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The Future Role of Hydropower in Developing Countries

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in Developing Countries

by

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Abstract

This paper was prepared as a contribution to a review of environmental issues associated with large dams by the World Bank and the National Resources Defense Council with the latter putting forward the views of the critics of large dams amongst Non-Governmental Organizations (NGOs). At the heart of the NGO criticism of large dams is a belief that if there were an accurate accounting of all environmental and social impacts, and full consideration of alternatives, rational decision makers would decide not to build large dams and would instead rely on alternative ways of providing the services the dams were intended to supply.

One of the most common justifications for construction of large dams is that they are required to meet the need for electric power. Environmentalists will not accept this justification unless there is clear and convincing evidence that the proposed dam is the least-cost way of meeting the energy needs in question. Critics of large dams believe that a number of myths have impeded clear thinking about how to meet the need for energy services in developing countries. The views of these critics are summarized at the beginning of the paper.

In response to the NGO criticisms, this paper first examines the critical issue of the need for a substantial increase in the supply of electricity in developing countries, even when full account is taken of energy conservation potential. It then reviews the options available to increase electricity supply on the scale required by developing countries. All supply strategies involve environmental trade-offs between the options since the use of nuclear power and fossil fuels is also subject to global environmental constraints. Special attention is therefore given to the scope for cogeneration and the prospects and drawbacks of renewable energy sources. It concludes that even though major energy conservation could result in a long-term reduction in global energy use, there would still be an increase over the long-term in demand for electricity in the developing countries. This analysis indicates that there is strong justification at the global level for substantial hydropower development with large dams on energy resource and environmental grounds. The World Bank's policy on power development, including the approach to the economic justification of individual hydropower projects, is summarized at the end of the paper.

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NGO Criticisms

1. One of the most common justifications for construction of large dams is that they are required to meet the need for electric power. Environmentalists concerned about the environmental impacts of these dams will not accept this justification unless there is clear and convincing evidence that the proposed dam is the least-cost way of meeting the energy needs in question. At present, few external funders of large dams have a procedure for ensuring that such a determination is made.

2. Environmental critics believe that a number of myths have impeded clear thinking about how to meet the need for energy services in developing nations, namely that:

- ° develcping nations need much more energy than they are now consuming.
- ° improved energy efficiency can play only a minor role in meeting the energy needs of developing nations.
- ° developing nations should focus first on ensuring "enough" energy supplies and then worry about efficiency improvements.
- ° efficiency improvements are uncertain and unreliable.

3. The environmental critics allege that, in reality, huge amounts of energy are being wasted and a "supply-side" mentality prevents planners from realizing the potential of energy efficiency and decentralized, renewable sources. They content that the focus must change from meeting predetermined energy "needs" through production of more energy to supplying <u>energy services</u> in ways that impose the least economic and environmental costs.

4. The essence of the least-cost approach is to examine <u>all</u> alternative ways of supplying energy services, rank them by cost, and implement enough of them in order of ascending cost to satisfy the need for energy services. When this approach is applied systematically, the cumulative impact of a number of measures, taken together, can be enormous.

5. In the case of dams, the task is to examine alternative ways of meeting electricity needs. Some of the alternatives suggested by the critics include:

- ° Saving energy through improved industrial processes.
- ° More efficient commercial lighting.
- ° More efficient residential lighting and appliances.
- ° Production of electricity from low-head hydro installations photovoltaics, or cogeneration.
- ° Non-electrical, such as biogas-fuelled water pumps.

Response to NGO Criticisms

6. In response to the NGO criticisms, this paper first examines the critical issue of the need for a substantial increase in the supply of electricity in developing countries, even when full account is taken of energy conservation potential. It then reviews the options available to increase electricity supply on the scale required by developing countries. All supply strategies involve environmental trade-offs between the options since the use

of nuclear power and fossil fuels is also subject to global environmental constraints. Special attention is therefore given to the scope for cogeneration and the prospects and drawbacks of renewable energy sources. It concludes that even though major energy conservation could result in a long-term reduction in global energy use, there would still be an increase over the long-term in demand for electricity in the developing countries. This analysis indicates that there is strong justification at the global level for substantial hydropower development with large dams on energy resource and environmental grounds. The World Bank's policy on power development, including the approach to the economic justification of individual hydropower projects, is summarized at the end of the paper.

Global Demand for Electricity

7. Electricity use should be considered in the framework of overall energy use, as determined by economic and population growth, with due regard for sensible energy conservation and substitution policies. A number of studies of long-term global energy demand and supply have been carried out in the 1970s and 1980s, primarily in response to oil price movements. One of the most comprehensively documented examples of a conservative scenario for global energy use is for the year 2020 against 1980 as the base year which is developed in "Energy for a Sustainable World"[1/]. This global projection is elaborated further in this section to show the need for substantial additional hydropower in developing countries even under a scenario that incorporates an improbably high degree of achievable energy conservation and thus, low energy demand. Some general observations on the feasibility of this scenario are also included. It is emphasized that this scenario is not a prediction of future energy demand, but is selected only for the purpose of this paper. This approach to the scenario is consistent with the approach of its authors, who developed it primarily to underpin their views about sustainable energy strategies rather than as a prediction. A perspective of energy use as far ahead as 2020 is required to illustrate the full impact of energy demand policies and thus to show the need for major investments in energy supply facilities with long gestation periods such as large hydropower schemes. Any attempt to view beyond this period is largely obscured by present major uncertainties about long-term economic and technological developments.

8. Under the above scenario (henceforth referred to as the ESW scenario), global energy use is projected to increase by only 9% between 1980 and 2020,[2/] equivalent to a compound annual growth rate of 0.2%. The low growth rate is predicated on widespread adoption of the most efficient current technologies for using energy, including those recently developed but not yet substantially exploited. This would require successful implementation of far-reaching energy policies and much greater political commitment and institutional efforts to improve energy efficiency than heretofore. Neverthe-

1/ Energy for a Sustainable World, J. Goldemberg, T. Johansson, A. Reddy and R. Williams (Wiley Eastern Ltd., 1988). A summary version with the same title has been issued by the World Resources Institute.

2/ Energy for a Sustainable World, page 302, Table 4.1.

less, the authors of the ESW scenario consider it to be consistent with plausible values of price and income elasticities and expectations about future energy prices and GDP growth (see Note 1 in the Annex to this section).[3/] These assumptions reflect the basic theme of the ESW approach, namely long-term global sustainability as a constraint on the use of natural resources, based on considerations of intra-generational equity. The main constraint that emerges in this context is on carbon use and hence fossil fuel consumption. The existing large degree of uncertainty about the thresholds of irreversible global environmental damage from this cause increases the importance of this consideration. This constraint imposes the postulated need for major energy conservation measures and the use of non-fossil fuel power technologies.

9. The level of energy demand in the ESW scenario for 2020 is by far the lowest of such exercises in recent years, largely because it envisages the greatest impact of energy conservation policies. However, the ESW scenario encompasses two opposing trends. Energy use in the industrialized countries[4/] by 2020 is projected to decline about 40% from its 1980 level, but in the developing countries to increase by about 110%. Demographic trends will be a major factor in slowing energy demand in the industrialized countries, with ageing of populations generally and absolute declines in the levels of many of these countries. Nevertheless, extraordinary conservation efforts would be required in both groups under the ESW scenario. By comparison, the corresponding projections developed in the 1983 World Energy Conference Report on World Energy Demand (WEC scenario) showed increases of 85% as the low case and 139% as the high case. These scenarios are summarized in the table below from a comparison of their energy supply mixes (Note 2 in the Annex).

3/ <u>Energy for a Sustainable World</u> - page 300.

4/ Comprises OECD and CMEA (basically USSR and Eastern European) countries.

Scenarios for Global Primary Energy Use [a]

	Actual 1980 (TWh/year) [b]	ESW [c] 2020	Change (%)	WEC [d] 2020 (TWh/yr)	Change (%)	ESW Additional Conservation Effort [e] (TWh/yr)	(% 1980)
Industrialized Countries	61320	37668	- 39	80424	+ 31	42756	70
Developing Countries	28908	60794	+110	120636	+317	59842	207
World	90228	98462	+ 9	201060	+123	102598	114

a/ Covers both commercial energy and non-commercial bioenergy.
b/ TWh = TeraWatt hours, equal to one thousand million kilowatt hours. The conversion factors used in translating energy quantities from various reference sources are: 1TWh of primary energy is equivalent to 123,000 tonnes of coal equivalent and 80,000 tonnes of oil equivalent. Quantities are converted from equivalent annual rates of energy use expresn TeraWatts to TeraWatt hours per year.
c/ Energy for a Sustainable World, page 302
d/ Average of the WEC Low and High Scenarios (ESW - page 429). The allocation of world total energy use between industrialized and developing countries is based on the ratio given in ESW Table 4.1 for a similar scenario which is based on 2%/year global energy growth and constant per capita energy use in industrialized countries.
e/ Defined as the difference between the energy uses in 2020 in the WEC and ESW scenarios.

Although the industrialized countries are indicated to reduce their energy consumption whilst developing countries increase them in the ESW scenario, the comparison of the ESW and WEC scenarios implies that a greater deliberate energy conservation effort will in fact be required from the developing countries under the ESW scenario, in terms of both absolute quantities and as a proportion of present energy use. Consideration of resource utilization and environmental concerns, as discussed later in this section, indicate that the conservation efforts may have to be sufficient to arrest and even reverse the trend to increasing energy use by 2020 in some of the developing countries.

10. Economic development is accompanied by a shift from lower to higher quality energy. Within total energy use, "Energy for a Sustainable World" anticipates further electrification of the global economy, so that the share of electricity in final energy use would increase from 10% in 1980 to 18% in 2020, which implies a near-doubling of global electricity use under the ESW scenario.[5] Given the trends in projected overall energy use, this implies a modest growth of 17% over the 1980 level in the industrialized countries, but in the developing countries a massive increase of four-and-a-half fold, as shown in the table below. Even so, the degree of electrification of the developing countries, i.e. the share of electricity in total energy use, would still be far below that of the industrialized countries. In fact, for the

5/ Energy for a Sustainable World - page 300.

industrialized countries electricity use in 2020 under the ESW scenario would be approximately the actual 1986[6] level, implying that any future growth would be reversed before 2020.

Increase in Electricity Use Under ESW Scenario: 1980 to 2020 [a]
(TWh/year)

	1980 (actual)[b]	%	1986 (actual)[b]	%	2020 (ESW Scenario)	%
Industrialized Countries [c]	6869	83	7985	80	8000 [e]	51
Developing Countries	1364	17	2038	20	7593 [e]	49
World	8253	100	10023	100	15593 [d]	100

a/ These data refer to final energy use, equal to primary energy use less conversion and transmission losses.
b/ Source: United Nations Year Book of World Energy Statistics.
c/ Comprises the OECD and CMEA countries.
d/ Assumed electricity supply in the Base Case Energy Demand Scenario from Energy for a Sustainable World (page 479).
e/ Projections for electricity in 2020 are derived from the source in (b) consistent with the world total (ESW-page 485).

11. The implied average annual growth rate of electricity use under the ESW scenario by industrialized and developing countries for 1980 to 2020 are shown below.

Growth Rates in Electricity Use Under ESW Scenario: 1980-2020 [a]

	1980 - 2020 (ESW projection) Total Energy	1980 - 2020 (ESW projection) Electricity	1980-1986 (actual) Electricity	1986 - 2020 (revised projection) Electricity
	(%/year)			
Industrialized Countries	-1.2	+0.4	+2.3	0
Developing Countries	+3.4	+4.4	+6.9	+4.0
World	+0.6	+1.6	+3.5	+1.3

a/ Based on data quoted in the previous paragraph.

6/ The 1986 actual situation is added for this paper as an additional reference point to update the projected long-term trends underlying the ESW scenario.

In a historical context these growth rates are relatively low in the case of developing countries, being 4.4% compared with actual growth rates of about 7% for 1980 to 1986, about 10% during the 1970s, and about 14% during the 1960s. This trend is consistent with the decline over time in the growth rate of electricity use in developing countries, following a similar trend in industrialized countries and reflecting the substantial conservation efforts that are presumed to take place under the ESW scenario. An approximate indication of the conservation impact under the ESW scenario is a reduction in the average annual increase in global electricity use to 2020 from nearly 4% under moderate conservation to about 1.5%, approximately halving the consumption level in 2020 (Note 3 in the Annex). The slowdown in growth of energy demand, and thus conservation efforts, will in fact have to be greater than indicated to achieve the scenario for 2020 since electricity use has increased more rapidly during the 1980s than the projected average long-term rate for 1980 to 2020. The table in this paragraph shows also the lower growth rates required from 1986 to meet the ESW 2020 levels.

<u>The Scope for Energy Conservation</u>

12. Energy conservation is a key component of optimal energy development strategies. Even though many conservation measures require substantial capital investments, they are needed to improve the feasibility of financing energy development programs in the developing countries. From a global perspective, the potential impact of energy conservation on the need for hydropower development will be most significant in developing countries, since they account for most of the global hydropower resource and market potential.7/ The main sources of conservation gains in developing countries are the adoption of more efficient commercial energy using technologies developed in the industrialized countries, a major improvement in end-use efficiencies of biomass energy, and the adoption of economic development strategies that capitalize on linkages between energy sectors and the other economic sectors. While these sources provide substantial scope for energy conservation in the developing countries, a number of factors will restrict their impact on energy demand and may prevent the achievement of the impact envisaged under the ESW scenario. At least three factors need to be considered in this regard: (i) the "natural" evolution of energy demand at low levels of development; (ii) the time required and cost to implement energy conservation measures; and (iii) system constraints on conservation.

13. At the earliest stages of economic development, industrialization and urbanization produce shifts towards more energy-intensive activities. This pattern reinforces the general trend towards greater use of energy, including electricity, that is required to raise output and to meet the demand for improved living standards that goes with rising incomes. This trend is accentuated under conventional energy strategies in which planning for each energy-using sector is done independently from other sectors. The approach rarely exploits the potential for energy conservation through coordination of

7/ The only significant hydropower resource and market potential in the industrialized countries is in USA, Canada and USSR.

development strategies across sectors. Examples of this potential are the use of agricultural wastes for industrial feedstocks and manufacture of fuels, the incorporation of energy conservation techniques in building designs, and consideration of national energy development priorities between transport modes. "Conservation" per se should not be considered as an alternative to energy supply but adopted as part of a comprehensive energy development strategy. However, in practice substantial constraints to exploiting this potential are imposed by limited national planning capabilities and conflicts with non-energy sectoral development priorities.

14. With the possible exception of some high-efficiency lighting systems, most electricity conservation programs take time to implement because the incorporation of modern energy-efficient equipment involves upgrading or replacement of energy-using capital stock. This applies to most household appliances, industrial processes and higher-efficiency motors and drives. It indicates that the scope for energy conservation is greatest in countries that have high levels of investment and growth in incomes, although these in themselves increase the demand for electricity. Among developing countries, this situation is presently found in the fast growing Asian middle income countries, but not in the debt-distressed middle-income Latin American countries and generally in the numerous low- income countries.

15. The role for conservation in a particular power system depends on the physical and economic characteristics of the country and the system. Estimates of the potential for conservation therefore vary widely depending on whether they are based on studies that are system-specific or more general.[8/] These studies commonly compare conservation options with average incremental costs or costs of specific alternatives such as nuclear power or hydropower. However, unless these options exactly offset the power which could be supplied by the least-cost alternative in terms of quantity, timing and reliability, this approach would not be valid. For example, using average costs, a study of conservation potential in Brazil [9/] determined that an aggressive conservation program could reduce total electricity consumption by about 20% over a fifteen-year period, which would permit cutting the short-term generation construction program by half. But the hydro-rich systems of Brazil actually have surplus energy and capacity in four years out of five, [10/] so the real benefit of conservation investments would be much less than claimed. Other options, such as low-cost thermal generation and interruptible contracts for energy-intensive industries, could likely yield similar savings

8/ See e.g. Amory Lovins' paper; "Saving Gigabucks from Negawatts".

9/ Howard Geller's report published as World Bank Energy Department Paper No. 32, End-Use Electricity Conservation Options for Developing Countries, 1986.

10/ The amount of installed hydropower capacity is determined on the basis of a conservative estimate of energy availability from these facilities, namely from energy to meet a given standard of supply reliability under hydrological uncertainty. The available firm energy is less than the actual average available energy.

but at lower cost than the proposed conservation program. Taking this factor into account, a viable long-term conservation program would reduce growth in electricity demand by about 10%. The Brazilian planners have incorporated such a reduction into their planning models, reflecting the expected results of current applicance-labelling programs and improvements in equipment efficiency (e.g. in air-conditioners).

16. Efficiency improvement within the power system itself is a special case of conservation. It takes two forms, reduction of system losses and improvement of service quality (better voltage and frequency control). In systems or parts of systems that experience demand suppression due to poor supply efficiency, improvements to service quality often stimulate paradoxically a short-term increase in the growth rate of total system demand. This means that power efficiency programs are not generally a substitute for new supply capacity, and in fact may increase the demand further.

17. Higher energy prices have stimulated progress during the 1980s on energy conservation through direct reaction by consumers and by deliberate public programs. Measuring the specific impact of these actions is difficult because electricity demand was also restrained by a concurrent decline in economic activity in many countries. Growth rates in electricity consumption in developing countries fell from about 10% p.a. in the 1970s to about 7% in the 1980s. By comparing changes in electricity use to changes in GDP, it may be deduced that about one third of this change, or a reduction of 1% in the average growth rate of electricity use, was due to conservation efforts. In the absence of better estimates, this may be a rough but realistic assessment of the impact of recent conservation programs, which would imply that they may have reduced the need for new generating capacity by about 10% in developing countries as a group during the 1980s. This is consistent with estimates of the impact of conservation measures in OECD countries. Unfortunately, it is not clear how much of this reduction in demand growth rate is permanent.[11/] For example, annual growth in electricity demand in the U.S.A. was less than 3% for several years during the 1980s, but some systems experienced on annual increase of as much as 14% in the summer of 1988. Furthermore, this level of impact on electricity demand from conservation is roughly consistent with the WEC scenario and is much less than the impact under the ESW scenario, thus highlighting the extraordinary conservation effort required to meet the ESW scenario.

Options for Increasing Electricity Supply

18. The previous discussion suggests that a substantial increase in electricity supply is required for developing countries even with the greatest feasible conservation efforts. Nearly all the options for increasing electricity supply involve significant environmental issues. Thus, trade-offs will be required to balance environmental issues against the need for

11/ Since much of the conservation gain during the 1980s has been obtained from the simplest types of measures, conservation gains will become increasingly difficult from present energy-using capital stock and technologies.

electricity in these countries. The continuing challenge is to balance prudent development of a mix of energy resources against the long-term costs and consequences of that development. From an analysis of the risks to the global environment of various energy supply strategies, "Energy for a Sustainable World" developed the indicative electricity supply scenario outlined below to meet its scenario for energy demand up to 2020.

19. Nuclear power is regarded in the ESW electricity scenario as an energy technology of last resort to reduce the risks of proliferation, and should be limited to those situations where viable alternative technologies are not available. The role of nuclear power is restricted to the estimated capacity already planned for the year 2000, so that beyond this date new plants would be built only to replace retired nuclear units. [12/] This eventuality implies that some countries may have to be persuaded to forego the nuclear power option, thus posing a formidable challenge to supporters of this policy.

20. Fossil fuels use is constrained in the ESW scenario by the imposition of an allowable ultimate level of atmospheric carbon dioxide. In this respect, coal is the worst source and natural gas the least damaging. It is assumed that: (i) half the released carbon dioxide remains in the atmosphere; (ii) virtually all presently estimated ultimately recoverable oil and gas resources are used up before the carbon dioxide level approaches the allowable ultimate level, so that concerns about carbon dioxide become constraints on coal consumption; and (iii) coal consumption thus falls exponentially over time from before 2020.[13/]

21. Coal use depends on the ceiling set for atmospheric carbon dioxide. For the ESW scenario, a ceiling was selected of 490 ppm, equal to 1.7 times the pre-industrial age level. To remain below this ceiling, global coal use would have to fall by about 20% from its 1980 level by 2020, and by 50% within one hundred years. The atmospheric carbon dioxide level in 2020 (380 ppm) would then be about 1.3 times the pre-industrial age level.[14/] Coal use would have to continue falling thereafter to ultimately about 20% of the 1980 level as the ceiling for the carbon dioxide levels is approached asymptotically in about 200 years time.[15/] This restriction would limit global coal use in the long run to about one quarter of known coal resources. It would provide a major challenge to global diplomacy since some nations would have to make most of the sacrifice to deal with a phenomenon of highly uncertain nature and impact. However, the concentration of about 90% of world coal resources in just three countries - U.S.S.R., U.S.A. and China -

12/ Energy for a Sustainable World - page 307.

13/ Energy for a Sustainable World - page 304.

14/ The level of atmospheric carbon dioxide in 1979 was 334 ppm (1.15 times the pre-industrial level), and in 1986 it was 340 ppm (1.17 times).

15/ Energy for a Sustainable World - page 483.

would facilitate the prospect of such control in the long-term[16] provided these countries would be prepared to regulate their consumption levels to limit global coal consumption.

22. Oil and Gas. The presently known recoverable resources of oil and natural gas in the world are approximately equal, on an energy equivalent basis, but gas would last for much longer at current consumption rates. The relative opportunities for alternative uses of these fuels in comparison to their global resources argues in favor of substituting oil by natural gas. Under the implicit resource depletion policy for the ESW scenario, increasing gas usage would catch up with declining oil usage in 2020. Together with the assumptions about overall fossil fuel and coal use, this would result in global oil use in 2020 of about 0.76 times the 1980 level, whereas gas use would be about 1.85 times the 1980 level. The combined global use of oil and gas would increase by about 8%. Such a scenario assumes global security in oil supplies to 2020. In particular, oil would have to be available for essential development purposes in developing countries as well as for non-substitutable uses globally. The ESW scenario for 2020 includes a large amount of cogenerated electricity, of which half would be fuelled by oil and natural gas and half from biomass.

23. Renewable Energy. The growing demand for electricity in the developing countries, even under major conservation efforts, requires reliance on renewable energy sources if the use of nuclear power and fossil fuels is constrained for environmental reasons. These sources consist of co-generation and non-conventional renewable sources such as wind and photovoltaic energy, and bioenergy as well as hydropower. Geothermal energy is also included in this category even though some sources are not renewable. The level and mix of renewables in the ESW scenario reflect a judgement about their technical feasibility without causing significant land use and social problems. Large installations of some renewable options would also have to contend with major environmental issues, such as local noise and scenic disruption with central wind power stations, and large scale land use with scenic disruption from central solar power stations. Only a small part of the non-conventional energy supply included in the ESW scenario is currently economic, but the remaining portion is expected to become viable through technological innovation and general trends in global energy economics, including rising prices for conventional fuels. Given their present technical, environmental and economic constraints, the build-up in non-conventional renewable energy production would have to occur mostly during the next century, especially in the decade leading to 2020 at an accelerating rate once the technologies and markets have been developed.

24. Cogeneration is the alternative technology that appears to be most promising in the short term, and several developing countries (Pakistan, Turkey, Thailand) are adopting strategies to promote it. Electricity and thermal energy for industrial purposes are produced from a single non-power utility generation source. Cogeneration offers potential savings in total primary energy use through achieving a total efficiency of energy utilization of up to 80%, compared with up to 40% in conventional power generation

16/ Energy for a sustainable World - pages 304 to 306.

plants. The industrial purposes are usually to provide process steam or heat and to warm or cool buildings. The generated electricity is used on site and often, there is sufficient potential to produce for export to the public power system. Estimates of cogeneration potential in the industrializing developing countries indicate that cogeneration could supply as much as 14% of the total demand, but more recent estimates suggest that 4 to 5% is a more realistic target for economically justified cogeneration. This potential is further constrained in developing countries because natural gas, the most attractive fuel for cogeneration (more than two-thirds of cogeneration in OECD countries is based on natural gas), is not a plentiful industrial fuel in most developing countries. Nonetheless, planners in many countries, including the hydro-rich countries, have not given sufficient attention to industrial cogeneration and the significant contribution that aggressive cogeneration programs can make to power development.

25. A recent study[17/] of wind potential in 105 developing countries identified no cases where wind-based power was clearly an economic choice for supply to the power grid, although 29 countries were classed as promising candidates for additional investigation. The most successful of the existing wind projects (California) utilizes a resource which uniquely peaks at the time of maximum system peak. Even there, although wind supplies up to 2% of the peak demand, the amount of energy is considerably less than 1% and the most mature wind farms have an annual capacity factor (actual energy output as a percent of the energy which would be generated if the plant ran constantly) of only 20%. The small-hydropower program in China (over 100,000 units) is considered a marked success because it provides electricity to communities which otherwise would go without. Half of these plants operate for only part of the year which fortunately, frequently coincides with the communities need for power. The average capacity factor of the Chinese units has been estimated at less than 8%, and they would not be suitable as a basis for grid supply to industry. It would be unrealistic to suppose that more than 5% of global small-hydropower potential would be realistically developed. Solar systems are most likely to find their niche in isolated applications, such as communications, until economical energy storage techniques are developed. Thermal-storage solar holds some promise, but the storage feature has been eliminated from the most recent solar-thermal projects (California) because it was not economical.

26. Reliability. Industry accounts for about half to two-thirds of the demand for electricity in the more economically-advanced developing countries, and requires a reliable and continuous supply. Unfortunately, with the exception of some cogeneration projects and OTEC (ocean-thermal energy conversion), alternative energy sources provides an intermittent power supply which varies significantly either diurnally (solar, wind) or seasonally (biomass, hydro, wind). Thus, even though general economic studies may show that alternative sources are competitive on a unit energy cost (¢/kWh) or power cost ($/kW) basis, they do not show the same cost advantages on a system basis. When integrated into a system development program, the alternative

17/ Study of the Potential for Wind Turbines in Developing Countries, Strategies Unlimited for U.S. Dept. of Energy and the World Bank, May 1987.

sources either generate some of their energy at a time when it is not needed, or more commonly, full back-up capacity is required from other sources in order to assure a reliable supply.

27. While substantial claims are often made about the potential scope for non-conventional renewable energy forms, a recent assessment by the International Energy Authority[18/] is sobering. It reviews the outlook for economic contributions to national energy supplies of the five principal renewable energy sources (solar, wind, biomass, geothermal and ocean energies) that are alternatives to the conventional energy sources. The present overall technical and economic status of the technologies is classified into four stages of development that are shown in Figure 1. The study concludes that remarkable progress has been made since the mid-1970s to develop these new technologies and that they will make an increasing contribution to energy supply, but that at least 30 years may be needed for these technologies to achieve a significant market penetration even with substantial support for development.

28. Electricity Supply for 2020. The indicative level and mix of energy sources for global electricity supply in the ESW scenario for 2020 is shown in the table below in this paragraph.[19/] It is emphasised that this scenario is based on global environmental considerations. A corresponding scenario based on present economic policies would probably show a higher overall demand through less conservation, being supplied mainly from more coal-based power production. The main features of the ESW scenario as compared to 1980, are no change in fossil fuels usage excluding cogeneration, (a large decline in industrialized countries usage being offset by an increase in use in developing countries), and a four-fold increase in generation from both nuclear power and all renewables as a group including hydropower. Within the trends in total fossil fuel use, electricity generated from coal would increase substantially between the 1980s and 2020, decline for natural gas and hardly change for oil (Note 4 in the Annex). The noteworthy difference between these and current patterns is the present trend towards greater use of natural gas to generate electricity. To illustrate the environmental trade-offs involved, the increase in hydropower from 1980 to 2020 would displace an equivalent amount of coal-fired power that would raise the ultimate level of atmospheric carbon dioxide to between 2.5 and 3 times the level of the pre-industrial age, rather than the 1.7 factor used for the ESW scenario. Such an addition could carry alarming implications for the global environment.

18/ Renewable Sources of Energy, International Energy Authority, Paris, 1987.

19/ The supply scenario in Energy for a Sustainable World only gives the global mix. The mixes for industrialized and developing countries given in the table were developed from this scenario for this Paper.

Figure 1

Current Status of Renewable Energy Technologies

Economic (in some locations)

Solar water heaters, replacing electricity, or with seasonal storage and for swimming pools
Solar industrial process heat with parabolic trough collectors or large flat-plate collectors
Residential passive solar heating designs and daylighting
Solar agricultural drying
Small remote photovoltaic systems
Small to medium wind systems
Direct biomass combustion
Anaerobic digestion (of some feedstocks)
Conventional geothermal technologies (dry and flashed steam power generation, high temperature hot water and low temperature heat)
Tidal systems

Commercial-With-Incentives

Solar water and space heaters replacing natural gas or oil
Electricity generation with parabolic trough collectors
Non-residential passive solar heating and daylighting
Biomass liquid fuels (ethanol) from sugar and starch feedstocks
Binary cycle hydro-geothermal systems

Under Development

Solar space cooling (active and passive)
Solar thermal power systems (other than parabilic trough collectors)
Photovoltaic power systems
Large-sized wind systems
Biomass gasification
Hot dry rock geothermal
Geothermal total flow prime movers
Wave energy systems

Future Technologies

Photochemical and thermochemical conversion
Fast pyrolysis or direct liquefaction of biomass
Biochemical biomass conversion processes
Ocean thermal energy conversion systems
Geopressured geothermal
Geothermal magma

Definition of Categories

Economic. Technologies are well developed and economically viable at least in some markets and locations, for which further market penetration will require technology refinements, mass production and/or economies of scale.

Commercial-with-Incentives. Technologies are available in some markets, but are competitive with the conventional technologies only with preferential treatments, so that they still need further development to be economically competitive.

Under Development. Technologies need more R & D to improve efficiency, reliability or cost to become commercial.

Future. Technololgies have not yet been technically proven, even though they are scientifically feasible.

Source: IEA, Renewable Sources of Energy, Paris, 1987

Indicative ESW Scenario for Global Electricity Supply Mix in 2020
(TWh/year)

Year		Energy Source: Fossil Fuels	Hydropower	Nuclear	Non-hydro Renewables	Total
1980 a/ (actual)	Industrialized Countries	4941	1270	668	10	6889
	Developing Countries	855	489	17	3	1364
	World	5796	1759	685	13 b/	8253
1986 a/ (actual)	Industrialized Countries	5095	1366	1482	42	7985
	Developing Countries	1292	661	74	11	2038
	World	6387	2027	1556	53	10023
2020	Industrialized Countries	2400	1600	2000 d/	2000	8000 f/
	Developing Countries	3382	2430	628 d/	1153	7593 f/
	World	5782	4030	2628 c/	3153 e/	15593 f/

a/ Source: United Nations Year Book of Energy Statistics.
b/ Geothermal power.
c/ Source: "Energy for a Sustainable World" - page 484: Projections for 2000.
d/ Allocated according to relative trends in actual 1986 production within ceiling set in note c.
e/ In ESW for 2020, this is indicatively identified as wind and photovoltaic power (788 TWh) and cogeneration energy (2365 TWh), which appear to be optimistic. However, this allocation is pessimistic in not crediting a contribution from the substantial geothermal potential.
f/ Source: Table in paragraph 10.

Hydroelectric Expansion in Developing Countries

29. In the ESW scenario, hydroelectricity supply in the developing countries in 2020 would have to be at least about five times the 1980 level and over three-and-a-half times the 1986 level. Nevertheless, its share of total electricity supply for developing countries would then decline slightly from 36% in 1980 and 33% in 1986 to 32% in 2020. At the average plant factor registered for hydropower capacity in developing countries during the 1980s, namely about 49%, this would require an installed hydropower capacity in 2020 of around 565,000 MW, compared with actual levels of 110,000 MW in 1980 and 154,000 MW, in 1986. Thus, even under relatively low electricity demand for 2020 outlined in the ESW scenario, there will be a massive requirement for additional hydropower capacity which will raise major strategic development issues. Furthermore, under the higher demand envisaged in the WEC scenario, based on a moderate energy conservation impact, the required amount of hydropower development could well be technically unachievable (Note 2 in the Annex), being about three and a half times the level under the ESW scenario.

30. Hydroelectricity is a fully proven power source with enormous untapped potential in developing countries, where less than 10% of the technically usable[20/] potential has been developed to date. Many of these countries view development of their hydro resources as a means to increase self-reliance in energy. Under the ESW scenario outlined for 2020, the hydropower output in developing countries would amount to about 30% of the technically usable potential.[21/] Although this level is a realistic target, it presupposes continuation of advances in long distance power transmission technology and in techniques for utilizing large low-head river flows. Moreover, the costs of power from many of the marginal hydro sites are likely to be higher than presently anticipated costs from directly competing sources (coal, nuclear, gas). The scenario thus, implies the possibility of a shift in some countries to policy-based resource selection for power development. Pressure to develop economically attractive sites that are ecologically disruptive would require continual and careful attention to evaluation of alternative sites and to mitigatory measures. Fortunately, the envisaged pace of hydropower expansion is sufficiently modest (4% average annual growth from 1986) to allow planning to be carefully integrated into the overall development process, taking account of the range of social and ecological concerns that have been raised about hydropower development.[22/]

31. There are marked imbalances of hydro potential and power market size at the national level in developing countries. The global supply scenario described previously, particularly for developing countries as a group, needs to be consistent with the aggregate of developments in each country. The distribution of these imbalances is indicated from a grouping of developing countries by the following three categories. First, developing countries with the largest hydropower potential and power demands, in which insufficient market size is unlikely to be a major restriction on developing their hydro potential (China, India, Brazil--accounting for about 42% of the total hydro potential and 55% of the 1980 demand). Second, countries with substantial hydropower potential in which lack of market size could be a moderate constraint on hydro development (notably Colombia, Turkey, Argentina, Chile, Mexico, Thailand, Malaysia, Indonesia, Pakistan, Nepal (including exports to India), Nigeria, and Zimbabwe--accounting for about 20% of the hydro potential and 24% of the 1980 power demand). Finally, development of much of the hydro potential in many other countries will be severely constrained for the foreseeable future by lack of demand (in particular Zaire, Burma, Vietnam, Papua New Guinea, Peru, Ethiopia, Angola, Laos, Cameroon, Gabon, Afganistan, and Mozambique -- accounting for 36% of hydro potential and only 2% [23/] of 1980 demand). On balance, the development of hydro potential in developing countries for power to the level required by the 2020 scenario discussed

20/ Global technically usable hydropotential is estimated by the WEC to be a little less than half the theoretical hydropotential.

21/ Energy for a Sustainable World, page 402.

22/ Energy for a Sustainable World - page 310.

23/ The remaining 19% of power demand in 1980 was for developing countries without sizeable hydropower potential.

earlier is unlikely to be significantly constrained by insufficient power demand, although it will probably depend on a significant increase in international trade in hydropower. This will require many countries to overcome their present reluctance to such a commitment.

The Need for Large Dams in Hydropower Development

32. Large dams are important for the economic development of hydropower potential. In particular, sixty one major dams[24/] out of many hundreds of dams of all sizes with hydropower installations in developing countries, are associated with about 60% of the hydropower capacity in these countries, as shown in the table below.

Present Installed Hydropower Capacity at Existing Major Dams

	Installed Hydropower Capacity Total a/ (MW)	Installed Hydropower Capacity w/Major Dams b/ (MW)	(%)	Major Dams with Hydropower b/ (number)
Industrialized Countries	413008	130856	31.7	89
Developing Countries	153815	90947	59.1	61
World	566823	221803	39.1	150

a/ Source: United Nations Energy Statistics Yearbook - 1986

b/ Source: Water Power and Dam Construction - Handbook 1989

There is furthermore, scope to add to the present hydropower capacity at the existing dams, which under present plans would amount to about 30000 MW (33%) at the dams in developing countries. Some of this additional capacity would increase the firm power capability of the complexes and thus contribute to meeting growth in power demand. However, some of the additions would only enable a greater proportion of the hydro energy to be used for meeting peak demands on power systems and thus, would not count as a net addition to total firm power supply. In addition to the expansion possibilities at existing dams, forty two major dams with associated hydropower facilities are presently under construction, of which thirty five are in developing countries with about 58000 MW of planned total hydropower capacity (Note 5 in the Annex). The scale of hydro development in developing countries during the 1980s reflects the momentum that has built up since the 1950s, especially the large hydropower installations that followed the oil price increases of the 1970s (Note 6 in the Annex). It is consistent with the future rate of expansion

24/ Dams included in this category are listed in Water Power and Dam Construction from a survey conducted under the auspices of the International Commission on Large Dams. They meet one of the following criteria: dam height of at least 150 metres; or dam volume of at least 15 million cubic metres; or reservoir capacity of at least 25 cubic kilometers; or hydropower plant installation of at least 1000 MW.

required even under the ESW scenario (around 400,000 MW by 2020 - para. 29). Thus, it is evident that large dams are a critical component of present strategies for developing hydropower potential.

33. Because hydropower is derived from falling water, in theory the same amount of energy could be generated from a given stretch or "reach" of river by either one or a few large dams or a series of smaller ones. The latter strategy may implicitly be assumed as preferable environmentally since it avoids problems particular to large dams, but the aggregated environmental impact of numerous smaller developments may be more disruptive especially if situated over long stretches of rivers in densely populated areas. However, many of the best sites for large dams are located in mountainous regions of basin headwaters where hydro developments would result in little, if any adverse environmental consequences. High voltage long distance power transmission technology enables the hydropower potential in these areas to be exploited economically. In many river basins the unit economic cost of obtaining hydropower from large hydropower complexes is a fraction of the unit cost of power from small and medium sized installations. 25/ In order to tap the potential of rivers which fall gradually, large dams are needed to create the necessary "head" or drop because hydro turbo-generators have yet to be developed which utilize efficiently large flows at very low head. Much of the undeveloped hydropower potential is associated with rivers of this type, particularly in Asia. Large dams are also required for substantial exploitation of hydro potential where topography limits the feasibility of development to a few sites.

34. Many of the environmental issues concerning large hydropower developments are related to storage reservoirs rather than dams. Substantial storage capacity is a feature of most large hydropower developments (Note 7 in the Annex). Because generally rainfall, and consequent river flow, varies markedly by season and from year to year, reservoir storage to regulate river flow is needed for power and irrigation needs in drier periods and to provide flood control benefits. Without this facility, the unreliability of hydropower would carry the economic disadvantage already noted for other renewable energy forms (para. 26).

35. Three strategies are available to provide firm power from a given hydro resource: (i) add storage capacity by increasing dam height if the dam structure and topography permits, subject to trade-offs between additional storage benefits and environmental costs; (ii) build additional hydropower capacity on new sites (the strategy adopted so far in countries like Brazil and Columbia); or (iii) add supplemental power generating capacity of other types, usually based on oil or gas, instead of adding hydro storage capacity. All three strategies require substantial capital expenditure and will affect the environment, yet development of available hydro resources will be essential to meet even the low estimate of future power needs outlined in

25/ The unit cost of power is particularly sensitive to hydraulic heads below 100 meters. This relationship is analysed in the IAEA Technical Report No. 241: Expansion Planning for Electrical Generating Systems - A Guidebook - Appendix 1: Parametric Costs of Conventional Hydroelectric and Pumped Storage Hydroelectric Plants.

the ESW scenario. The large additional needs for hydropower would require a wide range of types and scales of hydro developments. Past experience and the development factors discussed in this section indicate that large dams are essential to meeting much of this requirement.

World Bank Policy on Power

36. World Bank policy[26/] requires that any power project proposed for financing must be shown to be part of the least-cost program for meeting the demand which would develop at economically-efficient price levels. Implicitly, this approach incorporates all alternatives, including conservation measures, load management and efficiency improvement as well new generating capacity of all forms, in an integrated strategy for supplying all worthwhile demand. Measures to mitigate environmental impacts and compensate for social disruption have to be fully reflected in the costs of power projects. At economically-efficient price levels, it is assumed that consumers would choose end-use equipment of optimum efficiency. Of course, practical limitations on this ideal exist. Information on all alternatives may not be available, consumers have limited capital and therefore may choose the cheapest equipment regardless of efficiency considerations, and prices may not reflect real costs. Additional complications are the difficulty in determining costs accurately, especially social costs and those associated with environmental and other effects of individual alternatives, and allowing for differences in risks and uncertainties of alternatives. Because of these constraints, there is ample scope for energy conservation and improved utilization efficiency in all countries. In fact, the World Bank considers conservation to be a vital component of a national energy strategy. Through its Energy Sector Management Assistance Program (ESMAP) jointly funded with UNDP and many bilateral agencies, the World Bank already has a major program of assistance to its borrowers in areas of renewable energy and energy efficiency.[27/] The Bank has also produced a number of reports, listed at the end of this section, on these aspects to guide its staff and planners elsewhere as part of its efforts to stimulate greater use of these options.

26/ The role of the World Bank in the energy sector is described in the Industry and Energy Department Working Paper, Number 7: Recent World Bank Activities in Energy, September 1988.

27/ Activities under ESMAP are summarized in the Annual Reports for the Program.

[redacted]

RELEVANT WORLD BANK PUBLICATIONS ON ENERGY

Energy Policy

1. Recent World Bank Activities in Energy, Industry and Energy Department Working Paper - Energy Series Paper No. 7 - September 1988

Energy Conservation and Efficiency

2. End-Use Electricity Conservation Options for Developing Countries; Energy Department Paper No. 32, 1986

3. Energy Efficiency: Optimization of Electric Power Distribution System Losses, Energy Department Paper No. 6, 1982

4. Energy Efficiency and Fuel Substitution in the Cement Industry with Emphasis on Developing Countries, World Bank Technical Paper No. 17, 1983

5. The Potential for Energy Efficiency in the Fertilizer Industry, World Bank Technical Paper No. 36, 1985

6. Energy Efficiency in the Steel Industry with Emphasis on Developing Countries, World Bank Technical Paper No. 22, 1984

7. Energy Efficiency in the Pulp and Paper Industry with Emphasis in Developing Countries, World Bank Technical Paper No. 34, 1985

8. Energy and Transport in Developing Countries: Towards Achieving Greater Energy Efficiency, Transportation and Water Department, The World Bank, 1983

9. Railways and Energy, World Bank Staff Working Paper No. 364, 1984

Renewable Energy Sources

10. Prospects for Traditional and Non-Conventional Energy Sources in Developing Countries, World Bank Staff Working Paper No. 346, 1979

11. Mobilizing Renewable Energy Technology in Developing Countries: Strengthening Local Capabilities and Research, World Bank, 1981

12 Renewable Energy Resources in the Developing Countries, World Bank, 1980

13. A Methodology for Regional Assessment of Small Scale Hydropower, Energy Department Paper No. 14, 1984

14. A Survey of the Future Role of Hydroelectric Power in 100 Developing Countries, Energy Department Paper No. 17, 1984

15. The Commercial Potential of Agricultural Residue Fuels: Case Studies on Cereals, Coffee, Cotton and Coconut Crops, Energy Department Paper No. 26, 1985

16. Technical and Cost Characteristics of Dendrothermal Power Systems, Energy Department Paper No. 31, 1985

17. Guidelines for Assessing Wind Energy Potential, Energy Department Paper No. 34, 1986

18. Guidelines for Identifying and Preparing Forestry Projects, Energy Department Paper No. 33, 1986

19. Industrial Energy Rationalization in Developing Countries, Gamba, Caplin and Mulckhuyse, 1986

20. A Comparison of Lamps for Domestic Lighting in Developing Countries, Industry and Energy Department Working Paper - Energy Series Paper No. 6, 1988

ANNEX

Notes to Section on Electricity

Note 1: Trends in Macroeconmic/Energy Relationships under the ESW Scenario

The ESW scenario for 2020 implies a substantial decoupling of the historic correlation between energy consumption and GDP, especially in the industrialized countries but also in developing countries. Two factors are notable in this development, namely changes in the pattern of output of the economy to less energy-intensive products, and improvements in end-use energy efficiencies. The experience of the industrialized economies since the mid 1970s shows such a trend. The authors of the ESW scenario give a quantitative illustration of changes in modelling parameters linking energy and economic variables that are consistent with their projected changes in energy demand between 1980 and 2020, which are summarized in the table below.

Changes in Parameters Consistent with Energy Demand Changes to 2020 under ESW Scenario

	Industrialized Countries	Developing Countries
Income Elasticity of Energy Demand	0.8	1.4
Energy Price Elasticity of Energy Demand	-0.7	-1.0
Non-Price Induced Energy Efficiency Improvement Rate	1.0%/year	0.5%/year

Source: Energy for a Sustainable World - page 481.

The authors did not make explicit assumptions about movements in energy prices in the construction of the reference scenario, but they consider it reasonable to associate final energy prices in 2020 to be in the range of two to three times the 1972 values [a] (in constant price terms). For these values of the parameters, the authors consider the demand scenario for 2020 to be consistent with per capita increase in GDP from 1972 to 2020 of 50 to 100 present for

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a/ The year 1972 is chosen as the base year for this modelling exercise because it is the last year before the first oil price shock and thus, when the global economy was probably in equilibrium with energy prices.

industrialized countries and at least 200 percent for developing countries. The GrP increase for developing countr es would be greater at values for the income elasticity of energy demand lower than 1.4, which is expected to decline over time for this group with an expected decrease in the energy intensity of economic production. The price elasticity of energy demand given above is greater than typically adopted values for price elasticity of electricity demand (-0.1 to -0.4), which is a factor in the faster growth rate for electricity use than for total energy use.

Note 2: Comparison of Alternative Energy Scenarios

The ESW scenario for 2020 is based on some extreme assumptions about the impact of energy conservation measures. This point is shown in another a set of scenarios for global energy in 2020 which was presented at the 1983 World Energy Conference (WEC). The average of the WEC low and high projections for energy demand in 2020 is about double the ESW scenario. The projected energy supply mixes are compared in the table below.

Actual 1980 and Comparison of Primary Energy Supply Mixes in 2020
under Alternative Scenarios
(TWh/year)

Energy Source		Actual 1980	ESW Scenario	WEC Average Scenario	WEC to ESW Ratio
Fossil Fuels:	Coal	21350	17000	60360	3.55
	Oil	36857	28120	44000	1.56
	Natural Gas	15250	28120	34950	1.24
	Subtotal	73457	73240	139310	1.90
Nuclear Energy		1927	6570	24090	3.67
Renewable Energy:	Hydro a/	1759	4030	14450	3.59
	Biomass	13052	13840	}23210	}1.59
	Other a/	33	782	}	}
	Subtotal	14844	18652	37660	2.02
Global Supply		90228	98462	201,060	2.04

a/ The primary energy consumption associated with hydro, wind and photovoltaic electricity production is assumed to be the energy value of the output of these systems.

Source: Energy for a Sustainable World - Pages 429 and 486.

[redacted]

The comparison given in the table above shows significantly different patterns of energy supply between the scenarios for 2020, and it is clear that conservation and environmental considerations did not figure as prominently in the WEC scenarios as in the ESW scenario. In fact, the levels of energy supplied from the various sources in the WEC scenarios indicates an absence of policy based suppression of resource exploitation.

Under the different policies used for the WEC scenarios, about three and a half times the amount of hydropower would be required on average relative to the ESW scenario. b/ The feasibility of matching this level of hydropower potential development with the global distribution of power demand required under the WEC average scenario for 2020 would require even greater technological advances in power transmission over very long distances and a much greater willingness than in the past by countries to cooperate on multi-national power developments and trade than implied under the ESW scenario. There would also have to be a reduction in the politicization of power development between regions within some countries. In fact, meeting the WEC projected overall level of demand for 2020 from all energy sources would constitute a major challenge, and the postulated level of hydropower output may be unachievable in practice.

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b/ Obviously, under the much higher overall energy demand levels for 2020 in the WEC scenario, there would have to be substantial new hydropower development in the industrialized countries as well as the developing countries.

Note 3: Electricity Conservation Impact

An estimate of the additional impact of electricity conservation measures predicated under the ESW scenario is obtained by comparing growth rates in electricity demand to 2020 under the ESW and WEC average scenarios, as shown below. The WEC scenario indicates a moderate conservation impact. The proportion of total energy use accounted by electricity in the WEC scenario for 2020 is taken to be equal to that in the ESW scenario, namely 18%.

	1980 Actual	2020 ESW Scenario	2020 WEC Scenario
Global Electricity Use (TWh/year)	8224	15593	36191
Average Growth Rate (%/year)	-	1.6	3.8

Source: Energy for a Sustainable World - pages 429 and 485.

The additional impact of conservation under the ESW scenario is thus equivalent to a reduction from 3.8% to 1.6% in the average annual growth of electricity demand from 1980 to 2020.

Note 4: Use of Fossil Fuels for Electricity Production

	1980 Actual	1986 Actual	ESW 2020
Coal			
Total Primary Energy Use a/ (TWh)	21340	25622	17000
Electricity Production a/ (TWh)	3042	3936	3338
Ratio Electricity to Total b/ (%)	36	38	49
Oil			
Total Primary Energy Use a/ (TWh)	30623	30093	28120
Electricity Production a/ (TWh)	1734	1154	998
Ratio Electricity to Total b/ (%)	16	11	10
Natural Gas			
Total Primary Energy Use a/ (TWh)	14884	17013	28120
Electricity Production a/ (TWh)	1020	1297	1446
Ratio Electricity to Total	19	21	14

a/ Source: IEA World Energy Statistics and Balances 1971/87 for 1980 and 1986.

b/ Electricity production is converted to equivalent primary energy input at the following conversion factors (ESW - page 486):

Coal - 40%; oil and natural gas - 36%

These rates reflect the early 1980s performance. The 2020 conversion efficiencies are likely to be higher with corresponding lower ratios of electricity produced from total use of primary energy.

Note 5: Large Dams and Associated Hydropower Capacity

	Industrialized Countries b/	Developing Countries	World
Completed dams:			
Presently with hydrocapacity: (number)	89	61	150
- existing installed capacity (MW)	130856	90947	221803
- planned additional capacity (MW)	12424	28045	40469
- planned final capacity (MW)	143280	118992	262272
Presently without hydrocapacity (number)	6	4	10
- planned final capacity	9762	2260	12022
S/Total planned final capacity	153042	121252	274294
Dams under construction			
With hydrocapacity initially (number)	2	8	10
- initial installed capacity (MW)	921	8640	9561
- planned additional capacity (MW)	824	2562	3386
- planned final capacity (MW)	1745	11202	12947
Without hydrocapacity initially (number)	5	27	32
- planned final capacity (MW)	29600	47170	76770
S/Total planned final capacity (MW)	31345	58372	89717
Total planned final capacity all dams (MW)	184387	179624	364011

a/ As defined by ICOLD

b/ Turkey is classified as a developing country rather than a member of OECD.

Note 6: Historic Trends in Installed Hydropower Capacity

	1950		1960		1970		1980		1986
Industrialized Countries (MW)	39302		123582		222492		355768		413008
- growth (%/y)		12.1		6.1		4.8		2.5	
Developing Countries (MW)	12058		25989		68160		109628		153815
- growth (%/y)		8.0		10.1		4.9		5.8	
World (MW)	51360		149571		290652		465396		566823
- growth (%/y)		11.3		6.9		4.8		3.3	

Source: United Nations Energy Statistics Yearbook - 1982 and 1986.

Note 7: Distribution of Number of Completed Large Dams by Reservoir Size and Planned Final Hydropower Capacity a/

Reservoir Capacity (million cubic meters)	Size of Hydropower Installation (MW): Up to 1000	1000 to 2000	2000 to 4000	Over 4000	Total
Zero b/	0	7	0	0	7
up to 20000	38	57	16	4	115
20000 to 60000	5	9	6	5	25
Over 60000	2	3	3	5	13
Total	45	76	25	14	160

Distribution of Total Installed Hydropower Capacity by Reservoir Size and Planned Final Hydropower Capacity a/

Reservoir Capacity (million cubic meters)	Size of Hydropower Installation (MW): Up to 1000	1000 to 2000	2000 to 4000	Over 4000	Total
Zero b/	-	8534	-	-	8534
up to 20000	14770	74226	40189	26528	155713
20000 to 60000	2651	12146	16003	36685	67485
Over 60000	1032	4118	7134	30278	42562
Total	18453	99024	63326	93491	274294

a/ Source: Water Power and Dam Construction - Handbook 1989.

b/ Run-of-river hydropower installations.

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