Hydropower and the World's Energy Future

The role of hydropower in bringing clean, renewable, energy to the world

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Preface

The inherent technical, economic and environmental benefits of hydroelectric power make it an important contributor to the future world energy mix, particularly in the developing countries. These countries have a great and ever-intensifying need for power and water supplies and they also have greatest remaining hydro potential.

Development is a basic human right, as few would deny. Energy policy makers must meet their responsibility in exploring the most rational options for meeting the energy needs of the developing world, while protecting the environment to the maximum possible extent, for example by limiting greenhouse gas emissions.

Any infrastructure development inevitably involves a certain degree of change. The construction of dams, and their associated reservoirs and hydroelectric powerplants, creates certain physical and social aspects, and a large amount of attention has focused in recent years on the negative impacts only. Less account has been taken of the benefits of hydropower and of the knowledge and willingness which exists within the profession to anticipate, mitigate and/or compensate for negative aspects.

This paper therefore sets out:

- *The role hydropower can play in the future, in the context of demographic growth and increasing demands for energy.*
- *The potential for future hydropower development throughout the world.*
- *The inherent benefits of hydropower, both technical and environmental, in comparison with other energy options.*
- *A review of specific environmental and social impacts, and examples of mitigation measures.*
- *Recommendations on best practice for future projects.*
- *The potential way forward for hydropower development.*

As will be clear from this paper, the dam and hydro profession today does not only comprise technicians, but it is a multi-disciplinary body including environmental specialists, ecologists, biologists, social scientists and economists. Together they represent a wealth of expertise which can ensure that future projects are planned, constructed and operated with full respect for society and the environment.

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Introduction

As we move into the twenty-first century, global economic prosperity is driving the consumption of energy to record levels, with electricity consumption anticipated to increase at rates faster than overall energy supply. The vast majority (80 per cent) of energy today is provided from thermal sources, i.e. coal, gas and oil; but there are growing global concerns regarding the lack of sustainability of these forms of energy that bring into question their use in a long-term energy strategy.

Concerns over disruptive fossil fuel markets and uncertain pricing, the current decline of nuclear energy as a viable energy source and the significant environmental consequences of thermal energy sources have placed greater emphasis on sustainable energy policies that include the significant development of renewable energy supplies.

Renewable energy technology exists in many forms. Recent thinking often relates renewable energy to electricity from either wind energy, solar energy or geothermal energy. Yet the largest source of renewable energy comes from a proven technology, hydropower. Hydropower is renewable because it draws its essential energy from the sun which drives the hydrological cycle which, in turn, provides a continuous renewable supply of water. Hydropower represents more than 92 percent of all renewable energy generated, and continues to stand as one of the most viable sources of new generation into the future. It also provides an option to store energy, to optimize electricity generation.

The International Hydropower Association (IHA), the Implementing Agreement on Hydropower Technologies and Programmes of the International Energy Agency (IEA/Hydro), the Canadian Hydropower Association (CHA) and the International Commission Large Dams (ICOLD), are world-wide organisations that are proponents of responsible hydropower development. Together they have nearly ninety years of experience in the planning and development of hydropower projects and many of the world's leading experts on environmental and social aspects are working on their technical committees.

This paper, compiled by the IHA and the IEA-HA presents their policy for the further development of hydropower as a reliable, clean source of electricity, capable of being operated in a sustainable way. There are distinct benefits to hydropower that call for its continued and increased use in a growing global society. The document is supported by ICOLD and the CHA.

The Global Energy Picture

The Energy Information Agency at the United States Department of Energy and the World Energy Council monitor global energy consumption on a regular basis. EIA's latest report, "International Energy Outlook 2000" includes a forecast that total energy consumption, world-wide, from all sources, will grow by 60 percent between 1997 and 2020. Consumption is expected to increase from 111,000 TWh/year to 178,000 TWh/year.

When the electricity share of total energy consumption is considered, the increase becomes even more dramatic. The International Energy Outlook 2000 forecasts that global consumption of electricity will be 76 percent higher in 2020 than in 1997. Consumption will increase from 12,000 TWh (1997) to 22,000 TWh (2020).

By the year 2050, the world population is expected to increase by 50 per cent, from 6 to 9 billion. Energy consumption per inhabitant per year is generally in correlation with the standard of living of the population, which is characteristic of welfare from an economic, social and cultural point of view. Today the less developed countries in the world, with 2.2 billion inhabitants, have an annual per capita consumption of primary energy which is 20 times less than those of the industrialised countries (with 1.3 billion inhabitants), and per capita electricity consumption which is 35 times less.

Whatever the precise numbers, it is clear that world energy consumption, and especially electricity consumption, will increase considerably during this century, not only because of the demographic pressure, but also because of the development in living standards in the less developed countries, which will represent 7 billion inhabitants by 2050 (78 per cent of world population).

The challenge is therefore clear: an inevitable increase in energy consumption in the world, with the risk of a major environmental impact, and climate change, as a result of the combustion of fossil fuels.

The right for development is a basic human right, and there is no possible development without energy supply. Few organizations would deny this.

In view of this situation, all available sources of energy will be necessary, but for environmental reasons, the first priority should be the development of all the technically, economically and environmentally feasible potential from clean, renewable energy sources, such as hydropower.

A study by the Utility Data Institute, USA, predicts that a world total of 695 GW of new electricity capacity will come on line in the next ten years from all sources, 22 per cent of which will be hydro, 26 per cent gas, and 27 per cent coal, with the remainder coming from a variety of sources.

The world's total technical feasible hydro potential is estimated at 14 370 TWh/year, of which about 8082 TWh/year is currently considered economically feasible for development. About 700 GW (or about 2600 TWh/year) is already in operation, with a further 108 GW under construction [*Hydropower & Dams, World Atlas and Industry Guide*, 2000]. Most of the remaining potential is in Africa, Asia and Latin America:

	Technically feasible potential:	Economically feasible potential:
Africa	1750 TWh/year	1000 TWh/year
Asia	6800 TWh/year	3600 TWh/year
North + Central America	1660 TWh/year	1000 TWh/year
South America	2665 TWh/year	1600 TWh/year

At present hydropower supplies about 20 per cent of the world's electricity. Hydro supplies more than 50 per cent of national electricity in about 65 countries, more than 80 per cent in 32 countries and almost all of the electricity in 13 countries.

A number of countries, such as China India, Iran and Turkey, are undertaking large-scale hydro development programmes, and there are projects under construction in about 80 countries. According to the recent world surveys, conducted for the World Atlas & Industry Guide, published annually by Hydropower & Dams, a number of countries see hydropower as the key to their future economic development: Examples are Sudan, Rwanda, Mali, Benin, Ghana, Liberia, Guinea, Myanmar, Bhutan, Cambodia, Armenia, Kyrgyzstan, Cuba, Costa Rica, and Guyana.

Benefits of Hydropower

Hydropower provides unique benefits, rarely found in other sources of energy. These benefits can be attributed to the electricity itself, or to side-benefits, often associated with reservoir development.

Despite the recent debates, few would disclaim that the net environmental benefits of hydropower are far superior to fossil-based generation. In 1997, for example, it has been calculated that hydropower saved GHG emissions equivalent to all the cars on the planet (in terms of avoided fossil fuel generation).

While development of all the remaining hydroelectric potential could not hope to cover total future world demand for electricity, implementation of even half of this potential could thus have enormous environmental benefits in terms of avoided generation by fossil fuels.

Carefully planned hydropower development can also make a vast contribution to improving living stands in the developing world (Asia, Africa, Latin America), where the greatest potential still exists. Approximately 2 billion people in rural areas of developing countries are still without an electricity supply.

As the most important of the clean, renewable energy options, hydropower is often one of a number of benefits of a multipurpose water resources development project. As hydro schemes are generally integrated within multipurpose development schemes, they can often help to subsidize other vital functions of a project. Typically, construction of a dam and its associated reservoir results in a number of benefits associated with human well-being, such as secure water supply, irrigation for food production and flood control, and societal benefits such as increased recreational opportunities, improved navigation, the development of fisheries, cottage industries, etc. This is not the case for any other source of energy.

Characteristics of Hydropower

- Its **resources are widely spread** around the world. Potential exists in about 150 countries, and about 70 per cent of the economically feasible potential remains to be developed. This is mostly in developing countries.
- It is a **proven and well advanced technology** (more than a century of experience), with modern powerplants providing the most efficient energy conversion process (> 90 per cent), which is also an important environmental benefit.
- The production of **peak load energy** from hydropower allows for the best use to be made of base load power from other less flexible electricity sources, notably wind and solar power. Its **fast response time** enables it to meet sudden fluctuations in demand.
- It has the **lowest operating costs and longest plant life** , compared with other large scale generating options. Once the initial investment has been made in the necessary civil works, **the plant life can be extended** economically by relatively cheap maintenance and the periodic replacement of electromechanical equipment (replacement of turbine runners, rewinding of generators, etc - in some cases the addition of new generating units). Typically a hydro plant in service for 40-50 years can have its operating life doubled.
- The 'fuel' (water) is **renewable**, and is not subject to fluctuations in market. Countries with ample reserves of fossil fuels, such as Iran and Venezuela, have opted for a large scale program of hydro development, recognizing environmental benefits. Hydro also represents energy independence for many countries.

Electrical System Benefits

Hydropower, as an energy supply, also provides unique benefits to an electrical system. First, when stored in large quantities in the reservoir behind a dam, it is immediately available for use when required. Second, the energy source can be rapidly adjusted to meet demand instantaneously. These benefits are part of a large family of benefits, known as ancillary services. They include:

- Spinning reserve - the ability to run at a zero load while synchronized to the electric system. When loads increase, additional power can be loaded rapidly into the system to meet demand. Hydropower can provide this service while not consuming additional fuel, thereby assuring minimal emissions.

- Non-spinning reserve - the ability to enter load into an electrical system from a source not on line. While other energy sources can also provide non-spinning reserve, hydropower's quick start capability is unparalleled, taking just a few minutes, compared with as much as 30 minutes for other turbines and hours for steam generation.

- Regulation and frequency response - the ability to meet moment-to-moment fluctuations in system power requirements. When a system is unable to respond properly to load changes its frequency changes, resulting not just in a loss of power, but potential damage to electrical equipment connected to the system, especially computer systems. Hydropower's fast response characteristic makes it especially valuable in providing regulation and frequency response.

- Voltage support - the ability to control reactive power, thereby assuring that power will flow from generation to load.

- Black start capability - the ability to start generation without an outside source of power. This service allows system operators to provide auxiliary power to more complex generation sources that could take hours or even days to restart. Systems having available hydroelectric generation are able to restore service more rapidly than those dependent solely on thermal generation.

Avoided emissions

Today 85 per cent of the primary energy consumption is fossil (coal, oil and gas) or traditional (wood), with associated large-scale emissions to the atmosphere of greenhouse gases: carbon dioxide from combustion, and methane from processing coal and natural gas. It is well recognised at the international level that this is leading to major climatic changes, and will therefore also have consequences on the hydrological system (and thus on water supply and agriculture, as well as the sea level).

Recent research in North America [Gagnon, 1999] confirms that the GHG emission factor for hydro plants in boreal ecosystems is typically 30 - 60 times less than factors for fossil fuel generation.

Studies have also shown that development of even half of the world's economically feasible hydropower potential could reduce GHG emissions by about 13 per cent, and the impact on avoided sulphur dioxide (SO2) emissions (the main cause of acid rain) and nitrous oxide emissions is even greater. Taking into account the fuel required to build hydropower stations, a coal-fired plant can emit 1000 times more SO2 than hydropower systems. The magnitude of the impact of particulate emissions from fossil fuel is now also becoming recognised, particularly in connection with respiratory disease, and a recent estimate of the environmental cost of this form of pollution is put at US$100-500/t/year [Oud, 1999].

Research is continuing on emissions; and it is recognised that more research is needed particularly regarding tropical reservoirs. A theoretical calculation has been done for the case of Tucurui in Brazil, including 'worst case' assumptions concerning the decomposition of flooded biomass (that 100 per cent of the biomass would decompose over 100 years, and that 20 per cent of biomass carbon would be emitted as methane) and even if this were the case the emission factor for Tucurui would be 213 g CO_2 equivalent per kWh, a factor five times lower than that for coal. In addition, the on-going upgrading of the Tucurui plant, with a near doubling of its capacity, without added flooding, will decrease significantly the GHG output per kWh of the plant.

As an example of pollution from fossil-fuel generation, in China, 23 million tons of SO_2 are discharged into the atmosphere each year by thermal power plants, causing 40 per cent of the total land area to be seriously affected by acid rain. The resulting damage to crops, forests, materials and human health was calculated, in 1995, to be more than US$ 13 billion.

In North America the consumption of coal is at the same level.

Comparing options

In comparison with hydropower, thermal plants take less time to design, obtain approval, build and recover investment. However, they have higher operating costs, typically shorter operating lives (about 25 years), are important sources of air, water and soil pollution and greenhouse gases, and provide fewer opportunities for economic spin-offs.

Other renewable sources of power (solar, wind, etc) are valuable options in addition to hydropower in specific contexts, but, even if major efforts were made to develop them, they will not be able to produce large amounts of energy in the coming decades, or offer the same level of service, as they are intermittent sources requiring back-up supply. In assessing life cycle costs hydropower consistently compares favourably with virtually all other forms of energy generation.

Social and environmental impacts of hydropower

Any infrastructure development inevitably involves a certain degree of change. The construction of a dam and power plant, along with the impounding of a reservoir, creates certain social and physical changes. Difficult ethical issues, such as ensuring the rights of nations to develop, and ensuring that the rights of people and communities affected by a project are respected, are also likely to arise.

The critical thing is to explore and anticipate all social and environmental impacts early in the planning process so appropriate steps can be taken to avoid, mitigate, or compensate for impacts. The following sections outline the main social and environmental concerns in relation to hydro projects, and give examples of steps which can be taken to address them.

Social aspects

As with other forms of economic activity, hydro projects can have both positive and negative social aspects. Social costs are mainly associated with transformation of land use in the project area, and displacement of people living in the reservoir area.

Relocating people from the reservoir area is, undoubtedly, the most challenging social aspect of hydropower, leading to significant concerns regarding local culture, religious beliefs, and effects associated with inundating burial sites. While there can never be a 100 percent satisfactory solution to involuntary resettlement, enormous progress has been made in the way the problem is handled. The countries in Asia an d Latin America where resettlement is a major issue have developed comprehensive strategies for compensation and support for people who are impacted. The keys to success are clearly: timely and continuous communications between developers and those affected; adequate compensation, support and long term contact; and efforts to ensure that the disruption of relocation is balanced by some direct benefits from the project.

An increasing number of examples (China, India, Brazil, and Ghana) are demonstrating that current strategies are proving successful, and in some cases are being promoted as models from which lessons can be learned for future projects.

Although displacement by hydropower can be significant and must be well handled, it should be kept in mind that other generating options can also cause significant resettlement: coal mining and processing and coal ash disposal, also displace communities. GHG-induced climate change may eventually cause massive population migrations, if sea levels rise.

Social effects of hydro schemes are variable and project specific. However, if anticipated and tackled early in the planning stage of a project with the required resources, the negative impacts can be addressed in a positive manner for local people, or in some cases avoided altogether. Whenever these impacts cannot be avoided or mitigated, compensation measures can be implemented.

During the construction phase of a hydro scheme (often several years) there may be a large workforce, and access roads can lead to a sudden influx of outside labour and the development of new economic activities, with resulting tensions if populations in the area in question are unprepared. Issues of resettlement, sustainable livelihoods, cultural impacts and flood control must be addressed. Effective mitigation measures can be implemented if local authorities and project promoters acknowledge and address these issues. On the positive side, the additional economic activities create new employment opportunities.

During the operational stage, the hydro project may represent a significant source of revenues for local communities. The access roads, local availability of electricity and other activities associated with the reservoir are all possible sources of sustainable economic and social development. It is clear there must be good co-operation between proponents, authorities, political leaders and communities, and long-term benefits must be directed to affected communities.

Socially acceptable hydropower means that any proposal for a project must be discussed with stakeholders and adapted to their needs, and that successful negotiations must be concluded with affected local communities for a project to move ahead.

From a social point of view, the relative success or failure of a hydro project is determined by integrating social considerations early into the project design.

Environmental Impacts

As mentioned earlier, hydropower has a long history, and lessons have been progressively learned. It is clear that many hydro plants in the world have environmental problems, but today the profession is well aware of the problems to be addressed, the expertise exists to mitigate the known impacts to achieve an acceptable balance, and research is continuing. Reservoirs can in fact focus attention on existing problems in a watershed.

It would be virtually impossible today for a hydro plant of significant size to move ahead without detailed studies on its potential impacts being conducted, and a comprehensive report of environmental impacts being prepared. (However, the framework, criteria and degree of public involvement will vary from country to country).

The IHA Working Group on Environmental Impact Assessment calls for impact assessment to be an integral part of the multidisciplinary planning approach, and to include a strong element of public consultation. EIAs should cover both positive and negative impacts both upstream and downstream of a proposed project.

Sedimentation

Sedimentation occurs when weathered rock, organic and chemical materials transported in a river system are trapped in a reservoir. Over time these sediments build up and begin to occupy a significant volume of the original storage capacity. In addition, since they are trapped, the soils cannot continue to refresh the river system downstream of the dam. The lack of these freshening soils often have adverse impacts to sustainable riparian vegetation, and to the continued use of lands for agriculture. It should be noted that there are potential positive aspect of sediment retention as pollutants are often retained in sediments, rather than being allowed to migrate downstream.

While large dams and reservoirs are often designed for an operating life of 100 years, there are cases where reservoirs have faced sedimentation problems within a much shorter time. Although a relatively small proportion of the total number of existing dams have a serious problem, many future large dams are likely to be in areas where sedimentation will be a problem, if not anticipated at the planning stage, with appropriate measures being taken.

It is considered imperative to assess as accurately as possible at the conceptual stage of a project the average annual sediment load entering a reservoir, or passing through a run-of-river project, so that appropriate measures can be taken. Efforts also have to be made to reduce erosion in the catchment area. Work is on-going in improving modelling techniques and monitoring systems.

A number of measures can be taken such as periodic flushing or dredging from reservoirs (successful flushing has been reported in many countries, and especially in China). In the case of run-of-river projects, flow diversion structures can be provided with sediment excluding devices [S. Alam, 1999].

Fish protection

Hydropower projects have impacted fish and fisheries in a number of ways. These include changes in habitat quality and availability, changes in flow regime (maintenance flows and ramping), and fish passage.

During initial construction and filling river habitat is undated and lost from production while reservoir habitat is created. The loss in river habitat may be important to the maintenance of associated fish resources. Compensation programs may be essential to maintaining fish populations.

Many hydroelectric facilities rely on storage of water during high flow periods for use in generation of energy later in the year. This alteration of the natural river cycle can impact habitat availability and stability during periods of spawning and incubation. Determining appropriate flows for maintenance of habitat during all life phases is an important step in defining bounds on operations. However, these limitations can be readily identified and implemented.

The long term operation of storage facilities can also influence the recruitment of nutrients, sediment and gravel into rivers downstream of reservoirs. The loss of this habitat affects river productivity; but can be offset by restoration programs.

As projects are usually designed and dimensioned to make optimum use of available water, a large proportion of the natural flow passes through the turbines and it is inevitable that quantities of fish will enter the generating flow, particularly at the time of natural migration. In areas supporting an anadromous fishery the problem is further complicated as the dams form a barrier to returning populations, diminishing the reproduction cycle.

Much research has been done on the specific risks to different sizes and species of fish. Measures commonly used include fish screens at turbine inlets, and many countries require this by law. Finer meshed screens can be placed at times of year when fish are actively migrating. Various types of self-cleaning screen have been developed to cope with the build-up of debris. Behavioural methods have also been developed to defer fish from the intake, and guide them to the safety of a bypass channel. These include: louvre screens (which generate turbulence), bubble curtains acoustic barriers, electrical fields, and underwater lights [Turnpenny, 1999]. In certain extreme cases fish are often mechanically transported around dams, allowing them access to their natural reproduction areas. Well-designed behavioural systems (eg, louvre screens or the latest acoustic screening techniques), can achieve better than 90 per cent exclusion for certain species. However, certain dams have proven to have significant impacts to native fish.

Knowledge from experimental studies about the mechanisms of fish damage in turbines has in recent years led the development of 'fish-friendly' turbines. (Pressure and velocity characteristics within a rotating turbine can be modelled and the probability of different risk conditions estimated).

Other concerns regarding fish result from a change in water quality in a reservoir and in the river downstream. Water emerging from a dam tends to be colder, and often has altered levels of dissolved gases, minerals and chemical content, different from those present prior to the dam. The result, in some cases, is the native fish cannot tolerate the new conditions and are forced to relocate, or suffer mortality losses. However, many reservoirs provide an excellent environment for fish which develop in the new, expanded aquatic ecosystems. In several situations game management agencies have stocked fish in and below the reservoir, with high recreational value.

Water Quality

Changes in water quality are potential outcomes from locating a dam in a river. Effects are often experienced both upstream and downstream of a dam. Some of the effects can be increased or decreased dissolved oxygen, increases in total dissolved gases, modified nutrient levels, thermal modification and heavy metal levels. Relatively few reservoirs have acute problems, and mitigation measures can be adopted if necessary. Examples are multi-level drawoff works so that better quality water near the surface can be used, and to induce mixing of the water body at lower levels, and oxygenation of the water by auto-venting turbines.

Longer term water quality problems generally reflect changing land use in the watershed. A recent study sponsored by the Environmental Protection Agency in the USA identified agricultural practices to be the source of the majority of incidents, with industrial and municipal waste treatment and discharges also being major contributors. In the developing world the lack of waste treatment in the watershed will contribute significantly to the future availability of potable drinking water.

The small versus large debate

Measures favouring emerging renewable technology and “green” energy often exclude ‘large’ hydro, since small projects are perceived as having lower impacts.

Research has been done on this subject by a number of organisations, and a paper was recently presented by a member of the IHA Working Group on Social Aspects [Égré, 1999].This paper points out that valid comparisons must compare impacts per unit of output. The impacts of a single large hydro project must be compared with the cumulative impacts of several small projects yielding the same power and level of service. For example, small projects generally require a greater total reservoir area than a single large project, to provide the same stored water volume. Nevertheless, small hydropower is a necessary and useful complement to the electricity generation mix, particularly in rural areas.

The most fundamental determinant of the nature and magnitude of impacts of hydropower projects are the specific site conditions and not the scale of the project. It is also important to optimize development with respect to the complete river system.

Potential Path Forward for Hydropower

In assessing future energy production, clearly policies gaining favour are those which emphasize sustainability and the maximum use of renewable energy to meet future needs. Consequently, we cannot afford to dismiss any form of renewable energy from the supply mix.

While we acknowledge that hydropower has significant positive and negative consequences for society and the environment, we also recognize that all forms of infrastructural development, and in particular energy development, have different degrees of impacts.

But the scientific community has recently recognized that the main threat to biodiversity and food production is global climate change. In this context, the issue is to what degree will society accept some local impacts of hydropower, in order to mitigate the global impacts of climate change and other environmental threats from thermal pollution.

The IEA/Hydropower Agreement has recently completed a comprehensive five-year study on Hydropower and the Environment. The study analysed virtually all environmental aspects of hydropower and offers a compelling list of recommendations which address the issues of hydropower development and offer reasonable solutions for future development. Included in the analysis were considerations of social, cultural and economic impacts, as well as impacts to the natural environment. In considering the potential ramifications of development, the authors propose that a disciplined approach to planning needs to be implemented in the consideration of both existing and future projects. Their approach must consider:

- The need for an Energy Policy Framework
- The requirement for a Decision Making Process
- A Comparison of Hydropower Project Alternatives
- Improving Environmental Management of Hydropower Plants
- The Sharing of Benefits with Local Communities

These recommendations, taken cumulatively, could form the basis of guidelines for the development and management of hydropower projects.

- The Need for an Energy Policy Framework - Nations should develop energy policies which clearly set out rational objectives regarding the development of all power generation options, including hydropower, other renewable sources, and conservation.

- A Decision Making Process - Stakeholders should establish an equitable, credible and effective environmental assessment process which considers the interests of people and the environment within a predictable and reasonable schedule. The process should focus on achieving the highest quality of decisions in a reasonable period of time.

- Comparison of Hydropower Alternatives - Project designers should apply environmental and social criteria when comparing project alternatives, to eliminate unacceptable alternatives early in the planning process.

- Improving Environmental Management of Hydropower Plants - Project design and operation should be optimized by ensuring the proper management of environmental and social issues throughout the project operation cycle.

- Sharing local Benefits with Local Communities - Local communities should benefit from a project, both in the short term and in the long term.

Together, these five categories of recommendations constitute a sustainable approach to renewable hydropower resource development.

Summary and Conclusions

As robust global economic expansion continues, the question of where a growing world population will continue to get the electricity to drive the economic engine remains. While most of the new generation supply will come from thermal resources, conventional thinking on the development of new resources and supplies should provide greater emphasis on using sustainable, renewable resources.

Hydroelectric power has an important role to play in the future, and provides considerable benefits to an integrated electric system. This paper has demonstrated an awareness within the industry of the social and environmental impacts of hydropower which need to be addressed for any project; the expertise which exists to avoid or mitigate negative impacts; and the ongoing research.

The world's remaining hydroelectric potential needs to be considered in the new energy mix, with planned projects taking into consideration social and environmental impacts, so that necessary mitigation and compensation measures can be taken. Clearly, the population affected by a project should enjoy a better quality of life as a result of the project.

Hydro development should go hand in hand with further research and development in the field of other renewable options such as solar and wind power. Energy conservation measures should also be optimized and encouraged.

Any development involves change and some degree of compromise, and it is a question of assessing benefits and impacts at an early enough stage, and in adequate detail, with the full involvement of those people affected, so that the right balance can be achieved.

Two billion people in developing countries have no reliable electricity supply, and especially in these countries for the foreseeable future, hydropower offers a renewable energy source on a realistic scale.

Impacts of hydro projects are well understood today. Appropriate mitigation and compensation measures must be identified and taken to ensure that any project represents a net gain for affected populations. Systems exist to provide improved planning processes and better quality decisions, and in turn these ensure that social and environmental concerns are integrated with issues of economic and technical feasibility. The hydropower industry must collaborate with interested stakeholders including regulatory bodies, global financial leaders, and competent interest groups, to develop future standards to ensure balanced and reasonable planning, construction and operation of hydroelectric powerplants.

Description of the Authoring Organizations

This paper was prepared by the following organizations who, collectively have over 75 years of experience all aspects of Hydropower Development.

International Hydropower Association:

The International Hydropower Association is a non-governmental, multi-disciplinary, professional association which was created, with the support of UNESCO, to advance knowledge on various aspects of hydropower and to promote best practice. Through its six Permanent Committees, it tackles technical, administrative, social, environmental and financial problems. It aims to increase awareness on the role which hydropower can play in sustainable development, as the most important source of renewable energy.

International Commission on Large Dams

The International Commission on Large Dams (ICOLD) is a non-governmental International Organization which provides a forum for the exchange of knowledge and experience in dam engineering. The Organization leads the profession in ensuring that dams are built safely, efficiently, economically, and without detrimental effects on the environment.

ICOLD was founded in 1928 and has National Committees from 80 countries with approximately 6,000 individual members, who are practising engineers, geologists and scientists from governmental and private organizations, consulting firms, universities, laboratories and construction companies.

Implementing Agreement on Hydropower Technologies and Programmes International Energy Agency

The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organization for Economic Cooperation and Developlent (OECD). The IEA headquarters are in Paris, France, and it carries out a comprehensive program of energy cooperation among twenty five of the OECD's thirty member countries. At its inception, the work of the IEA concentrated on issues related to oil, but since that time the Agency has broadened its work to include virtually all energy issues. An important objective of the IEA is to encourage the increased deployment of renewable energies, and to collaborate on research and development in this area.

Implementing Agreements are working groups of IEA members, which work under the auspices of the IEA, but do not formally represent the IEA in any way. Hence the views presented in the web-sites or reports of Implementing Agreements do not necessarily represent the views of the International Energy Agency, nor the governments represented therein.

Canadian Hydropower Association

Founded in 1998, the Canadian Hydropower Association (CHA) is the national trade association dedicated to representing the interests of the hydropower industry. Its members span the breadth of the industry and, with more than 30 corporate members, include the owners of most of the existing hydroelectric facilities in Canada as well as manufacturers, developers, engineering firms and individuals interested in the field of hydropower.

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