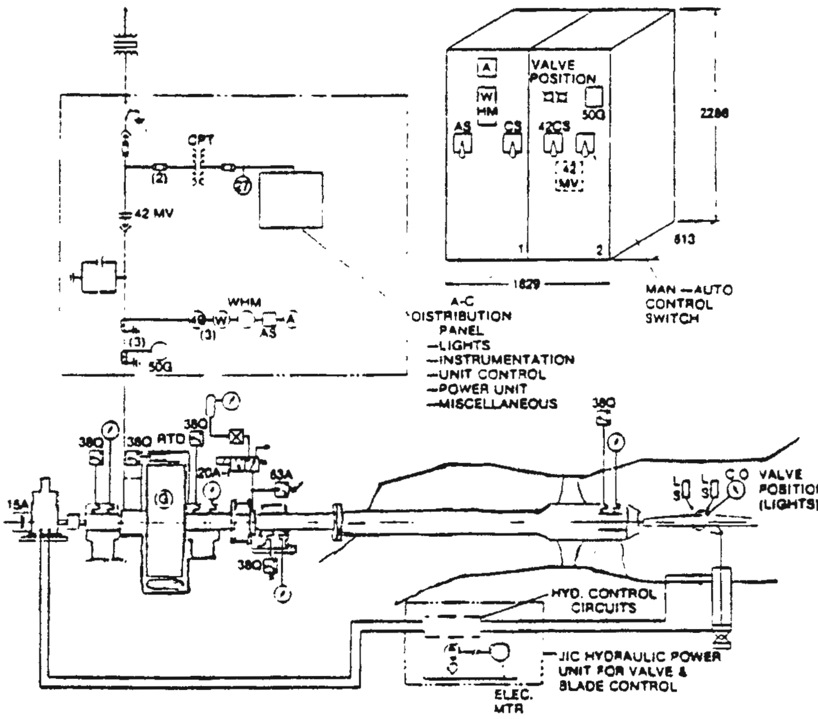
Remote control, which generally is essential for the economic operation of a small scale plant, can be performed satisfactorily with presently available and well proven facilities. With small scale generation, with the use of now available solid state inverters, direct current can be generated with greater efficiency, and excess power can be stored in a battery bank and then drawn upon to meet peak loads.

An example of this type of setup is the 50 kilowatt power unit for remote locations that is provided by the Independent Power Producers in the United States. In line with the usual practice for small scale units, a packaged unit is provided including turbine, generator, control equipment, energy storage facilities as needed, and whatever transformer facilities are required. Figure 10 illustrates the power flow of the unit: the direct current can be



SYNCHRONOUS GENERATORS — are required for

1. Isolated operation
2. High capacity installations
3. Power factor improvement
4. End of the line installations



INDUCTION GENERATORS — may be used for

1. Operation in conjunction with a large system
2. Low capacity and high generator speeds
3. Applications not requiring power factor correction

Figure 9. Synchronous and Induction Generators - Requirements and Controls

fed to the 60 Hertz 115/230 volt load through an inverter, or can charge a battery bank from which current is drawn through the inverter to meet peak demands. This almost "black box" system, with present day equipment, will produce electricity at remote sites fully competitive with other sources, such as diesel generators. Various other similar packaged units are available.

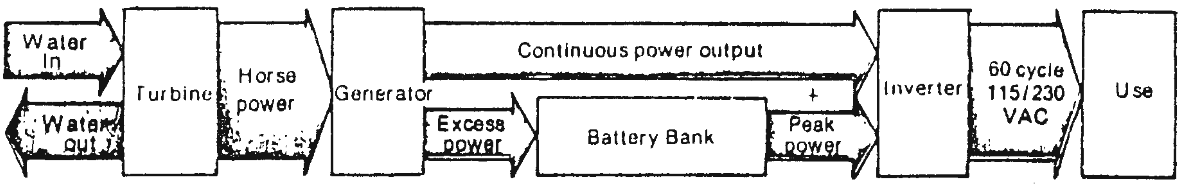


Figure 10. Illustration of Power Flow for Independent Power Developer's Packaged Unit

The Panel should review possible ways these packaged units can be improved to better meet the needs of remote areas in developing countries where little technical support is available. The potential is considered great as a first step toward improving human conditions. This can lead then to larger scale developments. For instance, with the tremendous program of small scale hydro developed in China, the need for much more energy as they move further ahead in improving human conditions is recognized. Six dams with a combined hydropower capacity of 21,000 megawatts are now being actively planned, and the Three Gorges Dam on the Yantze River which has a potential of 30,000 megawatts is scheduled to follow.

7. Electrical Transmission and Distribution Equipment. The technology of transmission and distribution facilities is excellent and can readily meet most requirements. The equipment is widely available. There is room for improvement in optimizing the specifics of a given site and its energy market.

Small scale hydro plants in remote areas will be close to the energy use and the distribution equipment can be simple. In a large interconnected system, the addition of a number of widely scattered small scale hydro plants can provide voltage support for the local areas and increase reliability.

Technology is well advanced for the long distance transmission of electrical energy with higher voltage, up to 1,500,000 volts, are being developed and may soon be utilized. With these high voltages, line transmission losses are low, and thus development of large hydro potentials in remote areas, such as on the lower Congo River, are more economically attractive. Interties of systems, such as the 800-mile, 800,000 volt direct current tie between the Northwest power grid and that of Southern California in the United States, have demonstrated the reliable technology application. Such interties result in more economical and efficient use of electrical generation capacity, and result in better utilization of hydropower as a part of a large interconnected system. The great number of international interconnections, such as those in Europe, not only result in lower costs of electricity, but have proven to be important factors working towards political stability. The Panel should consider where additional interconnections can be effective.

IV. HYDROPOWER ECONOMIC FACTORS

The usual economic analysis consists of determining the ratio of costs and benefits. Difficulties occur in fully and fairly determining the full costs and the full benefits; many of the factors are hidden, such as the benefits foregone by flooding out farms in a valley to create a reservoir. Many are difficult to quantify, such as the value of recreational features created with a man-made lake, or the economic catalyst provided to an area by having electric power available. Most hydropower developments will involve some type of water control, as discussed under item 3 of hydropower benefits. The determination of benefits from all multipurpose uses and the assignment of costs is not a straightforward exercise, but will vary greatly according to the specifics of each project, including political and social objectives.

1. Economic Analysis Methodology. The usual procedure of determining the economic feasibility is to compare the costs of the hydropower however determined,with the least-cost alternative, such as heat-powered plants. Generally the costs are based on life-cycle analysis. If the ratio is greater than one, the project would be considered economically feasible. While this is helpful as a guide, there are many factors in today's energy situation that complicate the determinations and considerations. For instance, the discount rate to apply to future benefits, in view of present widely fluctuating interest rates, is controversial.

The comparative costs of different sources of energy are under constant change and adjustment. Rising costs of and increasing demands for diminishing finite resources, such as oil and natural gas, and inflation which is not uniform for all factors, make life-cycle costs difficult to determine. The present methods usually fail to give adequate credit to the inflation-proof characteristics of hydropower. Most methods are based on past data and thus rarely reflect the likely future.

For instance, in the United States, the costs of oil or coal-fired powerplants just being completed are about 400 to 500 U.S. dollars per kilowatt. Most utilities in projecting costs of similar plants where planning is now underway, project costs by the time the plants are completed, of at least 1,000 U.S. dollars per kilowatt. Under present methods of analysis, economic justification for hydropower ranges from about 800 to 2,000 U.S. dollars per kilowatt, depending upon the plant factors, the timing of the availability of the power in relation to peaking demands, upon the specific market for the power, and upon the effects on pricing of various governmental actions which may vary interest rates or provide subsidies.

Figure 11 illustrates the effects of interest rates on comparative costs and also the value of the inflation-proof characteristics of hydropower. In preparing the curves the life of a hydropower installation of 50 years was used; 35 years was used as the life of an oil-fired plant. The curves are based upon the same capacity factor for the two comparison plants. While oil-fired and hydro plants in a large electrical system would likely have different load curves, for a specific purpose the comparisons are valid. Other elements of cost, such as differences in operation and maintenance and the probable greater transmission costs from a hydro plant, are not included in the curves. These factors must be considered, along with all others, in the analysis of a specific site.

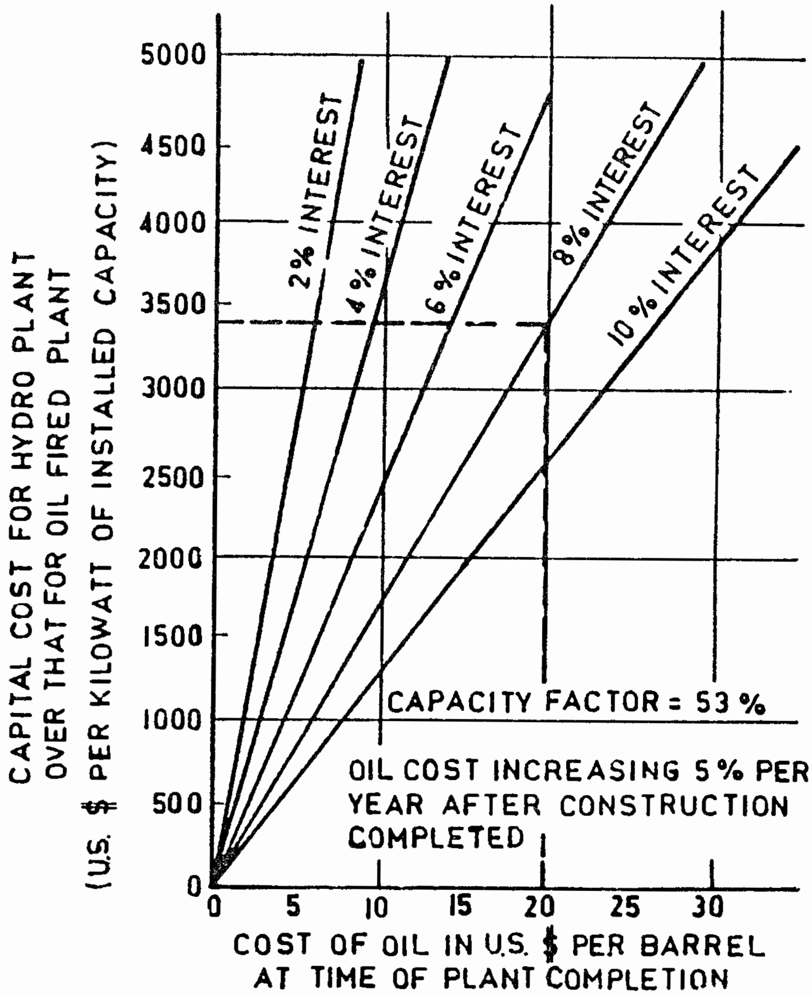


Figure 11. Additional Capital Cost Economically Justified For a Hydropower Plant Over That of an Oil-Fired Plant with Different Costs and Rates of Interest for Financing.

Thus the curves are simplistic and are illustrative only, but they do indicate the need for a fresh look at the present economic analysis methods. For instance, with the cost of oil at 20 U.S. dollars a barrel at the time of starting operation, and with an increase in the price of oil of 5% per year, with capital available at 8%, the capital cost of a hydropower plant that could be justified over that of an oil-fired plant, would be 3,400 U.S. dollars per kilowatt.

2. Project Financing. Determination of the economic value of a project may be quite different from that of the practical problems of obtaining financing. The latter will be affected by the risk involved compared to other investments, governmental guarantees or subsidies, if any, the availability of capital both for local costs and for costs of imported materials, the length of time for payback, and the expected return on the investment.

The amount of financing required will present a major problem. To increase the amount of hydropower to five times that now being produced will require an average expenditure of about 33 billion U.S. dollars (1976 dollars) for the next four decades; nearly half of the amount will be in developing countries (see Tables I and II).

3. Issues. The Panel should examine present practices around the world for the above analysis and suggest improvements that could be made. Further, ways that the continually renewable and pollution free characteristics of hydropower could be recognized should be examined. The finiteness of fossil fuels is considered only through the price structure which doesn't reflect problems 10 years or so ahead. Dependence upon oil or other energy sources outside the control of a country, and the effect this may have on internal inflation rates and currency values, need to be considered.

In view of the above, it would seem reasonable in some instances for governments to provide incentives to promote development of hydropower.

These could be in the form of various tax considerations such as investment tax credits, fast writeoff of capital costs, credit for equivalent finite fuel savings, and some have suggested elimination of property tax on hydropower developments. An outright governmental grant to cover some percentage of the cost might be justified in the overall public interest, both locally and worldwide. These issues should be examined by the Panel.

Reference 10 provides the United Nations prepared guidelines. The Panel should determine how effective they have been in application, and perhaps suggest improvements that could be made in evaluating hydropower developments.

V. HYDROPOWER ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

Rarely does a hydropower development concern only a local area; even small scale projects may have widespread effects. Water as an essential basic resource for all life has limitations and acts upon and interacts with all activities of people. In arid areas water is likely to be the controlling factor of present and future human activity. Even in humid areas it is an essential resource that requires careful husbandry. Thus any development will almost always have more than one purpose. For any utilization the full range of impacts on economic and social activity and on the environment need to be defined and carefully considered in formulating an optimum program for development.

1. Environment. Diversion and storage structures had an effect on the regime of a stream which must be evaluated to take full advantage of and improve positive effects and to minimize and mitigate changes that are adverse.

Tradeoffs will be required, and they need to be as fully defined and delineated as possible. Some uses are complementary and some are conflicting. The effects on the biological system requires careful consideration; for instance, the habitat of waterflwl may be an important factor. Flood prevention is generally a plus; other effects such as silt and debris retention, changes in the hydraulic properties of the stream, and the effects on the streambed can have both plus and minus aspects.

The effects of a reservoir and its operation on fishlife in a stream vary widely. On some streams, such as those in arid areas with naturally widely fluctuating flows, the effects will be mostly favorable. Food production from fish, as well as recreational values, can be greatly increased. Blocking of the upstream migration of anadromous fish can be mitigated, at least partly, by fish ladders along with fish hatcheries and related management programs.

Reservoirs can provide large water related recreation and other benefits, especially in arid areas. The aesthetics need evaluation as they can often be improved with careful planning without additional cost. The weighing of such factors will depend on the degree of development of an area, but they should usually be carefully considered.

2. Societal Effects. The short term effects, at least in the existing social cultures in an area, will depend upon the magnitude of the water resource development. Small scale hydropower installations, by providing electricity for house and street lighting, and perhaps for small cottage industry, with sometimes an assured culinary water supply as a by-product, can initiate a change from a primitive, poverty-stricken culture to improvement

in living conditions. Large developments that require the relocation of villages and large numbers of people present problems with serious impacts. There are no easy ways to accomplish such relocations, but often the conditions of those being moved can be improved with proper planning. Full knowledge and sound judgement are required.

Methods of determining and weighing national social effects, such as employment, redistribution of wealth and opportunity, foreign exchange problems, and the social value of investments and returns, need to be reviewed as related to hydropower developments. The importance of these factors will vary by project and from one country to another, but they should be considered.

3. Legal and Political Problems. These two problems in regard to water resources development are closely interrelated. The legal rights to water and its use vary widely. Some areas have essentially property rights, such as the doctrine of prior appropriation for beneficial use as found in the Western United States. Other areas have common law riparian rights, and some have little or no legal framework. As the uses of water approach the supply capabilities, the legal and political problems become more difficult, both within a country and between two or more countries.

In international rivers, and especially those in developing areas such as those of the Congo and Mekong Rivers, a major difficulty is arriving at an equitable division of costs, benefits, responsibilities, and construction and operation activities. Fully seasoned and objective perspectives and judgements are required to arrive at agreements. 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 and Powerhouse on the Danube River involving Romania and Yugoslavia; a number of rivers in Europe such as the Rhine; and the Parana River in South America involving Brazil, Uraguay, and Argentina.

The Panel should consider how the United Nations could provide assistance in resolving these international problems, especially in the developing country areas. The issues are complex--technically, socially, politically, and economically--and there are no easy answers. Legal and closely related political problems can be overwhelming. The most knowledgeable, balanced, and objective evaluations and judgements are necessary.

VI. UTILIZATION OF HYDROPOWER

The flexibility of electrical energy applies to that produced from hydropower. It can be utilized in the full range of development of an area and in all the areas of energy need: agriculture, industry, domestic, commercial, transportation and telecommunications. However, the Panel could review how it can be best utilized in various stages of development for maximum benefit.

Various ways to store the excess energy produced by streamflow that may be required when electrical load demands are less than the energy generated, should be considered. With small scale units, a battery bank as shown in Figure 10, can be effectively utilized. For large scale developments, pumped storage is the most efficient and effective ways to store energy. It is also effective in a system where large size heat-power units, which require continuous full load operation for economy, produce excess energy during nighttime.

As discussed in item 7 of Hydropower Advantages, about four units of energy are required at low demand time to produce three units during peak loads; the former is low cost energy and the peaking power may have market value several times the cost.

The present state-of-the-art of pumped storage is quite well advanced and is described in Reference 11. The Panel should evaluate the present pump-turbine technology to identify possible improvements. The possibility of using off-the-shelf present pumps as pump-turbines, especially for small scale use should be examined.

The Panel should also consider bringing the developments of underground pumped storage now being made or planned into focus for possible increased use in developed countries with low topography relief. Other possible methods of energy storage could be examined.

VII. MEASURES TO PROMOTE HYDROPOWER IN DEVELOPING COUNTRIES

1. Technology Required. As has been discussed, the technology required is not high level, except possibly the controls and equipment for high voltage generation and transmission of electricity. Technology is not considered a deterrent to development. Factors determining the pace of hydropower development are as follows:

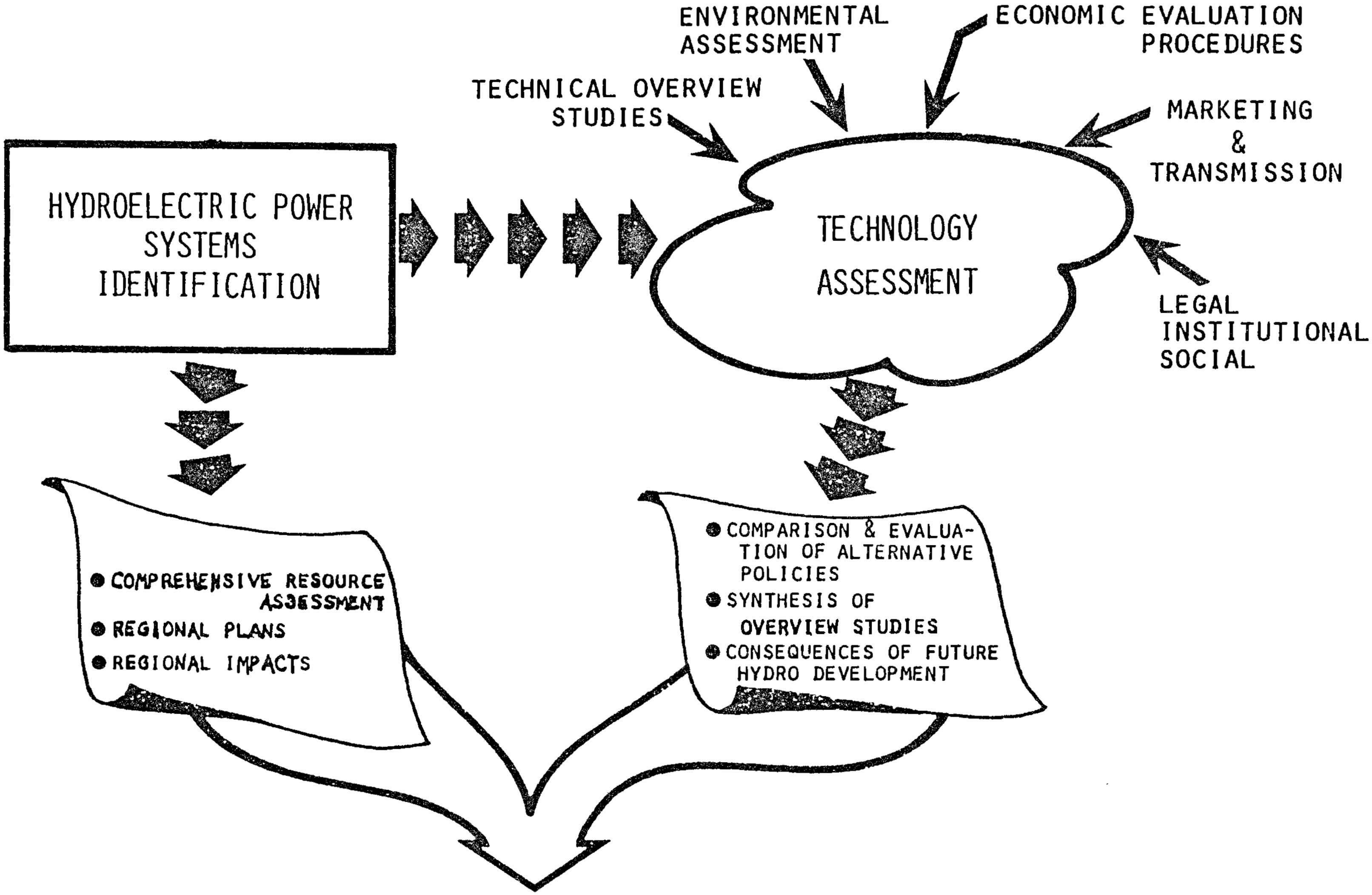
   a. Energy demand in the market area
   b. Availability of capital
   c. Cost of energy from alternate sources
   d. Institutional framework and stability
   e. Methodology effectiveness in formulating projects

f. Organization structure to carry out programs

g. Financial assistance to train personnel, provide technology transfer, and to initiate programs

2. Obstacles to Development. For small scale hydropower, the big problem is the relatively high cost of investigations and project formulation so that financing can be obtained. Consideration should be given to a systematic evaluation of an entire river basin, determinations made on priorities of development, and then development planned in a systematic program. There is need to provide assistance to the developing countries to accomplish this type of approach. Some programs are now underway, such as United Nations evaluations, the energy evaluations and determination of options available recently completed in Peru and Egypt with assistance from U.S. AID, the programs being planned and carried out by the World Bank, and a number of others. The Panel should determine the worldwide status of such studies, and identify areas and countries where additional efforts should be made. Financial assistance from the developed countries will be required, but such programs are essential. Methods to provide this essential financial assistance should be determined.

While the natural resource agencies in developing countries have competent personnel and direction, there often is a need for utilization of systematic methodologies of analyzing and developing programs. Figure 12 is from Reference 12 and illustrates the type of study plan needed for a national assessment of hydropower. Figure 13 shows the components of a reconnaissance study, and Figure 14 illustrates the components of project formulation. These two figures, 13 and 14, are from Reference 13. The Panel should evaluate ways these or similar methodologies can be better utilized, especially in developing countries. Reference 14 provides an excellent guide for hydropower evaluation.



- RECOMMEND PLAN FOR HYDROELECTRIC POWER RESOURCES
- ANALYSIS OF POLICY OPTIONS

Figure 12. Flow of Studies to Develop a National Plan for Hydropower Development

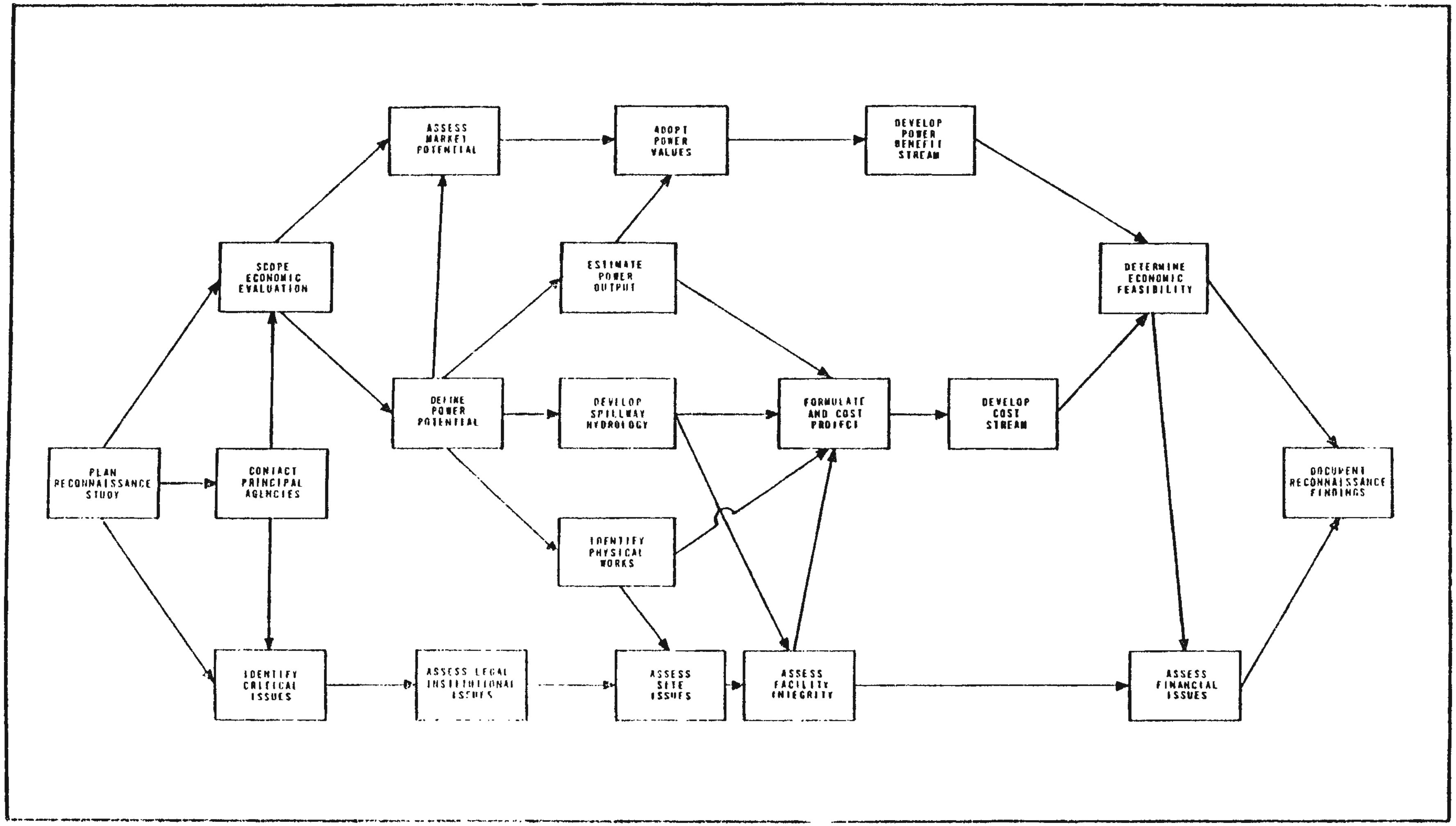


Figure 13. Components of a Reconnaissance Study.

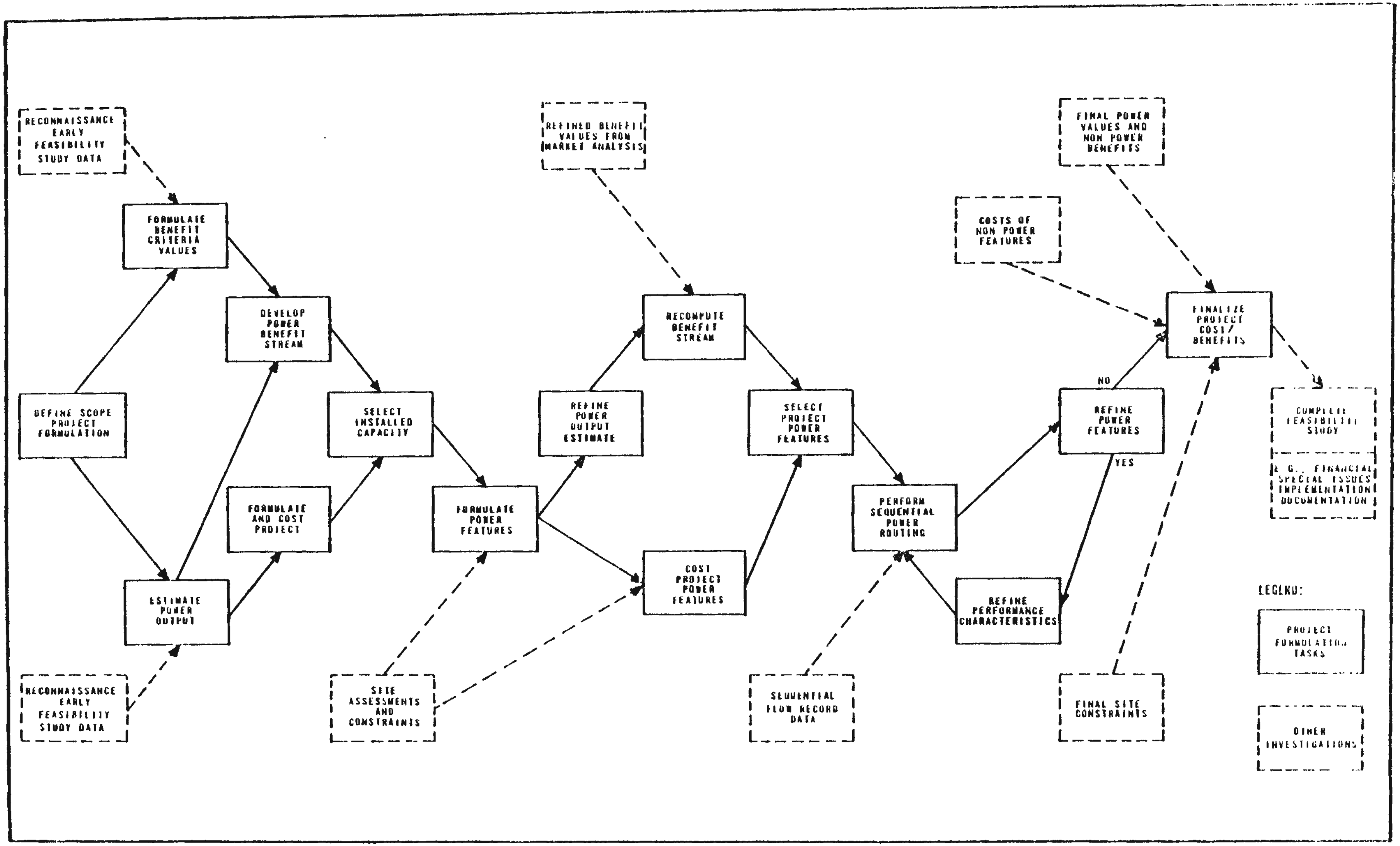


Figure 14. Components of Feasibility Studies for Project Formulation.

Cost information for reconnaissance studies have been developed in series of cost curves such as those shown in Reference 15. There are other sources equally reliable, and data is available to adapt the cost curve data to sites at most locations.

Some of the smaller and more simple projects can lend themselves to planning and development by the private sector and financing by private investors. However, even the simple projects will involve interface of some type with Government organizations. Most of the large, complex projects will be planned, constructed, and operated by Government, or by Government direction utilizing some type of development and operation authorities, such as a national power authority. Further, there needs to be close coordination with the electric utility industry where one exists separate from Government. There generally is a critical need of developing organizational structures that can provide the needed coordination, and that can plan and accomplish programs. The Panel should consider ways experienced assistance in this area can be provided to the developing countries.

Shortage of trained and experienced personnel for hydropower planning and development is a worldwide problem. The Panel should review various programs now underway and develop whatever additional programs of seminars, direct training of Government personnel, use of short term consultants to assist in formulating and organizing programs, periodic conferences such as the October, 1979 International Conference on Water Power held in Washington, D.C., scholarships for university training, and various other methods of technology transfer that can be effective.

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APPENDIX

Hydraulic Energy - Use and Potential

(From Reference 1, World Energy Conference Survey of Energy Resources - 1974)

	Total Resources / *Ressources totales* at G_{95} MW	at G_{95} GWh/yr	at G_{95} TJ/hr	at G_{av} MW	at G_{av} GWh/yr	at G_{av} TJ/yr	Use Factor at G_{av}, hours/yr / *Facteur utilisé pour G_{av} (heures/an)*	Resources at G_{av} / *Ressources pour G_{av}* — Per Unit Area / *Par zone*: Area, Mm^2	$\frac{kW}{km^2}$	$\frac{MWh}{km^2}$	Per Capita / *Par habitant*: Population, Millions	$\frac{kW}{cap.}$	$\frac{MWh}{cap.}$	Current Capacity & Annual Production / *Puissance actuelle et production annuelle*: MW	GWh/yr	TJ/yr	Percent of Resources Presently Utilized, Annual Energy at: / *Pourcentage des ressources actuellement utilisées, Energie annuelle pour*: G_{95}	G_{av}
Africa																		
Western	9 720	77 763	279 950	53 222	222 839	802 213	4 187	6.104	8.71	36.51	113	0.47	1.97	1 579	5 248	18 893	6.7	2.4
Eastern	30 446	243 563	876 823	140 080	667 267	2 402 162	4 763	5.523	25.36	120.81	90	1.56	7.41	2 201	11 959	43 053	4.9	1.8
Middle	100 890	807 120	2 905 632	208 064	1 022 400	3 680 638	4 914	6.613	31.46	154.60	33	6.30	30.98	1 104	4 901	17 642	0.6	0.4
Northern	2 633	21 062	75 824	25 764	80 930	291 348	3 141	8.510	3.03	9.51	86	0.30	0.94	3 090	7 310	26 316	34.7	9.0
Southern*	1 529	12 233	44 038	9 974	26 498	95 393	2 657	2.671	3.73	9.92	23	0.43	1.15	180	750	2 700	6.1	2.8
Total	145 218	1 161 741	4 182 267	437 104	2 019 934	7 271 754	4 621	29.421	14.86	68.66	345	1.27	5.85	8 154	30 168	108 594	2.6	1.5
Asia (less USSR)																		
Japan*	7 900	63 201	227 524	49 592	130 004	468 014	2 621	0.372	133.31	349.47	102	0.49	1.27	19 897	82 270	296 172	130.2	63.3
Eastern	62 014	496 110	1 785 996	339 146	1 343 208	4 835 549	3 961	11.353	29.87	118.31	809	0.42	1.66	14 752	55 261	198 938	11.1	4.1
Middle South	36 789	294 315	1 059 534	108 683	451 698	1 626 113	4 156	6.873	15.81	65.72	747	0.15	0.60	8 664	45 900	165 240	15.6	10.2
Southeast	26 507	212 056	763 402	168 796	637 298	2 294 271	3 775	4.493	37.57	141.84	283	0.60	2.25	2 571	11 083	39 899	5.2	1.7
Southwest	6 078	48 623	175 042	18 120	75 961	273 460	4 192	4.531	4.00	16.76	77	0.24	0.99	1 234	3 919	14 108	8.1	5.2
Total	139 288	1 114 305	4 011 498	684 337	2 638 169	9 497 407	3 855	27.672	24.73	95.34	2 018	0.34	1.31	47 118	198 433	714 357	17.7	7.5
Europe (less USSR)																		
Western	14 769	118 146	425 325	48 874	161 266	580 557	3 300	0.985	49.62	163.72	144	0.34	1.12	33 928	118 266	425 758	100.1	73.3
Southern	11 643	93 140	335 304	80 589	218 654	787 154	2 713	1.317	61.19	166.02	126	0.64	1.74	33 465	109 108	392 788	117.1	49.9
Northern	23 631	193 046	694 965	64 951	279 406	1 005 862	4 303	1.573	41.29	177.62	79	0.82	3.54	30 429	139 159	500 972	72.1	49.8
Eastern	2 918	23 344	84 038	20 993	63 042	226 951	3 003	0.991	30.00	63.61	105	0.20	0.60	6 176	15 784	56 821	67.6	25.0
Total*	52 961	427 676	1 539 632	215 407	722 368	2 600 524	3 354	4.866	44.27	148.45	454	0.47	1.59	103 998	382 317	1 376 339	89.4	52.9
USSR*	50 000	400 000	1 440 000	269 000	1 095 000	3 942 000	4 071	22.272	12.08	49.16	245	1.10	4.47	31 500	123 000	442 800	30.8	11.2
North America																		
Northern*	57 728	461 824	1 662 567	290 209	1 272 709	4 581 753	4 386	21.674	13.39	58.72	226	1.28	5.63	85 905	434 950	1 565 820	94.2	34.2
Southern	14 107	112 862	406 303	37 846	203 138	731 297	5 367	2.506	15.10	81.06	65	0.58	3.13	4 109	17 796	64 065	15.8	8.8
Caribbean	300	2 400	8 640	2 400	12 000	43 200	5 000	0.239	10.04	50.21	26	0.09	0.46	196	588	2 117	24.5	4.9
Total	72 135	577 086	2 077 510	330 455	1 487 847	5 356 250	4 502	24.419	13.53	60.93	317	1.04	4.69	90 210	453 334	1 632 002	78.6	30.5
South America																		
Tropical	68 132	545 053	1 962 190	215 877	1 317 935	4 744 566	6 105	13.666	15.79	96.44	154	1.40	8.56	14 670	79 076	284 674	14.5	6.0
Temperate	13 089	104 710	376 956	72 412	319 096	1 148 746	4 407	4.140	17.49	77.08	39	1.86	8.18	4 103	12 339	44 421	11.8	3.9
Total	81 221	649 763	2 339 146	288 289	1 637 031	5 893 312	5 678	17.806	16.19	91.94	193	1.49	8.48	18 773	91 415	329 095	14.1	5.6
Oceania*	12 987	103 897	374 030	36 515	202 071	727 456	5 534	8.521	4.29	23.71	19	1.92	10.64	7 609	28 897	104 030	27.8	14.3
World Total	553 810	4 434 468	15 964 083	2 261 107	9 802 420	35 288 703	4 335	134.927	16.76	72.65	3 591	0.63	2.73	307 362	1 307 564	4 707 217	29.5	13.3
*Developed Nations	183 105	1 468 831	5 287 791	870 697	3 448 650	12 415 140	3 960	60.376	14.42	57.12	1 069	0.81	3.23	249 320	1 052 491	3 788 965	71.6	30.5
Developing Nations	370 705	2 965 637	10 676 292	1 390 410	6 353 770	22 873 563	4 570	74.551	18.65	86.23	2 522	0.55	2.52	58 042	255 073	918 252	8.6	4.0

Regional and Continental Totals of Hydraulic Energy Resources and Their Present Utilization

Totaux des ressources hydrauliques et de leur utilisation actuelle pour les régions et les continents

Hydraulic Energy

Name of Continent, Region, Country and National Subdivision	Gross Theoretical Capability (TJ)	Development Status: Operating: Capacity (MW)	Operating: Probable Annual Generation (TJ): at G95	Operating: Probable Annual Generation (TJ): Average	Under Construction: Capacity (MW)	Under Construction: Probable Annual Generation (TJ): at G95	Under Construction: Probable Annual Generation (TJ): Average	Planned: Capacity (MW)	Planned: Probable Annual Generation (TJ): at G95	Planned: Probable Annual Generation (TJ): Average	Other: Capacity (MW)	Other: Probable Annual Generation (TJ): at G95	Other: Probable Annual Generation (TJ): Average
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
AFRICA													
Western Africa													
Nigeria (a,b)													
Kainji(c)	8064	320.0	8064	15588	-	-	-	-	-	-	-	-	-
Kainji Extension	3650	-	-	-	230.0	3650	-	-	-	-	-	-	-
Jebba	7812	-	-	-	-	-	-	500.0	7812	10152	-	-	-
Shiroro Gorge	2844	-	-	-	-	-	-	400.0	2844	2844	-	-	-
Gongola	684.0	-	-	-	-	-	-	40.00	684.0	792.0	-	-	-
Benue-Plateau (NESCO)	432.0	25.00	432.0	432.0	-	-	-	-	-	-	-	-	-
Losses	993.6	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL Nigeria	24480	345.0	8496	16020	230.0	3650	-	940.0	11340	13788	-	-	-
Ghana													
Entire Nation	U	948.0	29536	9515	-	-	-	140.0	4415	U	526.5	22037	U
Ivory Coast													
Bia	3240	50.00	360.0	900.0	-	-	-	-	-	-	-	-	-
Cosoe	44280	-	-	-	-	-	-	U	U	5292	U	U	2160
Bandama	37800	175.0	1728	1908	-	-	-	210.0	2880	3780	U	3420	5040
Sassandra & Bafing	94681	-	-	-	-	-	-	345.0	4860	6408	U	U	3600
Cavally	50400	-	-	-	-	-	-	U	U	6480	U	U	3600
TOTAL Ivory Coast	230402	225.0	2088	2808	-	-	-	555.0	7740	21960	-	3420	14400
Portugese Guinea (a)													
Entire Nation	-	-	-	-	-	-	-	-	-	-	-	-	-
Eastern Africa													
Ethiopia (a,b)													
Abbai (Blue Nile)	585876	108.0	U	2117	-	-	-	950.0	U	16333	7602	U	108342
Awash Basin	14782	114.0	U	1789	-	-	-	40.00	U	720.0	U	U	2185
Alamata	164.2	-	-	-	-	-	-	-	-	-	U	U	44.28
Barca	1076	-	-	-	-	-	-	-	-	-	U	U	277.2
Mareb-Gash	6284	-	-	-	-	-	-	-	-	-	U	U	2049
Taccazze-Setit	53448	-	-	-	-	-	-	-	-	-	U	U	18172
Angareb	950.4	-	-	-	-	-	-	-	-	-	U	U	255.6
Atbara	547.2	-	-	-	-	-	-	-	-	-	U	U	147.6
Baro	10861	-	-	-	-	-	-	-	-	-	U	U	4360
Ghelo	1260	-	-	-	-	-	-	-	-	-	U	U	340.2
Omo	57842	-	-	-	-	-	-	400.0	U	7200	U	U	9344
Acobo	978.5	-	-	-	-	-	-	-	-	-	U	U	165.6
Giuba	8183	-	-	-	-	-	-	-	-	-	U	U	2354
Wabi Shebelli	77624	-	-	-	-	-	-	-	U	2520	U	U	22841
TOTAL Ethiopia	819876	222.0	-	3906	-	-	-	1390	-	26773	7602	-	170877
Mozambique													
Entire Nation	180002	90.00	1134	U	3700	64801	U	2500	46800	U	5000	54000	U
Malawi (a)													
Entering Lake Malawi	U	-	-	-	-	-	-	-	-	-	U	-	-
Leaving Lake Malawi	U	40.00	252.0	-	-	-	-	-	-	-	-	-	-
TOTAL Malawi	-	40.00	252.0	-	-	-	-	-	-	-	-	-	-
Zambia (a)													
Entire Nation	U	756.0	U	U	910.0	U	U	768.0	U	U	1400	U	U
Middle Africa													
Zaire (a,b,c)													
Upper Zaire	U	559.0	9932	U	-	-	-	-	-	-	-	-	-
Middle Zaire	U	38.00	360.0	U	-	-	-	-	-	-	-	-	-
Lower Zaire	U	-	-	-	289.0	2081	U	-	-	-	32000	-	-
TOTAL Zaire	-	597.0	10292	-	289.0	2081	-	-	-	-	32000	-	-
Angola													
Entire Nation	252002	284.0	2880	U	80.00	720.0	U	300.0	12240	U	9000	216002	U
Sao Tome and Principe (a)													
Entire Nation	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern Africa													
Tunisia (a)													
Entire Nation	81.00	29.00	181.3	136.7	-	-	-	-	-	-	-	-	-
Southern Africa													
South Africa (a)													
Orange River	U	180.0	1192	2700	420.0	1145	2866	-	-	-	-	-	-
Tugela River (b)	U	-	-	-	-	-	-	4000	14400	25200	-	-	-
TOTAL South Africa	-	180.0	1192	2700	420.0	1145	2866	4000	14400	25200	-	-	-
ASIA													
East Asia													
Japan (a,b)													
Entire Nation	2412021	19897	161915	296174	4396	4630	16730	25327	60981	155114	-	-	-
Korea, Rep. of (a)													
North-West Region	U	573.0	U	5699	0	U	0	512.0	U	2916	776.0	U	U
North-East Region	U	0	U	0	90.00	U	576.0	200.0	U	1422	338.0	U	U
South-West Region	U	34.00	U	655.2	0	U	0	250.0	U	1757	591.0	U	U
South-East Region	U	13.00	U	144.0	0	U	0	80.00	U	741.6	57.00	U	U
TOTAL Korea, Rep. of	-	620.0	-	6498	90.00	-	576.0	1042	-	6836	1762	-	-
Eastern Asia													
Taiwan (a)													
Entire Nation	380 000	1131	5537	13630	234.0	277.6	1411	266.5	340.2	3977	-	-	-

(See Appendix pages 7 to 12 inclusive for notes concerning the tabulation data).

Hydraulic Energy

Name of Continent, Region, Country and National Subdivision	Gross Theoretical Capability (TJ)	Development Status											
		Operating			Under Construction			Planned			Other		
		Capacity (MW)	Probable Annual Generation (TJ)		Capacity (MW)	Probable Annual Generation (TJ)		Capacity (MW)	Probable Annual Generation (TJ)		Capacity (MW)	Probable Annual Generation (TJ)	
			at G95	Average		at G95	Average		at G95	Average		at G95	Average
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
ASIA													
Middle South Asia													
India (a,b,c,d)													
Northern	203041	2150	46440	U	2700	-	-	12150	156960	U	-	-	-
Western	135360	1000	17730	U	1000	-	-	10000	117990	U	-	-	-
Southern	153000	3100	61470	U	2400	-	-	5500	91890	U	-	-	-
Eastern	50760	430.0	10800	U	500.0	-	-	4070	40320	U	-	-	-
Northeastern	235441	70.00	720.0	U	200.0	-	-	24730	235441	U	-	-	-
TOTAL India	777602	6750	137160	-	6800	-	-	56450	642602	-	-	-	-
Bangladesh (a,b)													
Entire Nation	U	120.0	U	U	-	-	-	86.90	U	U	1100	U	U
Iran (a)													
Khuzestan	U	520.0	6548	9356	1000	12539	14832	-	-	-	6800	68400	84240
Tehran	U	113.0	648.0	720.0	-	-	-	168.0	720.0	774.0	-	-	-
Azarbaijan & Gharb	U	26.00	262.8	356.4	-	-	-	100.0	777.6	1008	350.0	4320	6084
Mazandaran & Gilan	U	87.00	1440	1800	-	-	-	-	-	-	800.0	10080	12816
Esfahan	U	52.00	540.0	720.0	-	-	-	-	-	-	-	-	-
Jonoob Sharghi	U	-	-	-	-	-	-	30.00	180.0	288.0	-	-	-
Other	U	-	-	-	-	-	-	-	-	-	150.0	1440	1800
TOTAL Iran	-	798.0	9439	12953	1000	12539	14832	298.0	1678	2070	8100	84240	104940
Southeast Asia													
Indonesia													
Sumatra	126001	-	-	-	-	-	-	-	-	-	7000	U	U
Java	27000	-	-	-	-	-	-	1500	U	U	-	-	-
Kalimantan	117001	-	-	-	-	-	-	-	-	-	6500	U	U
Sulawesi	105301	-	-	-	-	-	-	-	-	-	5850	U	U
Irian Jaya	162001	-	-	-	-	-	-	-	-	-	9000	U	U
Nusa Tenggara & Maluku	2700	-	-	-	-	-	-	-	-	-	150.0	U	U
TOTAL Indonesia	540005	-	-	-	-	-	-	1500	-	-	28500	-	-
Philippines (a)													
Luzon Region	43514	431.7	3298	3298	1290	9860	9860	-	-	-	3971	30355	30355
Visayas Region	4457	2.000	43.20	43.20	-	-	-	-	-	-	196.2	4414	4414
Mindanao Region	22572	207.2	2898	2898	795.0	11120	11120	-	-	-	611.4	8554	8554
TOTAL Philippines	70543	640.9	6239	6239	2085	20981	20981	-	-	-	4778	43323	43323
Vietnam, Rep. of (a)													
North	-	-	-	-	-	-	-	1247	-	20650	-	-	-
South (Mekong)	-	-	-	-	-	-	-	2368	-	44738	-	-	-
Central (Dong Nai)	-	709.0	-	13000	-	-	-	1274	-	22929	-	-	-
TOTAL Vietnam, Rep. of	-	709.0	-	13000	-	-	-	4889	-	88316	-	-	-
Malaysia (a,b,c)													
West Malaysia only	U	295.5	U	3812	348.0	U	3269	341.0	U	3377	334.4	U	5623
Portugese Timor (a)													
Entire Nation	-	-	-	-	-	-	-	-	-	-	-	-	-
Southwest Asia													
Turkey (a to e)	-	-	-	-	-	-	-	-	-	-	-	147400	-
Meric	4068	-	-	-	-	-	-	-	-	-	0	0	0
Marmara	18576	-	-	-	-	-	-	-	-	-	0	0	0
Susurluk	37368	-	-	-	-	-	-	-	-	-	10.34	U	115.2
K. Ege	11383	-	-	-	-	-	-	-	-	-	10.80	U	100.8
Gediz	14011	89.00	U	1202	-	-	-	-	-	-	-	-	-
K. Menderes	5929	-	-	-	-	-	-	-	-	-	0	0	0
B. Menderes	27911	179.4	U	2966	-	-	-	-	-	-	-	-	-
B. Akdeniz	65373	-	-	-	-	-	-	338.1	U	5800	-	-	-
Antalya	88554	500.2	U	9000	-	-	-	-	-	-	-	-	-
Burdur	3658	-	-	-	-	-	-	-	-	-	0	0	0
Akarcay	2491	-	-	-	-	-	-	-	-	-	0	0	0
Sakarya	37685	588.2	U	5713	-	-	-	-	-	-	-	-	-
B. Karadeniz	72029	-	-	-	-	-	-	-	-	-	288.1	U	4788
Yesilirmak	66763	711.8	U	8316	-	-	-	-	-	-	-	-	-
Kizilirmak	69286	1017	U	15333	-	-	-	-	-	-	-	-	-
Konya	4637	30.40	U	259.2	-	-	-	-	-	-	-	-	-
D. Akdeniz	98868	328.4	U	5879	-	-	-	-	-	-	-	-	-
Seyhan	81426	440.0	U	7956	-	-	-	-	-	-	-	-	-
Asi	15862	3.000	U	46.80	-	-	-	-	-	-	-	-	-
Ceyhan	70831	637.1	U	8806	-	-	-	-	-	-	-	-	-
Firat	309876	6285	U	106593	-	-	-	-	-	-	-	-	-
D. Karadeniz	150744	1604	U	19145	-	-	-	-	-	-	-	-	-
Coruh	89407	415.9	U	5094	-	-	-	-	-	-	-	-	-
Aras	48629	277.8	U	3452	-	-	-	-	-	-	-	-	-
Van	8924	-	-	-	-	-	-	-	-	-	17.80	N	208.8
Dicle	166195	1481	U	24311	-	-	-	-	-	-	-	-	-
TOTAL Turkey	1570482	14589	-	224073	-	-	-	338.1	-	5800	327.0	147400	5213
Iraq (a)													
Samarra	U	96.00	1868	U	-	-	-	-	-	-	-	-	-
Dokan	U	-	-	-	560.0	4068	U	240.0	-	-	-	-	-
Haditha	0	-	-	-	-	-	-	-	3600	U	-	-	-
Mosul	U	-	-	-	-	-	-	-	8388	U	✓	-	-
Bakhma	U	-	-	-	-	-	-	-	9720	U	-	-	-

Hydraulic Energy

Name of Continent, Region, Country and National Subdivision	Gross Theoretical Capability (TJ)	Development Status: Operating: Capacity (MW)	Operating: Probable Annual Generation (TJ): at G95	Operating: Probable Annual Generation (TJ): Average	Under Construction: Capacity (MW)	Under Construction: Probable Annual Generation (TJ): at G95	Under Construction: Probable Annual Generation (TJ): Average	Planned: Capacity (MW)	Planned: Probable Annual Generation (TJ): at G95	Planned: Probable Annual Generation (TJ): Average	Other: Capacity (MW)	Other: Probable Annual Generation (TJ): at G95	Other: Probable Annual Generation (TJ): Average
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
ASIA													
Southwest Asia													
Iraq													
TOTAL Iraq	-	96.00	1868	-	560.0	4068	-	240.0	21708	-	-	-	-
Israel													
Entire Nation	0	-	-	-	-	-	-	-	-	-	-	-	-
EUROPE													
Western Europe													
Germany, F.R. of (a)													
Danube	72184	1843	23220	34146	17.00	194.4	284.4	706.0	8986	13216	-	-	-
Rhine	40616	993.0	11844	17417	198.0	3132	4608	367.0	3254	4784	-	-	-
Weser and Elbe	6336	104.0	856.8	1260	-	-	-	180.0	1987	2923	-	-	-
TOTAL Germany, F.R. of	119136	2940	35921	52823	215.0	3326	4892	1253	14227	20923	-	-	-
France (a,b,c)													
Entire Nation	972009	15600	151201	194402	2800	6840	8640	-	-	-	2600	18360	23760
Netherlands													
Entire Nation	0	0	0	0	0	0	0	0	0	0	0	0	0
Belgium (a)													
Entire Nation	1922	67.00	-	738.0	-	-	-	10.00	-	111.6	63.00	-	691.2
Austria (a)													
Entire Nation	158040	5691	64440	71640	2993	23760	26442	-	-	-	3616	54000	59958
Switzerland (a)													
Entire Nation	-	11000	-	115200	-	-	-	-	-	-	-	-	-
Luxembourg													
Entire Nation	N	-	-	-	-	-	-	-	-	-	N	N	N
Southern Europe													
Italy (a,b)	-	-	138960	-	-	3600	-	-	15840	-	-	-	-
Northern Mainland	835201	11200	-	124200	1800	-	3240	1800	-	16200	-	-	-
Southern Mainland	342360	[illegible]	-	32760	400.0	-	1080	200.0	-	1800	-	-	-
Sicily	27000	300.0	-	1080	-	-	-	N	-	N	-	-	-
Sardinia	22680	100.00	-	1800	-	-	-	N	-	N	-	-	-
TOTAL Italy	1227241	15000	138960	159840	2200	3600	4320	2000	15840	18000	-	-	-
Spain (a)													
Entire Nation	[illegible]	11355	U	118524	2326	U	11416	8835	U	68141	6808	U	44885
Yugoslavia													
Entire Nation	396004	[illegible]	59221	74881	910.0	8244	10080	9500	0	107641	2300	0	36360
Portugal													
Mainland	63433	1805	[illegible]	27778	802.0	4176	8136	498.0	2520	4018	2985	12420	23343
Azores and Madeira	676.8	18.00	216.0	262.8	-	-	-	40.00	180.0	234.0	40.00	108.0	180.0
TOTAL Portugal	64109	1823	18900	28041	802.0	4176	8136	538.0	2700	4252	3025	12528	23523
Northern Europe													
United Kingdom (a,b,c)													
Entire Nation	27900	2157	12377	14717	300.0	230.4	334.8	-	-	-	-	-	-
Sweden (a)													
Southern	72001	1430	-	20880	0	-	0	0	-	0	600.0	-	15120
Northern	633606	9930	-	176042	1260	-	14400	1530	-	12240	5380	-	122401
TOTAL Sweden	705606	11360	-	196922	1260	-	14400	1530	-	12240	5980	-	137521
Finland (a,b,c)													
Entire Nation	100801	2270	27000	39960	115.0	-	1800	30.00	-	360.0	1300	-	22680
Norway (a,b)													
Entire Nation	1800016	14020	228602	240842	3570	33480	35280	5700	72721	75961	6300	79201	83521
Ireland (a,b)													
Entire Nation	3240	219.0	U	2689	-	-	-	-	-	-	80.00	U	550.8
Iceland													
Entire Nation	126001	376.0	8640	-	163.0	3600	-	-	-	-	U	88561	-
Eastern Europe													
Poland (a)													
Entire Nation	U	820.4	6908	U	-	-	-	-	-	-	-	-	-
Romania (a,b)													
Entire Nation	252001	2300	18000	27720	1200	5400	8640	-	-	-	-	32760	50400
Germany, D.R. of													
Entire Nation	N	N	N	N	N	N	N	N	N	N	N	N	N
Bulgaria (a)													
Danubian	23652	-	-	-	-	-	-	778.8	-	8163	-	-	-
Danube	19157	-	-	-	-	-	-	-	-	-	-	-	-
Black Sea	2170	-	-	-	-	-	-	35.30	-	402.1	-	-	-
Aegean	50065	-	-	-	-	-	-	3355	-	28322	-	-	-
Other	33.48	-	-	-	-	-	-	0.200	-	19.08	-	-	-
TOTAL Bulgaria	95078	-	-	-	-	-	-	4169	-	36906	-	-	-
EUROPE-ASIA													
Northern													
USSR (a,b)													
Northwest (c)	529205	4000	-	54000	-	-	-	-	-	-	17600	-	126001
Central European USSR (d)	532805	11500	-	147601	-	-	-	-	-	-	11000	-	79201
North Caucasas	457204	2000	-	21600	-	-	-	-	-	-	7800	-	68401
Transcaucasas	810007	3800	-	43200	-	-	-	-	-	-	10900	-	118801
Ukraine-Moldavia	169202	4000	-	39600	-	-	-	-	-	-	5000	-	25200
Western Siberia	982808	400.0	-	7200	-	-	-	-	-	-	16700	-	270002
Eastern Siberia	3646832	20800	-	338403	-	-	-	-	-	-	50200	-	903608
Far East	4352439	2100	-	28800	-	-	-	-	-	-	58200	-	1047609

Name of Continent, Region, Country and National Subdivision	Gross Theoretical Capability (TJ)	Development Status											
		Operating			Under Construction			Planned			Other		
		Capacity (MW)	Probable Annual Generation (TJ)		Capacity (MW)	Probable Annual Generation (TJ)		Capacity (MW)	Probable Annual Generation (TJ)		Capacity (MW)	Probable Annual Generation (TJ)	
			at G95	Average		at G95	Average		at G95	Average		at G95	Average
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
EUROPE-ASIA													
Northern													
USSR													
Central Asia-Kazakhstan	2710824	7400	-	111601	-	-	-	-	-	-	35600	-	511205
TOTAL USSR	18191324	56000	-	792007	-	-	-	-	-	-	213000	-	3150026
NORTH AMERICA													
Northern America													
United States (a,b,c)													
New England	48283	1511	U	21913	10.00	U	26374	-	-	-	3308	U	-
Middle Atlantic	136401	4252	U	92135	0	U	44266	-	-	-	12296	U	-
East North Central	35039	984.0	U	15898	0	U	19145	-	-	-	1305	U	-
West North Central	101978	2726	U	36792	72.00	U	65185	-	-	-	4257	U	-
South Atlantic	123354	5473	U	55408	499.0	U	67987	-	-	-	8490	U	-
East South Central	102410	5225	U	75723	206.0	U	26687	-	-	-	3671	U	-
West South Central	40345	2096	U	20858	160.0	U	19487	-	-	-	2969	U	-
Mountain	431821	6219	U	99411	898.0	U	332396	-	-	-	25276	U	-
Pacific	882831	24862	U	504750	5725	U	378073	-	-	-	31605	U	-
Alaska	621794	77.00	U	1145	70.00	U	620642	-	-	-	32408	U	-
Hawaii	1210	19.00	U	385.2	0	U	824.4	-	-	-	35.00	U	-
TOTAL United States	2525463	53404	-	924418	7640	-	1601024	-		-	125620	-	-
Canada (a,b)													
British Columbia	855857	4803	U	104912	2540	U	60077	6135	U	145106	9943	U	188289
Yukon	273343	26.00	U	702.0	0	0	0	30.00	U	709.2	3176	U	60135
Northwest Territories	183083	35.00	U	842.4	0	0	0	0	0	0	2127	U	40277
Alberta	254439	724.0	U	5638	0	0	0	0	0	0	2956	U	55977
Saskatchewan	51372	567.0	U	11250	0	0	0	0	0	0	597.0	20459	11304
Manitoba	181654	1863	U	37372	1760	U	41627	0	0	0	4221	80940	79928
Ontario	57633	7010	U	148213	87.00	U	2059	0	0	0	670.0	14080	12679
Quebec	970518	13766	U	279672	1213	U	28689	8330	U	197023	11275	U	213514
New Brunswick	7452	670.0	U	10634	0	0	0	0	0	0	87.00	914.4	1642
Nova Scotia	5785	162.0	U	2837	0	0	0	0	0	0	67.00	673.2	1274
Prince Edward Island	28.80	0	0	0	0	0	0	0	0	0	0.400	7.200	7.200
Newfoundland & Labrador	210429	2875	U	39341	3325	U	78643	0	0	0	3505	U	66367
TOTAL Canada	3051592	32501	-	641414	8925	-	211095	14495	-	342838	38624	117073	731393
Greenland													
Entire Nation	U	-	-	-	-	-	-	-	-	-	-	-	-
Middle America													
Mexico (a,b)													
Northwest	16741	192.2	3482	2808	135.0	2695	U	0	0	0	429.0	10564	U
Pacific Central	15208	68.40	1448	U	0	0	0	540.0	6840	U	231.0	6920	U
Balsas River Basin	58579	1215	20413	U	340.0	4504	U	900.0	13543	U	1337	20119	U
Isthmian Zone	11049	22.40	U	U	0	0	0	0	0	0	732.0	11049	U
North	3144	73.40	1007	756.0	0	0	0	0	0	0	142.0	2137	U
Gulf-North	11455	473.7	5767	U	0	0	0	0	0	0	378.0	5688	U
Papaloapan River Basin	45294	218.1	4311	U	0	0	0	360.0	4763	U	2407	36220	U
Grijalva River Basin	131052	727.9	6674	U	900.0	13543	U	1990	24179	U	5768	86655	U
North Closed Basin	842.8	0	0	0	0	0	0	0	0	0	56.00	842.8	U
Central-Lerma	12593	547.1	10485	U	0	0	0	0	0	0	140.0	2108	U
Mexico-Puebla	347.8	21.00	347.8	U	0	0	0	0	0	0	0	0	0
TOTAL Mexico	306304	3559	53934	3564	1375	20742	-	3790	49325	-	11620	182303	-
Guatemala (a,b,c)													
Entire Nation	46008	95.60	1021	1152	-	-	-	1100	12579	-	-	-	-
Costa Rica (a)													
Entire Nation	802807	214.0	U	4266	270.0	U	2282	1635	U	36112	4881	U	86941
SOUTH AMERICA													
Tropical South America													
Brazil (a)													
North	223276	0	0	0	100.0	1577	3154	3900	61495	122991	U	U	U
Northeast	337879	1204	18986	24113	851.0	13435	17064	4700	74110	94119	6980	110060	139774
Southeast	1071251	8200	137056	172689	9000	150426	189537	13150	219791	276938	11000	183856	231657
South	697992	846.0	10937	15966	1438	18594	27148	1574	20351	29711	26133	337893	493324
Central-West	38358	234.0	3690	6275	246.0	3877	6599	684.0	10786	18346	U	U	U
TOTAL Brazil	2368755	10484	170669	219043	11635	187910	243501	24008	386533	542104	44113	631809	864755
Colombia (a)													
Caribbean	3024003	1680	U	U	290.0	U	4842	19030	U	U	10600	U	U
Pacific and Atrato	835201	220.0	U	U	360.0	U	6336	1820	U	U	4500	U	U
Orinoco and Amazon	784801	N	N	N	500.0	U	12528	2500	-	-	8500	-	-
TOTAL Colombia	4644004	1900	-	-	1150	-	23706	23350	-	-	23600	-	-
Venezuela (a,b)													
Lago de Maracaibo	106561	-	-	-	-	-	-	-	-	-	-	-	-
Costa Noroccidental	2520	-	-	-	-	-	-	-	-	-	-	-	-
Centro Occidental	6480	-	-	-	-	-	-	-	-	-	-	-	-
Llanos Centro Occidentales	199442	-	-	-	240.0	-	3456	692.0	-	10847	-	-	-
Sur del Apure	86401	-	-	-	-	-	-	-	-	-	-	-	-
Central	3240	-	-	-	-	-	-	-	-	-	-	-	-
Centro Oriental	7200	-	-	-	-	-	-	-	-	-	-	-	-
Oriental	10440	-	-	-	-	-	-	-	-	-	-	-	-
Guayana Oriental	373323	895.0	17781	26338	1540	18580	43164	8277	179872	267929	-	-	-

Hydraulic Energy

Name of Continent, Region, Country and National Subdivision	Gross Theoretical Capability (TJ)	Development Status											
		Operating			Under Construction			Planned			Other		
		Capacity (MW)	Probable Annual Generation (TJ)		Capacity (MW)	Probable Annual Generation (TJ)		Capacity (MW)	Probable Annual Generation (TJ)		Capacity (MW)	Probable Annual Generation (TJ)	
			at G95	Average		at G95	Average		at G95	Average		at G95	Average
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
SOUTH AMERICA													
Tropical South America													
Venezuela													
Guayana Occidental	300963	-	-	-	-	-	-	-	-	-	-	-	-
Territorio Amazonas	191162	-	-	-	-	-	-	-	-	-	-	-	-
Guayana Esequiba	408604	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL Venezuela	1696333	895.0	17781	26338	1780	18580	46620	8969	179872	278776	-	-	-
Temperate South America													
Argentina (a)	8755279	-	-	-	-	-	-	-	-	-	-	-	-
Patagonia	-	47.00	U	687.6	440.0	U	8460	1667	U	30028	600.0	U	10800
Comajue	-	1670	U	12168	565.0	U	6458	5228	U	48932	2360	U	16704
Cuyo	-	364.0	U	4910	376.0	U	2761	3672	U	33145	589.0	U	5947
Centro	-	209.0	U	1109	12.00	U	165.6	2085	U	11167	2720	U	13119
Noroeste	-	84.00	U	885.6	162.0	U	1246	862.0	U	8186	849.0	U	9958
Noreste	-	-	U	-	-	U	-	11312	U	201915	12294	U	258608
TOTAL Argentina	8755279	2374	-	19761	1555	-	19091	24826	-	333374	19412	-	315136
Chile (a)													
Northern	12600	32.00	288.0	468.0	10.00	144.0	144.0	30.00	432.0	720.0	182.0	1836	3132
Central	476641	1419	17640	19800	940.0	13500	18360	6500	84636	123480	2400	34380	55080
Southern	316080	3.000	72.00	108.0	0	0	0	65.00	1188	1296	4199	77184	96372
Antarctic Territory	U	U	U	U	U	U	U	U	U	U	U	U	U
TOTAL Chile	805321	1454	18000	20376	950.0	13644	18504	6595	86256	125496	6781	113400	154584
Uruguay (a,b)													
Rio Negro	54386	230.0	0	3780	-	-	-	480.0	0	4320	112.0	0	1944
Rio Uruguay	50458	-	-	-	1620	3960	23256	-	-	-	15.00	0	230.4
Rio Santa Lucia	558.0	-	-	-	-	-	-	-	-	-	U	U	U
Laguna Merin	3715	-	-	-	-	-	-	-	-	-	55.00	0	655.2
TOTAL Uruguay	109117	230.0	-	3780	1620	3960	23256	480.0	-	4320	182.0	-	2830
OCEANIA													
Australia & New Zealand													
Australia (a)													
Western	43.20	2.000	36.00	36.00	-	-	-	-	-	-	-	-	-
Central	U	-	-	-	-	-	-	30.00	432.0	432.0	16.50	U	-
Eastern	192924	4308	39838	44435	2107	14184	15192	707.0	594.0	1260	1434	21420	26784
TOTAL Australia	192967	4310	39874	44471	2107	14184	15192	737.0	1026	1692	1451	21420	26784
New Zealand (a,b,)													
Entire Nation	1800016	3200	51120	57601	544.0	13320	14400	850.0	14040	15120	5400	101521	111601
Melanesia													
Papua-New Guinea (a)													
Entire Nation	707761	29.50	U	648.0	72.00	U	1512	2000	U	58644	15660	0	377208
Polynesia													
Fiji I. (a)													
Entire Nation	-	-	-	-	-	-	-	-	-	-	-	-	-
Western Samoa													
Entire Nation	U	15.00	252.0	21.60	-	-	-	-	-	-	-	-	-

Notes on Hydraulic Energy

Name of Continent, Region and Country	Note No.	
AFRICA		
Western Africa		
Nigeria	(a)	Gross theoretical capability has been provided for individual sites and is based on calculations by consultants of energy available with risk of failure not greater than once in every 50 years for Kainji, Jebba and Shiroro. Estimate for Gongola is subject to revision as studies proceed. Published output for NESCO System was used.
	(b)	Data on G(av) annual generation have been provided by consultants for Kainji, and by inference for Jebba, which is immediately downstream and has 2/3 of Kainji head. Data on G(95) annual generation are not readily available and are approximate.
	(c)	G(av) annual generation includes Kainji Extension.
Portugese Guinea	(a)	Hydraulic resources are small but not negligible.
Eastern Africa		
Ethiopia	(a)	The gross theoretical capacity is defined as the upper limit of hydropotential available in an average year based upon surface run-off, and assumes that the physical resources of the River basin are fully available for power production, i.e. complete utilization of seasonal flows with no flow losses and complete utilization of head, generating efficiency at 100%, and theoretical plant utilization factor at 100%. The theoretical gross head for each River basin is determined as the difference between the medium elevation of the catchment above sea level and the elevation of the River at the Ethiopian border (when this River leaves Ethiopia) or the sea level when other wise.
	(b)	For developed or planned sites annual generation in Gwh is the product of 0.07 (m(3)/s) (m). For river basins it is gross theoretical capability (GWh) times the utilization factor.
Malawi	(a)	Malawi reported gross theoretical capacity in terms of capacity as follows: entering Lake Malawi (Lake Nyassa) - 150Mw and leaving Lake Malawi - 500Mw, turbined down to the nation's lowest elevation, not to sea level.
Zambia	(a)	Gross theoretical capability is based on average rainfall (30 year period) over Zambezi basin catchment area which is approximately equal to the area of the whole country, less 25% for evaporation and 25% for run-off. Calculations were based on Zambezi exit elevations, not at sealevel. Development of the Zambezi River along the Zambia-Rhodesia border are based on 50% of the flow in this area. Gross theoretical capability was given as 60,000 MW. Proable annual generation was also given as capacity rather than annual energy. Annual capacity of operating units are 556 and 388 MW for G 95 and Gav conditions respectively. Corresponding values for facilities under construction are 760 and 760 MW, for planned units 768 and 760 MW and for other possible installations 1062 and 1062 MW.
Middle Africa		
Zaire	(a)	Upper Zaire (Congo) includes all rivers above 1000 m altitude, Middle Zaire is all rivers below 1000 m elevation to Kinshasa and Lower Zaire is the Zaire (Congo) River between Kinshasa and the sea.
	(b)	Estimates of gross theoretical capability were based on an electromechanical yield of 82.5% and average flow. For rivers whose flows are not known estimates were made from rainfall data and assumed outflow coefficients. Data on annual energy are unavailable, but capacity for the three regions were given as 4800, 41600 and 84000 MW. The total national capacity of 132,000 MW is exact to plus or minus 20%., Average national on-stream efficiency is 4000 kwh/kw.
	(c)	Total installable capacity on the Zaire river and its tributaries above Kinshasa is not known.
Sao Tome and Principe	(a)	Hydraulic resources are small but not negligible.
Northern Africa		
Tunisia	(a)	Gross theoretical capability is based on storage of rainfall in reservoirs and recovery of all potential energy, without losses, down to sealevel. Annual generation is based on actual experience over seven years. About 6.8% of electricity generated in Tunisia is from hydraulic resources. Facilities are in operation at El Aroussia, Nebbeur, Kassab, and Periana, and a facility is planned at Sidi Salem.
Southern Africa		
South Africa	(a)	Two methods were used for calculating probable annual generation: (1) the simulation method which involves computing what the result would have been over the period of available hydrological record had the dams and their associated power stations been in operation during this period, and (2) the extreme-value analysis, as developed by Gumber and others, to determine the available generation with reference to various severities of droughts
	(b)	The installable capacity in Column 9 given as range of 3000 to 5000 MW.
ASIA		
East Asia		
Japan	(a)	Gross theoretical capability of 670,000 Gwh/yr. is based on total power of 77,340 MW x 8760hrs/yr. It is realized that this total energy is too high but more accurate data are not available.
	(b)	Average annual generation at G(95) is the sum of firm output of run-of-river type power plants plus firm output based on modified flow of plants with reservoir regulatory ponds. Average annual generation at G(av) is actual average annual generation for existing plants and 10-year average actual potential for plants under construction or undeveloped sites based on 10-year discharge records.
Korea, Rep. of	(a)	Gross theoretical capability has been calculated using a plant factor of 20 to 60%. Annual generation is based on historical flows. Gross theoretical capability was given in terms of capacity (MW) and is the same as installed and installable capacity.
Eastern Asia		
Taiwan	(a)	Gross Theoretical Capability estimated by Water Resources Planning Commission as 12037 MW, annual energy equivalent not available. Probable annual generation based on past 15 continuous hydro years average output in Columns 5, 8, and 11, and lower flow duration curve of 95% in Columns 4, 7 and 10
Middle South Asia		
India	(a)	The country has been divided into five major regions as shown on Hydraulic Energy Map II.
	(b)	Values in column 2 are for 60% load factor and 95% availability only.
	(c)	Data in columns 3 and 6 are as of February, 1973. Balance of Potential generation is at about 30% load factor for both planned and other projects.
	(d)	Data for column 7 are included in column 4 data. Data for column 13 are included in column 10 data.
Bangladesh	(a)	National subdivision are based on hydroelectric projects

Notes on Hydraulic Energy

Name of Continent, Region and Country	Note No.	
ASIA		
Middle South Asia		
Bangladesh	(b)	Gross theoretical capability is taken from project reports. Power capacities have been calculated on the basis of optimum utilization of available river flows to meet the requirements of irrigation, flood control and power.
Iran	(a)	Probable annual generation in columns 4, 7, 10 and 13 are for G95
Southeast Asia		
Philippines	(a)	Calculation of gross theoretical capability is based on data on available flows, net heads and plant capacities. Annual generation is determined as rated capacity of units times 8760 hours in a year times a load factor which varies froe 30% to 60%. Major facilities use reservoirs for hold-over of water during the dry season. Releases are based on adopted "Rule Curves" that optimize energy generation as much as possible.
Vietnam, Rep. of	(a)	In the northern region 18 hydroelectric projects are being planned, in the southern region, 21 projects are under study and in the Dong Nai basin, 20 projects.
Malaysia	(a)	Data are for West Malaysia only. Hydraulic energy resources also exist in Sarawak and Sabah, but data are not available
	(b)	Probable annual generation determined as average continuous 24-hour power times number of hours in a year
	(c)	Five projects totaling 410 MW are planned in West Malaysia for operation by 1982 or later. Facilities at Tembeling, Pergau and Kuala Trengganu will be 100 MW each, one at Bentong Raub 50 MW, and in Jahore, 60 MW. The Tembeling and Kuala Trengganu units will be multipurpose facilities
Portugese Timor	(a)	Hydraulic Resources are small but not negligible.
Southwest Asia		
Turkey	(a)	The regional divisions of the country are based on 26 river basins
	(b)	Gross Theoretical Capability was determined for 92 natural catchments, which together cover all territory, by using the following equation: N=9.8 (Hb-Hc). Qc where N (kw) = Gross hydro potential between the points B and C of the river basin. Hb (m) = Level at B, Hc (m) = Level at C, Qc (m3/s) = Average flow at C
	(c)	B. Menderas, Konya, Seyhan, Ceyhan include planned, Gediz, B. Akdeniz, D. Akdaniz, Firat, Aras and Dicle include other. Sakarya includes under construction and other. Yesilirmak, Kizilirmak, and D. Karadeniz include planned and other. and Antalya includes under construction, planned and other
	(d)	The G95 value for total probable annual generation is known only for the entire country and is listed under "other". The G95 value for the entire nation was calculated by using economically exploitable hydro-electric potential (EEHP) values which were estimated by means of "modulas coefficient" or "dimensionless run-off", for each basin flow and includes other, planned and facilities under construction. The derived ratio through the frequency analysis of EEHP for 31 years is 0.627. Probable annual generation figures for historical average flow are based on feasibility studies of the potential areas for the hydroelectric power plants. The methods of computing annual generations are not available
	(e)	There are essentially no non-electrical units in the country.
Iraq	(a)	Iraq reported gross theoretical capacity in terms of capacity as follows: Samarra 84Mw, Dokan 400Mw, Haditha 345Mw, Mosul 500Mw, and Bakhma 600Mw
EUROPE		
Western Europe		
Germany, F.R. of	(a)	Pump Storage facilities with a pumping capacity of 2634MW and a turbine capacity of 3595 MW are now in operation. Additional capacity of about 2070 MW are under construction.
France	(a)	Gross Theoretical capability obtained by considering the flowing portion of atmospheric precipitation from average altitude to sealevel.
	(b)	Probable annual generation at G95 corresponds to a hydraulic coefficient of 0.78, and for the historical average generation as 97.5% of production capability
	(c)	Pump storage installations are not included.
Belgium	(a)	Pump storage facilities with a capacity of 436 Mw and an annual output of 2100 TJ (585 GWh) are now installed. Plans exist for additional capacity of 571 MW with an annual output of 2760 TJ(767 GWh)
Austria	(a)	Data for facilities under construction include planned facilities
Switzerland	(a)	Installed capacity of all units greater than 1Mw is 9630 MW and their total annual generation is 106,000 TJ (29,470 GWh)
Southern Europe		
Italy	(a)	Data on planned capacity includes other
	(b)	Gross theoretical capability was calculated as per the method described in the paper ST/ECE/EP/39. Annual generation was calculated using UNIPEDE publication "Statistical Terminology employed in Electricity Supply Economics". G95 Generation from each region are not shown because the Italian system, being strictly interconnected, is operated as a whole. Futhermore, regional data are not applicable since their total is lower than the corresponding national datum. The capacity of pure pumped-storage stations is not included, however, the capacity of mixed pumped-storage stations (that is, the stations for which producibility from natural contributions is not negligible) is included. Capacity increases due to the rebuilding of obsolete plants and use of "other" sites will become economically feasible in accordance with the evolution of the energy situation.
Spain	(a)	Gross theoretical capacity was determined by integrating the head-rainfall curve along the full length of each river. Annual generation for installed facilities were based on statistical averages.
Northern Europe		
United Kingdom	(a)	Gross theoretical capability was determined from the average annual runoff for each plant based on average annual rainfall (less evaporation) and its catchment area erculding any indirect catchment feeding upper cascade plants. The runoff was assumed to be turbined down to sea level, i.e. the head was assumed to be equal to the maximum level of the reservoir above sea level. An average overall efficiency of 100% was assumed.
	(b)	Annual generation at G95 was based on 50% storage drawdown and on an annual runoff of 69% of long term average annual flow, which corresponds to the quantity available 95% of the time. Generation at G(Av) was based on the estimated long term average output of each plant. Installed capacity includes pumped storage, but only natural runoff is included

Notes on Hydraulic Energy

Name of Continent, Region and Country	Note No.	
EUROPE		
Northern Europe		
United Kingdom	(c)	Additional capacity is available only from pumped storage sites having essentially no natural runoff. Planned units total 1700 MW capacity and "other" units 1200 MW capacity.
Sweden	(a)	Gross theoretical capability has been calculated on the basis of actual elevations, and historical average flows at an efficiency of 100% utilization. Probable mean annual generation is defined as the available production of stations including loss of production due to power balance spills.
Finland	(a)	In determining gross theoretical capability the linear energy potential of the most important rivers in the country has not been calculated by uniform methods for the most important water-courses.
	(b)	Nonelectrical units are used by the Finnish pulp mills. The total capacity of the five existing units are 30 MW, the largest is 14 MW.
	(c)	Annual energy generation has been determined by means of the duration curve of 30 hydrological years' generation (1931-60).
Norway	(a)	Gross Theoretical Capability was determined as the average yearly precipitation multiplied by the actual height above sea level, evaporation was taken into account
	(b)	Annuel generation was determined as per January 1973. The value reported for G95 generation is that obtainable about 90% of the time for each plant if working separately. The value under historical average generation is the mean total system condition.
Ireland	(a)	Gross Theoretical Capability: Based on harnessing of all sites with a potential of not less than 8 MW
	(b)	Probable annual generation: Based on recorded, and estimated hourly outputs for each station
Eastern Europe		
Poland	(a)	Data on probable annual generation apply to installed capacity and generation of electricity in hydropower stations, commissioned prior to 31 December 1972.
Romania	(a)	Gross theoretical capacity corresponds to the length of the water course with a specific potential, in general, of about 100 kw/km.
	(b)	Includes half the potential of the Danube River between Romania and Bulgaria.
Bulgaria	(a)	Includes 50% of Danube along Bulgarian-Romanian border
EUROPE-ASIA		
Northern		
USSR	(a)	Values provided for gross theoretical capability are for total river flow. National total for all surface water run-off is 6370 Twh (22,932 x 10(15) J).
	(b)	Operating data includes units under construction, other includes planned units. Total national installed capacity is 31,500 MW with an output of 123,000 GWh/yr. (443 x 10(15) J/yr). Facilities under construction total 24,500 MW with an output of 95,000 GWh/yr (342 x 10(15) J/yr).
	(c)	Includes Northwestern European-USSR, Baltic Region and Belorussian SSR.
	(d)	Includes Central European-USSR, Central-Chernozem, Volga-Viatsky, Povolzhsky and Ural Regions.
NORTH AMERICA		
Northern America		
United States	(a)	Gross theoretical capability is stated as the total of developed and undeveloped sites of not less than 5,000 kW. (18 GJ).
	(b)	Average annual power generation of 256.8 x 10(9) kWh (925 x 10(3) TJ) includes 253.1 x 10(9) (911 x 10(3) TJ) credited to electrical utility plants and 3.7 x 10(9) kWh (13 x 10(3) TJ) to Industrial plants.
	(c)	Annual generation data represents recent annual average generation as well as that predicted for undeveloped sites. Data to separate probable annual generation into units under Construction and Other components are not available.
Canada	(a)	Gross Theoretical Capability for "other" sites only has been estimated on the basis of harnessing of all such sites and on arithmetical mean annual flows assuming 100 per cent efficiency in the machinery and driving water works. No nonelectrical units have been included. Data listed for "Other" sites was computed by assuming that the anticipated annual generation would be developed at an average capacity factor of 60 per cent.
	(b)	Annual generation values were estimated on the same basis as the figures given for gross theoretical capability, except that an 88 per cent efficiency was assumed. It was considered that to add the actual or anticipated values for annual generation in the operating, under construction and planned categories to the historical average or G95 figures in the "other" category would not be meaningful. Accordingly the values given under historical average generation are really actual or anticipated annual generation, which includes, in the case of the "Other" category, the best available current estimate of generation which would eventually be installed. All data as at December 31, 1972. The values for historical average annual generation for the "other" category only are as follows : B.C. 209,208 Gwh, Yukon 66,817 Gwh, NW Terr. 44,753 Gwh, Alberta 62,196 Gwh, Saskatchewan 12,558 Gwh, Manitoba 44,404 Gwh, Ontario 14,088 Gwh, Quebec 237,236 Gwh, New Brunswick 1,822 Gwh, Nova Scotia 1,414 Gwh, PEI 7 Gwh and Newfoundland and Labrador 51,438 Gwh for a total of 745,941 Gwh.
Middle America		
Mexico	(a)	Gross Theoretical Capability was calculated on the basis of harnessing of all sites. The values listed under "Other" indicates places with limited utilization possibilities. Preliminary studies have shown that utilization of these sites will be very expensive because of problems of water regulation, geology, topography and capacity.
	(b)	Baja California has no developed or developable hydraulic resources.
Guatemala	(a)	Gross theoretical capability is based on the maximum average flow expected during a typical year.
	(b)	Annual generation is based on the average annual flow multiplied by the installed capacity of each plant.
	(c)	Three new facilities are planned. The Atitlan station at Solola now under construction will have a capacity of 430 MW (1007 Gwh/yr), will cost $ 124 million and is planned for startup in 1978. The Aquacapa station at Escuintla with a capacity of 80 MW (410 Gwh/yr) is set for 1977. A feasibility study was completed in 1973 for a 550 MW (2077 Gwh/yr) Chixoy station in northern Guatemala at an as yet undetermined cost. All planned stations will use Pelton turbines.
Costa Rica	(a)	Major resources are on the Rio Grande de Terraba, and on the Reventazon, Pacuare, and Chirripo

Notes on Hydraulic Energy

Name of Continent, Region and Country	Note No.	
NORTH AMERICA		
Middle America		
Costa Rica		Rivers.
SOUTH AMERICA		
Tropical South America		
Brazil	(a)	Gross theoretical capability was determined from installable capacity by employing appropriate coefficients that differ for each region. These coefficients were obtained both from actual measurements (where available) or estimations of regularized river flows. Annual generation data are the regulated firm energy for the critical period observed: this period is variable for the different regions.
Colombia	(a)	Gross Theoretical Capability was determined from the average annual atmospheric precipitation for each of the three drainage basins by applying different runoff percentages according to data recorded by flow gaging stations. Each drainage basin was subdivided into subareas according to hipsometric distribution, and the mean rate of discharge was calculated for different altitudes above sea level.
Venezuela	(a)	The territorial subdivisions have been made in line with the Venezuelan Water Resources Deveopment Plan. The information relates to COPLANARH regions.
	(b)	The calculation of gross theoretical capability is based on the formula PHB=9.8x HxQ, in which PHB is the gross hydroelectric power potential, H the difference of elevation in meters between the extremes of the stretch of river under consideration, Q the average annual flow in m3/s at entrance and outlet, 9.8 a correction constant from Kgm/s to Kw. The resulting values, in MW, were then converted to annual energy capability by using a turbine efficiency of 93% and a generator efficiency of 97%. No consideration has been given to whether or not the potential is technically developable and resulting figures are used only as a basis for judgment at the planning level. Their values are below the real figures because of the exclusion of rivers having a relatively low production. Results are not the outcome of homogeneous criteria, since they relate not to the hydroelectric power potential of basins but to the generation of the main water courses.
Temperate South America		
Argentina	(a)	Gross theoretical capability was calculated as per UN publication "Hydroelectric Resources of Latin America, Their Measurement, and Development," Vol I (E/CN/12/630).
Chile	(a)	Gross theoretical capability has been estimated on the basis of flow along the principal rivers and tributaries from their source to the lower control section of water runoff but not to sea level. Annual generation is taken at an 89% use factor. Reservoir operation has been performed by simulation.
Uruguay	(a)	Gross theoretical capability (GTC) was calculated from GTC = (V) (H) (9.81/3600) (Kwh/yr) where V is average annual flow of river or average annual rainfall (m(3)) and H is average height of the river basin (m).
	(b)	The reservoir on the Rio Santa Lucia will have as its primary purpose provision of municipal and industrial water.
OCEANIA		
Australia & New Zealand		
Australia	(a)	The Gross Theoretically Capability was defined as the total energy available if flows at the points of development are turbined down to sea level with 100% efficiency. These figures generally have limited practical significance since development of the energy is often improbable or impractical because of topography, economics or the committal of the water for irrigation purposes. Annual generation was assessed mainly from historical records of flows. Installed capacities are as of June 30, 1972.
New Zealand	(a)	Gross Theoretical capability in North Island 306,000 TJ (85,000 GWh) and in South Island 1,494,000 TJ (415,000 GWh). Data not provided for outlying islands
	(b)	Gross theoretical capability was derived as the product of the flow of all rivers and streams in New Zealand that enter the sea times a weighted mean land elevation using the work of Benham (1959) and Toebes (1972) with local modifications. Installable capacity of both planned and other facilities are to a large degree speculative being largely dependent on developing attitudes on conservation, pollution, fossil fuel exhaustion and overseas earnings. The values for installed capacity are generally based on 50% plant factor, but in some stations special conditions have influenced capacities and in future works a tendency to install additional peaking capacity may cause stations to be built with larger installed capacities than are implied by this table. Annual generation at G.95 values were derived from experience or planned outputs based on 85% to 95% or higher utilization. Planned figures have usually been exceeded as the system has grown and diversified. About 10% of the theoretical capability might under present day conditions find economic development. Annual generation at G(Av) are to a large degree speculative. To implement them, additional water storage, or additional station generating capacity, or a bigger generating system, or all three would be needed.
Melanesia		
Papua-New Guinea	(a)	Papua-New Guinea is an undeveloped area with enormous hydro potential but lack of stream flow data prevents assessment of annual generation. Accordingly the values in Columns 13 and 14 are not comparable and are only broad estimates. See Also Australia.
Polynesia		
Fiji I.	(a)	Surveys on the use of hydraulic energy are now being made but data are not yet complete or available.

Notes on Hydraulic Energy

Name of Continent, Region and Country	Ref. No.
AFRICA	
Western Africa	
Nigeria	1. Niger Dams Project Report, Vol. 2, modified in accordance with NEDECO report on "Review of Kainji Hydrology" October 1972, (Kainji, Jebba, Shiroro)
	2. Estimated by Shawmont consultants, from preliminary analysis of flow data (Gongola)
	3. Nigerian Electricity Supply Co., (NESCO), Annual report.
Eastern Africa	
Ethiopia	1. United States Department of the Interior, Bureau of Reclamation, for the Department of State Agency for International Development. Land & Water Resources of the Blue Nile Basin. - Ethiopia - Seven Volumes - 1964.
	2. Ethiopian Electric Light and Power Authority Studies.
Middle Africa	
Zaire	1. R. Bette, Puissance Hydraulique Existante dans le Bassin du Congo, Bulletin des Seances de l'Institut Royal Colonial Belge, No. 16, 1945, 1.
Southern Africa	
South Africa	1. Electricity Supply Commission, P.O. Box 1091, Johannesburg
ASIA	
East Asia	
Japan	1. Ministry of International Trade and Industry, Department of Public Utilities, Agency of Natural Resources and Energy
Eastern Asia	
Taiwan	1. Taiwan Power Company, Ministry of Economic Affairs, Republic of China
Middle South Asia	
India	1. Central Water & Power Commission, Hydro-Electric Directorate, Bikaner House, New Delhi, India
Bangladesh	1. Bangladesh Water Development Board
Southeast Asia	
Indonesia	1. Direktorat Jenderal Pengairan(Directorate General of Irrigation, Ministry of Public Works), Indonesia
	2. Indonesian National Committee, World Energy Conference
Philippines	1. National Power Corporation
Southwest Asia	
Turkey	1. Turkiye Genel Enerji Raporu, 1968
	2. Tubitak - Project No.: 206, Assist. Prof. Ing. Unal Ozis, 1971
EUROPE	
Western Europe	
Germany, F.R. of	1. J. Frohnholzer, "Systematization of hydro resources of the Federal Republic of Germany", Munich, 1962, Rev 1973
	2. J. Frohnholzer, "Characterization of the running of pumped storage plants for the power supply of the Federal Republic of Germany", "Energie", February 1973, pages 29 to 47
Netherlands	1. The Central Bureau of Statistics.
Southern Europe	
Italy	1. Ente Nazionale per l'Energia Electrica
Spain	1. Ministerio de Obras Publicas - Jefatura de Servicios Hidrograficos
	2. Ministerio de Obras Publicas - Jefatura de Servicios Electricos
Northern Europe	
United Kingdom	1. North of Scotland Hydro-Electric Board
	2. South of Scotland Electricity Board
	3. British Aluminum Company Limited
	4. Central Electricity Generating Board
Sweden	1. Swedish Power Association, Swedish State Power Board, CDL (Central Operating Management).
	2. Energiprognosutredningens lagesrapport juli 1973 (Status Report, July 1973, of the ad hoc Government Committee on Energy Forecasting). In Swedish. Reviews Swedish and world energy resources in light of domestic energy forecasts to 1995.
	3. Vattenkraft (Hydro power). In Swedish. Booklet published April 1974 by the Swedish Power Association and the Swedish State Power Board. Broad assessment of Swedish hydraulic resources and their use, including discussion of environmental problems.
	4. Utredning om vattenkraftutbyggnader i mellersta Sverige (Investigation of the hydro power development in middle Sweden). In Swedish. To be published in 1974. Assessment of future development of hydraulic resources on five rivers in middle Sweden.
	5. Statistisk arsbok for Sverige (Statistical Abstracts of Sweden), Stockholm. Published annually in Swedish (headings also in English) by the Central Bureau of Statistics. Contains general statistical information concerning resources of hydroelectric power, of wood, peat and slate. Latest edition 1973.
Finland	1. The Statistics of the Finnish Association of Electricity Supply
	2. "Hydro Power Resources in Finland" ECE Study, 1965, by Imatran Voima Osakeyhtio
Norway	1. Norwegian Water Resources and Electricity Board
Eastern Europe	
Poland	1. Statistical yearbook 1972
NORTH AMERICA	
Northern America	
United States	1. U.S. Federal Power Commission, 1972, "Hydroelectric power resources of the United States, developed and undeveloped, January 1, 1972", U.S. Government Printing Office, 126 p.
Canada	1. Department of Energy, Mines and Resources, Energy Sector
	2. Alaska Power Administration
	3. British Columbia Water Resouces Service
	4. British Columbia Hydro and Power Authority
	5. Department of Indian Affairs and Northern Development
	6. "Upper Yukon River Power Market Potential, Working Papers and Summary Report" (July 1970)
	7. Statistics Canada, "Electric Power Statistics, Volume II (Annual)" 1971, Statistics Canada, "Electric Power Statistics, Monthly", February 1972
	8. Department of Environment, Inland Waters Directorate
	9. Department of Northern Affairs and National Resources, Water Resources Branch, (now part of Environment Canada), "Position Paper - Power Development on the Yukon River" (October 1965)

Name of Continent, Region and Country	Ref. No.
NORTH AMERICA	
Northern America	
Canada	10. Department of Northern Affairs and National Resources, Water Resources Branch, "Report on Hydro-Electric Power Resources of the Porcupine, Peel and Rat River Region, Yukon and Northwest Territories" (April 1965)
	11. British Columbia Energy Board, "Provincial Power Study" (April 1972)
	12. Energy Resources Conservation Board of Alberta - "The Hydro and Hydro-Electric Energy Potential of Alberta, A Preliminary Appraisal" (April 1973)
	13. Newfoundland and Labrador Power Commission
	14. T. Ingledow & Associates Limited, Consulting Engineers, "Hydro-Electric Resources Survey of the Central Yukon Territory, Volumes 1 and 2" (January 1968), "Power Survey of the Liard River Basin, Yukon and Northwest Territories, Final Report" (February 1970), "Power Survey of the Central Mackenzie District, Northwest Territories, Volumes 1 and 2" (January 1969), "Power Survey of the Kazan, Dubawnt, Thelon and Hanbury River Basins, Northwest Territories, Final Report" (March 1970)
	15. Gepac Consultants Ltd., "Yukon and Northwest Territories Power Survey - Pre Reconnaissance Study, Final Report" (September 1971)
Middle America	
Mexico	1. Mexican National Committee, World Energy Conference
	2. Comision Federal De Electricidad
Guatemala	1. Instituto Nacional de Electrificacion (INDE)
Costa Rica	1. Bureau of Generation Programs, Costa Rican Institute of Electricity
SOUTH AMERICA	
Tropical South America	
Brazil	1. Eletrobras - Centrais Eletricas Brasileiras S.A.
Colombia	1. Departamento de Hidrologia, Ingetec
	2. Servicio Colombiano de Meteorologia e Hidrologia (SCMH)
	3. Instituto Colombiano de Energia Electrica (ICEL), La Electrificacion en Colombia, (Informe 1971 - 1972)
	4. ICEL, ISA, EEEB, EEPPM, CVC, CORELCA, Informe del Sector Electrico, (Revista ETA No. 25 Vol. IV Ano VII, August, 1973)
	5. G. Jaramillo, Energia e Hidroelectricidad en Colombia, V Congreso Panamericano de Ingenieria Mecanica, Electrica y Ramas Afines (Agosto, 1973)
	6. J. Tejada Saenz, Potencial Hidroelectrico del Rio Cauca, V Congreso Panamericano de Ingenieria Mecanica, Electrica y Ramas Afines (Agosto, 1973)
	7. Gibbs & Hill and Electricite de France, Potencial Hidroelectrico Economico de Colombia (1955).
Venezuela	1. "Potencial Hidroelectrico Bruto Nacional", Publication Number 10 of the Venezuelan Water Resources Development Planning Commission (COPLANARH).
Temperate South America	
Argentina	1. "Inventory of Hydroelectric Resources of the Republic of Argentina," Publication 104, July, 1967
Chile	1. Oficina de Evaluacion de Proyectos Hidroelectricos de la Empresa Nacional de Electricidad S.A. "ENDESA"
Uruguay	1. Depto. de Generacion y Transmission de U.T.E. (Usinas y Telefonos del Estado.)
OCEANIA	
Australia & New Zealand	
Australia	1. Department of Minerals and Energy, Australia
	2. Department of the Northern Territory, Australia
	3. State Electricity Commissions of N.S.W., Victoria, Queensland, W.A., S.A., Australia
	4. Hydro-electric Commission of Tasmania, Australia
New Zealand	1. Ministry of Works, New Zealand Electricity Department
Melanesia	
Papua-New Guinea	1. Department of External Territories, Australia