INTRODUCTION

A "remarkable feat in the history of mankind to reshape and exploit the resources" was how Chinese President Jiang Zemin described the closure of the Yangtze River in November 1997.[1]

Similar statements have been made by every major politician in developed and developing countries in the past 60 years. Scientists, economists, artists and naturalists have also been 'impressed and inspired' by the human endeavour to 'exploit' rivers to produce food and energy.[2]

Differing Viewpoints

Dam construction has raised concerns and sentiments in many countries (see, for example, comments on the Three Gorges Dam, Box 1). The greatest challenge now is to start a genuine and fruitful debate on finding the most suitable ways and means to meet energy needs, water requirements and food production, while conserving biodiversity. Dams have to be seen as a means to an end, rather than an end in themselves. The conservation of natural resources and an improvement in the quality of human life should be at the heart of this issue.

The issues and debates over large dams have not changed significantly since the 1940s and 1950s. What has changed is that dam construction has shifted geographically from developed to developing countries. Several developing countries that are now building similar, or even larger, dams than those in the west emphasise the same arguments of the benefits of dams.

> The large dam debate is highly polarized and has become an end in itself.

WWF, in principle, does not favour the construction of any new large dam as they all lead to environmental damage. In the past, WWF has expressed concern over many proposed dams – Gabcikovo and Hydrovia, for example. However, WWF opposition to dams has not always been voiced in the same manner, depending on WWF's capacity to deal with such issues and the perception of those working in the field. In addition, many considerations must be taken into account when taking a public position on a particular dam. To some extent this has given the impression that WWF's opposition to specific dam projects is not as strong as it should have been.

Although there is a general feeling that issues related to large dams have been debated extensively, most of the debate has been the reiteration of pre-determined positions and stances. As a result, no progress has been made regarding the debate itself, while dam construction continues. There are several reasons for this, including:

- Recent data on large dams is scarce. Prior to the publication of the *World Register of Dams* (ICOLD, 1998), most analyses were based on 10-year old data. Other sources give ample data on hydropower but little on dams *per se*.
- The organizations supporting and opposing dams have become polarized. Each camp essentially gathers data suitable for their pre-determined positions.[3]
- Recent opposition to dams is primarily, if not entirely, based on poor rehabilitation and resettlement of displaced people.
- The methods of opposing dam construction have further widened the gap, removing any scope

for genuine dialogue. Efforts to stop loans from the World Bank and other aid agencies for prominent projects have, for example, meant that some governments proceeded without external loans or did not even request support.[4]

- The debate has taken on a North-South structure. Countries in the South consider that they need more energy and that dams are a means to increase domestic energy production. On the other hand, the most vocal dam opponents come from the North, with supporters in the South.
- Opposition to dams has led some countries to opt for more environmentally harmful ways of producing electricity – coal fired thermal plants, for example.

Box 1. China's Three Gorges: Public Opinion or Western Perceptions?

I am just back from a trip to China.... I think of the little farms, the small temples, and the archaeological sites that will be lost forever and my sympathy goes out to the displaced people. Who knows what their new homes will be.

Barbara Madison
Cherry Hill, New Jersey

It is absurd to sacrifice unique species for the sake of more television sets and washing machines.

Raymond Watt
Albuquerque, New Mexico

Opponents of the Three Gorges Dam claim that the reservoir would lead, for example, to the destruction of the river dolphin habitat, thus endangering the species. But this unbridled habitat has flooded many times and killed hundreds of thousands of humans. The ideal solution would be to protect all life impacted by the river. But even if only one human is saved from the floods, wouldn't the Three Gorges project be considered a success?

Douglas Foran
Aloha, Oregon

The power the dam will generate will surely increase the quality of life for millions of Chinese. A hydroelectric dam is a good compromise between many different political and environmental concerns.

Moses A. Fridman
Cleveland, Ohio

How could a government initiate such a project without undertaking a full social and environmental impact assessment?

Stewart Green
Scottsville, South Africa

Source: "Forum", *National Geographic*, September 1997

Some progress has been made, such as in the operational and technological fields. Many countries have improved rehabilitation plans and environmental impact assessments. Governments and international organizations that promote dams have acknowledged that the impacts on local people and the environment are significant both in the short- and long-term. It has also been acknowledged that the benefits of dams were over-estimated. Similarly, both sides understand the need for more power (hydropower) for economic growth and social welfare.[5] Some interesting debate has emerged concerning the role of hydropower in reducing/increasing carbon dioxide emissions (see Chapter 2, Section 2.4).

In such a charged situation it is not only difficult to continue any useful debate, but also to obtain reliable and relevant data. Furthermore, it is difficult for conservation organizations to debate the issue as they are considered to be biased.

Dams and Large Dams

What's In A Number?

There is much confusion in the literature regarding the definition of large dams compared with other dams. In addition, there is considerable disparity in the figures commonly cited in reports.

For the purpose of this paper, a 'large dam' is considered as being an artificial barrier with a dam wall higher than 15m, a crest length over 500m and a reservoir capacity greater than 1,000,000m^{3}, built for the purpose of providing hydroelectricity, water for irrigation, domestic and/or industrial uses, or containment of flooding (see also Box 1.1).

There is no accepted figure of the number of dams worldwide. However most literature refers to the fact that the 'world's rivers are now obstructed by more than 40,000 large dams' (McCully, 1996). Additional figures are provided in Box 2.

The National Inventory of Dams (Army Corps of Engineers, 1995-1996) lists 75,187 dams in the USA (WRI, 1998). Others sources suggest that 'there are around 90,000 dams of any consequence in the USA'. China has around 86,852 dams, of which 84,228 are small. Again, however, estimates of size classifications vary even within a country: ICOLD lists 6,375 dams higher than 15m in the USA, while other estimates put the figure at 5,055.

Box 2. Dams: Some Comparisons

Worldwide, there are 41,413 dams higher than 15m. Individual descriptions for 25,410 of these are reported in the ICOLD (1998) register. Together these dams have a reservoir capacity of 6,703km^{3}, a water storage equivalent to about 70 lakes the size of Lake Geneva. Expressed in other terms, this is equivalent to 1m^{3} (1,000 litres) of water for each person in the world. There are, of course, considerable differences between countries: water stored in the USA, China, Switzerland, India, and Egypt is 2m^{3}, 1.4 m^{3}, 0.5 m^{3}, 0.3 m^{3}, 2.6 m^{3} per capita, respectively.

The total area occupied by dams listed by ICOLD is 384,138km m^{2}, an area roughly the size of Germany and Belgium together. The area covered by 6,375 dams in the USA alone 60,544km^{2}, 1.5 times the size of Switzerland.

While ICOLD does not publish data for every country, its 80 member states are among those which can be considered as having been the most important dam builders in the past: many are likely to remain in this position in future years. ICOLD's 1998 World Register of Dams noted that "the list is only partial (member countries reported 41,413 operational dams in 1996), and is not consistent between different countries". The first edition of the ICOLD register (1993) recorded details of just 102 dams. The 1998 register contains information on 25,410 dams higher than 15m.

Dams Worldwide

As might be expected, dams are not being constructed uniformly throughout the world. Five countries – the USA, India, China, Spain, and Japan – together have more than 5,000 dams higher than 30m, or about 60 per cent of the world's total of dams of this size. Europe, Asia and North America together have more than 88 per cent of the world's dams: the entire African continent has only 2 large dams (Fig. 1).

The 10 highest dams worldwide are listed in Table 1.1. Tajikistan and Switzerland have the distinction of having two dams each in this selection. All of these dams produce hydroelectricity and, together, have a reservoir capacity of 55 billion km^3. Reservoir capacity varies greatly even among the top 10 – obviously the capacity of the dam is not directly proportional to the height or length of the dam.

Table 1.1 The World's Highest Dams (ICOLD, 1998)

Dam	Country	Year Completed	Height above Foundation (m)	Length (m)	Reservoir Capacity (10^3 x m^3)	Purpose
Rogun	Tadjikistan	Not indicated	335	660	13,300,000	Hydropower
Nurek	Tadjikistan	1980	300	704	10,500,000	Irrigation & Hydropower
Grande Dixence	Switzerland	1961	285	695	401,000	Hydropower
Inguri	Georgia	1980	272	680	1,100,000	Hydropower & Irrigation
Vajont	Italy	1960	262	190	150,000	Hydropower
Manuel M. Torres	Mexico	1980	261	485	1,613,000	Hydropower
Tehri	India	Not indicated	261	610	3,540,000	Hydropower & irrigation
Alvaro Obregon	Mexico	1946	260 (raised in 1980)	88	13,000	Irrigation & water supply
Mauvoisin	Switzerland	1957	250 (raised in 1991)	520	211,500	Hydropower
Mica	Canada	1972	243	792	25,000,000	Hydropower

Twenty dams with the highest capacity of reservoir volume are listed in Table 1.2. Such dams generally have considerable impacts on the environment, both upstream and downstream, and at the regional and global levels.

Reasons for Building Dams

Most dams are constructed for irrigation and electricity generation. Worldwide, some 11,814 dams (48 per cent) have been built for irrigation, while 6,225 (20 per cent) are for hydroelectricity generation. In the USA, more than 2,552 dams are used for recreation and tourism. As with other features, there are regional variations in terms of their purpose. More than 40 per cent of Europe's dams are for electricity generation. Total global hydroelectricity production is about 2 million GWh: Canada, the USA, Brazil, China, Russia, and Japan together produce 66 per cent of the global production. Two countries – the USA and Canada – together account for more than 30 per cent of global production.

Dams are now increasingly being built to ensure domestic water and urban requirements. More than 5,000 dams are used worldwide for this purpose. Irrigation too remains an important activity associated with dams in many countries, in particular in India, China, and the USA.

Table 1.2 Dams with largest Capacity Reservoirs (ICOLD, 1998; Gleick, 1993)

Dam	Country	Year of Completion	Reservoir Volume (10^6 x m^3)
Kabira	Zambia/Zimbabwe	1959	180,600
Bratsk	Russia	1964	169,000
High Aswan Dam	Egypt	1970	162,000
Akosombo	Ghana	1965	150,000
Daniel Johnson	Canada	1968	141,851
Xinfeng	China	1960	138,960
Guri	Venezuela	1986	135,000
Bennett W.A.C	Canada	1967	74,300
Krasnoyarsk	Russia	1967	73,300
Zeya	Russia	1978	68,400
LG Deux Principal CD-00	Canada	1978	61,715
LG Trois Nord; Sud Barrage	Canada	1981	60,020
UST-ILIM	Russia	1977	59,300
Boguchany	Russia	1989	58,200
Kuibyshed	Russia	1955	58,000
Serra da Mesa	Brazil	1998	54,400
Caniapiscau Barrage KA-3	Canada	1981	53,790
Cahora Bassa	Mozambique	1974	52,000
Bukhtarma	Kazakhstan	1960	49,800
Tucuri	Brazil	1984	49,536

Do all Dams Damage the Environment?

All artificial water storage schemes interrupt the natural flow of a river and surrounding ecosystems, the extent of damage depending on the location and size of the scheme.

Recognition must be given to the fact that reservoirs can provide certain benefits: some of the world's most important wetlands – which include Ramsar and World Heritage Sites – were created as a result of a dam/reservoir being built.

Issues Addressed in this Discussion Paper

The main objective of this Discussion Paper is to provide up-to-date, accurate information to begin a constructive debate within WWF. It starts with a fundamental assumption – dams do damage the environment, contribute to the loss of biodiversity and disrupt human settlements. Certain aspects are not addressed (see Box 3) and the paper does not offer ready-made solutions about present and future energy problems. Instead, relying on existing documents and studies, the paper attempts to examine just how we might deal with dams that are currently being planned or built. A conscious effort is made to explore new dimensions and directions.

> Every dam, irrespective of its size, location and shape, obstructs the natural flow of rivers, and thus has an impacts on biodiversity.

Among the questions raised in the following chapters are:

- How have people's perceptions of dams changed with time?
- Is it possible to adopt a universal position on dams?
- What are the current 'dam scenarios' in various countries/regions?
- In which countries/regions is dam construction most likely to occur?
- Which course of action should WWF follow, keeping in mind the complexity of the debate as well as the organization's presence in various countries?
- How can WWF influence the newly created World Commission on Dams in advancing the debate, as well as initiating some positive measures to conserve the most important river ecosystems?

A number of factors, particularly the lack of reliable data, as well as the scope of the enquiry and resources available, make it difficult to answer all of these questions. Because of this, the following analysis is somewhat limited. The paper does, however, add several new dimensions to the debate such as a categorization of countries, identification of specific countries where future issues and challenges are likely to emerge, and an assessment of international mechanisms to deal with these issues. Conclusions include proposals for policy options, without making any preferences. This is a conscious attempt, as policy options must emerge from specific enquiries and discussions of local/national situations.

This Discussion Paper should be viewed as part of a process to develop a strategy for the WWF Network which will help deal with future issues related to dam construction. Conservation organizations like WWF must take the lead not only in analysing the situation, but also in shaping the agenda of the World Commission on Dams. This paper is expected to contribute positively towards that process.

The following steps have been taken to develop an appropriate strategy for the WWF Network:

- A draft of this paper was circulated for comments to people within and outside the WWF Network. Such contributions have helped mould the current paper.

- Three chapters have been added, which deal with aid and privatization, irrigation, and the African power sector.
- Much time was spent in reviewing and updating data.
- Based on the conclusions of the paper and recommendations made to the World Commission on Dams, a draft position statement has been developed.

Box 3. What This Discussion Paper Is Not About

- The paper does not support or oppose large dams. It starts from two fundamental premises: that dams have major environmental impacts; and that water is a medium to producing food and energy.
- It does not review the range of costs associated with large-scale dam projects. These have been extensively documented elsewhere.
- It does not provide a comprehensive and detailed analysis of irrigation dams. However, recognition is made of the fact that many dams, especially in the southern hemisphere, are built for irrigation purposes. In this respect, the paper suggests that the same analytical framework developed for hydropower dams can be applied to irrigation dams and that the analysis is commensurate with findings in the energy sector.
- The paper does not compare hydropower with nuclear or fossil fuels. It does not suggest what form of energy is most damaging for the environment and society. Nor does it argue in favour or against a specific energy strategy. The premise is that a number of countries do need to increase their energy use for economic and developmental goals.
- It does not give prescriptions or solutions to dam building. Considering that the World Commission on Dams is presently the only international platform addressing the large dams controversy, the paper suggests issues and matters to be explored by the Commission.

Conclusions

Debates on dams have largely centred on the number of these structures already built, or in the planning process. The number of dams, however, should not be an issue. Future debate and the search for solutions to protect the environment and respect people's rights will largely depend on specific issues such as a country's needs, rather than on numbers alone. It is important that issues are put into perspective: slightly more than 2 per cent of the dams reported in ICOLD's 1998 register are more than 100m high. Such dams are likely to cause most ecological damage and human disruption. Analysis indicates that most of these dams are constructed for hydropower generation. These dams could be further investigated with a view to identifying solutions that might be applied. This paper proposes a number of options which should help clarify key issues related to dams and their environmental dimensions.

Recent studies indicate that apart from size, the location of the dam site appears to be a crucial factor in determining the extent of damage. Future debate should focus on particular sites and the specific impacts on the environment and society. As a first step, the World Commission on Dams should prepare a list of existing and proposed dams which either have had or might have significant environmental impacts. Such information is a prerequisite to developing strict guidelines and procedures which need to be followed by all the countries involved in dam building. This Discussion Paper sets the scene for such a move forward.

PART I. LARGE DAMS AND THE ENVIRONMENT

Chapter 1

A NEW LOOK FOR DAMS

The World Commission on Dams was officially launched in Cape Town, South Africa, on 16 February 1998. The Commission is to carry out a two-year review of the effectiveness of large dams (see Box 1), and develop standards and guidelines to advise countries on future dam-building decisions, including an assessment of alternatives. Its report will be delivered in the year 2000.

Box 1.1 Defining 'Large Dams'

The International Commission on Large Dams (ICOLD) defines large dams as dams with a height of 15m or more from foundation to crest. Dams between 10 and 15m are also classified as 'large dams' if they meet the following requirements: crest length over 500m; spillway discharge over 2,000m^3 per second; reservoir capacity of more than 1,000,000m^3; 'specially difficult foundation problems'; or 'unusual design'. Using this classification, worldwide there are about 40,000 large dams and an estimated 800,000 small dams.

The International Journal on Hydropower and Dams uses the term 'major dam project' for projects that fulfil one or more of the following criteria: dam height of more than 150m; dam volume of more than 15,000,000$m^{3;}$ reservoir volume of at least 25 billion m^3; and installed capacity of more than 1,000MW. There are more than 300 dams of this category worldwide.

The 1998 World Register of Dams contains data on 25,410 dams. The first edition (1933) recorded just 102 dams. The new register contains national statistical tables for each of the 80 member countries and a table for all non-members (60). The list is still only partial (member countries reported 41,413 operational dams in 1996) and it is not consistent between different countries. The most important feature of the 1998 edition is the breakdown according to purpose, in addition to an analysis of dam types and worldwide construction trends. According to ICOLD, this provides insight into the actual role and utility of dams with respect to water management issues, in particular.

Sources: ICOLD (1998); Oud and Muir (1998)

The Commission's mandate is to:

- assess the experience with present and future large dam projects so as to improve existing practices, social and environmental conditions
- develop decision-making criteria, policy and regulatory frameworks to assess alternatives for energy and water resources development
- evaluate the development effectiveness of large dams

- develop and promote internationally acceptable standards for the planning, assessment, design, construction, operation and monitoring of large dam projects and, if dams are built, to ensure that affected people are better off
- identify implications for institutional policy and financial arrangements so that benefits, costs, and risks are equally shared at the global, national and local levels
- recommend interim modifications – where necessary – of existing policies and guidelines and the promotion of "best practices".

Establishment of the Commission, which was due to begin work in December 1997, was delayed as there was not enough 'confidence and consensus' among participants for work to begin. Some considered that the Commission's main objective was mitigation and reparation: "The Commission offers the potential for the first ever objective review of actual overall costs and benefits of large dam projects. It also offers an opportunity for recommendations on the issues of reparations to affected communities and the restoration of dam-impacted ecosystem."[6] Others emphasized the importance of the Commission as the opportunity "to establish a set of guidelines, standards, and criteria for future generation" acknowledging that it will have "to address the difficult trade-offs that affect the biodiversity value of ecosystems and the daily life of communities when decisions about water resources and energy development are made."[7]

The World Commission on Dams is an independent body with 11 commissioners.

The first meeting of the World Commission on Dams was held from 22-23 May in Washington, D.C. (see Box 1.2 for members). Discussions concentrated mainly on the functioning of the Commission, including guidelines for establishing a comprehensive work programme for the next two years. The principles guiding the Commission were established and agreed upon, as were the key results to be achieved during the Commission's mandate (Box 1.3). The overall budget was also reviewed and additional fundraising targets identified.

Box 1.2 Membership of the World Commission on Dams

Chairman Prof. K. Asmal, South Africa's Minister for Water and Forestry, announced in February 1997 that the Commission would include:

- Wolfgang Pircher of Austria, Honorary President of ICOLD.
- Shen Guoyi, Director General of the Department of International Cooperation, Ministry of Water Resources, China.
- Donald Blackmore, Chief Executive of the Murray-Darling Basin Commission, Australia.
- Judy Henderson, Chair of Oxfam International and board member of the Environmental Protection Agency of NSW, Australia.
- Laxmi Jain, former Chairman of the Industrial Development Services, India, and currently India High Commissioner to South Africa.
- Göran Lindhal, President and CEO of ABB Ltd.
- José Goldemberg, former Secretary of Environment in Brazil, now a professor at the University of Sao Paulo.
- Joji Carino, Executive Secretary of the International Alliance of Indigenous-Tribal Peoples of the Tropical Forests.
- Deborah Moore, Senior Scientist at the Environmental Defence Fund, USA.
- Medha Patkar, social scientist and Founder of Narmada Bachao Andolan, India.
- Thayer Scudder, Professor of Anthropology at the California Institute of Technology.

Sources: The International Journal on Hydropower and Dams; Environmental Defence Fund website: http//www.edf.org

The second meeting of the Commission, scheduled to take place in New Delhi from 19-21 September 1998, was cancelled. Time was to have been set aside during this meeting for the Commission to hear submissions from governments, the private sector, non-governmental organizations and the public on large dam issues in India. The Commission had to cancel planned hearings from displaced people from the Sardar Sarovar Project in Gujarat, following threats that members of the Commission would be arrested if they went to the site. As a result, and because of underlying pressure, the Government of India decided to stop the visit.[8]

Box 1.3 Principles and Key Result Areas of the World Commission on Dams

Guiding Principles

- The need to build consensus and take decisions based on the concept of sufficient consensus.
- The development of an effective and comprehensive communications strategy to ensure transparency and easy access to the Commission.
- The need to build a common knowledge base using available networks and links with different institutions.
- The confidentiality of the proceedings of the Commission to ensure openness between the Commissioners.

Three key result areas were identified:

- A global review of development effectiveness of dams.
- A framework of methodologies and tools for options assessment for the development of water and power-related services and institutional decision-making.
- A set of international criteria and guidelines to provide decision support for the sustainable management of river basin resources.

Source: World Commission on Dams web site: http://www.dams.org/update (June 1998).

The aborted visit of the World Commission on Dams to India emphasizes several principles that the Commission should follow if it is to succeed in its task. First, the Commission should focus on general policy guidelines and criteria, and avoid being involved in country and/or dam-specific projects. As an advisory body, it is imperative that the neutrality and legitimacy, as well as the representativeness, of the Commission is guaranteed and recognized in the work it undertakes. In addition, the Commission should not seek a universal solution to dam building. It is unlikely that a single strategy could be developed. Finally, to overcome the stalemate position that has dominated the large dams debate for so many years, the Commission should determine the most appropriate choices for dam-building (or not) in site- and country-specific conditions.

> The WCD is an unprecedented opportunity for meaningful debate in the context of sustainable development.

Chapter 2

LARGE DAMS AND THE ENVIRONMENT

2.1 Introduction

The environmental consequences of large-scale water schemes have been well documented. However, no consensus has been reached on the environmental benefits of large dams, nor on the magnitude and extent of the environmental costs of hydroelectric facilities. Some people believe that hydropower is a benign source of electricity generation. Compared to non-renewable sources of energy such as coal and oil, it is argued that hydropower is a clean source of power that produces no carbon dioxide, sulphur dioxide, nitrous oxides or other air emissions. In addition, no solid or liquid wastes are produced. Others have concluded that new large dam projects may be "arguably the worst electricity option in terms of damage to ecosystems per unit of electricity" (OECD, 1998). These, and related, issues are still being discussed. Recent studies for example suggest that emissions from large dam reservoirs may be a significant source of greenhouse gases (see Section 2.4).

This chapter outlines the main environmental impacts associated with large dams, considering that:

- interpretations of the environmental costs and benefits of large dams vary greatly
- effects on aquatic ecology are not well known
- the majority of dams were built in the past 50 years – some impacts may not yet be evident.

This chapter examines the effects of dams to the impoundment area and the downstream section of the river, in particular. Impacts on the upstream section are summarized in Box 2.3. Although the environmental impacts of dams can be broadly categorized (see Box 2.1), they vary considerably depending on the size of the dam, the characteristics of the reservoir, and site specificity such as topography, river flow, climate, ecology and land use. An attempt has been made to illustrate each of the following points with specific examples from different countries and regions. Additional information can be obtained from the studies cited.

Coverage of details should not be taken as comprehensive. As mentioned above, the objective of this Discussion Paper is not to review the range of environmental impacts associated with large dam projects. This has been extensively documented elsewhere, for example, Goldsmith and Hildyard (1984), Rich (1994), and McCully (1996).[9] Instead, this paper gives attention to what measures might be undertaken in the future.

2.2 Reservoirs

The physical construction of a reservoir (impoundment area), as well as the existence of a large body of water, affects the local environment. The most important impacts are outlined below.

Box 2.1 Impacts of Large Dams on the Environment

Impacts due to the presence of a dam and reservoir:

1. Upstream from river valley to reservoir.
2. Changes in downstream morphology of river bed and banks, delta, estuary and coastline due to altered sediment load.
3. Changes in downstream water quality: effects on river temperature, nutrient load, dissolved gases, concentration of heavy metals and minerals.
4. Reduction of biodiversity due to the blocking of the movement of organisms and because of changes 1, 2 and 3.

Superimposed upon the above impacts may be impacts due to the pattern of dam operation:

1. Changes in downstream hydrology – change in total flows; change in seasonal timing of flows; short-term fluctuations in flows; and change in extreme high and low flows.
2. Changes in downstream morphology caused by altered flow pattern.
3. Changes in downstream water quality caused by altered flow pattern.
4. Reduction in riverine/riparian/floodplain habitat diversity, especially, because of elimination of floods.

Source: McCully, 1996.

2.2.1 Inundation and land losses

Large areas of forests and land, including agricultural lands, are flooded (Table 2.1). Such areas often include wetlands, which are important wildlife habitats, and low-lying floodplains which are often fertile crop lands. Flooding of forest land also means the loss of valuable timber and species diversity.[10]

Examples of where this phenomenon has been recorded include:

- the Balbina Dam, Brazil, flooded an area of 2,750km^2, equivalent in size to Rhode Island.
- in India, the Srisailam hydroelectric scheme near Hyderabad flooded 43,300ha of farmland which, until the dam was closed, had provided a livelihood for around 100,000 people.
- India has lost an estimated 479,000ha of forest land to various river valley projects between 1950 and 1975 (Goldsmith and Hildyard, 1984).

2.2.2 Chemical water quality[11]

The change in quality of a reservoir's water depends on the kind of retention practised, on the reservoir's soil, and on clearance policy in the reservoir, especially if the area flooded is large compared with the annual volume of water passed.

Hydropower can cause many effects on water quality, including:

- *Reduction in oxygen content and gas release (methane, sulphuretted hydrogen)(Goodland, 1990)*

Anaerobic decomposition of inundated vegetation consumes large amounts of oxygen and produces noxious gases that are toxic to aquatic life and harmful to machinery (Box 2.2).

- Slow water flow can lead to thermal stratification, with warm water on top and cold water underneath. Since the cold water is not exposed to the surface, it loses oxygen and becomes uninhabitable for fish.

Table 2.1 Hydropower Generated Per Hectare Inundated

Project and Country	Rated Capacity (Megawatts)*	Normal Area of Reservoir (hectares)*	Kilowatts per Hectare*
Pehuenche (Chile)	500	400	1,250
Guavio (Columbia)	1,600	1,500	1,067
Rio Grande II (Columbia)	324	1,100	295
Paulo Alfonso (Brazil)	1,299	7,520	173
Aguamilpa (Mexico)	960	12,000	80
Sayanskaya (USSR)	6,400	80,000	80
Churchill Falls (Canada)	5,225	66,500	79
Itaipu (Brazil and Paraguay)	10,500	135,000	77
Grand Coulee (United States)	2,025	32,400	63
Urra I (Columbia)	340	6,200	55
Jupia (Brazil)	1,400	33.300	42
Sao Simao (Brazil)	2,680	66,000	41
Tucurui (Brazil)	6,480	216,000	30
Ilha Solteira (Brazil)	3,200	120,000	27
Guri (Venezuela)	6,000	328,000	18
Paredao (Brazil)	40	2,300	17
Urra II (Colombia)	860	54,000	16
Carbora Bassa (Mozambique)	4,000	380,000	14
Three Gorges (PR China)	13,000	110,000	12
Furnas (Brazil)	120	135,000	9
Samuel (Brazil)	110	15,000	7
Aswan High Dam (Egypt)	2,100	40,000	5
Curua-una (Brazil)	40	8,600	5
Très Marias (Brazil)	400	105,200	4
Kariba (Zimbabwe & Zambia)	1,500	510,000	3
Sobradinho (Brazil)	900	450,000	2
Balbina (Brazil)	250	124,000	2
Akosombo (Ghana)	833	848,200	1
Brokopondo (Suriname	30	150,000	0.2

* Approximate data only.
Note: This table is indicative only since it does not reflect the value of the land inundated. Some of the 'land inundated' is river bed.
Source: Goodland, (1990).

Box 2.2 Eutrophication

The condition known as ‘eutrophication’ (from the Greek “*trephein*” to nourish) involves water and bottom sediments becoming enriched with nutrients to a point where the water quality deteriorates. Excess nutrients produces a bloom of plankton, algae and weed growth which, when they die and rot, use up the available oxygen at depth. Sulphuretted oxygen is formed and the water is unfit for domestic use.

Eutrophication was, until recently, a slow process affecting natural and man-made lakes. In the past few decades, more widespread use of fertilizers and detergents, and growing quantities of waste water, have accelerated this process.

Source: *Dam Projects and Environmental Success*, ICOLD , Bulletin 37, 1981.

- *Mercury contamination*
  Stones and soils contain naturally occurring mercury and other metals. When land is flooded, mercury dissolves in the water and passes into fish and other species. Cases have been recorded in the US, where people and animals have suffered from mercury poisoning as a result of having eaten such fish. This can result in brain damage, birth defects and other ailments.

- *Water retention (flow, volume)*
  Water falling over spillways can force air bubbles into the water: bubbles can be absorbed into fish tissue, ultimately killing the fish.

- *Water weeds*
  Stretches of stagnant waters can host disease-carrying organisms and promote the invasion of weeds and alien plants, such as the water hyacinth, at the cost of native species. The proliferation of water weeds affects water quality and can increase water loss (through evapotranspiration).

2.2.3 Sedimentation and erosion

The volume of natural silt transported by rivers is often underestimated by dam-builders. When a dam is constructed, silt collects behind the dam wall. If accumulated silt is not removed, this can reduce the reservoir area and interfere with turbines and other machinery. Human activities, which contribute to erosion rates in watershed areas, speed up the process of reservoir sedimentation.

Interruption of silt flow may also have an adverse impact on the environment. One of the consequences of the construction of the Akosombo hydroelectric dam, Ghana, was the cessation of sediment flow along the River Volta to the coast. As coastal silt is no longer being replaced, offshore currents result in severe land erosion, threatening villages, tourism and industry in Ghana and neighbouring Togo. This process could have devastating effects on Benin’s coastal oil wells (Bourke, 1987).

2.2.4 Shoreline erosion

Erosion of a reservoir’s banks depends on the shore exposure, wind velocity and duration, water-level fluctuations, vegetation, and water currents. Upstream erosion in the catchment area leads to sedimentation or land slips, which can impair storage. The erosion process may also damage buildings, roads and bridges (ICOLD, 1981; Goodland, 1990).

2.2.5 Fish production

Dams often block fish migrations, resulting in fisheries loss and reduced fish diversity.[12] New reservoirs can, however, provide significant freshwater fishery opportunities both for sport and commercial exploitation, but increased fish numbers may not last in the long-term (Goldsmith and Hildyard, 1984; McCully, 1996).

- Fisheries developed rapidly in Lake Nasser with an annual production of about 35,000 tonnes. Local factories have been constructed to support the fishing industry (Abu-Zeid and El-Shibini, 1997).
- Five years after Lake Kariba was created, 3,628 tonnes of fish were caught each year by some 2,000 fishermen. A few years later, however, landings dropped off dramatically (Goldsmith and Hildyard, 1984).[13]

2.2.6 Landslides

Landslides may occur in steep valleys due to the filling of the reservoir. During planning stages of the Clyde Dam project in New Zealand, it was noted that the stability of existing landslides would be affected by the dam's reservoir (ICOLD, 1993).

2.2.7 Dam breaking

The risk of a dam breaking should not be ignored. In earthquake prone areas, dam construction could be a risky venture for populated areas downstream. This is compounded by the fact that large and heavy reservoirs may put additional pressure on tectonic plates, provoking earthquakes in areas where this might not have been a serious problem (see Section 2.2.8).

- The great Johnstown flood in Pennsylvania was the result of a dam breaking: 2,000 people were killed.
- In northern India and Nepal, planned hydroelectric projects could create large reservoirs in a geographically unstable region. [14]

2.2.8 Seismic Activities

Earthquakes may be induced by the impoundment of large bodies of water, but this is often linked with the height of a reservoir and local seismo-tectonic conditions.

- In France, the Vouglans Dam was first filled from April 1968 to November 1969, and then partially emptied from December 1970 to March 1971. Thereafter it was rapidly filled, reaching maximum capacity in July 1971. On 21 July, an earthquake occurred, measuring 4.5 on the Richter scale, shortly followed by 20 other earthquakes epicentered 5km south-east of the reservoir. No earthquake had previously been registered in the region (Johansson et al, 1993).

2.2.9 Climate

Large reservoirs affect the local climate and may create new microclimates, for example, through fog formation and modified or increased rainfall patterns.

Box 2.3 Upstream Section

Dam construction also affects areas upstream of the impoundment area. Some of the most important upstream effects include:

- cultivation on marginal sites leading to soil erosion and sedimentation
- logging, usually unplanned and often illegal, which results in denudation, unsustainable resource exploitation and erosion
- poaching, i.e. unsustainable exploitation of wildlife
- removal of vegetation for cultivation, fuel collection and logging
- loss of wildlife and wildlife habitat, with impacts on endangered species and reduction of biological diversity
- negative impacts on aesthetic and scenic qualities of the area
- pollution from settlements and cultivation.

Source: Dixon et al, 1989.

2.3 Downstream Section

The downstream section of the watershed often suffers the biggest losses. The main impacts of a dam on the downstream section are outlined below.

2.3.1 Loss and damage to freshwater habitats and species

Habitats for fish that spawn in the river bottom, and for invertebrates such as insects, molluscs and crustaceans, are reduced or destroyed by intense flooding and depletion of river bed gravel. Reduced biodiversity and destruction of wildlife habitat are commonly associated with dams.

- Studies of the effects of dam construction on the Colorado, Niger and Volga rivers have revealed significant changes in fish species composition, often with an increase in predatory species, and a massive reduction in catches. For example, fish catches on the Missouri River dropped from 680 tonnes in 1894 to 122 tonnes in 1963. The decline of fisheries in the Nile, and sardine fisheries in the eastern Mediterranean have been attributed to lower silt and sediment inputs caused by dam construction (Maltby, 1986).
- In the USA, dams in the Pacific Northwest have blocked the migration of coho, chinook and sockeye salmon from the ocean to upstream breeding grounds. Fish ladders were built but their efficiency is controversial. Some argue that the salmon population in the Northwest is near extinction, having fallen from 16,000,000 to 300,000.
- According to the International River Network, changes in the physical habitat and hydrology of rivers are implicated in 93 per cent of freshwater fauna declines in North America.[15]
- In South America, 80 per cent of the hydroelectric potential is in rainforests. The Rosana Dam in Brazil destroyed one of the few remaining habitats of the black lion tamarin, a rare species of monkey.

2.3.2 Reduction in silt due to filters and the dam wall

Silt reduction aggravates the erosion process of downstream channels and river banks, undermining bridges and other riverbank structures. River bed deepening also lowers the ground water table along a river. Sediment trapping by reservoirs can have repercussions not only on the dammed rivers and coastal waters, but also on sea basins (Box 2.4).

Box 2.4 Unexpected Side-effects of the Iron Gates Dam

The Iron Gates Dam, built on River Danube some 1,000km from the Black Sea, has resulted in decreased dissolved silica from the Danube and a change in the character of primary production in the Black Sea. "Data reveal a reduction in the dissolved silicate load of the river by about two-thirds since dam construction in the 1970s. A concomitant decrease in wintertime dissolved silicate concentration by more than 60 per cent was observed in Central Black Sea surface waters". A consequence of these changes has been a shift in phytoplankton from siliceous to non-siliceous species.

In addition to modifying the food web structure, a dam may also influence water circulation within the sea. "If all the major rivers leading to the Black Sea were completely dammed, the decreased freshwater flux to the Black Sea could diminish the mixed freshwater layer, perhaps leading to a shoaling of deeper waters rich in hydrogen sulphide and possible environmental repercussions for the sea and its bordering countries."

Sources: Humborg *et al* (1997); Milliman (1997)

2.3.3 Changes in groundwater level

Following dam construction, groundwater levels may be raised or lowered in different areas, affecting water supply, agriculture and forest production. Lower levels of groundwater threaten vegetation and may disrupt supplies of fresh water in local wells.

2.3.4 Changes in flow and impact on downstream hydrology

Modification of natural flooding regimes due to water storage in dams can impair river and floodplain ecosystems dependent on seasonal flooding, including areas that may be important for fisheries or for traditional flood-recession agriculture (Box 2.5). In addition, the changes in land use patterns, if extensive, may affect the timing and magnitude of run-off, especially during major storms. Altered vegetative patterns may also influence dry season stream flow.

- In Zambia, the population of the Kafue lechwe, a small antelope, declined from 94,000 to 50,000 following construction of the Kafue Gorge Dam in 1972. Closure of the dam wall disrupted the river's flooding cycle on which the reproductive and migratory patterns of the lechwe are based (Maltby, 1986).

2.3.5 Waterlogging and salinity

Major irrigation works and extensive transmission channels contribute to increasing the process of salinisation, which seriously affects land fertility.[16] After soil erosion, waterlogging and the associated problem of salinity is the second major cause of land degradation (Goldsmith and Hildyard, 1984). In addition, it is very difficult and expensive to mitigate the problem of soil salinisation.

Box 2.5 Dam-building Activity and Ageing of Continental Run-off

Studies suggest that the total volume of water stored behind dams represents a 700 per cent increase in the standing stock of water, compared with natural river systems. “The apparent age of impounded river water in individual reservoirs ranges from less than one day to several years, with a global volume-weighted mean of nearly two years.”

The effects of reservoir storage can be observed on a river’s downstream hydrology. It is estimated that “the mouths of several large rivers show a reservoir-induced ageing of continental run-off that exceeds three months. Globally, the mean age of river water has likely tripled to well over one month.” The storage and ageing in continental run-off in large reservoirs can lead to significant changes in water balance, flow regime, sediment transport and re-oxygenation of surface water.

Source: C.J.Vörösmarty *et al (1997).*

2.4 New Environmental Concerns

Modern dams, particularly those with large capacity reservoirs, are known for various environmental concerns which are visible, measurable and qualifiable within a reasonable time frame. “Dams, irrigation systems and their associated engineering structures all bring about far-reaching – and often drastic – changes to the ecology and management of floodplains and other wetlands. They reduce or eliminate downstream flooding cycles; alter water chemistry, discharge and sediment behaviour, and block and interrupt the migration of fish. They also create bodies of open water with their own new ecological systems, different from the previous river system” (Maltby, 1986).

New environmental concerns are now being added to the list of impacts described above. Among these are greenhouse gas emissions from large dam reservoirs (Box 2.6), and the role of dams in the local and global rise of sea level (Box 2.7).

Box 2.6 Greenhouse Gas Production From Dam Reservoirs

Some estimates suggest that hydroelectric reservoirs may increase the flux of greenhouse gases to the atmosphere and that this may be significant compared with emissions by fossil-fuelled electricity generation. “Greenhouse gases (CO_2 and CH_4) are produced during bacterial decomposition of flooded peat and forest biomass. The amount emitted will be positively related to the area flooded. Early data from hydroelectric reservoirs in northern Canada support this hypothesis.”

Source: Rudd, J. *et al*. ‘Are Hydroelectric Reservoirs Significant Sources of Greenhouse Gases?’, in *Ambio,* Vol.22(4), June 1993, pp.246-248.

Reaction to such findings observed that “this conclusion [emissions from hydro plant being a significant source of greenhouse gases] does not apply to most hydroelectric projects for two reasons: first, the Freshwater Institute’s studies concerned flooded peatland and shallow reservoirs that are not typical of most hydro projects; and second, the Institute analysed a hydro project with a ratio of flooded area to energy production that is 6 to 10 times higher than typical projects in Canada.” They further conclude that using a typical project in northern Quebec as the basis for analysis, none of the studies dispute the considerable advantages of hydroelectricity regarding greenhouse gas emissions. Taking into account all components of energy systems, emissions of greenhouse gases from natural power plants are 24-26 times greater than emissions from hydroelectric plants.

Source: *Ambio,* Vol.22(8), December 1993, pp 568-570.

Box 2.7 Reservoir Sedimentation and Sea Level Rise

Dams trap huge quantities of sediments, leading a reduced capacity of the dam and an overall decline in expected benefits. It is now suggested that sedimentation also contributes to sea level rise and subsidence within coastal areas. “The effects of natural and accelerated subsidence, combined with a probable decreased influx of fluvial sediment, may accentuate greatly the rise of sea level in low-lying deltas over the next 100 years”.

For example, about one billion tonnes of sediments are transported annually by the Ganges-Brahmaputra river system passing through Bangladesh. Any reduction in such sediment load due to river diversion could contribute to a local rise in sea level from 19-209cm by the year 2050. The best case (19cm) will result in a 1 per cent loss of the country’ total land; in the worst case, 18 per cent of the land would be under water. Some estimates also suggest that both Egypt and Bangladesh could lose 26 to 34 per cent of current habitable land by the year 2100. “The additional loss of shoreline by erosion, loss of mangrove forests, and decreased agriculture and fisheries would exacerbate environmental and economic impacts.”

Source: Milliman, J.D. *et al*. ‘Environmental and Economic Implications of Rising Sea Level and Subsiding Deltas: The Nile and Bengal Examples’, in *Ambio,* Vol.18(6), 1989, pp.340-345.

2.5 Small Dams: An Alternative?

Unlike large dams, small hydro schemes are not perceived as being uneconomic and socially and environmentally destructive sources of energy. As Anil K.Malhotra, a Regional Energy Advisor in the Asia Infrastructure Unit of the World Bank's Asia Technical department comments: "Current hydropower used to generate hydropower can be economic at around 50MW. When projects are small scale, it is easier to secure financing for them; quicker execution is possible; and social and environmental dislocations may be more easily handled. Rather than constructing a single large project, developers may wish to consider building a portfolio of smaller projects in a country or across the region" (Hildyard, 1998).

Many consider that small dams have a potentially important role to play in any future sustainable energy strategy and that any proposed dam should be as small as possible. According to Nicholas Hildyard, "small hydro is proving a growth markets in many countries, not least as a result of regulatory changes which encourage independent power producers to sell electricity to the big power generation and distribution utilities."[17] Despite such enthusiasm, it is not clear that small hydro plants necessarily result in less environmental degradation and more electricity for local indigenous people (Box 2.8).

Box 2.8 Small Dams: Big Problems?

While small dams (less than 15m high) are generally preferred over large dams by the environmental community, experience of a micro-hydropower project in Laos suggests that this is not always the best option.

The Houay Chaloi dam is one of the Pilot Micro-Hydropower Projects included in the Mekong Committee Programme funded by the Japanese government. Built on a small stream, the dam is planned to provide electricity to small villages: a 6km transmission line runs from the power house to the district town. The dam cost US$550,000. Unfortunately a number of adverse effects have been identified on the environment and local populations. Fish migrations (more than 32 fish species usually migrate upstream at the beginning of the rainy season) have been interrupted, resulting in losses to local fisherfolk. In addition, project developers ignored local advice regarding rising water levels and the subsequent height of the dam: 'They only came to investigate in the dry season, so how could they know how high the water would rise?' As a result, the dam broke twice because of heavy rainfall and flooding. In addition, power from the project is only serving relatively well-off people, 'even though the lines pass right through the middle of the village on their way to the district centre'. As one local villager said: "The dam hasn't benefited us at all. It has only caused us problems, and wasted government's money. The people from Vientiane should have listened to us, but they didn't. The dam is going to wash away before long – just wait and see."

Source: 'Houay Chaloi Micro-Hydropower Project, Lao PDR: Dams as Aid at the Local Level', in *Watershed*, Vol.3(3), March-June 1998, pp.41-42.

PART II. HISTORY OF THE BIG DAM DEBATE: FROM SYMBOLS OF PROGRESS TO 'TEMPLES OF DOOM'[18]

Damming rivers is not a recent invention or practice: records of dams and their role in shaping economic and political systems can be traced back to the ancient civilizations of Sumeria, Babylonia, Egypt, Ceylon and Cambodia. The world's oldest dam is thought to be the Sadd-el-Kafra, or 'dam of the Pagans', built around the time of the first pyramids. The dam, 14m high and 113m long, was made of sand, gravel and rock and consisted of two separate walls with a 24m thick base. Its function was never fulfilled as it broke before construction was complete (McCully, 1996).

Dams had become popular around the Mediterranean basin by Roman times. They were first introduced into western Europe during the late Middle Ages. The first dam over 15m high was constructed in Great Britain in 1787. In the 19th century, additional large dams were built in Britain and the United States, but these earthen embankments were often unreliable.

The era of large dams started in the early 1900s, and increased swiftly after 1950. According to ICOLD, 11,000 dams were built between 1951 and 1982 – an average of 344 dams per year. Although this number fell to 260 dams a year in the early 1990s, the rate of dam construction has continued to increase in some countries. There are now about 40,000 large dams worldwide, almost 90 per cent of which were built after 1950 (Fig. 2). [19]

> The world's highest dam, Nurek, built in Tajikistan in 1980, is 300m high, as tall as the Eiffel tower.

Symbolizing modernity and scientific prowess, large dams were initially regarded as a way to promote economic and industrial development. Priority was given to technical and economic issues: environmental and social concerns received scant attention until the 1970s and 1980s. Since then, attempts have been made to address environmental and social concerns when planning hydroelectric projects.

The controversy over large dams is not, however, a product of the 1990s. The environmental impacts of dams have long been debated. The difference between past and present debates is that in former times, the international community and industrialized powers supported the development of a technology thought to be beneficial to their own, and other, countries. Today, such countries are much more cautious in their assessment of the overall benefits of large dam projects.

Another difference between past and ongoing debates is that in recent years attention has also focused on human rights issues with relation to dams, particularly issues of displacement and resettlement.

Chapter 3

THE EARLY STAGES OF DAM-BUILDING: ENVIRONMENT-RELATED ARGUMENTS FOR AND AGAINST DAMS

From the 1930s to the mid-1960s a concerted effort was made to increase the scale of hydroelectric generation – the prevailing view was one of optimism and faith in dams. If the ecological impacts of dams were debated, widespread opinion was that there were no viable and realistic alternatives to large-scale dam projects.

3.1 What Were The Motives Behind Large Dam Construction?

The motivating forces in the early stages of dam construction were technological, economic and emotional. Technological progress in concrete construction and electro-mechanical engineering allowed higher dams and bigger power stations to be built. Advances in turbine design, which permitted an increase in the range of developable head from 30m in 1900 to 240m by 1930, had a direct impact on the hydroelectric potential a country could exploit. Installed capacity in the United States grew from 2.5 gigawatts in 1890 to 10.4 gigawatts in 1930, with proportional increases in the rest of the industrialized world (Johansson et al, 1993).

Economics figured too, because dams played a vital role in ensuring future economic development (Box 3.1).

Finally, dams were viewed as status symbols reflecting a country's prestige and 'grandeur'. At the opening of the Nanga Canal in 1954, Indian Prime Minister Nehru, compared the Bhakra dam to a modern temple: "What a stupendous, magnificent work – a work which only that nation can take up which has faith and boldness!... It has become the symbol of a nation's will to march forward with strength, determination and courage..." (McCully, 1996). When Franklin D.Roosevelt dedicated the Hoover Dam six decades ago, he called it a "twentieth-century marvel".[20] The 221m high dam was a monument of national pride and a symbol of American ingenuity – "I came, I saw, and I was conquered", were the

Box 3.1 Main Economic Benefits of Dams

1. Cheap and abundant electricity generation.
2. Regulation of water courses and improved navigation facilities.
3. Development of industrialised cash crop agriculture .
4. Supply of water for domestic and industrial use.
5. Employment in construction and manufacturing.
6. Boost to tourism industry (recreation, aquatic sports).
7. Increased economic potential.
8. Increased revenue and living standards.

words of the President.
The first countries to rush into water development programmes were the United States, Canada, Japan and some European powers such as Italy, Germany, France, Switzerland, Norway and Sweden. In 1929, the US produced 37.038Twh/y of hydroelectricity, France 6.495Twh/y and Italy 9.97Twh/y, while world hydro production amounted to 111.3Twh/y. In 1950, world production rose to 331.8Twh/y, of which 44 per cent came from North America, 34 per cent from Europe, 3 per cent from Latin America and less than 1 per cent from Africa (see Table 3.1 and Fig. 3).

Table 3.1 World Hydroelectric Production 1929, 1937 and 1950 (Twh/y)

	1929	% of 1929 world production	1937	% of 1937 world production	1950	% of 1950 world production
North America	50.8	45.6	72.1	40.6	145	43.7
Europe	43	38.6	65.1	36.7	112	33.7
Oceania	0.9	0.8	1.7	1	4.5	1.3
USSR and others	0.4	0.3	5.8	3.2	10.6	3.2
Africa	0.1	0.08	0.5	0.3	1.4	0.4
Latin America	2.2	1.9	5.2	2.9	10.5	3.1
Asia	13.9	12.4	26.9	15.1	47.8	14.4
Developed countries	**82.7**	**74.3**	**126.7**	**71.4**	**242.5**	**73**
Underdeveloped countries	**28.6**	**25.6**	**50.6**	**28.5**	**89.3**	**26.9**
World	**111.3**	100	**177.3**	100	**331.8**	100

Source: *World Energy Supplies in Selected Years 1929-1950*, UN Statistical Publications, 1952, Vol.1-7, p.32.

Technological and institutional breakthroughs in the United States played an important role in world hydropower development. The Hoover Dam and the Tennessee Valley Authority (TVA), established as a federal autonomous agency in 1933, introduced a new generation of high-rise dams and a new approach to river management based on the concept of a multi-purpose project.

The different functions of the TVA programme – navigation, flood control and hydropower – were planned with the aim of achieving integrated development of the entire river basin. Benefits of the TVA experience were discussed at the 1949 United Nations Scientific Conference on the Conservation and Utilization of Resources. Commenting on the process, one of the reports states that "electricity in greater abundance on the farms and in the homes and factories of the Tennessee Valley has helped to spark a great economic change. Per capita income in the Tennessee Valley, as one index of that change, is now 60 per cent of the national average compared with 40 per cent in 1933".[21]
Proceedings of the conference concluded that "The TVA has come to signify the idea of progressive change toward the improvement and better utilization of resources" (Cole, 1951). It is important to

note that the TVA not only represented a technological breakthrough – a system of 27 dams and reservoirs; a 580km navigation channel; and 16 billion kilowatt-hours/y of energy for a million consumers over a territory of

80,000 square miles — but also a conceptual one: the efficient application of engineering techniques to water management embodied in the notion of a multi-purpose project.

The TVA ushered in a new era of multi-purpose development which spread worldwide irrespective of a country's political system and ideology.[22] Diametrically opposed countries, like the communist USSR and capitalist USA, had similar views on hydropower, proving that large-dam building responded to the age-old and universal will of man to dominate nature, be it embodied in "the creation of capitalist wealth, the spreading of the fruits of socialism or the great march of communism" (McCully, 1996).

3.2 What Arguments Fuelled the Debate over Large Dams?

During the early years of dam-building, governments, conservation organizations and scientists backed the construction of large dams as a matter of national interest. The overall argument for dam construction seems to rely on the idea that hydropower favoured an efficient allocation of resources – either economic or natural. Since hydroelectricity increases a nation's productivity, some have argued that more financial resources could be devoted to the protection and conservation of natural resources. In other words, "conservation is easier in a rich country than in a poor country".[23]

> The debate on large dams is not new. Environmental issues were already well known in the 1930s.

Despite such views, it should not be concluded that the "evils of dams" were unknown.[24] Quotations below (Box 3.2) show that both opponents and proponents of dams seized the opportunity to firmly assert their position in various United Nations and IUPN (now IUCN — World Conservation Union) conferences on hydroelectricity and nature protection.

Participants at an IUPN technical meeting held in Caracas (1952) discussed the positive and negative aspects of hydropower projects at length (Table 3.2). The first objective of the discussion was 'to make a clearer evaluation of the actual effects produced in man's environment by enterprises which generate hydroelectricity.'[25] Three main adverse environmental effects were analysed during the meeting:

- by modifying the ecosystem's natural balance, dams have immediate impacts on environmental resources, such as loss of wildlife, interference with migratory flows, erosion from clearance of vegetation, road building and construction, and the loss of agricultural and timber resources
- large dams cause damage to the landscape and indirectly to tourism. Flooding can also destroy historic archaeological sites or unique caves (Steyermark, 1955)
- risk and more uncertain long-term factors may be associated with dam construction: breakage, earthquake and seismicity, proliferation of insects and diseases.

The second objective of the conference was 'to make concrete and constructive recommendations leading to an improvement of these effects on nature, an improvement in the sense of restoring or making the least possible alteration to the biological balance on the environment'.[26] Two approaches were suggested: greater cooperation between the actors involved in the project for coordinated planning and action; and the development of integrated programmes of management of land, water, forests and soil conservation. Participants hoped to "gear the high economic productivity of our hydropower and industrial operations to the rehabilitation and maintenance of the all important basic resources which underlie even industrial prosperity: namely, soil, forests, wildlife, and water."[27]

Table 3.2 Environment-related Arguments in the Early Stages of Dam Building

FOR	AGAINST
Aesthetic factor • Artificial lakes are beautiful: they improve the climate, suppress erosion and degradation of mountain basins • Hydroelectric works are truly decorative for the landscape: the trellises, generators, transmission wires, etc., comprise a decorative element	• The landscape is disfigured by hydroelectric equipment
Hydrological balance • Hydroelectric plants serve as regulating factors for the flow of streams and rivers and, therefore, as protection against floods	• Changes in flow and water quality • Concrete dangerously speeds up run-off • Lowering of the underground water level • Diversion of water into a different catchment
Soil characteristics • Maintenance of a reservoir leads to balanced plant cover: reforestation is possible which is beneficial to nature	• Flooded lands • Dried up lands (marshes) • Erosion
Fauna and floral balance • A dam can provide resting places for aquatic birds, breeding places upstream and downstream, and good fishing conditions • A reservoir's bank attracts mammals as well as birds	• Habitat destruction by submersion, damage to birds, fur-bearing animals • Congestion of fish downstream and danger of disease; problem of fish-passes • Progressive uprooting of river bank vegetation • Disappearance of species by habitat destruction

Source: *Procès-Verbaux et Rapports de la Réunion Technique tenue à Caracas du 3 au 9 septembre 1952,* IUPN, 1954.

3.3 Conclusions

Discussion on the virtues of large dams has been underway from the onset of world dam construction. The debate then, however, was not as intense and polarized as it is today – Chapters 4 and 5 explain why dams have become such a contentious subject – and opponents' claims were on the whole marginalized since the majority endorsed large dam projects. Not only did world dam construction proceed, but progress in dam technology and acceleration in the pace of dam-building in industrialized countries strongly influenced the development of hydropower in developing countries. For them, power, and in particular cheap power, was considered a *sine qua non* of development.

The 'big dam' debate also reflects the quantitative and qualitative evolution of dam construction. Prior to the 1960s, environment-related arguments focused on the physical and ecological impacts of dams, such as damage to fisheries, channel degradation and reservoir sedimentation (Petts, 1988). Although the problem of displaced people was mentioned, issues and concerns of resettlement were not yet a burning issue.[28]

Box 3.2 Hydroelectricity: For and Against

Mr. Enrique Perez Arbelaez, Colombia (1952)
'Hydroelectric enterprises have been invaluable factors in forming public opinions and developing action in favour of the conservation of protective forests, having stopped their destruction, prohibited uncontrolled fires, and encouraged the planting of native as well as foreign trees.'

Procès Verbaux et Rapports de la Réunion Technique tenue à Caracas du 3 au 9 sept.1952, IUPN, 1954, p.177.

UN Secretary General Mr. Trygve Lie
'Dramatic evidence of the interdependence of resources is given in such integrated developments as that of the Tennessee Valley Authority in the United States. I am happy to learn that the US government will give participants from other countries the opportunity to see TVA at work following the conference. Such programmes can bring beneficial results not only in terms of higher living standards but in their contributions to stability and peace. In my annual report to the General Assembly on the work of the Organisation, I have, for these reasons, suggested that high priority in the programme of technical assistance be given to the development of the valleys of the Tigris, the Euphrates and the Jordan and further development of the Valley of the Nile, as steps to the stability and peaceful economic and social progress on the whole middle east.'

IUPN General Assembly 1950

J.Bernard, President of IUPN (1952)
'A grave danger hangs over Switzerland in that both ideologists and international politicians are hoping to use its rugged configuration to turn the country into an immense hydroelectric plant furnishing high voltage current to all Europe, as an American programme of help to the Old World. Fortunately this bold plan encounters many difficulties in international law, for example, the problem of neutrality of Switzerland while furnishing electric current to possible belligerent countries, yet it is still being studied.'

Procès Verbaux et Rapports de la Réunion Technique tenue à Caracas du 3 au 9 sept.1952, IUPN, 1954, p.182.

J.A.Steyermark, Department of Botany, Chicago Natural History Museum (1955)
'Even though the scientific evidence against dam construction is very great, other major considerations – such as despoiling the natural scenery, flooding valuable farm land, ruining dwellings and established communities, spoiling natural fishing and spawning grounds, and creating unnatural conditions — make the construction of dams the most serious threat today to our greatest natural resource: water. If construction of dams can be prevented, it will not only save for all time the naturalness, scenic value and enjoyment by the public of the streams, but it will also preserve the countless millions of plants and animals, with their natural habitat...Thus we will preserve the natural heritage handed down to our civilization for our prosperity.'

'Hydro-Electricity and Nature Protection: Stating the Case', in *Pro Natura*,Vol.II, IUPN, 1955, p.184.

Chapter 4

GROWING OPPOSITION FROM 1970-1980: ASSESSING THE ENVIRONMENTAL AND SOCIAL COSTS OF DAMS

As operational and performance problems developed, conservation organizations, scientists and the general public began to question the extent to which the basic objectives of dams – cheap power and irrigation for agriculture – had been fulfilled, and whether expected project benefits outweighed financial, environmental and social costs (Box 4.1). In short, the benefits of dams were increasingly questioned.

Box 4.1 Do Dams Fulfil Their Promises?

According to proponents of large dam projects, the natural benefits outweigh any disruption. However, the technical, social and environmental problems associated with dams weaken this argument. Goldsmith and Hildyard (1986) provide examples of the kind of problems that large dams create.

Hoover Dam. Salinity in the soils downstream of the Hoover Dam on the Colorado River first became apparent in the 1950s. In 1961, Mexico formally complained to the US because water from the river was too salty to use. In 1969, the average level of salinity rose from 250 parts per million (ppm) to 655ppm. The US had to spend several hundred million dollars on a desalination plant: each increase of 1ppm salinity costs US$100,000 in remedial measures.

Aswan High Dam. Experts agree that this dam has led to a steady deterioration in the fertility of Egypt's soil — the Nile no longer deposits silt traditionally used as fertilizer by Egyptian farmers. In addition, the bed and banks of the dam are becoming eroded downstream of the dam; the coastline in the Nile delta is retreating; vast amounts of pesticides and fertilizers have killed fish; and the rising water table has weakened the foundations of many buildings.

Volta River Project. The main objective of the Volta River Dam was to produce electricity to manufacture aluminium. When started in 1962, the project was estimated to cost US$10 million: nine years later, the real costs amounted to US$34 million. The resettlement of 64,000 displaced people was poorly planned and transformed independent farmers into a dispossessed rural community entirely dependent on the state for food, shelter and work. By 1970, only 25,000 of the original 64,000 people remained in the new villages.

Source: *New Scientist*, 15.01.1987, No.1543, pp 37-42.

4.1 The Environmental Impacts of Dams

At the end of the 1960s, international conferences, reviews and reports emphasized the importance of considering the consequences of dams on the entire river watershed. Concern was expressed for immediate and long-term impacts – upstream and downstream. The first international conference on environmental impacts of large dams on downstream ecosystems was held in 1973.[29] This was followed in 1979 by a Symposium on Regulated Streams, held at Erie in the United States.[30]

Although impacts on the environment vary significantly depending on the characteristics of the dam and its location, several important factors can be identified (see Chapter 2). As soon as the dam reservoir is filled, agricultural land and forests are flooded and effectively lost for productive purposes (see Table 4.1 for areas inundated by dam closure).

Table 4.1 Area Inundated by Selected Dams

Project	Country	Normal area of reservoir (ha)
Paulo Alfonso	Brazil	7,520
Sayanskaya	USSR	80,000
Churchill Falls	Canada	66,500
Itaipu	Brazil/Paraguay	135,000
Grand Coules	USA	32,400
Jupia	Brazil	33,300
Sao Simso	Brazil	66,000
Tucurui	Brazil (ultimate area)	216,000
	(initial area)	216,000
Ilha Solteira	Brazil	120,000
Mazaruni	Guyana	39,000
	(projected ultimate area)	259,000
	(projected initial area)	328,000
Guri	Venezuela	2,300
Paredao	Brazil	380,000
Cabora Bassa	Mozambique	135,000
Furnas	Brazil	15,000
Kabalebo	Suriname (ultimate)	145,000
Aswan High	Egypt	400,000
Curua-una	Brazil	8,600
Très Marias	Brazil	105,200
Kariba	Zimbabwe/Zambia	510,000
Sobradinho	Brazil	450,000
Baibina	Brazil	124,000
Volta	Ghana	848,200
Brokopondo	Suriname	150,000

Source: Goldsmith and Hildyard (1984).

Goldsmith and Hildyard (1984) outline that "for the promoters of large-scale dams, the loss of forests is generally seen only in economic terms – that is, in terms of the market value of the timber submerged", the 'intangible ecological value of forests' are not considered.

Changes in a river's landscape also affect the ecosystem's flora and fauna. In the case of fisheries, even though some species are lost and migrations are eliminated by dam construction, it should be noted that fish catches might increase due to controlled reproduction in the reservoir.[31] If the environmental impacts of dams are not always harmful, conservation organizations nonetheless argue that the balance sheet is more often than not on the negative side. Apart from effects on river fisheries, downstream impacts of dams involve changes in groundwater levels and traditional floodplain cultivation, loss of silt, and an overall reduction in fertility due to erosion, salinisation and destruction of wildlife resources.

> Some 20 per cent of the world's 8,000 freshwater species are threatened with extinction because of changes in river hydrology.

4.2 Social Impacts of Large Dams

Poorly planned resettlement schemes in the 1970s led to increased awareness of the effects of dams on the well-being and health of people. Publication of *The Social and Environmental Effects of Large Dams* (Goldsmith and Hildyard, 1984) represented a critical step in increasing public awareness of the human consequences of dams.

Large artificial lakes created by a dam's reservoir and perennial irrigation schemes provide a habitat in which water borne diseases and parasites thrive.[32] Scientists are now convinced that the spread of schistosomiasis over the past 35 years is the result of large-scale water projects. The 1977 UN-sponsored conference on the environmental problems of irrigation concluded that "invasion by schistosomiasis of irrigation schemes in arid lands is so common that there is no need to give examples. The non-invasion of schemes in a region where the disease exists is exceptional".[33]

Despite the vast amount of literature on the impact of hydroelectric stations on human health, this remains a side issue in the assessment of a project's overall cost and benefit. Examining health-related aspects of dams, Goldsmith and Hildyard (1984) stated that "the truth is that the totally predictable increase in the incidence of malaria as a result of introducing irrigation into tropics and arid sub-tropics is considered an acceptable political price to pay for the political and economic gains to be made from the schemes. Foreign exchange must take priority over health".

Anthropological studies conducted by specialists like Elizabeth Colson and Thayer Scudder have provided a deeper understanding of involuntary resettlement and its impact on people. Their studies of the Tonga People suggest that relocated communities are often impoverished, economically and culturally, as a result of resettlement (Box 4.2).[34]

In general, opponents argue that the social costs of dams are either neglected or underestimated by governments and promoters, and most resettlement schemes fail due to:

- the industry's insensitivity to social and environmental aspects of hydroelectricity, and thus its lack of competence in dealing with these issues
- the lack of political will on the part of governments
- inappropriate compensation schemes, such as resettlement on inferior land, and poor housing and living conditions
- deliberate attempts to ignore ethnic and cultural differences.

Box 4.2 The Kariba Dam and the Tonga People

From 1957-1958, 57,000 Gwembe Tonga people were involuntarily resettled due to the construction of the Kariba Dam on the Zambezi River between Zambia and Zimbabwe. Resettlement exacerbated the problem of over-cultivation due to land shortage and population pressure. The result was erosion on a devastating scale. "Yet the measures which were proposed for dealing with the problem were ones which the authorities knew in advance would be unacceptable to the Tonga. Thus, attempts to stop the Tonga from cultivating the banks of the river tributaries, as they had done in the past, were singularly unsuccessful, not least because the soil on the river's edge was the most fertile available. Similarly, efforts to persuade the Tonga to practise regular crop rotation and manuring were stymied because they conflicted with traditional farming practices" (Goldsmith and Hildyard, 1984).

In his study of the Tonga people, Scudder argues that although their livelihoods improved initially, the Tonga people were relocated to an area infested by tsetse flies; the farmland they were given turned out to be poor; and relations with their new neighbours quickly worsened. The second generation was therefore worse off than the first.

Although it may be difficult to quantify the impacts of dams on human societies, it is nonetheless a genuine concern. Relocated communities are often impoverished, both economically and culturally, as a result of resettlement. However, resettlement necessitated by dam construction has often been emotionalized to the extent that, in many cases, it is unclear whether subsequent poverty and deprivation were caused by the dam; already existed before the construction of the dam; or have worsened or improved since the dam was built.

This Discussion Paper considers that the resettlement issue does not in itself constitute a valid argument against large dams. Many infrastructure projects and even conservation initiatives also involve the displacement of local communities.[35] Moreover, western notions of impoverishment and deprivation are not necessarily the same as those of project-affected people, especially in developing countries. At the individual level, dams may confer some important benefits. Li Chenling, a farmer now resettled in a city apartment because of the Three Gorges Dam project, told a journalist that what she appreciates most now is "tap water and an indoor toilet".[36] It is therefore important not to refute or belittle the real social and human costs of dams, but to emphasize that the problems of resettlement, like other controversial aspects of dam building, need to be assessed in a wider context.

4.3 Conclusions

It became increasingly clear in the 1970s and 1980s that the debate over large dams brought into opposition two camps that did not speak the same language, and had no intention of doing so.[37] Proponents adopted a technical-economic approach dominated by engineering, economic and financial priorities.[38] Following this logic, governments in developing countries perceived hydroelectricity as a critical supply of new electricity and a factor of economic development and prosperity. From the mid-1970s onwards, hydropower production rapidly increased in some countries, especially in Asia and Latin America (Fig. 4).

From 1975 to 1990, hydroelectric production tripled in Central and South America (from 117Twh/y to 353Twh/y). Although western Europe and North America remain the largest producer of hydroelectricity, power production increased at a much slower rate during this period (from 390Twh/y in 1975 to 466Twh/y in 1985 for Europe; and from 521 to 611Tw/y for the US over the same period).

Opponents to large dams have protested against the number of people evicted from their homes by World Bank-funded dams, arguing that the environmental and social costs of dams were deliberately kept "on the side". The strengthening of the anti-dam movement resulted in at least two important changes: increased public interest in large dam projects; and increased transparency and participation, which implied broadening the constituency of the design team and improving public consultation in resettlement schemes.[39]

Chapter 5

THE END OF THE BIG DAM ERA?

A HIGHLY POLITICAL DEBATE

If the construction of dams was initially considered as some sort of index of a nations' ability to use water resources for irrigation and power generation, dams have now become symbols of natural destruction, biodiversity loss and a source of human rights violations. Anti-dam movements and critics have succeeded in popularising the idea that large dams are harmful to the environment and people. Many people are now of the view that the dam-building era is coming to an end.[40]

5.1 What is the Current Situation?

Despite the polarity of the dam debate, there now seems to be a certain common understanding of the problems and challenges.

Bowing to domestic and international pressures, proponents have "corrected their language" and modified their positions, recognizing the need to examine socio-environmental impacts of dams and to plan for their mitigation (Box 5.1). Opponents have reached an understanding of the complexity of the types of effects induced by river impoundment and much has been published on this subject. Opponents estimate that the benefits of dams have been deliberately exaggerated and that their services could be provided by other, more efficient and sustainable, means (Box 5.2). To date, however, no viable alternatives have been proposed (see Section 6.5).

In 1995, the World Bank Group launched a review of 50 large dam projects in order to assess the degree of acceptability of projects funded by the World Bank since 1960.[41] This review, prepared by the institution's Independent Operations Evaluation Department was used as a starting point for the IUCN/World Bank workshop on the future of large dams held in April 1997 in Gland, Switzerland. The joint initiative by the World Bank and IUCN brought together leading experts and representatives of governments, the private sector, international financial institutions and civil society, to initiate an open and transparent dialogue.

> A recent initiative by IUCN and the World Bank has resulted in the establishment of an international body, the World Commission on Dams, whose mandate is to examine the social, economic and environmental impacts of dam construction.

The most important issues addressed by participants at this workshop were: critical advances needed in knowledge and practice; methodologies and approaches required to achieve these advances; and proposals for a follow-up process involving all stakeholders. Three areas were identified in which future work would be conducted to debate the role of large dams in sustainable development – social, environmental and economic/engineering issues.[42] A major conclusion of the workshop was to establish an international commission on dams to review the development effectiveness of large dams and to develop standards, criteria and guidelines to advise future decision-making (see Chapters 1 and 2). To this end, workshop participants established an Interim Working Group that held a series of preparatory meetings in the period preceding the official start of the Commission.

Box 5.1 The Revisited Discourse of the Pro-dam Lobby

ICOLD Position Paper on Dams and the Environment, May 1997
"But more and more we also recognize an urgent need to protect and conserve our natural environment as the endangered basis of all life. And there is also a social side to the comprehensive conception of environment: the people, their land and settlements, their economy and traditions. The impact of dams and reservoirs on this environment is inevitable and undeniable: land is flooded, people are resettled, the continuity of aquatic life along a river is interrupted, and its run-off modified and often reduced by diversions. In our never ending quest to provide a growing number of people with a better life, the need to develop natural resources, including water, means that the natural environment cannot be preserved completely unchanged. But great care must be taken to protect the environment from all avoidable harm or interference. We must cooperate conscientiously with nature's inherent fragility as well as its dynamism without overtaxing its powers of regeneration, its ability to adapt to a new but ecologically equivalent equilibrium. And we must ensure that the people directly affected by a dam project are better off."

World Bank, *OED Précis*, September 1996 [43]
"The Bank's guidelines now provide that any project-induced environmental degradation must be avoided, mitigated or offset as part of project design and implementation. It is too early to judge compliance with the new standards, but it appears that many problems identified by the OECD review are more prevalent in early projects than in recent ones… The changes introduced in the Bank's environmental and resettlement guidelines mark a significant shift in the Bank's threshold of acceptability of dams."

5.2 A Highly Political Debate

The past decades have been marked by an intense polarization of the Big Dam debate (Box 5.3). Following are some of the main reasons explaining why this issue remains so controversial:

1. **Population displacement.** "Involuntary resettlement is arguably the most serious issue of hydro-projects nowadays"[44] and the most difficult problem to solve. The lack of records and statistics makes it difficult to evaluate the number of displaced people.

   It is estimated that 30-60 million people have been displaced by dams, the majority of them in China and India. At present, some two million people are displaced every year. Protest and resistance from affected communities, environmentalists and human rights group resulted in:
   - temporary or permanent abandonment of certain large dam projects (Bakun Dam, Malaysia; Arun III Dam in Nepal) because of intense media coverage and powerful anti-dam campaigns (Sardar Sarovar campaign, Three Gorges campaign)
   - the Manibelli and Curitiba Declarations in 1994 and 1997, which called for a moratorium on World Bank funding [45]

- a shift in World Bank's policies regarding dam safety, involuntary resettlement and the environmental aspects of dams and reservoirs.[46]

Box 5.2 What the Critics of Dams Say

Patrick McCully *Silenced Rivers, the Ecology and Politics of Large Dams*, 1996.
"The extensive construction and operational problems of dams, the increasing requirements to pay for environmental and social mitigation measures, delays due to public opposition, and the fact that most of the best sites have already been dammed, combine to have a devastating impact on the economics of large dams".

"Proponents of dams have long boasted of the benefits of 'cheap hydroelectricity". Significantly, the phrase seemed to have dropped from the dam builders' vocabulary at the meeting in Frankfurt in September 1994. "Cheap hydroelectricity' is on its way to joining the nuclear power lobby's notorious claim that it could produce electricity 'too cheap to metre' as an ironic and rather quaint expression of the 1950s technological fantasy".

IRN, *Questions and Answers on the International Movement against Large Dams,* 1996.
"In nearly every case which has been studied, the majority of people evicted — usually poor farmers and indigenous people — are further impoverished economically and suffer cultural decline, high rates of sickness and death, and great psychological stress. In some cases people receive no or negligible compensation for their losses. Where compensation is given, cash payments are very rarely enough to compensate for the loss of land, home, jobs and businesses and replacement land for farmers is usually of poorer quality and smaller than the original holdings".

2. **Increased role of the private sector** (partly as a consequence of the above). Public funding, multilateral loans and aid for large dam projects have decreased as international lending agencies such as the World Bank become more reluctant to get involved in such sensitive projects.[47] The move from public funding to private investment raises a number of complex issues, which are further examined in Chapter 7.

Box 5.3 Dam Flashpoints

Bakun Dam, Rajang River, Malaysia
Since proposals began in the 1980s, deep public concern has been expressed about the social, economic and environmental aspects of this proposed scheme. The initial plan was to provide cheap electricity for industrial purposes. However, the project will involve the clearance of 69,640ha of forest for the reservoir. This would force 10,000 forest dwellers to leave their land. The proposal was revived in July 1993 but was again halted when the main contractor and shareholder opted out. The government took over the project on 24 November 1997 and, in June 1998, Malaysia's Industrial Development Minister confirmed that the revival of the project would depend on the economic situation. "But when the economy recovers, we may build Bakun on a smaller scale. This will depend on the Federal Government."

Biobío, Chile
ENDESA, the largest private company in Chile, is planning to construct six hydroelectric dams on the Biobío River. Environmental and indigenous rights groups oppose the project not only because it would damage forests, harm wildlife resources and displace more than 600 people, but also because projection of Chile's future energy requirements indicate that the energy it would produce is not needed.

The Epupa Dam, Cunene River, Namibia
The objective of the Epupa Hydroelectric Scheme is to provide Namibia with its own source of electricity. The project will flood 250 square miles of land inhabited by the Ovahimba people, a group of semi-nomadic pastoralists. Despite the existence of sizeable offshore gas fields which could generate more than enough energy for Namibia, the government still plans on building the scheme.

Nam Theun 2 Dam, Mekong River, Laos[48]
More than 100 dams are proposed to develop the Mekong River's hydroelectric potential: 60 are envisaged for Laos alone. The Nam Theun 2 Dam project was first formulated in the 1970s. Although the project was shelved due to monetary reasons and risk factors, it was recently revived. The Nam Theun 2 Dam will inundate part of the Nakai Plateau, an area of extensive biological diversity and displace an estimated 5,000 people.

Sardar Sarovar Project, Narmada River, India[49]
The decade-long struggle against the Sardar Sarovar Dam has become a worldwide symbol of opposition of destructive development projects. The dam and its associated irrigation canals would lead to the eviction of 320,000 people and deprive many more of their means of livelihood. Most of the affected people refuse to move and have succeeded in stalling work on the dam. Proponents claim that the dam will be the 'life line' for a huge drought-stricken area, and provide electricity and flood control. Opponents say the benefits are greatly exaggerated and the full costs concealed.

Three Gorges Dam, Yangtze River, China[50]
The Three Gorges dam, is a highly controversial project. The Chinese government boasts that the dam will have an installed electric capacity of 17,680MW to service eastern and central China. Strong citizen opposition and foreign critics are concerned about extensive environmental harm caused by the 600km lake that would inundate scenic gorges and displace 1.2 million people in towns and villages around the river. Opponents consider that similar benefits and fewer environmental problems would result from a series of smaller dams on tributaries of the Yangtze.

5.3 Positions of Developed and Developing Countries

While more attention is now being given to the adverse social and environmental effects of hydroelectric schemes, it is important to note that the consequences of such awareness is not the same in all cases. Indeed, for most OECD countries that have developed their hydro potential, implications are rather minimal since they are already energy self-sufficient. Nations still in the process of constructing dams, as well as those that have not yet started to exploit their potential face a different scenario (see Table 5.1).

Table 5.1 The World's Technically Exploitable Hydropower Potential and Existing Development by Region (1990)

Region	**A** Technically Exploitable Potential (Twh/year)	**B** Total Installed Capacity (Gw)	**C** Hydro Generation in 1988 (Twh)	**C/A** %
Africa	1,150	15,84	36	3
South Asia and the Middle East	2,280	45,44	171	8
China	1,920	32,69	109	6
Former Soviet Union	3,830	62.20	220	6
Japan	130	20.26	87	67
North America	970	129.09	536	55
South America	3,190	75.98	335	11
Central America	350	10.71	32	9
Eastern Europe	160	16.56	49	31
Western Europe	910	128.44	436	48
Australasia	200	12.00	37	19
World	**15,090**	**549.2**	**2,040**	**14**

Source: Johansson et al. (eds). *Renewable Energy: Sources for Fuels and Electricity*, chapter 2, table 3, p.77.

High disparities exist between industrialized countries, where hydropower is most intensely developed, and the former Soviet Union and developing countries whose annual technical exploitable potential is about 3,800Twh and 8,900Twh respectively. "Between 1992 and 1993 the OECD countries increased their hydroelectric production by 70,000 Gwh, more than the total produced by the entire African continent" (Gujja, 1996). Table 5.1 shows that 3 per cent of Africa's technically exploitable potential is in operation, while North America, Japan and western Europe have each developed 50 per cent or more of their potential.

Although it is difficult to predict the level of economic development of present industrialized countries if they had not developed their hydropower potential, the role of dams in building modern economies cannot be ignored. Countries with the most dams are also the richest ones. Such findings explain why the views and interests of developed and developing countries have departed considerably on the issue of hydroelectricity. In the absence of proven alternatives to address problems of water supply, food production and basic amenities, and because they have no choice, governments in developing countries are likely to continue to engage in large-scale hydroelectric projects.

The crux of the problem revolves around which strategies should be developed for future dam projects. Given the disparities between regions and countries, the analysis seems to suggest that the international community may have to consider several options and strategies, the main guiding principle being economic viability. In this context, "it is [...] paradoxical that as concern for long-term strategies is growing, little is known about hydroelectric potential. The issues involved simply have not received the attention they deserve perhaps because the scope for hydropower is limited in most industrialized nations" (Johansson *et al*, 1993). Parts III and IV of this Discussion Paper further analyse the present challenges and future developments of large-scale hydroelectric projects.

5.4 Conclusions

The main events surrounding the Big Dam debate are summarized in Box 5.4.

Box 5.4 Evolution of the Big Dam Debate over the Past 50 Years[51]

1950s: large dams are mainly regarded as a way to promote economic and industrial development. For nations, they are a symbol of progress and prestige.

1960s: conservationists question the need for large dams while scientists outline irreparable changes caused by river impoundment. The loss of fisheries, interference with migratory flows and reservoir sedimentation are of prime concern.

1970s: landscape damage by dams begins to attract public attention. In 1973, the first international symposium addressing downstream environmental impacts of dams is held in Madrid.

1980s: publication of *The Social and Environmental Effects of Large Dams* (Goldsmith and Hildyard, 1984), which reflects not only the growth of international awareness of the environmental impacts of dams but also an increasing concern in the social costs of dams, such as the spread of disease and resettlement of displaced people.

1990s: involuntary resettlement is the main reason for worldwide opposition. International development agencies, such as the World Bank, begin to change their attitude on dams. In line with the anti-dam lobby, many people in the northern hemisphere believe that dams are an evil construction and that the Big Dam era is over. Opposing this view, governments of the developing world still engage in large dam projects. For them, hydroelectricity is strategically important both now and for the future.

In 1994, the Commissioner of the US Bureau of Reclamation, once the world's leading dam-building agency, said "the dam-building era in the US is now over. We no longer can count on public or political support for dam construction projects. Our future lies with improving water management and environmental restoration activities".[52] It would have been unthinkable to hear such remarks 50 years ago.[53] The US now not only produces enough electricity, but also enjoys a surplus of electricity generating capacity. This means that even if it was to remove dams, as "dambuster" activists suggest, the US would not be threatened by energy shortages. [54] Not surprisingly, the US as well as many other industrialized powers are more cautious in their appraisal of dam-building activity in their own countries, especially as worldwide opposition is causing pressure on governments and international lending agencies to reduce support and cancel loans.

On the other side of the world, where 90 per cent of future population increases will occur, water availability and energy resources remain fundamental concerns. As a result, governments of developing countries such as Brazil, China and India are adopting a rather aggressive stance, considering hydroelectricity to be strategic for long-term economic growth and prosperity. Their drive to develop hydroelectricity generation should not be seen strictly in political-economic terms; there is also a genuine aspiration to reach internationally accepted standards of living. In short, these societies demand a better quality of life.

> Newport Number 11, on the Clyde River in Vermont, US, was the first dam to be removed for purely environmental reasons.

In 10-15 years time, some developing countries may have the same opinion as the Commissioner of the US Bureau of Reclamation. But the question will be "at what cost?"

PART III. PRESENT CHALLENGES OF DAM BUILDING

Over the years, controversies surrounding large dams have become more polarized, the benefits and problems of dams often being presented in an exaggerated and inaccurate manner (Box 3.1). One has the impression that the big dam debate has reached a dead-end from where it is difficult to see any scope for further development and progress. However, given the present challenges posed by rapid global population growth, increased demands for food, water and energy, and increases in pollution and global environmental degradation, the international community cannot remain silent on this subject.

The following actions must be taken into consideration for this debate to move forward:

1. Open up the big dam controversy to the international community, giving attention to economic, social, environmental and technological issues. This will involve an assessment of the role of hydroelectricity in expanding world electricity supply and meeting the world's energy needs, as well as evaluating the advantages and disadvantages of using dams for electricity, irrigation and water supply purposes. Hydroelectricity must not be considered as an end in itself but rather as a means to other ends, the main one being socio-economic development. Therefore, the debate should focus on how to reach such socio-economic goals given a specific country's resources and constraints.

2. Provide a comprehensive and realistic appraisal of hydroelectricity consumption and production patterns by countries and regions. Part II of this Discussion Paper has emphasized that countries have not exploited their hydropower potential to the same extent, and are not producing similar amounts of hydroelectricity. Such differences must be taken into account when determining a future strategy: issues surrounding large dams cannot be considered solely from a global standpoint.

3. Discuss alternatives to conventional sources of energy. Energy demands can be expected to rise in the coming decades. How will these be met? The energy debate is therefore not only a management question – assessment and projections of energy consumption and production over the next decades – but also a philosophical one: what should future energy trends look like? What are we prepared to do to ensure sustainable development for present and future generations?

4. Evaluate the long-term effects of not using some of the world's hydroelectric potential in order to protect riverine forests and other important floodplain wetlands. There is a need to examine rational plans for conservation and development and to conduct integrated management programmes of water, land, forest, soil and energy resources.

> There is a need to reconstitute the large dam debate according to the realities of the 1990s and early 21st century.

These points are analysed in the following chapters. Chapter 6 presents key issues of the global freshwater crisis (although this should not be viewed as comprehensive) and assesses how these can have an impact on current and future energy and hydroelectricity development. According to the World Energy Council, energy consumption will approximately double between 1990 and 2020, most of this increase occurring in developing countries. Per capita energy consumption in emerging markets remains far below the world average, with many households still without electricity. Even with the Asian economic crisis likely to slow the growth rate in energy consumption in that part of the world, the upward trend in energy demand is set.

In the present context of globalization and privatization, it is also relevant to consider the increasingly important role of the private sector in financing dams. If large dams have historically been supported by public funding and subsidies, financial constraints, performance problems and public opposition are now forcing countries to consider alternative institutional arrangements. Chapter 7 examines some of the questions raised by the trend towards greater private sector involvement and reflects on subsequent changes in the role of traditional stakeholders, such as public aid agencies and development banks.

Box 3.1 Interpreting Statistics

The paucity of reliable data on large dams is related more to inadequate data interpretation than availability of information. As far as the dam controversy is concerned, data gathering reflects and supports the pre-conceived ideas of dam proponents and critics. Data are often misinterpreted according to who is expressing their views on the subject.

Much of the data on dams and hydroelectricity is based on information from government departments which do not always conduct regular surveys and which use different criteria and calculation measures to process data. The technical hydro potential of Pakistan, for example, was estimated at 15,531Gwh/y and gross theoretical potential at 25,443Gwh/y. In reality, however, production in 1989 was 18,000Gwh/y, which increased to 21,388Gwh/y in 1993 and 25,858Gwh/y in 1996, implying that Pakistan was producing more hydro power than was available!

Resettlement data too varies enormously. Opponents to the Narmada project claim that over one million people will be displaced and that the government cannot find the land required for resettlement. Proponents of the dam argue that such figures are exaggerated and without basis: more than 6,100 families have apparently already been resettled and many farmers, including previously landless ones, were given land.

Some studies suggest that reservoirs may be a significant source of greenhouse gas. It is claimed that the Balbina dam in Brazil has “26 times more impact on global warming than emissions from an equivalent coal-fired power station”. Others argue that when all components of energy systems are taken into account, emissions from hydroelectric plants are 24-26 times less than those from natural gas power plants.

Sources: Ambio, Vol.22(8), December 1993, pp.568-570; *Ambio*, Vol.22(4), June 1993, pp.246-248; P.McCully (1996).

Chapter 6

Global Freshwater Issues

6.1. Introduction

Reference to the emerging global freshwater crisis cannot be avoided in a paper dealing with large dams and water management. Dams and aqueducts were, after all, first built in response to the uneven distribution of the Earth's freshwater resources.[55]

Pressure on freshwater resources is likely to increase in all countries, irrespective of their economic status, present consumption levels, and the availability of resources. The main reasons why such demands are likely to increase are:

- the need to produce more food
- increased hydropower generation
- increase in basic needs such as drinking water, as well as various human amenities
- increased domestic and international consumption of goods
- expansion of trade due to World Trade Organization regulations, promoting certain crops that require irrigation.

Other factors that will also contribute to a reduction in freshwater availability include pollution from the industrial sector, agricultural run-off, diversion of water for cities, and depletion of ground water resources.

In developing countries, where per capita water consumption is still relatively low, water stress will increase at a higher rate than in developed countries. Societies in the developing world are characterized not only by high population growth rates but also by a rural sector that is highly dependent on water availability for agricultural production.

Given current and future water problems, one should consider where dams are an appropriate solution to water management. Clearly, answers and opinions are bound to diverge, as the following remarks show.

At an international meeting of dam builders in Vienna, the ICOLD chairman declared that "80 nations face serious shortage of water; 1.2 billion people are without safe drinking water... the management of the world's water is the greatest challenge facing mankind in the decades ahead". Dams are "the key to our management of the life-giving waters of the rivers" and the means to defeat "nature's scourges... droughts, flood and epidemics". "They are essential to our way of life... many more have to be built".

To appreciate the other side of the argument, consider the comments of D.P. Beard, former Commissioner of the US Bureau of Reclamation, speaking at The International Dam Summit in Japan in 1996: "The time when large dam projects are a realistic answer to solving water problems is now behind us. The world is now moving toward a new era… Future water debates should not be about dams. In most cases, dams aren't going to be an acceptable approach. The debate should be about using other approaches to solve water problems".[56]

The purpose of this chapter is not to review the polemics about large dams but to situate the big dam debate within the context of the emerging global freshwater crisis.[57] Having defined the notion of 'water stress', Sections 6.3 and 6.4 examine the links between water resources, food production, and the demand and use of water and energy (note that Chapter 9 specifically deals with irrigation dams and food security issues). The role of water for human health, welfare and living standards will also be emphasized.

6.2 Is There a Water Stress?

Most of the debate on the global freshwater crisis revolves around the rapid increase in world population and shortages in freshwater availability. Yet, the emerging water crisis in many parts of the world is not due to a decline in resources as such. About 50 developing countries, particularly in Africa, use less than 1 per cent of their annual freshwater resources (Table 6.1).

Table 6.1 Global Freshwater Withdrawals (1994)

% of annual freshwater withdrawal	# of countries		Population (million)	
	Developing	Developed	Developing	Developed
Up to and including 1	39	2	806.1	7.8
1-2	6	4	207.8	46.7
2-5	15	3	302.4	32.8
5-7	8	0	58.4	0
7-10	3	2	149.4	20.6
10-15	4	1	54	9.9
15-20	7	4	2,251.3	501.9
Above 20	17	4	547.8	180.6
Above 50	4	2	95.5	15.5
Above 100*	2	1	32.6	2.4
Missing data	3	2	8.9	7.7

Compiled from the World Bank, UNDP Publications, 1994.

Per capita freshwater consumption in some of these countries is as low as 50m^3, compared with a world average of 645m^3 and 1,839m^3 in the USA (WRI, 1998). Not only do great disparities exist in the amounts of water used between different regions, but also between consumption and per capita water availability of a given country. This implies that:

- water problems do not necessarily reflect situations of water deficiency
- water scarcity in certain countries, especially in Africa, is more a management issue focusing on a governments' technical, financial and political ability (or inability) to deal with the problems at hand, rather than water sufficiency.

The international community has expressed concern over the fact that freshwater availability is finite,[58] while population growth will continuously increase water demands (Box 6.1). The debate on the freshwater crisis should not, however, be limited to such global issues. Attention should also focus on regional/local particularities and differences, the main point being that many developing countries have low water demands and that given their water availability potential, more water could be used to improve socio-economic development in these areas. The challenge for these countries is to find ways and means to increase freshwater use while conserving biodiversity. For this to happen, the future role of dams must be considered in achieving this goal.[59] On the other hand, developed countries with high per capita water consumption may have to consider reducing water use and removing some dams to restore free-flowing rivers (see Chapters 11 and 12).

Freshwater resources are limited and unevenly distributed.

Box 6.1 Water is Not a Luxury but a Fundamental Need

By the year 2025, the urban population will have reached five billion inhabitants. In the past, towns and cities were of a size compatible with nature's capacity to regenerate polluted water. But as urban areas are expected to increase by a factor of 12 between 1950 and 2025, this will no longer be possible. Ninety per cent of the future water market will be concentrated in towns and cities, and the volume of wastewater treatment will exceed that of drinking water treatment. But water companies continue to distinguish between needs and profitable markets, showing an interest only in industrialized countries, the newly industrialized countries of South-east Asia, and the modern sectors of South American cities. The handful of firms that actively work to meet the growing need for advanced technologies around the world face a colossal task.

Water needs in poor countries can be satisfied, provided that new distribution systems are developed in order to achieve a more equitable balance between, for example, residential areas, business districts and poor outlying urban districts. The poorest sectors of the population already have to spend a large share of their income on water supply. Appropriate technologies – simple and inexpensive solutions – can provide access to good quality water for everyone. Yet in order to meet the needs of the developing world and Central and East European countries, massive support is required by international funding organizations. To finance the enormous investment required to modernise or construct treatment stations, international public funding (already estimated at US$8 billion a year) must be succeeded by equally substantial injections of private capital.

6.3 Food Production and Freshwater Crisis

"*The need to increase food production to meet the expanding needs of population will put enormous pressure on natural resources*" (*Agenda 21*, 14.34).

The Green Revolution of the 20th century largely depended on expanding the availability and use of irrigation technology and water. Between 1950 and the end of the 1980s, the global irrigated area more than doubled, from 94 million hectares to over 230 million hectares. Present estimates of the world's total irrigated land range from 225-250 million hectares.

Today, two-thirds of the fresh water used worldwide goes to agriculture: more will be required in coming decades as populations increase (Box 6.2). However, the Food and Agriculture Organization (FAO) predicts that the growth rate of irrigated land in developing countries will slow down, from an annual increase of 2.2 per in the 1970s to 0.8 per cent.[60] The reasons for declining expansion of irrigated land are:

- increasing cost of irrigation (development and maintenance)
- low commodity prices and comparatively high energy prices (following the oil crisis of the 1970s)
- new pressure to transfer water away from agriculture to cities, and growing competition for water
- increased environmental damage from heavy irrigation and inadequate drainage
- global climate change.

Box 6.2 Irrigation

Irrigation is the prime user of fresh water. In 1800, the total area under irrigation worldwide was estimated at 8 million hectares. By 1900, 48 million hectares of land were under irrigation, while developments in the 20th century brought this to a total of 272 million hectares by 1990. It is expected to reach 347 million hectares by the year 2000.

Demand for irrigation water in 1990 represented 69 per cent of the global water demand, while industry and municipal water demand accounted for 27 per cent.

If global figures show a rapid increase, it should be noted that irrigation is not uniform throughout the world. About 60 per cent of the world's total irrigated land is in Asia, mostly in India and China, which account for one-third of the total irrigation area, or 100 million hectares. The US accounts for about 8 per cent, while Africa and South America have respectively 5 per cent and 4 per cent of the world's irrigated land.

And Food Production

Irrigation has helped increase food production in many parts of the world. According to the FAO (1990) irrigated land accounted for more than 50 per cent of the increase in global food production from the mid-1960s to the mid-1980s. Today, one-third of total production comes from 16 per cent of the world's cropland that is irrigated. China depends on irrigated land to produce 70 per cent of the grain for its huge population.

As the need for fresh water grows, the loss of irrigation capacity to salt and silt is becoming a serious global threat. The environmental impacts of irrigation, such as salinization and waterlogging, are not new. Irrigation water which has neither evaporated nor been used by plants has a higher salt concentration which can seriously reduce yields and ultimately render agricultural land useless.[61] "Salt has been the scourge of irrigated agriculture for

It is estimated that one-quarter of the world's irrigated land has been damaged by inadequate irrigation and drainage practices.

thousands of years. Its slow accumulation in fields and drains doomed the Mesopotamian civilizations, where land watered by the Tigris and Euphrates once fed 25 million people" (Pearce, 1987). Silt, like salt, undermines the efficiency of irrigation systems.

If global food production is to keep pace with population growth and reduce food security problems for many developing countries, agricultural efficiency and output must be increased. The possibility of expanding irrigated croplands is, however, declining, and it is costly to avoid or mitigate silt accretion and salt accumulation. Agricultural expansion and intensification is often associated with resource degradation and adverse environmental impacts. Minimizing the negative effects on resources and the environment, and guaranteeing agricultural sustainability is of particular importance for low-income countries where agriculture is the mainstay of the economy (see Chapter 9 for further analysis).

6.4 Water, Energy and Hydroelectricity

Fossil fuels (coal, oil and natural gas) are the main sources of energy, accounting for almost three-quarters of the world's primary energy consumption. Renewable energy sources (biomass, hydropower and geothermal) account for some 20 per cent of the total, and nuclear power 6 per cent (Fig. 5).[62]

According to the World Energy Council, energy consumption will almost double from 1990 to 2020, most of this increase occurring in developing countries. At present, energy consumption per capita in the emerging markets remains far below the world average.[63] "More than two-thirds of the world's people use little more than 20GJ per person per year (or 15 kilowatt hours a day), averaging about one-tenth the energy use in [OECD] countries."[64] In 1993, per capita energy consumption in Ethiopia was 1GJ, approximately 100 times less than that of Venezuela (100GJ). For the same year, US per capita energy consumption (317GJ) was 10 times that of Turkey (33GJ).[65]

Much of the developing world needs more energy. Higher levels of energy consumption and use through traditional expansion of fossil fuel combustion will lead to severe environmental problems, including enormous increases in consumptive use of water in regions where pressures on water availability already exist. At the same time, improvements in health, economic conditions and the overall quality of life require improved access to clean drinking water, sanitation services, and adequate electricity provision and energy supply.[66]

Key issues on water and energy include:

- the ways and means to find the best energy resource mix. If no single solution can meet society's energy needs, environmentally and economically sound energy policy options need to be determined on a country-by-country basis. This will probably involve some kind of ranking of renewable and non-renewable energy sources.
- energy conservation and efficiency measures. Even with biomass, wind, solar and other alternative forms of energy supply, more energy will be required (see Section 6.5). Determining the extent to which conservation and efficiency can be part of the solution calls into question not only energy consumption patterns in industrialized countries but also the possibility to apply conservation measures such as demand-side management to countries where energy demand is very low.[67] Once again, disparities between countries make it difficult to apply a universal formula. It is in this context that studies of the future role of hydropower as a safe and sustainable source of energy are

recommended.

Hydropower is the second most important source of electricity in the world, currently accounting for about 20 per cent of the world's generated electricity. Details of global electrical production are given in Table 6.2.

In 1986, world hydropower production was equal to 176.4 million tonnes of oil equivalent. In 1996, this increased to 218.1 million tonnes of oil equivalent.[68] Today, there is 634Gw of installed hydro capacity worldwide, generating about 2,460Twh/year. It is estimated that global production of energy from hydropower will grow from the present 2,460Twh/ year to 5,000TWh/y by 2020. This implies a growth rate of about 4 per cent, or half of that of the 1970s and 1980s.

Table 6.2 World Electricity Production, 1994

Power Source	Terawatt hours (Twh)	Per cent
Coal	4,778.7	37.7
Oil	1,194.7	9.4
Gas	1,991.1	15.7
Biomass	51.5	0.4
Nuclear	2,203.5	17.4
Hydro	2,402.5	18.9
Geothermal	49.0	0.4
Wind, solar	9.7	0.1
Total	1,2680.8	100.0

Source: *Renewable Energy Sources: Market Survey,* VTZ, 1997, p.11.

In order to appreciate what global hydropower data signify in both absolute and comparative terms, consider the following:

- hydroelectricity production in 1994 is the equivalent of burning annually 1,144x10^6 tonnes of coal (based on 1 tonne equals 2,100 kilowatt hours) which is roughly equal to Chinese coal production figures – 1,021x10^6 tonnes – in 1996 (based on 1 million tonnes of oil equals 1.5x10^6 tonnes of coal).

- in 1996, world hydroelectric production was 2,460Twh. Considering that a conventional coal-fired plant generates on average 1,000 tonnes CO_2 equivalent/Gwh (McCully, 1996), more than 2 billion tonnes of CO_2 would have been released into the atmosphere if this amount of electricity were produced by a coal-fired plant, which is about one-third of global annual CO_2 emissions.[69]

  The advantages of hydroelectricity regarding greenhouse gas emissions have recently been disputed.[70] McCully (1996) has suggested that the Balbina Dam is Brazil has "26 times more impact on global warming than the emissions from an equivalent coal-fired power station". According to McCully, 26,200 tonnes of CO_2 emanated from the dam's reservoir which produces on average 970Gwh/y of electricity. It was also concluded that the Tucurui Dam in Brazil had only 40 per cent less impact on global warming than a coal plant generating the same amount of electricity. Pearce (1996) argues that the amount of land flooded by large dam reservoirs – about 600,000 km^2 – would produce more than 400 million tonnes of CO_2 equivalent, or 7 per cent of total man-made emissions of CO_2 (based on an emission rate of 400-700g of CO_2 per square metre of a typical reservoir in northern Canada).[71]

- World Bank calculations show that solar energy could provide 3-5 times the current demand for electricity in all developing countries, on less area than is currently used by large hydroelectric plants (Jones, 1996).

6.5 Non-hydro Renewables

Documents and articles opposing dam construction often suggest a number of alternative sources of energy that countries could/should adopt to meet growing energy demands. Basically, they argue that the development of renewables such as solar, wind and biomass can avoid further dam building.[72]

This Discussion Paper considers that renewables can play a significant role in countries where more than basic energy needs have been met and where there is food and social security. The use of alternative energy sources does not appear to be a viable proposition for developing countries: "The harsh reality is that there is limited scope for a rapidly industrializing country to meet their energy needs through non-hydro renewable energies".[73] For many developing countries, these alternatives are just too expensive and inadequate given their present energy growth. The cost of photovoltaic electricity, for example, is a major obstacle: it costs US$4,000 to produce 1Kw of electricity with photovolatic cells, while the same amount of power can be produced with natural gas for US$700 (Flavin and Lenssen 1994). There remains much disagreement on the actual cost of renewables and the viability of these alternatives is often a subjective assessment.[74]

> Non-hydro renewables contribute to less than 2 per cent of global energy supplies.

It is also important to note that, despite long-debated arguments[75], renewable sources of energy have not yet taken off. As some suggest, "non-hydro renewables are positive contributions in many countries, but do not yet contribute substantially to any industrialized nation. For example, the share of wind energy is declining in the world's leaders, United States and Denmark".[76]

Whatever the reasons, non-hydro renewables have not yet replaced so-called traditional sources of energy.[77] In this respect, the challenge for anti-dam lobbies may be to undertake comprehensive studies at the national/local level to assess the viability of alternative sources of energy, including non-hydro renewables, taking economic, social and ecological conditions and constraints into account.

6.6 Conclusions

The analysis suggests that there are strong links between the growing freshwater crisis and pressure on land and energy resources. Where water is insufficient, agriculture fails and food insecurity ensues. Limitations on the availability of fresh water in certain regions may restrict the type and extent of energy development which, in turn, will limit the provision of adequate clean water and the development of sanitation services. Water management needs to be based on probable trends at global and local levels, such as population growth, urbanization, globalisation, evolution of technology and information, and environmental degradation.

A comparison of different sources of energy also shows that complex trade-offs exist between the costs and benefits of renewable and non-renewable energy sources. It appears that any option will have some kind of impact on the environment and that finding the best energy mix partly consists of choosing the 'least worse' option.

Dam development is clearly part of a much broader question of how to feed and supply energy to the world's swelling population, while respecting the environment. Questions to be raised include: can, and should, hydropower be part of the solution? If water is a medium to producing food and energy, can other media be used? What alternatives exist?

There is no single answer to these questions. Only by examining precise situations and local needs, through country and area-specific criteria, can we hope to arrive at a fair solution.

Chapter 7

AID AND THE PRIVATIZATION OF THE DAM-BUILDING INDUSTRY

7.1 Introduction

Large construction projects were previously financed almost exclusively by governments, with financial support from multilateral and bilateral aid agencies. Large dams were treated as a 'public good', serving the needs and interests of the nation. They were/are also an attractive destination for aid funds.[78] After World War II, the technology of dams was 'sold' to many developing countries as part of a development package. Most projects were commissioned by large public monopolies – neither subject to public scrutiny nor efficiency. If governments, development banks and donor agencies were omnipresent, private contractors were not absent from the scene. Northern-based private companies have long been responsible for the construction of hydropower schemes in the developing world, providing the necessary technological and technical know-how.

Donor funding restrictions started to be imposed on large infrastructure projects by the mid-1980s, either due to public image problems and/or to financial constraints. The World Bank, for example, funded 26 dams a year between 1970 and 1985, with annual lending at around US$2 billion (at 1993 rates); only 4 dams were supported a year in the 1990s.[79] In developing countries, the availability of public funding for infrastructure projects has been further reduced by restrictions on public expenditure imposed by the World Bank and the International Monetary Fund through structural adjustment programmes. Far from being restricted to dam building, this trend reflects a broader shift towards private sector financing of infrastructure projects within both developed and developing markets, as a result of the liberalization and globalization of economic policies. Since the early 1990s, private sector flows have overtaken public transfers as the driving force of economic change in Asia, Latin America and, to a lesser extent, Africa.[80]

> Private capital is now playing an increasingly central role in building dams.

The debate over large dams, particularly opposition from northern-based NGOs, made it difficult and at times impossible for developing countries to raise the necessary finances to build large dams. In several cases, agreed loans by international donors were cancelled and withdrawn.[81] To a certain extent, this benefited the dam-building industry in the north which needed to invest abroad to keep itself going: dam-building being more or less complete in industrialized countries, private companies have had to find sites in the developing world. From an environmental and social standpoint, withdrawal of public funding from multilateral agencies like the World Bank has often resulted in closing the discussion on such issues. Indeed, the role and responsibility of private investors in dealing with environmental and social concerns is not debated in many developing countries.

A final dimension of the privatization of dam building should be outlined. Due to international pressure on lending institutions and subsequent lack of public funding for large dams, many developing countries chose to develop an alternative energy source and are now relying on coal fired electricity production. Clearly, these countries have not adopted a more environmentally friendly way to produce energy. Despite the fact that these issues are important, this paper will not examine them further as it is not strictly within the scope of the present report.

Some suggest that private investors and developers are less prepared than governments to accept cost and time overruns, and to deal with public opposition. The prognosis is that private sector will invest in small and medium run-of-river hydro dams where risks are low.[82] Others maintain that hydropower schemes will only be built with some form of public support. 'Some even go as far as to say that private power will not build hydropower projects.'[83] Whatever the outcome, it is clear that the shift to private ownership and financing has not brought dam-building to a halt; and that some future dam projects will be privately-financed. In this respect, the question which needs to be asked is "what are the consequences of such a change for the environment and for local communities?"

The efforts to block public loans may not be a productive strategy in achieving the goals of stopping dam-building.

Far from judging whether privatization of dam construction is a good or bad thing, this chapter examines issues raised by this changing political, economic and financial landscape. The main questions to be addressed include:

- will the move from public to private funding result in better integration of social and environmental concerns?
- will the environment benefit from such changes?
- will resettlement issues be dealt with in a more participatory and open manner?
- will a privatized structure be more accountable than large public monopolies?
- what will/should be the role of governments, NGOs and development aid in the context of increased private sector financing?
- will governments be able to negotiate appropriate conditions and contracts, considering that some multinationals are far more politically and economically powerful than many developing countries?
- how will such changes affect dam construction in developing countries?

7.2 The Transition from Public to Private Development

The involvement of private sector financing is a relatively new phenomenon: it is difficult to foresee the likely consequences of this process (Box 7.1). However, debates and discussions should focus on the following issues:

1. There is a risk that the introduction of private capital leads to a focus on cost optimization, economic and financial viability at the expense of environmental and social concerns, resulting in the construction of destructive projects. On the other hand, privatization may put an end to poorly-planned and inefficient public work ventures where accountability is hard to define. Given the poor performance of some public-dominated hydropower projects, some suggests that private developers will have no choice but to take account of environmental concerns and local communities' needs.[84]

The extent to which private developers can be held accountable and responsible for the projects they finance is open to question. Further analysis is required on how the private sector values economic, environmental and social costs, whether private investors have short- or long-term horizons, and whether they will recognize the need for adequate mitigation measures and for monitoring environmental and social impacts.

Box 7.1 Consequences of Increased Privatization

- Emphasis on financial project efficiency, resulting in reduced availability of time and funds for planning, investigation and construction work, and also an emphasis on cost-cutting operation and maintenance procedure.
- Externalization of the indirect costs associated with the project to the maximum extent possible.
- Levying of water (or power) tariffs that guarantee an attractive financial internal rate of return on the investment, with these rates typically being higher than those projects financed conventionally in the past from grants and concessionary loans.
- Off-loading as much risk as possible onto other parties, particularly the government.

In short, the consequences of increased private sector financing are the drive to cut project costs, to shorten the duration of design and construction, and to reduce financial risks.

Source: Oud and Muir, 1997.

2. The role of various actors needs to be defined, for example, the public sector could be responsible for strategic planning and then hand over the project to the private sector for implementation. In this respect, Churchill (1997a, b) advocates a new model of public-private partnership, whereby the private sector agrees to undertake greater responsibility for project results, and the government agrees to treat electric power as a commercial business subject to the discipline of the market. How competition among the private and public sectors may affect choice of options, especially for developing countries, is also an issue to consider. Governments must evaluate the trade-offs of working with the private sector or development aid agencies.

3. Many believe that the future of privately-financed hydroelectric projects depends on government support in the form of guarantees. However, the outcome might be that private developers offload as much risk as possible onto other parties, particularly the host government.[85] Clearly, there is a need for adequate regulation and control in order to maintain environmental and safety standards, guarantee reasonable tariffs and government benefits, avoid government exposure to undue levels of financial risks and mitigate environmental and social risks.

   In this respect, one of the most important criteria is site selection. Not only does the dam site largely determine the amount of environmental and social damage from a specific hydroelectric project, but "the most effective environmental and social mitigation measure is good dam site selection" (Ledec et al, 1997).

7.3. The Politics of Aid

With the increasing influence of private capital in the hydro sector, the role of traditional financing sources is evolving. While this is true of bilateral and export credit agencies, it is particularly so for multilateral institutions.

Development banks such as the World Bank and Asian Development Bank no longer have sufficient funds to satisfy the goals of economic and social advancement. Direct concessionary loans will continue to be an important element, but new mechanisms and structures, including public/private partnerships, are emerging. As part of the World Bank's push for privatization, the International Finance Corporation (IFC), the private sector funding section of the World Bank, is increasing its investment in large dams. Although created in 1963, it was not until 1993 that the IFC began to fund large dams when it provided USD$216 million for the construction of dams in Chile and Belize, and transmission lines linked to the Yacyreta Dam. Unlike the public sector of the World Bank, the IFC often becomes a co-owner of the project it finances, as in the case of the Pangue Dam (Sklar and McCully, 1994).

The Theun Hinboun Dam in Laos, for example, was partially financed by the private sector as a 'build, own, operate and transfer', or 'BOOT' scheme.[86] Under such schemes, groups of investors agree to finance and construct a dam and then run it for 20-30 years, selling the electricity and taking their share of the revenue at an agreed rate. After the allotted time period, the agreement is renegotiated or management of the dam transferred to the national government. Theun Hiboun Dam, which is estimated to cost US$260 million, will be owned for 30 years by the Theun Hinboun Power Company, a joint venture comprising:

- Electricité du Laos, the State Utility, which has a 60 per cent share in the venture
- MDX Public Company, a Thai property company (20 per cent share) now diversifying into infrastructure investments
- Nordic Hydropower – also with a 20 per cent share – a consortium dominated by two dam-building state utilities, Norway's Statkraft and Sweden's Vattenfall.

Critics have highlighted the dubious benefits of BOOT private financing arrangements pointing out that projects may serve the interests of foreign contractors more than those of the local populations (Pahlman, 1996). Within the context of the Theun Hiboun Dam, a 1994 SIDA-financed review of the Lao energy sector warned that "massive inflow of foreign capital that would be required to finance the planned hydropower development may jeopardise the Lao PDR's possibilities to maintain a minimum of national control over basic natural resources and, indeed, over the general economic development of the country (DeVylder, S. and Sonnerup, B. 1994)."

> The politics of aid are clearly dominated by a range of interests, including foreign policy goals, trade imperatives, corporate interests, consultants, academics and NGOs.

The World Bank currently lends an average of US$1 billion per year for large dams: it is the most important single donor in this field.[87] Bilateral aid agencies also play an important role, providing loans and grants for dam projects through co-financing arrangements with the World Bank or regional development banks, as well as financing projects on a bilateral basis. While some emphasize that multilateral institutions are the least accountable of all aid institutions, being furthest removed from local realities both in donor and recipient countries, the close links between aid agencies, the dam industry and consultancy firms poses a number of questions as to the role of aid, including:

- who benefits from aid?
- to what extent does aid support sustainable development and poverty alleviation?
- is Overseas Development Assistance (ODA) big business?
- is the notion of aid fundamentally flawed?

It is important to emphasize at least three issues:

1. The link between aid and trade/market access is becoming increasingly blurred.
'Around a quarter of the US$60 billion in aid loans and grants provided by the major donor nations each year is estimated to be directly tied to the purchase of goods and services from donor countries.'[88] Aid is therefore 'tied-aid' (Box 7.2, 7.3).

2. The role of aid agencies as guarantors for private investors and corporate interests
There is a growing tension within the western aid establishment between professed environmental and social concerns and the imperative to support and subsidise national dam-building companies. As domestic market shrinks, aid money is used to subsidize northern construction and engineering companies to find new markets abroad, especially in the developing world (Box 7.4).

3. The relationship of 'rivalry' between different aid agencies
Government-supported export finance agencies (export-import banks and investment insurance agencies) play a critical role in privately financed projects in developing countries and the former Soviet Union. Not only do many of the agencies lack adequate environmental standards, but the absence of common environmental standards at the international level means that financing agencies may find themselves in competition. For example, in 1996, the US Export-Import Bank refused to fund China's Three Gorges Dam project, a project the World Bank also rejected largely out of concern for the environmental consequences of the dam as well as the project's risky financial viability. Later, however, Germany's Hermes Guarantee approved US$800 million of loan guarantees for the project. promises of loans from agencies in Japan and several European countries followed.[89]

Box 7.2 British Development Aid

Large sums of British development aid were spent on Sri Lanka's Victoria and Samanalawewa dams and Malaysia's Pergau project, despite objections on technical and economic grounds from ODA officials. The political decision to finance such projects rested on the prospect of substantive commercial advantages to British firms and on increased exports, rather than on benefits to local people. While ODA is officially supposed to decide how Britain's aid budget is spent, the latter is jointly administered by the Department of Trade and Industry and ODA, the purpose being to support "overseas aid projects of development value which are of particular industrial or commercial importance to the UK." As usual, aid is tied. Some also suggested that British involvement in Sri Lanka and Malaysia was part of a strategy to build and enhance the country's expertise and reputation as dam-builders. Poor geological assessment of the potential dam sites, subsequent operational and technical problems – leaks, risk of earth slippages – insufficient production of electricity, and high project costs, have tarnished the image of British civil engineering firms and brought British dam-building abroad to an end. As one local professor of Geography displaced by the construction of Victoria Dam (Box 7.3) said: “Little did the British tax payer know that their aid money has done more harm than good and created more ill-will than good-ill.”

Box 7.3 The Victoria Dam, Sri Lanka

Victoria Dam, once the jewel in the crown of British engineers’ in Sri Lanka, was the centrepiece of the Mahaweli Development Programme, which aimed to turn Sri Lanka into ‘the new Singapore’ by harnessing the country’s major river for irrigation and power. The dam, which was built in the late 1970s, was 130m high and 500m long. It was designed to provide 870 gigawatt-hours of electricity par year, equivalent to about 30 per cent of the country’s annual demand. Nearly 60 per cent of the cost of the Dam was met by British aid on conditions that British firms received the main contracts that amounted to UK£117 million.

The main problem with the construction of the dam was incorrect hydrological estimates or rather, ‘over-optimistic forecasts of how much water was available.’ Due to poor rainfall in the river’s upland catchment and two major droughts, the dam reservoir was low in 1987 and almost empty for much of 1991 and 1992. As a result, output was less than 500 gigawatt-hours in 1987 and 1991 while, on average, only 30 per cent of the planned hydro generation capacity were produced. Local specialists claim that matters are made worse by increasing leaks.

For many, the dam is a calamity. It flooded $28km^2$ of the productive and densely populated Dumbara Valley, displacing 30,000 people. Export crops such as cocoa, coffee, coconuts and rubber were grown in the valley, which was also the market garden for Kandy, Sri Lanka’s second city. According to Pearce (1994) “much of this loss can be attributed directly to British advice. Before Sri Lanka turned to the West for financing, its engineers had wanted to construct the Victoria Dam to provide irrigation for up to 40,000ha of new farmland, and only secondarily to generate electricity. But after 1977 the priorities changed and British engineers and aid officials advised Sri Lanka ministers, against the wishes of some local engineers to maximise the dam’s hydroelectric potential.”

Source: Pearce (1994).

7.4 Conclusions

The real purpose or driving force behind the principle of aid is ambiguous. While some official aid programmes do provide funds for economic and social development, it is often pointed out that aid is a vehicle for advancing specific economic and geopolitical interests. During the Cold War, aid was a key component of the politics of spheres of influence. The dispute over financing the Aswan Dam in Egypt, reflected the desire of various camps (the World Bank and the governments of the UK, USA and Russia) to strengthen their influence on the African continent (McCully, 1996). Today, aid is often ‘commercial aid’ and its role in supporting the commercial and export interests of private companies from donor countries cannot be denied.

In recent years, financing from official development assistance has been drying-up because of political pressures, performance problems and cost over-runs. Moreover, given the changes affecting most economies in the world – changing roles of government, infrastructure privatization, globalization – there is no doubt that private capital will play a major role in dam project development, management and operation. However, there is much uncertainty and confusion as to the exact consequences of such a trend. Will private dams be more environmentally-friendly and socially-acceptable than public-funded projects? How will risk factors – hydrologic, geologic and environmental – be allocated and assumed? Will large-scale projects be co-financed by private investors, governments and aid agencies?

Box 7.4 Dams as Aid: The Case of Nordic Aid Agencies

The relationship between Nordic dam building companies, consulting firms and Nordic aid agencies has been the subject of one study (Usher, 1997). Examining dams as 'aid phenomena' within the context of Norwegian and Swedish ODA, the book attempts to explain the process of Nordic aid financing in three developing countries – Laos (Theun Hiboun Dam), Tanzania (Pangani Dam) and Chile (Pangue Dam). According to the author, these projects "highlight a pattern in the aid-financing of hydro-power projects linking donors, consultants and dam-building firms that exists with other bilateral and multilateral projects. But while the pattern is usually obscured by a bewildering number of countries, companies and institutions, many of which are highly secretive, the Nordic focus provides the opportunity to observe the process in a clearer, more transparent form."

The main conclusion of the book is that the environmental impact assessments carried out by Nordic aid agencies of the dams they finance are rigged. "There is a pressure to lend, a bureaucratic momentum, a bias in favour of projects which ensures that Swedish and Norwegian aid funds subsidise contracts on dams for Swedish and Norwegian companies". The negative impacts of hydropower projects are systematically down played and swept aside, a process described by the author as "the mechanism of pervasive appraisal optimism." If the outcome of such a process is clear, the actual mechanism by which projects are approved is very obscure. As one Swedish official said: "This is a long process linking so many different commercial and political actors. It's very hard to trace, even for us...It's very difficult to describe how this game is played."

Three principal actors can nonetheless be identified: the dam-building companies, aid agencies and consultancy firms. While it is clear that dam-building companies seek arrangements with bilateral aid agencies, who offer money towards contracts, the relationship between consultancy firms and Nordic companies is an essential characteristic of the decision-making process. Consultants are at the heart of the issue since they write the assessments on which the donors base their decisions. Not only are many consultancy firms partially or entirely owned by Swedish or Norwegian utilities, but consultants are somewhat 'hidden' from public view. "The word expert seems to create a protective screen through which ordinary people – in the donor country and particularly at the recipient end – have little hope of penetrating". Consequently, it is not surprising that EIAs written for Nordic aid agencies tend overwhelmingly to favour the hydro projects that they are asked to review.

Source: Usher (1997).

The privatization of dam-building is modifying the role of the different players. Conservation organizations, which traditionally oppose loans and funds from international donor institutions, will have to deal with private companies responsible for the construction of new dams. Private developers will be confronted with issues of resettlement and compensation of displaced people that were usually left to governments and their respective power companies. Although public financiers may be withdrawing from the sector, dam construction will require the involvement of official development assistance in helping set internationally-accepted standards on when dams are appropriate investments, and how to plan, design, build and operate them (see Chapters 11 and 12). In this respect, the focus should be on 'good site selection', to ensure that the proposed dam will not have adverse environmental and social impacts in the first place (Ledec et al, 1997).

PART IV. CATEGORIZATION SCHEME

In the same way as the large dam issue is one of the standpoints from which environmental and socio-economic development should be addressed at the international level, dam-building cannot be disassociated from local situations and needs. Having looked at the larger dimension of dam-building, this paper now turns to a more detailed analysis.

The analysis of country-specific criteria does not challenge the assertion that large dams are, in general, bad for the environment. Although there may be some disagreement about the qualification and magnitude of the negative environmental effects of large-scale dam projects, there is enough evidence proving that dams do cause environmental damage. Realization of such adverse impacts, however, has not brought an end to dam-building. This suggests that:

1. Many developing countries are of the opinion that unless they too construct dams, their socio-economic and ecological well-being will not improve.[90] It should also be noted that these are the countries where major dam building is, or will be, taking place and where the big dam debate is most intense.

2. Mechanisms to induce countries not to construct dams may be inappropriate. Far from undermining the importance of the role played by international NGO campaigns and anti-dam movements, this proposition considers that it is necessary to examine why, despite such efforts and methods, dam construction is continuing, and why other instruments and strategies may need to be envisaged.

3. As long as there is no clear indication that by stopping public lending and loans for large dams respective countries are turning to more environmentally friendly ways to produce energy and manage water, existing mechanisms may not only be inappropriate but also counter-productive.[91]

The starting point of the analysis is that hydro potential has been unevenly developed around the world. While hydropower seems to decreasing in industrialized countries – since the most promising sites have been developed and/or excluded because of environmental and social concerns – dams are being built in many developing countries where most of the world's undeveloped hydro potential lies, in particular in South America and South Asia. Some countries have not yet started to build dams.

In light of such disparities, it seems not only impossible but also undesirable to adopt a universal stance on dams. The aim of this section is therefore to develop an alternative approach to the large dam issue, which is essentially an attempt to categorize countries based on the level of dam construction.

Chapter 8, which consists of an initial analysis of hydropower generation and development in different countries, suggests that present producers of hydropower can be classified into three categories. Although the categorisation scheme is by no means complete, different scenarios can be outlined.

Chapter 9 shows that the same analytical framework developed for hydropower dams can be applied to irrigation dams and that the analysis is commensurate with findings in the energy sector.

The outcome shows that it is very difficult to separate the national aspirations of many developing countries, both in terms of water management and power generation. It is also counter-productive to assume that these countries are embarking on dam-building with some sinister motives to displace people and damage the environment.

In arguing that every country should have an equal opportunity to develop its hydro power potential, this paper is not saying that countries should have equal opportunity to damage ecosystems. Therefore, there is a need to think about international mechanisms and institutions that can define and ensure compliance of each country's responsibility and duty to preserve certain ecological zones, and to address the following questions:

- what instruments exist to compensate for a country's energy needs if that country has to stop constructing dams in the larger interest of world heritage conservation?
- if the country has only one potential source of hydroelectricity, but such development would lead to the destruction of unique ecosystems, what should the obligation of that country be?
- is it possible to use a pricing mechanism to evaluate the opportunity cost of dams, taking into account discount rates, externalities such as CO_2 emissions, and short- and long-term factors?[92]

Chapter 8

DEVELOPED COUNTRIES AND DEVELOPING NATIONS

8.1 Introduction (1)

In elaborating the categorization scheme, the following is considered:

1. Consumption of hydroelectricity is not, and has not been, equal in every country or region. Although some countries began to produce hydroelectricity by constructing dams as early as the 1920s, others have not yet started (see Fig. 6).

2. Hydroelectricity is not based so much on national area, run-off, or the presence of rivers or mountains but largely depends on the economic, financial and technical ability of the country. For instance, Norway and Ethiopia have roughly the same exploitable hydro potential (171,400Gwh/y and 162,000Gwh/y, respectively) but annual hydropower production differs widely (112,676Gwh/y and 2,000Gwh/y in 1995).

3. Hydroelectric potential is not equally exploited. Each country/region finds itself at one of the following three stages:
   - development peak reached
   - development is in process
   - very low (almost insignificant) development.

As a result, three categories have been identified depending on a country's percentage of technically feasible hydropower potential that is developed:[93]

- Group 1 – countries that have developed more than 50 per cent of their potential
- Group 2 –10-50 per cent of their national potential developed
- Group 3 – less than 10 per cent of national potential developed.

(1) Before turning to data analysis, the following is an outline of the tables and graphs presented below. The first set of tables and graphs traces the evolution of hydroelectricity consumption and production over the past 50 years. These should be analyzed in conjunction with graphs presented above on world hydropower production (1970-1990) and consumption (1986-1996). (*Note: for reasons of consistency, production and consumption data were never mixed despite the relatively small amounts of hydroelectricity that is generally traded between nations.*)

The second set of tables and data aims to establish some correlation between hydroelectricity and economic development. Have the richest countries developed their hydro potential simply because they could afford it, or should one also consider the role of large dams in fostering industrial development?

These categories are by no means exhaustive and not all countries are listed in this schema. Instead, six countries have been selected as representative of each category. The percentage of technically feasible hydro potential developed is the main criterion used for classification. However, other indicators were taken into account, such as per capita electricity consumption, abundance of hydroelectric resources, and the percentage of electricity production by water power. On the basis of these criteria, it can be noted that:

1. Group 1 countries have a high percentage of hydropower potential developed. Per capita energy and electricity consumption is also high, which indicates that other sources of energy (nuclear, gas, etc.) have been developed. In general, Group 1 countries are 'rich' countries where basic energy and electricity needs are largely met. Some even have surplus electricity generating capacity. Canada, for instance, which has developed a relatively small part of its hydro potential compared to other Group 1 countries (mainly due to geographical reasons since much of the hydro potential located in the northern part of the country is likely to remain untapped because of financial and technical constraints) exports a significant part of its hydropower production – mainly from Quebec – to the USA. [94]

2. Hydroelectric production is increasing rapidly in Group 2 countries. Per capita energy use and electricity consumption is lower than in Group 1 countries. Group 2 countries not only produce less hydroelectricity in absolute terms but they also use less energy and electricity on a per capita basis. In addition, it is interesting to note that most large dams being constructed are in Group 2 countries.[95] If the number of dams is also an index of hydropower development, the relationship between the number of dams and hydropower production is more difficult to assess. For example, Norway has 330 registered large dams and an annual hydro production of 112,676 Gwh/y (1995). China, which generates about the same amount of hydroelectricity – 166, 800 Gwh/y in 1995 – has 1,855 registered dams. In addition Norway has developed more than 50 per cent of its hydro potential while China is currently exploiting about 9 per cent. In other cases, the number of dams erected may prove to be a useful indicator. For example, Romania technically belongs to Group 2 countries (40 per cent of hydro potential developed). However, due to the actual number of dams (some say that Romania has built 400 dams), Romania's dam-building policy/strategy should be along the lines of Group 1 countries. Like Romania, several other countries can be classified as 'border line' countries.

3. For the past 50 years, hydropower generation in Group 3 countries has remained low, although it has gradually increased. Per capita electricity consumption and energy use is also very low. In general, these countries have ample hydro resources and a large part of their electricity production comes from hydropower. This suggests both a dependence on hydropower as a source of electricity and the absence of alternative sources. In addition, many of these countries are home to important and unique species, as well as some of the last tropical forests. The challenge for these countries is to preserve their ecosystem's biodiversity whilst improving living standards (see Section 8.5).

Finally, it is important to emphasise that the categorization scheme is only indicative and that, like any generalization, it is limited. The essential point to retain is that countries cannot be put in the same basket. As a result, a single, universal approach to dam-building should not be adopted: different strategies and options are required.

8.2 Group 1 Countries: Development Peak Reached

Group 1 countries are those that have developed more than 50 per cent of their hydro potential. This category is not necessarily based on the quantity of hydropower generated. Six countries have been selected for discussion (Table 8.1): others include Austria, Australia, France, Finland, New Zealand, Germany, Portugal, Spain, and Sweden.

Group 1 countries are generally located in the northern hemisphere and are the so-called industrialized nations. These countries started to develop hydroelectricity at an early stage: for instance, the United States began to exploit its hydro resources at the turn of the century. In 1900, it produced 2,736Gwh/y of hydroelectricity (more than what Zimbabwe is currently producing) a figure that increased 10-fold in 1920 (20,311Gwh/y). Italy was amongst the first European countries to launch hydropower development schemes: in 1920, it produced 4,520Gwh/year of hydroelectricity. In the same year, Japanese hydroelectric generation amounted to 3,166Gwh/y (Etemad and Luciani, 1991). By the end of World War II, priority was given to hydropower development in all Group 1 countries, which explains why many reached 90 per cent of their 1996 hydro production level rather rapidly. In 1959, Italy produced more than 90 per cent of the amount of hydropower it used in 1995; the USA and Japan reached 90 per cent of their 1995 production level by the end of the 1960s-early 1970s.

After the development of hydropower reached a certain level (by the late 1970s, early 1980s), attention shifted to other energy resources such as nuclear power. In addition, as the best sites for dams have already been developed, the construction of new hydroelectric facilities gradually slowed down (see Fig. 7 showing flatter production curves in the 1980s and 1990s).

The six countries outlined in Table 8.1, which represent 8.5 per cent of the world's population, produced almost 37 per cent of world hydroelectricity in 1995. In comparison, countries in Group 2 produced almost 25 per cent of the world's hydroelectricity in 1995 and account for 44 per cent of the total population.

Table 8.1 Hydroelectric Production 1950-1995 (gigawatt-hours/year)

Group 1	1950	1960	1970	1980	1990 (a)	1995 (b)
Canada	46,624	105,883	156,709	253,072	296,919	330,690
Italy	21,605	46,106	41,300	47,511	35,079	41,425
Japan	37,784	58,481	80,089	92,092	95,835	91,301
Norway	17,705	30,914	57,260	83,962	121,382	112,676
Switzerland	10,318	18,826	29,330	33,513	30,982	35,597
USA	100,884	149,915	250,699	277,721	286,099	296,378

Source for 1950-1980 data: B. Etemad and J. Luciani, *World Energy Production 1800-1985*, Geneva, 1991.
(a) Source for 1990 data: *UN Energy Statistical Yearbook 1993*, UN Publications, New York.
(b) Source for 1995 data: *World Atlas and Industry Guide 1997*, The International Journal on Hydropower and Dams, IHA, UK.

The percentage of hydropower potential developed is generally very high. Switzerland has developed more than 85 per cent of its potential, Japan 68 per cent and Norway 65 per cent (Table 8.2). These numbers are even higher if the "economically feasible potential" is considered: for the US, it reaches 79 per cent, 96 per cent for Switzerland and almost 90 per cent for Japan.

Table 8.2. 1995 Data

Group 1	Technically feasible hydro potential *Gwh/y*	Installed capacity *Mw*	Hydropower production *Gwh*	% of world installed capacity	% of known exploitable potential developed
Canada	631,713	64,770	330,690	10.2	**52.3**
Italy	69,000	12,925	41,425	2.0	**60**
Japan	134,200	21,171	91,301	3.3	**68**
Norway	200,000 (a)	26,000	112,676	4.1	**56.3**
Switzerland	41,000	10,118	35,597	1.6	**86.8**
USA	528,500	74,856	296,378	11.8	**56.1**

Source: *World Atlas and Industry Guide 1997*, The International Journal on Hydropower and Dams, UK. World installed capacity in 1995 was 634,147Mw.
(a) data corresponds to economically feasible potential.

Norway, like Canada, has abundant hydropower resources. In 1995, 99 per cent of the country's electricity production came from hydropower, while hydro consumption represented 44 per cent of total primary energy consumption in 1996. Oil accounted for 52 per cent.

In Canada, hydro consumption accounted for 13.5 per cent of total primary energy consumption in 1996 after oil (35.5 per cent) and gas (29.5 per cent). Coal accounted for 10 per cent.[96]

Installed capacity in the United States ranks first on the world scale, yet hydropower consumption is not of a higher percentage of total primary energy consumption (2.2 per cent in 1996). This is due to the fact that the US has other energy resources such as natural gas, petroleum and coal. As a consequence, less than 10 per cent of electricity is produced by hydropower plants. Canada and the US accounted for 10 per cent and 12 per cent of 1995 world installed capacity, respectively. This is due to both their size and significant development in hydro potential.

Table 8.3 shows that Group 1 countries, with some exceptions, have relatively high per capita income and per capita energy consumption. For example, per capita electricity consumption in Norway is 26,000 kWh/y, the highest in the world. In the US, per capita domestic electricity consumption is 3,982 kWh/y, while total per capita consumption is 11,483 kWh/y.

Table 8.3. Installed Hydro Capacity and GNP, 1995					
Group 1	Installed capacity *Mw*	GNP *US$ millions* (a)	GNP per capita *US$*	Per capita energy use *Gigajoules* (b)	Per capita electricity consumption *kWh/y* (a)
Canada	64,770	573,695	19,380	319	16,413
Italy	12,925	1,088,085	19,020	118	4,610
Japan	21,171	4,963,587	39,640	141	6,028
Norway	26,000	136,077	31,250	210	26,000
Switzerland	10,118	286,014	40,630	139	7,183
USA	74,856	7,100,007	26,980	317	11,483

Sources:
(a) *World Bank Atlas 1997*, pp.36-37.
(b) *World Resources 1996-97*, pp.286-287. (Data relates to 1993)

Most countries in Group 1 are industrialized, rich countries that could afford to develop hydropower capacity and who deliberately chose this path to become economically strong. The extent to which dam-building activity contributed to fostering economic development is a crucial but difficult question to answer.

> Industrialized countries and their scientific bodies which supported the construction of large dams in the 1950s-1960s, have now started to reduce their reliance on dams.

Given present levels of hydroelectricity generation, sufficiency and reliability of electricity and energy supply systems, as well as growing public opposition to large dams, many governments in Group 1 countries are adopting a rather cautious approach to dam-building. Some even oppose the construction of new dams. In certain circumstances, dams are being removed and river courses restored. At the same time, however, northern governments and companies have developed mechanisms and expertise and are therefore contributing to the building of new dams in other countries.[97]

The extent to which a single stance can be taken to oppose a dam anywhere in the world – the “no more dams at any cost” debate – is debated in Chapter 11.

8.3. Group 2 Countries: Development in Process

Group 2 countries have presently developed 10-50 per cent of their hydropower potential and are likely to continue to increase hydropower generation in the coming years. Most future developments of hydroelectric facilities and large dams are likely to occur in these countries.[98]

In addition to Group 2 countries listed in Table 8.4, the following could be included: Argentina, Chile, Colombia, Ecuador, Greece, Indonesia, Malaysia, Mexico, Myanmar, Panama, Paraguay, and Romania. The former Soviet Union would also probably fit into this category. However, given the difficulty with locating accurate data, it is not considered in this paper although it is an important producer of hydropower (the Russian Federation produced 162,800Gwh/y in 1995;[99] Russia has an estimated technically feasible potential of 1,670Twh/y of which less than 10 per cent has been developed).

Table 8.4. Hydroelectric Production 1950-1995 (gigawatt hours/year)

Group 2	1950	1960	1970	1980	1990(a)	1995(b)
Brazil	5,850	18,384	39,863	128,907	206,708	250,000
China	850	11,900	27,000	58,200	126,720	166,800
India	2,535	7,847	25,263	46,557	71,656	72,283
Pakistan	122	680	3,300	8,719	16,925	22,858
Turkey	30	1,001	3,033	11,348	23,148	36,104
Venezuela	174	95	4,104	14,337	36,983	63,000

Source for 1950-1980 data: B. Etemad and J. Luciani, *World Energy Production 1800-1985*, Geneva, 1991.
(a) Source for 1990 data: *UN Energy Statistical Yearbook 1993*, UN Publications, New York.
(b) Source for 1995 data: *World Atlas and Industry Guide 1997*. The International Journal on Hydropower and Dams, IHA, UK.

Group 2 countries began to construct large-scale hydropower plants around the 1960s-1970s (Table 8.4). Apart from Brazil, few countries had even started producing hydroelectricity before the 1920s. In the early 1930s, India generated 500Gwh/y; 14Gwh/y were produced by Turkey in 1940 and, by 1945, this had increased to 24Gwh/y (Etemad and Luciani, 1991).

As these countries have potential for hydropower development and because they are capable of developing it, most future hydroelectric development is likely to occur in these countries. Several are currently witnessing a rapid increase in hydropower production (Fig. 8). This acceleration is perhaps best illustrated by the fact that many of these countries reached 90 per cent of their 1995 production level 2-3 years ahead of schedule: Brazil and Pakistan reached this level in 1992, China and Turkey a year later while Venezuela produced 90 per cent of its 1995 hydro production in 1994. Such findings should be compared to what was noted above for Group 1 countries.

Most of the world's undeveloped hydro potential lies in the former Soviet Union, South America and South Asia. Many countries in Group 2 have considerable hydropower resources (especially Brazil and China) which have not been fully exploited. In general, percentages of hydro potential developed fall between 10 and 50 per cent with a majority situated between 15 per cent and 20 per cent. Both Brazil and Venezuela exploit about 20 per cent of their technically exploitable potential; Brazil and China accounted for roughly the same amount (8 per cent) of the world's total installed capacity in 1995 (Table 8.5). Some estimates predict that China's Three Gorges Dam, if constructed, will move the country into fourth position after the United States, the former Soviet Union and Canada.[100]

Group 2 countries rely primarily on hydropower as a source of electricity. In Brazil, 97 per cent of electricity came from hydropower in 1995, while data for Venezuela and Pakistan were 72 per cent and 45 per cent, respectively. Yet, the percentage of hydro production and consumption to total power generation remains relatively small. In 1996, China consumed much more coal and oil than hydroelectricity, the latter equalled the amount of natural gas consumed and accounted for less than 2 per cent of total consumption of primary energy.[101] From 1994-1995, the main sources of electricity production in China were: thermal (75 per cent), hydro (18 per cent), and nuclear and others (7 per cent). In Brazil, hydroelectricity comes second – 20 per cent of primary energy consumption – after oil, which represents almost 66 per cent.

These data show both a dependence on oil and coal as a source of energy, and the potential for hydropower development. If percentages are low, hydroelectricity often ranks second or third (after oil and coal) in the list of energy resources these countries depend upon.

Major dam building activity is currently taking place in Group 2 countries where, as expected, the big dam debate is most intense and passionate.[102] It is difficult to develop an appropriate strategy for these countries. Given that dam-building has negative impacts on the environment, one must question the extent to which a country can retain its biodiversity without engaging in sound water and energy development schemes. It is on such grounds that a dam-building strategy may need to be considered in certain circumstances, and for countries facing food and energy needs (see Chapter 11).

Developing countries argue that the developed world cannot deny them the use of a technology, which they largely relied upon to expand their own industrial and productive base

Table 8.5 1995 Data

Group 2	Technically feasible hydro potential *Gwh/y*	Installed capacity *Mw*	Hydropower production *Gw/y*	% of world installed capacity	% of known exploitable potential developed
Brazil	1,166,600	51,100	250,000	8.0	**21.4**
China	1,923,304	52,180	166,800	8.2	**8.6**
India	84,044Mw*	20,576	72,283	3.2	**12**
Pakistan	24,000Mw *	4,825	22,858	0.7	**20**
Turkey	215,000	9,993	36,104	1.5	**16.8**
Venezuela	260,720	13,216	63,000	2.1	**24.1**

Source: *World Atlas and Industry Guide 1997*, The International Journal on Hydropower and Dams, IHA, UK. World installed capacity in 1995 is 634,147 Mw.
* Technically feasible potential is given as a measure of capacity. According to the *World Atlas and Industry Guide 1997*, about 12 per cent and 20 per cent of technically feasible potential has been developed in India and Pakistan respectively.

The main problem with the ‘certain dams at certain locations’ option is the ability to define boundaries, conditions and circumstances that would enable decisions to be taken. An underlying factor in any such decisions should be an evaluation of the minimum/maximum level of hydroelectricity a country should develop.

Although per capita electricity consumption is not uniform among Group 2 countries, it is on average lower than Group 1 countries: average per capita electricity consumption of the six countries presented

in Table 8.6 (1,097kWh/y) is about 10 times lower than the average of those listed in Table 8.3 (11,952kWh/y).

Table 8.6. Installed Hydro capacity and GNP, 1995

Group 2	Installed capacity *Mw*	GNP *US $ millions* (a)	GNP per capita *US$* (a)	Per capita energy use *Gigajoules* (b)	Per capita electricity consumption *kW/y* (a)
Brazil	51,100	579,787	3,640	24	1,600
China	52,180	744,890	620	25	692
India	20,576	319,660	340	10	397
Pakistan	4,825	59,991	460	9	328
Turkey	9,993	169,452	2,780	189	1,078
Venezuela	13,216	65,382	3,020	100	2,491

Sources:
(a) *World Bank Atlas 1997*, pp.36-37.
(b) *World Resources 1996-97*, pp.286-287. (Data relates to 1993)

8.4 Group 3 Countries: Very Low Development

Countries in Group 3 have not (or only to a small extent) developed their hydropower potential: current production levels account for less than 10 per cent of known exploitable potential.

Most Group 3 countries are African and are among the poorest of the world's nations. In addition to those shown in Table 8.7, others include: Afghanistan, Bolivia, Cambodia, Congo, Czech Republic, Ecuador, Guatemala, Guinea, Guyana, Iran, Iraq, Laos, Madagascar, Mozambique, Panama, Tanzania, Zambia, and Zimbabwe.

Table 8.7. Hydroelectric Production 1950-1995 (gigawatt hours/year)

Group 3	1950	1960	1970	1980	1990(a)	1995(b)
Angola	4	111	520	1,100	1,360	1,800
Bolivia	174	350	641	1,080	1,253	1,582
Cameroon	-	898	1,145	1,364	2,635	2,778
Democratic Rep. of Congo	588	2,425	3,152	4,100	6,000	5,550
Ethiopia	17	47	259	478	1,088	2,000
Nepal	3	7	54	177	704	1,116

Source for 1950-1980 data: B. Etemad and J. Luciani, *World Energy Production 1800-1985*, Geneva, 1991.

(a) Source for 1990 data: *UN Energy Statistical Yearbook 1993*, UN Publications, New York.
(b) Source for 1995 data: *World Atlas and Industry Guide 1997*. The International Journal on Hydropower and Dams, IHA, UK.

Production levels have never really grown in these countries. Over the past 50 years, hydropower generation has remained low, although it has gradually increased. Hydropower generation was almost non-existent prior to the 1950s. For example, Ethiopia produced no hydroelectricity before 1935; in 1940, it produced 2Gwh a year. Hydroelectricity production started at a slightly earlier stage in the Democratic Republic of Congo – 30Gwh/y were produced in 1929, 154Gwh/y in 1935 and 433Gwh/y in 1945 (Etemad and Luciani, 1991).

Today, the six countries in Table 8.7 produce less than 1 per cent of the world's hydropower. Hydroelectricity production is, however, increasing and may accelerate in coming decades. The majority of Group 3 countries reached 90 per cent of their 1995 production level either before or during that same year.

Group 3 countries are relatively well endowed with hydropower resources. Nepal, Ethiopia, and Bolivia are estimated to have 179,000Gwh/y, 162,000Gwh/y and 126,000Gwh/y of known exploitable potential, respectively. However, only a small percentage is currently developed (Table 8.8). For most countries, the percentage of potential developed is less than 5 per cent: in the case of the Democratic Republic of Congo and Nepal it is less than one per cent. Moreover, many countries in Group 3 account for less than 1 per cent of the world's installed capacity. In 1995, installed capacity in Africa accounted for 3 per cent of world capacity. Excluding Brazil and Venezuela, installed hydro capacity in South America is 5 per cent.

Table 8.8. 1995 Data

Group 3	Technically feasible hydro potential *Gwh/y*	Installed capacity *Mw*	Hydropower production *Gw/y*	% of world installed capacity	% of known exploitable potential developed
Angola	90,000	554	1,800	0.08	**2.0**
Bolivia	126,000	315	1,582	0.05	**1.2**
Cameroon	115,000	723	2,778	0.11	**2.4**
Democratic Rep. of Congo	774,000	2,523	5,550	0.39	**0.7**
Ethiopia	162,000	540	2,000	0.08	**1.2**
Nepal	179,000	254	1,116	0.04	**0.6**

World Atlas and Industry Guide 1997, The International Journal on Hydropower and Dams, IHA, UK. World installed capacity in 1995 is 634,147 Mw.

Group 3 countries are often highly dependent on hydropower as a source of electricity (Fig. 9). Bolivia produces 59 per cent of its electricity using hydropower, Angola 75 per cent, Cameroon 98 per cent, Ethiopia 87 per cent, Nepal 86 per cent and the Democratic Republic of Congo almost 100 per cent (World Atlas and Industry Guide, 1997). This dependence on hydropower for electricity raises important questions on the type of hydroelectric strategy these countries can/should adopt. In addition, both per capita energy and electricity consumption are usually very low – per capita electricity consumption is 22kWh/y in Ethiopia, 60 kWh/y in Nepal and 131 kWh/y in the Democratic Republic of Congo (Table 8.9).

Table 8.9. Installed Hydro Capacity and GNP, 1995					
Group 3	Installed capacity *Mw*	GNP *US$ millions* (a)	GNP per capita *US$* (a)	Per capita energy use *Gigajoules* (b)	Per capita electricity consumption *kWh* (y)
Angola	554	4,422	410	3	140
Bolivia	315	5,905	800	12	413
Cameroon	723	8,615	650	3	218
Democratic. Rep of Congo	2,523	5,313	120	2	131
Ethiopia	540	5,722	100	1	22
Nepal	254	4,391	200	1	60

Sources:
(a) *World Bank Atlas 1997*, pp.36-37.
(b) *World Resources 1996-97*, pp.286-287. (Data relates to 1993)

8.5. Concluding Remarks: Concern for Biodiversity

If the big dam controversy does not exist in Group 3 countries (mainly because of low hydro production levels), there are indications that hydroelectricity production will increase substantially in the near future. Comparing figures for average hydro production for the three groups of countries, Figure 10 estimates the level of hydro production for the year 2000.

The level of hydroelectricity produced in Group 2 countries will probably equal (if not exceed) that of Group 1 countries. Hydroelectric production in Group 3 countries will remain much less, although it will increase rapidly.[103] Estimates suggest that hydroelectricity generation will be 261Twh/y in 2025 in Africa (Africa generated 45.3Twh/y in 1985) and will be twice this figure in 2050. In comparison, hydroelectricity generated by Japan, Canada, western Europe and the United States will remain at the same level from 2025-2050. In 2050, countries from central Asia will probably rank first in terms of generated hydropower (911Twh/y), followed by East European countries (800Twh/y) and Africa (Johansson *et al*, 1993).

Considering the broad gap in the percentage of hydro potential developed between Group 3 countries and the rest of the world, it is evident that a sound dam strategy must be a priority for these countries (see Figures and Chapter 10). Of prime concern is the question of their socio-economic development within the context of global biodiversity. Group 3 countries are home to important species, as well as much of the planet's remaining tropical forests (Table 8.10). About 42 per cent of Cameroon, for example, is covered by forests: other countries have similar areas of forest – Bolivia (45 per cent), Democratic Republic of Congo (50 per cent), Nepal (34 per cent) (World Bank Atlas, 1998).

Table 8.10 Threatened Species - Mammals, Birds, and Higher Plants - in Group 3 Countries

Group 3	Mammals		Birds		Higher Plants	
	Threatened species	No. species per 10,000 km^2 (a)	Threatened species	No. species per 10,000 km^2 (a)	Threatened species	No. species per 10,000 km^2 (a)
Angola	17	56	13	156	25	1,017
Bolivia	24	67	27	x	49	3,500
Cameroon	32	83	14	193	74	2,237
Dem.Rep. of Congo	38	69	26	153	7	1,817
Ethiopia	35	54	20	133	153	1,378
Nepal	28	70	27	255	21	2,716

Source: *World Resources 1998-99*, Table 14.2, pp.322-323. (a) Values are standardized using species-area curve.

Tables 8.11 and 8.12 show that Group 3 countries often have the highest numbers of species per unit area. Thus, taking the preceding account into consideration, future dam construction will occur in regions known for their high concentrations of biological diversity. However, before reaching any conclusion on which country has the most freshwater species, it is important to compare Tables 8.11 and 8.12. Megadiversity criteria do not take into account the different size of countries. Large countries are therefore classified as such simply because they are larger and have more species. Table 8.12 shows that the list of countries with the most freshwater fish species per unit area differs from the 12 megadiversity freshwater fish countries. According to the data, most of the countries are tropical or lie on the edge of subtropics.

Table 8.11 Megadiversity Countries -those with the most freshwater fish species

Countries richest in species	*No. fish species*	*Species/1000 km^2*	*No. amphibian species*
Brazil	3000	0.355	516
Indonesia	1300	0.718	270
China	1010	0.108	265
Democratic Republic of Congo	962	0.424	216
Peru	855	0.668	251
United States	779	0.085	205
India	748	0.252	182
Thailand	690	1.351	101
Tanzania	682	0.770	127
Malaysia	600	1.826	171
Venezuela	512	0.580	197
Vietnam	450	1.383	72

Source: *Sea Wind*, Bulletin of Ocean Voice International, Vol. 11(3), July-September 1997, p.32 .

The future of biodiversity in these countries depends on existing freshwater resources and the policies and strategies that each country will adopt in coming decades. Although this is not a new issue, this Discussion Paper argues that great opportunities exist for research and cooperation between governments, international organizations and NGOs in the elaboration and evaluation of new dam and hydroelectric strategies (see Chapters 11 and 12).

Table 8.12 Densely Speciose Countries -those with the most fish species per unit area

Country	*Number of species*	*Species/1000 km^2*
Burundi	209	8.148
Malawi	361	3.837
Bangladesh	260	1.997
Malaysia	600	1.826
Sierra Leone	117	1.634
Cambodia	260	1.473
Viet Nam	450	1.383
Thailand	690	1.351
Uganda	247	1.238
Lao PDR	262	1.135
Philippines	330	1.107
Ghana	224	0.984

Source: Sea Wind, Bulletin of Ocean Voice International,Vol.11(3), July-September 1997, p.34.

Chapter 9

IRRIGATION, AGRICULTURE AND DAMS

9.1 Introduction

This Discussion Paper does not intend to provide a comprehensive analysis of issues relating to irrigation and irrigation dams. However, recognition is made of the fact that many dams, especially in the southern hemisphere, are built for irrigation purposes. According to ICOLD (1998), 48 per cent of multipurpose dams store water for irrigation, followed by flood control (39 per cent), hydropower (36 per cent), domestic and industrial water supply (36 per cent), and recreation (24 per cent). Irrigation dams are the main reason for dam construction in South Africa, Australia, India, China, Egypt, Cyprus, Syria, Tunisia, and Zimbabwe, to name but a few countries.

While dams built for irrigation are numerically important, they are usually smaller than hydropower dams. Indeed, certain technical specifications, such as height and storage volume, are required for building hydropower dams. For instance, 96 out of 140 dams classified as large dams (height ≥ 150m) were built mainly for hydroelectricity generation; 67 were built for hydropower. In comparison, there are only two irrigation dams and irrigation is listed as the main purpose for just 26 of these dams.[104] As a result, the debate over large dams and their associated environmental and social impacts is concerned more with hydropower dams than with irrigation dams *per se*. Such a statement does not, of course, exclude multi-purposes dams built for hydropower, irrigation, flood control, etc.

> Irrigation is increasingly mentioned as the main purpose of new dams, a trend possibly reflecting growing food and water needs in many developing countries.

On the basis of water use and food production data, this chapter aims to show that the same analytical framework developed for hydropower dams can be applied to irrigation dams (see Chapter 8). The three categories of countries presented in Chapter 8 will therefore be used. The analysis should demonstrate that countries using less water, and which have relatively low areas of irrigated land, produce less food.

9.2. Group 1 Countries

High levels of per capita water use in developed countries has already been pointed out (Chapter 6), especially in North America. This reflects large-scale agriculture and industrial development. At the same time, industrial countries located in humid, temperate zones use less water for agriculture than developing countries in arid regions. For example, water use for agriculture in Group 1 countries is less than 50 per cent, with Canada using 12 per cent of total freshwater resources for agriculture, Norway 8 per cent and Switzerland 4 per cent. On the other hand, agriculture represents more than 90 per cent per cent of water withdrawal in India, Pakistan, and Nepal.

Although Group 1 countries may use less water for agriculture on a percentage basis, per capita data show a different result. Most Group 1 countries have a relatively high per capita water use for agriculture – 772m^3 in the US, 493m^3 in Italy and 367m^3 in Japan –comparable to Group 2 countries such as India, China and Turkey (Tables 9.1 and 9.2). Per capita irrigated land is also high for Group 1 countries – 813m^2 in the US, 473m^2 in Italy and more than 200m^2 for Canada, Norway and Japan. In comparison, per capita irrigated land is only 2m^2 in the Democratic Republic of Congo and 15m^2 in Cameroon. Such data suggest that industrialized countries tend to use more water for agriculture production on a per capita basis than developing nations.

Countries with high per capita water use and high per capita irrigated land have relatively high food production levels. Most Group 1 countries reached the critical level of 3,000 calories per person per day in the 1960s. In 1992, average calories/capita/day was 3,350 in developed countries and 2,520 in the developing world (FAO, 1996a). Group 1 countries are not only food self-sufficient but also experience a surplus of food production. According to the FAO, from 1969-1971 and 1979-1981 cereal production in North America and Australia increased by 105 million tonnes (41 per cent), of which 95 million tonnes went to increase their net exports (FAO, 1996a). Per capita cereal production is therefore high in these countries: 1,665kg in Canada and 1,052kg in the US.

> Although there is a wide variety of irrigation methods, it is not coincidence that most food exporting nations are heavily dammed.

Table 9.1 Annual Water Use and Food Production (1995)

Group 1	Per capita water use (m^3) **(A)**	Per capita agriculture water use (m^3) **(B)**	Per capita irrigated land (m^2) **(C)**	Per capita cereal production (kg) **(D)**
Canada	1,602	192	239	1,665
Italy	986	493	473	343
Japan	735	367	219	113
Norway	488	40	229	282
Switzerland	173	7	35	182
USA	1,839	772	813	1,052

Sources:

(A): *World Bank Atlas,1998*. Annual use of water per capita refers to any year from 1980-1996 and cover domestic, industrial and agriculture uses.

(B): Per capita use of water for agriculture is calculated on the basis of per capita water use and percentage of water used for the agricultural sector given by *World Resources,1998-1999*, WRI, data table 12.1. Data is for the period 1970-1998.

(C): Annual irrigated land per capita is calculated on the basis of data from FAO statistical database FAOSTAT (1995 data). As is mentioned in FAOSTAT, data on irrigation relate to areas equipped to provide water to the crops. These include areas equipped for full and partial control irrigation, spate irrigation areas, and equipped wetland or inland valley bottoms. For Japan, data refer to irrigated rice only. Data for population refer to year 1995 (*World Bank Atlas, 1997).*

(D): Annual per capita cereal production is calculated on the basis of total domestic production of cereal given by FAOSTAT and 1995 population data from *World Bank Atlas, 1997.*

9.3. Group 2 Countries

China, India and Pakistan have relatively high levels of irrigated land, respectively 40 per cent, 33 per cent and 81 per cent of total arable land. In China, irrigated agriculture contributes to about 70 per cent of food production, while in India irrigation contributes to more than half of the total (FAO, 1996b).

Data show that most countries in Group 2 are progressing towards food self-sufficiency in spite of high population growth and density. Water control and development has played an important role in the development of domestic food production, the reduction of aid dependency and the improvement of household food security. Currently, food security problems relate more to achieving a nutritionally balanced diet rather than to energy availability. It is expected that by the year 2010 the Near East, North Africa, and Latin America and the Caribbean regions, as well as East Asia (including China) will be at, or above, the 3,000 calorie mark (FAO, 1996a). While per capita cereal production for Group 2 countries is comparable to some countries in Group 1, it is interesting to note that average per capita cereal production in the latter (606kg) is double that of the former (272kg).

Per capita water use is on average lower than in Group 1 countries, apart from Pakistan (Table 9.2). Given the total amount water resources in this country (255,000 million m^3), this highlights a situation of severe water stress. Canada, which has a similar per capita water use, has 10 times more water resources (2,849,000 million m^3). Per capita irrigated land is low in Pakistan, which highlights the importance of considering per capita data to provide an accurate estimate of a country's water use, the latter depending on a range of factors such as population and socio-economic development. If countries in Group 2 tend to use a large percentage of their water resources for agriculture (and more than Group 1 countries), this does not automatically translate into higher per capita irrigated land and/or agriculture water use.

For low income countries with a high dependence on agriculture, the main challenge is to exploit agricultural and natural resources in a sustainable manner.

9.4. Group 3 Countries

Agriculture consumes most water in Group 3 countries. According to the FAO, agriculture represents more than 85 per cent of water use in Africa and Asia, compared with 33 per cent in Europe (industry accounts for more than 50 per cent of water used in Europe). Considering the significant allocations of water to agriculture it seems paradoxical that the percentage of irrigated land in Group 3 countries remains low. Cameroon and the Democratic Republic of Congo irrigate less than 1 per cent of total arable land, while less than 5 per cent of arable land is irrigated in Angola, Bolivia, and Ethiopia.

Table 9.2 Annual Water Use and Food Production (1995)

Group 2	Per capita water use (m^3) **(A)**	Per capita agriculture water use (m^3) **(B)**	Per capita irrigated land (m^2) **(C)**	Per capita cereal production (kg) **(D)**
Brazil	246	145	199	293
China	461	401	415	349
India	612	570	581	230
Pakistan	1,269	1,230	132	191
Turkey	544	392	685	460
Venezuela	382	175	85	112

Sources: as for Table 9.1

However, as noted above, per capita data again need to be taken into consideration. Compared with countries in Groups 1 and 2, it is clear that Group 3 countries use less water both in absolute and per capita terms (note that Nepal is an exception with per capita irrigated land equal to 412m^2). Some of these countries, like the Democratic Republic of Congo, have considerable water resources but their level of development is such that per capita irrigated land and water use for agriculture is very low (Table 9.3).

Considering data on food production, it appears that countries using less water have lower per capita cereal production. Group 3 countries, particularly those in Africa, have very low per capita cereal production: 28kg and 30kg in Angola and Ethiopia respectively (Table 9.3). As expected, countries with a higher level of cereal production per person use more water, both in general and for agriculture. In other words, there is a relationship between water use, water used for agriculture and irrigation, and food production.

Given the precarious food situation of most Group 3 countries, their dependence on food imports and aid is easily understood. According to the FAO, the dependence of developing countries on food imports is likely to increase with net imports of cereals growing to 160 million tonnes in 2010. However, many countries, especially the least-developed ones, have limited potential to import food. As population and food needs rise, often at a faster rate than total production, their average food situation is declining.

Table 9.3 Annual water use and food production (1995)

Group 3	Per capita water use (m^3) **(A)**	Per capita agriculture water use (m^3) **(B)**	Per capita irrigated land (m^2) **(C)**	Per capita cereal production (kg) **(D)**
Angola	57	43	69	0.028
Bolivia	201	170	105	0.148
Cameroon	38	13	15	0.093
Ethiopia	51	44	33	0.030
Nepal	154	146	412	0.287
Dem. Rep. of Congo	10	2	2	0.040

Sources: as for Table 9.1

Water scarcity and food security problems in different parts of the world need to be examined in a holistic manner. Emerging water shortages in China, which could lead to a significant increase in demand for grain imports and a subsequent rise in world grain prices, is likely to aggravate food insecurity and malnutrition in low-income countries with already low per caput food supplies. "For the 1.3 billion of the world's people who live on US$1 a day, or less, higher grain prices could quickly become life threatening" (Brown and Halweil, 1998).

The decline in the supply of irrigation water for Chinese agriculture, and subsequent problems of food self-sufficiency in the country, cannot be disassociated from world food security. Import demands for grains are also increasing elsewhere.[105] However, world grain exports have not grown since 1980 and global supply is unlikely to increase much in coming years. 'The question of whether or not [more] exports will be available has become a matter of acute concern for the low-income developing countries that already depend on grain imports to feed their growing populations. While China can afford to pay the elevated prices in tight global grain market, even a modest rise in prices could – in some other, less affluent, countries – drain precious foreign exchange, boost local food prices, and trigger food riots" (Brown and Halweil, 1998).

9.5 Conclusions

Water control and irrigation development will play a critical role in increasing agriculture production and in improving food security.

Far from considering that irrigation is the panacea to world food problems, water storage and distribution can nonetheless be effective technical means to increase food production. Irrigation also has negative effects in terms of soil degradation and subsequent yield and productivity losses. Moreover, it is not the sole factor responsible for expanding world food supplies; other factors include increased fertilizer use, higher cropping densities, etc.

This analysis shows that the pattern of water use can serve as an indicator of development: as wealth increases, water withdrawal shifts from agriculture to industry and the domestic sector. For example, agriculture represents 69 per cent of total water withdrawal in Africa, the industrial sector accounting for just 5 per cent. In North America, the industrial sector claims 47 per cent of total water use, 39 per cent going to agriculture (WRI, 1998). Moreover, there is a link between the level of water withdrawn in a country, water use for agriculture and irrigation, and food production. Low water use on a per capita basis is reflected in low per capita food production. This seems to be the situation for many countries in Group 3. The rather high per capita water use for agriculture in industrialized countries demonstrates that a basic minimum of water is needed to produce food. Below that level, there is food insecurity (e.g. Angola, Ethiopia, and Democratic Republic of Congo). It appears therefore that developed countries tend to use more water to produce one unit of food.

It can also be concluded that dams contribute to food production. The categorization scheme reveals that:

- most countries in Group 1 are food self-sufficient and a majority are food exporters. Many dams have been built in these countries
- Group 2 countries are progressing towards food self-sufficiency
- Group 3 countries have food shortages and are net food importers.

It is important to note, however, that irrigation is not only, and perhaps not principally, dependent on large dams. There are many irrigation techniques – small-scale and traditional. The link between irrigation, dam building and food production can nonetheless be brought to the fore for certain countries, mainly those in Group 3, that need to expand domestic agriculture production in order to improve their average food situation. In such countries, especially in Africa, there will be a pressure to resort to large-scale irrigation schemes. The manner in which the irrigation potential of these countries should be exploited clearly needs to be addressed.

Chapter 10

AFRICA: FUTURE DAMS AND THE ENVIRONMENT

10.1 INTRODUCTION

Despite having vast water resources, the hydropower sector is relatively undeveloped in most of Africa. According to the World Atlas and Industry Guide (1997), less than 7 per cent of the total 1,000,000 Gwh/year of economically feasible hydro potential was in operation in 1997. The African continent as a whole generates 67,000Gwh/year of hydroelectricity, which represents almost 3 per cent of the total hydropower produced worldwide.

Compounding abundant, low-cost and unexploited hydro potential, a second feature of the power sector in Africa is people's low access to electricity. In Botswana, for instance, only 2.5 per cent of the population have electricity. In Lesotho, 3 per cent of the population is served with electricity. Per capita electricity consumption is 18kWh/year in Burkina Faso, while it reaches 1,000kWh/year in Egypt (Table 10.1). Improving people's access to electricity is therefore a key issue.

A number of factors – institutional, economic and political – explain why people's access to electricity has been largely ignored. Power sector reforms are dependent on political stability, strong macro-economic demand, and foreign aid not distorting policy. Regional cooperation is also essential in securing least-cost supply. Given present per capita energy consumption and production in Africa, it seems both justified and legitimate that energy demand increases in this part of the world. How is that demand likely to be met? Is hydropower the most likely means of producing electricity in Africa? If so, what are the future impacts likely to be?

This chapter attempts to examine the role of dams as suppliers of energy in Africa. A specific analysis of the power sector in Africa is required for at least three reasons:

1. Future dam-building activity may be in Africa: major river basins remain untapped (Table 10.4).
2. Actual electricity consumption and production are very low in Africa. Countries may decide to rely on hydropower to increase electricity generation and boost economic growth.
3. Wood and fossil fuels are extensively used in Africa and are causing serious environmental degradation (Tables 10.3 and 10.4).

Table 10.1 The 'Electricity Gap'

Country	Electricity production 1994 *GWh/y* (a)	GNP per capita 1995 *US$* (b)	Per capita electricity consumption 1994/95 *kWh/y* (c)
United States	3,473,620	26,980	11,483
Switzerland	65,724	40,630	7,183
Madagascar	-	230	2,180
Brazil	260, 682	3,640	1,837
Egypt	51,947	790	1,000
Zimbabwe	7,334	540	800
Rwanda	-	180	720
China	928,083	620	692
India	386,500	340	397
Malawi	-	170	350
Ghana	6,115	390	256
Angola	955	410	140
Tanzania	1,913	120	77
Burkina Faso	-	230	18

Sources:
(a) & (b): *World Bank Atlas 1997*, pp.42-43 and pp.36-37.
(c) *World Atlas and Industry Guide 1997,* The international Journal on Hydropower and Dams, IHA, UK.

10.2 The African Power Sector in Figures

> In 1995, per capita energy consumption in Africa was 13.1Gj. Elsewhere, figures were 144.6Gj in Europe, 326.3 Gj in North America and 35.6 Gj in Asia.

Africa is the second most populated continent after Asia. In 1998, total population was 778,484,000, with a land area of under three billion hectares. Most people live in rural areas (65 per cent) but urban population has been rising rapidly in recent decades (WRI, 1998). Commercial energy production and consumption were respectively 22,610 petajoules and 9,451 petajoules in 1995. Traditional fuels represent 72 per cent of commercial energy in Africa (3 per cent in North America and 2 per cent in Europe) (WRI, 1998). Other sources of energy include petroleum, gas, wood and biomass.

While per capita and total energy consumption in Africa, and the developing world in general, remain far below that of developed countries, the rate of growth is much higher in developing countries than in the developed world (see Table 10.2). Consequently, the share of non-OECD regions in the world energy demand expanded to 44 per cent in 1995, with energy demand in Asia passing that of OECD-Europe. Following a 7 per cent growth peak in 1994, energy demand in Africa grew by nearly 3 per cent in 1995, which is still above the average annual growth of the past seven years.[106]

Three main reasons explain the rapid increase in energy consumption in developing countries:
- rapid population growth
- faster economic growth than in industrialized countries
- urban migration.

Additional factors include expansion of energy intensive industries, and the development of energy intensive technologies coupled with limited use of energy efficiency measures.

Table 10.2 Average Growth Rate of Primary Energy (1973-1987)

Countries	*Per cent per year*
Middle East	5.8
Africa	5.8
China	5.8
Asia	5.2
Latin America	4.3
USSR	3.4
Eastern Europe	2.6
Other OECD	1.1
United States	0.2
World	2.2

Source: *Planning and Management in the African Power Sector,* AFREPEN, Zed books, 1998, p.148.

As mentioned above, many African countries have ample hydro resources – Angola, Cameroon, Congo, the Democratic Republic of Congo, Egypt, Ethiopia, Gabon, Madagascar and Mozambique have more than 50,000Gwh/year of technically exploitable hydro potential. In total, technically feasible hydropower potential in Africa is 1,665,000Gwh/year which represents almost 12 per cent of world hydro potential. Installed hydro capacity is, however, relatively low (20,512MW) and accounts for only 3 per cent of total installed capacity in the world (see country breakdown, Table 10.6).

Hydropower supplies more than 90 per cent of electricity production in Burundi, Cameroon, Congo, the Democratic Republic of Congo, Guinea, Malawi, Mozambique, Namibia, Rwanda, and Zambia, other generation being from diesel plants and/or thermal plants. Despite the significant proportion of electricity supplied by hydro power plants in several African countries, much hydro potential is unexploited. Moreover, there is actual surplus of hydropower production in certain countries (e.g. Zambia, Ethiopia).[107] The paradox is that these surpluses coexist with diesel generation, often costly and unreliable, and the fact that few people have access to electricity.

10.3 Electricity Consumption and Production

Electricity consumption in Africa, especially sub-Saharan Africa, is among the lowest in the world. A study of 96 developing countries shows that 29 have per capita electricity consumption of less than 100kWh/year, the majority of these countries being in sub-Saharan Africa (Schramm, 1990). In Rwanda and Uganda, less than 6 per cent of the population have access to electricity. Per capita power consumption for those connected to the grid is about 720kWh/year.

The difference between domestic per capita electricity and total per capita consumption is important: in Burundi, per capita electricity consumption is 6,300Kwh/year total and 1,948kWh/year for domestic consumption. In Ghana, domestic electricity consumption was 256kWh/people/year in 1996, based on the 1996 total domestic consumption of 4,097Gwh. In Madagascar, figures are respectively 2,180kWh/year total and 880kWh/year for domestic consumption. In Malawi, per capita electricity consumption in 1995 was 350kWh/year total, and 108kWh/year for domestic consumption.

Data reflect the general situation in Africa where the industrial and mining sectors are the largest consumers of electricity (even though there is insufficient demand for electricity from industry in many countries), while governments have failed to satisfy the electricity needs of the population. Clearly, the main problem of the African power sector is not the lack of electricity supply to remunerative segments like industry, but a greater and more reliable access to electricity for the people. Up to now, governments have not considered electricity as a service – a public and social good. According to a recent book on the African power sector, other inhibiting factors include: "high distribution costs; a constraint on funds; and a misguided policy which required the full connection costs to be borne by customers in one go, thus creating an entry barrier to new customers. This is to be contrasted with countries like India, where poor households are given a free supply of electricity through a single-point connection, as a basic need" (AFREPEN, 1998).

It is obvious that the lack of electricity production, even at a base level, is resulting in high deforestation of primary tropical forests.

Wood is frequently the main energy source in Africa (see Table 4). Both rural and urban households use wood, either as dead wood or in the form of charcoal. Household consumption of woodfuel exceeds agricultural, commercial and industrial uses. It should, however, be noted that despite being the major consumer of electricity in most African countries, industry also relies heavily on woody biomass and charcoal. In Ethiopia for instance, biomass is the major source of industrial energy (70 per cent) while electricity accounts for only 7 per cent of industry's total energy requirement.[108] Deforestation is therefore a serious problem in many African countries. This pattern of energy consumption also has adverse effects on soil fertility, as well as the ecosystem as a whole.[109]

Table 10.3 Wood and other Sources of Energy

	Main sources of energy % (a)				Forest Coverage (b)	
Country	*Wood*	*Petroleum*	*Electricity*	*Others*	*Average annual deforestation % 1990-1995*	*As % of total land area*
Burkina Faso	85	8	2	5	0.7	16
Burundi	92	6	1	1	0.4	12
Madagascar	86 (incl. charcoal)	12	2	0	0.8	26
Malawi	90	4	3	3	1.6	35
Mali	88	10	1	1	1.0	9
Zambia	65 (incl. charcoal)	14	12	9	0.8	42
Zimbabwe	74 (incl. charcoal)	14	12	0	0.6	23

Sources:
(a) *Hydropower and Dams, 1997 World Atlas and Industry Guide*, IHA, Sutton, UK, 1997
(b) *World Atlas and Industry Guide 1997,* The international Journal on Hydropower and Dams, IHA, UK.

Wood consumption and related problems of deforestation can be observed on the basis of country analysis as well as at the river basin level. Table 10.4 presents data on 17 major African river basins. As indicated, most have high deforestation rates: 10 per cent for the Volta watershed, 9 per cent for Zambezi basin, and 8 per cent for the Mania river basin. For certain watersheds, the loss of original forest is equal to 100 per cent (Lake Chad, and the Senegal and Orange rivers) and for others exceeds 95 per cent (Limpopo, Mangoky, Mania, Niger and Volta). This clearly indicates that people are using wood as a source of energy. The future of Africa's river ecosystems is dependent on the existence and condition of these forests. Any debate on large dams must therefore consider the advantages of hydropower development compared with forest depletion and subsequent environment degradation.

Table 10.4 African River Basins

River basin	Forest (%)	Loss of original forest (%)	Deforestation rate (per decade)	Large dams	Planned major dams
Congo	44	46	7	3	-
Lake Chad	0	100	2	0	-
Jubba	5	2	6	0	-
Limpopo	1	99	5	1	-
Mangoky	3	97	7	0	-
Mania	6	98	8	0	-
Niger	0	96	6	6	1
Nile	2	91	6	7	-
Ogooue	75	9	5	0	-
Okavango Swamp	2	0	5	1	-
Orange	0	100	-	4	2
Oued Dra	0	84		0	-
Senegal	0	100	5	1	-
Shaballe	1	88	1	0	-
Lake Turkana	12	60	3	1	-
Volta	0	97	10	2	-
Zambezi	4	43	9	6	-

Source: C. Revenga, S. Murray, J. Abramovitz and A. Hammond, *Watersheds of the World*, a joint publication by the World Resources Institute and Worldwatch Institute, 1998.

10.4 Hydropower Development

Given the problems posed by the depletion of woodlands and the reliance on costly diesel or thermal power generation, as well as the need to respond to increasing energy demands, the development of hydropower in Africa has to be addressed.

This paper has suggested (Section 6.4) that increased demand for energy in developing countries seems justified, as the basic needs of industry and population are far from being satisfied. In this respect, demand side management and conservation measures are not relevant to the African scenario where actual energy consumption is very low. As the authors of an African power sector study note: "A number of studies conducted in industrialized countries addressing the environmental effects of increasing energy demands in developing countries have sidetracked the focus of Africa power sector development away from making electricity available to the population and toward adopting an environmentally benign power development by focusing on demand side management and renewables. This may be a priority for developed countries, but hardly one for the development agenda of Africa - which hardly contributes to the global warming problem at present" AFREPEN, 1998).

> If a country's energy needs are not met, this may lead to social unrest and environmental degradation.

The above analysis clearly demonstrates that people's dependence on wood is due to a lack of other choices. Future power sector development has to take into consideration the dangers of diminishing and damaged forest ecosystems as opposed to adverse environmental impacts of alternative sources of energy. Similarly, electricity from hydropower must be weighed against power generated by burning fossil fuels. For countries with ample hydro resources, the solution might be to build dams provided that environmental damage is minimal or 'acceptable'. Sites should be chosen where the building of the dam is least damaging from an environmental and social standpoint.[110] On the other hand, it may be preferable to promote alternative energy sources, including fossil fuels, if the proposed dam project has high environmental and social costs.

Ethiopia, a country with considerable hydro potential, provides an interesting example of the choices which might apply. The technically feasible potential is 162,000Gwh/year: less than 2 per cent has been exploited so far. In 1995, there was 372MW of hydro capacity in operation, which was generating 1,259Gwh/year (about 87 per cent of power production). There was also 168 MW of hydro capacity under construction. According to some estimates, 97 per cent of present generated electricity comes from hydropower sources (AFREPEN, 1998). A number of factors point to certain advantages in future hydropower development:

- topography – the availability of large water flow, which allows for high head development and geographic conditions permitting less land to be submerged
- low power development cost (mainly due to favourable topographic conditions) at a cost that is low by world standards
- high costs of oil-based electricity production
- serious degree of deforestation.

Domestic power demand is expected to increase to approximately 13,500Gwh/year by 2020. To meet this, and to provide power for possible export, hydropower development on the Nile Basin could be envisaged. However, both economic and environmental considerations must determine whether hydropower development is the most suitable alternative, given present and future energy needs, the cost of relying on alternative sources of energy, such as diesel or geothermal power plants, and the overall socio-economic development of the country.

Table 10.5 Future Dam Development in Ethiopia

Dam	Scheduled Year	Capacity *MW*	Estimated Cost *US$ million*	Cost/MW *US$ million*
Aleltu	2001	400	480	1.2
Chamoga Yeda	2006	320	384	1.2
Halele Warabesa	2006	430	516	1.2
Tana Beles	2001	270	324	1.2

Source: *Planning and Management in the African Power Sector,* AFREPEN, Zed books, 1998, p.206.

10.5 Conclusions

Energy production and use have environmental impacts that cannot be denied. Concern about environmental issues is also on the agenda in Africa. At the same time, energy development is crucial to the socio-economic development of developing countries. There is widespread recognition that more energy will be produced and consumed in future and that such a trend is necessary to satisfy the basic requirements of the population. A study in Zambia emphasizes the shortcomings of electricity shortages: “they handicap productive capacities and delay social development” (AFREPEN, 1998). As some estimate, ‘electrification will be the major path for economic growth worldwide.’[111] In view of rising food, water and energy needs in developing countries, and in Africa in particular, it seems important to address the question of water and energy strategies to meet some of these needs, while minimizing ecological damage and ensuring the sustainable use of these resources.

This chapter has deliberately focused on the African power sector. Energy issues in Africa are complex, and vary from one country to another. However, two factors should be emphasized:

- the availability of surplus power
- the percentage of the population with access to electricity.

Many African countries have large but unexploited hydro potentials. As a result, expensive diesel power plants are used to generate electricity. Many urban and rural households rely on wood as a source of energy. Given the economic and environmental costs (carbon dioxide emissions, depletion of forest land) associated with fossil fuels and wood, it is essential to discuss the possibility and advantages of building certain dams on specific river basins in Africa. The purpose is not to oppose or support dam construction but to outline important issues/challenges that are likely to arise. For example, there is a need to identify which hydro schemes are scheduled for the next couple of years and whether such investments are justified, both in economic and environmental terms. Other factors include the choice of the construction site and use of the most appropriate technology. These are some of the issues that the World Commission on Dams should take on board whilst discussing the development effectiveness of dams in Africa (see Chapter 11).

Table 10.6 Hydro Potential and Development in Africa

Country	*Technically feasible hydropower potential (GWh/year)*	*Installed hydro capacity (MW)*	*Production from hydro plants (GWh/year)*	*% of hydro potential developed*	*% of electricity production by hydro*
Algeria		275	353		0.9
Angola	90000	554	1800	2	75
Benin	2500	0	0	0	0
Botswana	5	0	0	0	0
Burkina Faso	138.9	32	95	68.4	39
Burundi	1500	40.6	147	9.8	100
Cameroon	115000	103000	2778	0.6	98.5
Congo	50000	89	352	0.7	99.5
Côte d'Ivoire	12400	895	1098	8.8	68
DRC	774000	2523	5550	7.5	99.9
Egypt	50000	2825	8500	17	20
Ethiopia	162000	540	2000	1.2	87
Gabon	80000	1666	710	0.8	80
Ghana	10600	1072	6100	57.5	97
Guinea	19400	52.3	228	1.2	32
Kenya	4710	598.5	2920	62	80
Lesotho	2000	3.3	0	0	0
Liberia	11000	81	175	1.6	43
Madagascar	180000	225	411	0.2	75
Malawi	6000	218.5	850	14.2	99.5
Morocco	4700	693	443	9.4	25
Mozambique	72000	2184	336	0.5	92.2
Namibia	8645	240	1134	13.1	90.1
Nigeria	30690	1938	13365	43.5	37
Rwanda	3000	56	230	7.6	98
South Africa		661	2090		1
Sudan	19000	240	950	5	71
Swaziland	560	43	135	24.1	15
Tanzania	20000	380	1539	7.7	85
Togo	1700	69	154	9	12
Tunisia	250	64	40	16	0.3
Uganda	12500	186	940	7.5	98
Zambia	28753	1648	8102	28.2	99.8
Zimbabwe	17500	666	2500	14.3	20

Source: *World Atlas and Industry Guide 1997*, The international Journal on Hydropower and Dams, IHA,UK.

PART V. STRATEGIES, CONCLUSIONS AND RECOMMENDATIONS

Chapter 11

STRATEGIES

A strategy dealing with future dam-building projects will have to address several complex issues. Three main options arise from the analysis presented in Chapters 8 and 9.

11.1 The 'no' option

Any type of construction, anywhere in the world, has an impact on biodiversity, submerging forests and other lands, and displacing local populations.

The main rationale for a ‘no’ strategy is based on the global vision of environmental degradation. There are already 40,000 dams in the world and most important river ecosystems have already been obstructed and destroyed in some way or another. Economic arguments must also be considered – dams do not add to the economic prosperity of a country.

According to this paper, the 'no more dams anywhere in the world' strategy is ruled out. It is neither realistic of viable. Dams are still being built in many countries. In 1997, 242 new dams were commissioned in 27 countries; 1,705 dams were actually under construction in the same year, 36 of which are in the USA.[112]

While this Discussion Paper questions the 'no' dam option, it argues that Group 1 countries do not need more dams. Further dam construction should be opposed in these countries and environmental organizations must lobby for the removal of some dams to restore wetlands and floodplains. Further increases in hydropower generation on both a per capita basis and in absolute terms should not be envisaged.

Group 1 countries, together with environmental organizations and international institutions, have a role to play in setting the benchmark for environmentally friendly dam construction and in contributing to international mechanisms and guidelines to advise other countries on future dam-building decisions. Moreover, they have the technical and financial resources to invest in the development of energy-efficient technologies, particularly renewable forms, to reduce the need to build dams in less developed regions. As the prime beneficiaries of hydropower, Group 1 countries have an obligation to preserve remaining free-flowing rivers. These countries should therefore be persuaded to generate required funds to protect untapped rivers by imposing a nominal tax on dams and hydropower.

11.2 Certain Dams at Certain Locations

This approach is based on the following understanding:

1. It is possible to build dams in certain locations (and only in some countries), ensuring that measures to reduce the negative impacts of dams are implemented. The argument is that dam-building is not uniform worldwide and it may not be possible for some countries to fulfil economic objectives without expanding and improving power generation and water use.

2. The environmental impacts of dams depend much on technical specifications, such as height, size and type. The same benefits (i.e. power generation, irrigation) can be secured by changing the design as well as the location (Ledec *et al,* 1997). In other words, environmental damage is somewhat linked with 'bad design' and 'bad location'.

3. Building a dam in a particular location may lead to environmental degradation, but not building a dam may lead to a more unfavourable situation in the short- and medium-term. Certain compromises have to be made in the larger interests of the country while minimizing the negative impacts.

This strategy would probably apply to Group 2 countries. As this subject is often a sensitive issue in these countries, a mixture of new policies and strategies have to be considered and elaborated in a culturally-sensitive manner. Earlier attempts to stop dam projects by opposition (the Narmada campaign in India, for instance) and cancellation of public international loans often resulted in strengthening the nationalistic and patriotic sentiments associated with the achievement of large infrastructure projects, a situation used by governments to rally the population and limit consultation and discussion procedures.

More dams may be required at certain locations providing that environmental assessment and mitigation measures are an integral part of any project study. At the same time, some river basins may need to be protected at any cost, either for their uniqueness or because they already are over-developed.

The strategy for Group 3 countries would also be similar. Studies on the technical specifications of dams have to be carried out before dam construction occurs. There is a need to determine the extent to which the environmental effects of dams depend on the size, type and height of the dam, or on the dam *per se*. Construction companies should have no choice but to construct only ecofriendly dams in appropriate places. Where no dam-building is allowed, questions of national sovereignty, regional imbalances and the difficulty of satisfying everyone will have to be addressed; however, the latter should not override the overall aim to protect the environment.

11.3 No Dams on Certain Rivers and Limited Dams at Exceptional Circumstances

This approach is based on the rational outlined above (Option 2) but also considers that some river basins may need to be protected at any cost either for their uniqueness or because they are already over-developed.

11.4 Dam Removal Option

A fourth strategy can be mentioned, which should be viewed as complementary to those outlines above: some dams should be removed in certain countries and at appropriate locations. This is based on the understanding that existing dams, particularly in many developed countries, do not make a significant contribution in terms of additional social and/or economic benefits.[113]

11.5 Conclusions

A number of strategies are outlined in this Discussion Paper, based on a thorough analysis of available data on dams worldwide. Other options may exist that would be more country- or river basin specific, but these would not radically change the main strategies outlined above.

Each approach/option has several constraints, both in terms of policy development and implementation. These are outlined below:

Option 1: No dams at any cost
Although the 'no' option may be the easiest to implement, there are some difficulties which need to be emphasized:

i) implications for human development in certain countries
ii) economic growth and disparities in countries with and without dams
iii) future energy needs
iv) proven alternatives and their effectiveness
v) compensation to countries if they have to forego certain benefits in order to keep rivers in their natural state.

Option 2: Certain dams at certain locations
Difficulties in implementing such a strategy include:

i) technical specification of the dam (e.g. ideal size, location, type)
ii) guidelines on the implementation of technical standards
iii) identification of the suitable/not suitable locations on rivers
iv) difficulty to satisfy everyone
v) questions of national sovereignty and, within a country, regional imbalances
vi) difficulty to guarantee that the locations are less damaging to the environment.

Option 3: Identification of the countries/rivers that do not need, or cannot support, any dam
This may be relatively easy as far as rivers are concerned but very complicated regarding countries as many countries share the same river basin. Other difficulties include:

i) identification of the river basin where no further dam-building should occur under any circumstances
ii) identification where a specific dam may be the less damaging to the environment.

Chapter 12

CONCLUSIONS AND RECOMMENDATIONS

12.1 Overview

The debate on dams, as reviewed in this document, has to take into consideration the complexity of the situation. Environmental issues at existing and planned dam sites, social concerns, as well as the energy needs of some of the poorest countries have to be addressed.

Deciding on these issues, already a difficult and sensitive issue, is expected to become even more complex in the era of privatisation and globalisation. Until recently, in many developing countries, the energy sector was the public sector. Due to various reasons – low efficiency, massive financial losses, distribution problems, bureaucracy – the power sector, like many others, is being handed over to private venture. There are already active campaigns in some countries to privatise the hydropower sector. Now, for the first time, the private sector may support and lobby in favour of dams, not as a means of obtaining construction contracts but in terms of owning and operating them for long-term profit.

The work of the World Commission on Dams is also particularly complex as the World Bank, which is the main promoter of the Commission, has long supported and funded the hydropower industry and still considers that it has a "rosy future" in developing countries in a "warming world". The Commission must deal with this approach, together with the views and concerns of the vocal anti-dam NGOs who have also joined the Commission.

This Discussion Paper offers the following conclusions based on the review of existing data.

- Dams have a major environmental impact, no dam is environmentally benign.

- It is not possible to think of a single strategy on dams that will be globally acceptable.

- Hydropower development and the construction of the dams are not uniform in all countries. This paper has categorized countries according to various criteria – resulting strategies must reflect and accommodate such different categories and needs.

- Many countries have not yet begun to use their hydro potential. The low per capita consumption of power and food security in these countries could be detrimental to ecosystems in the long-term.

- Many countries have the possibility of removing some dams to rehabilitate certain ecosystems, without significantly lowering per capita energy consumption. Removing dams should become an active tool for ecosystem rehabilitation.

- International efforts to stop dam building in many developing countries have had mixed results: they have succeeded in countries with low financial and technical capabilities but some countries, due to international anti-dam campaigns, have not approached the World Bank or other lending agencies for financial assistance.

- A strategy to deal with future dam issues requires a flexible and open approach. Governments need to be convinced about meeting their growing needs by adopting more environmentally friendly ways of energy production and management. Environmental agencies too must work towards conserving unique species and spaces, rather than taking a rigid stance opposing the construction of any dam in a developing country.

- The debate is likely to become more complex and complicated due to the private sector taking over the hydropower industry in some countries.

- There are examples where countries have resorted to more environmentally destructive ways of producing electricity in order to avoid dam construction.

Future debate on dams will be influenced by the following:

- Hydropower provides an image of being renewable and non-polluting.

- Growing energy needs of many developing countries are genuine and need to be addressed by producing more energy.

- Privatisation and globalisation in many countries has not only led to more energy demand, but to more polluting methods of energy production.

- World Bank lending for hydropower has declined by 25 per cent in the 1990s. This will lead to private sector investments in the hydropower sector.

- The social issues related to dams are both real and disturbing. The poorest of the poor are being affected by dam construction. But the social issues related to dams cannot be the only reason for opposing dam construction – dams are not the sole cause of human misery in many developing countries. In the long run, it may be more detrimental to the environment and local people if some countries do not make use of their hydropower potential.

The challenge to the World Commission on Dams is to look at the hydroelectricity issue in a much broader context. The hydroelectricity industry, if it is to survive, has to develop and adopt specific measures that will conserve ecosystems. The Commission should identify general guidelines and specific suggestions suitable for global and national applications. An outline of recommendations is provided in Section 7.3.

12.2 Agenda for the World Commission on Dams

The formation of the World Commission on Dams is a positive step towards resolving key issues related to dams. WWF suggests the following directions to the Commission to help it reach its objectives.

- The Commission should not seek a universal solution to dam-building: it is not possible to have a single solution to this issue.

- The Commission should focus on general policy guidelines and criteria and avoid being involved in country- and/or dam-specific projects.

- The Commission must take firm and immediate action to overcome the stalemate position that has dominated the dam debate for so many years. The question which needs to be addressed is simple – what is, and what is not, acceptable under the present realities and for ecosystem sustainability? There have to be trade-offs: countries have to have choices.

The following recommendations are made to the World Commission on Dams:

1. Identify specific sites in different countries that are ecologically sensitive, important, and in need of conservation. The sites have to be conserved in order to protect ecological process and to maintain biodiversity. Any future dam construction should not damage these sites. A preliminary list of ‘off-limit’ sites should be based on existing scientific data and established protected areas, such as World Heritage Sites, Ramsar sites, and WWF’s Global 200 Ecoregions.

2. Based on the approach suggested in this paper, the Commission should develop three categories of countries that require different approaches to future dam building and water management programmes.

3. Establish a set of guidelines, standards and criteria to create an appropriate framework for future dam-building activity. In this respect, country or regional quotas for producing hydroelectricity, particularly where dam construction is very low, may be advisable.

4. Identify countries that should not build any more dams under any circumstances. This should be based on an assessment of present energy production, per capita consumption and the level of dam building, as well as basic water needs of urban and rural populations.

5. Establish an inventory of dams to be removed by 2010 from countries that have large numbers of dams and which are energy sufficient.

6. The Commission has a role to play in supporting the development and transfer of the most appropriate and efficient technologies (which are not tied to any aid or trade conditions). Scientific and technical expertise is required to enhance the prospect of ecofriendly dams, provided that such technology exists. As a minimum, every dam project needs to fulfil

international environmental norms, i.e. independent environmental impact assessments and cost-benefit analyses.

7. The Commission should establish a list of countries that should increase their hydro-electricity production using ecologically-friendly techniques. The Commission should establish guidelines on the types of dam that are ecologically acceptable in different conditions. Such countries must strictly abide by internationally recognized standards and methods. No dams should be built that would damage important sites identified by the Commission.

8. The Commission should identify international mechanisms to compensate a country for foregoing its hydropower potential in the interest of humanity. Such compensation mechanisms should only be provided in exceptional circumstances where the country does not have any other source for minimum power production.

9. The Commission should also suggest workable solutions for large dams that are under construction in many developing countries. The Commission's role should be to persuade these countries to stop the projects. If it does not succeed, or the country has to continue construction, the Commission must provide strict measures/guidelines to reduce damage to ecosystems and local people.

10. Studies should be initiated on the following:
    - the role of hydroelectricity in meeting future energy needs of some of the poorest countries, while preserving the integrity of ecosystems
    - specific country analysis of dams and their impacts (positive or negative) on ecosystems
    - the ecological impacts of small dams. Studies should consider comparative advantages in terms of ecosystems
    - a holistic evaluation of the advantages and disadvantages of hydropower. For example, a specific dam site should be examined in light of the alternatives available that might allow the country to produce a similar level or electricity.

11. The Commission should play an active role in channelling international scientific opinion on dams. In many developing countries, support of any type of dam under any circumstance is criticised as being 'anti-environment' or 'anti-people'. Similarly, opposition to dams is branded as 'anti-national' and 'anti-development'. Such simplified interpretations have done immense damage to people and ecosystems.

12. The World Bank is already advocating greater participation of the private sector in hydropower. This needs to be monitored and analysed by the Commission, particularly in the context of impacts to ecosystems.

13. There is a real danger that the private sector may support the construction of larger numbers of small dams, largely as this option is more economically attractive to this sector. The Commission needs to monitor this situation as the impact of small dams could be more damaging compared with a larger dam in a suitable location.

14. Finally, the Commission should prepare a long-term plan to conserve important world rivers, particularly free-flowing rivers. The Commission might initiate a process whereby an

international fund based on collecting a nominal fee on hydropower could be used to initiate projects to conserve major international rivers.[114]

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WEB SITES OF INTEREST

Deccan Chronicle: http://www.deccan.com
Environmental Defence Fund: http://www.edf.org

FAO: http://www.fao.org
International Court of Justice: http://www.icj-cij.org
International Energy Agency: http:/www.iea.org
International Rivers Network: http://www.irn.org
IUCN: http://www.iucn.org
Sardar Sarovar Narmada Nigam ltd: http://www.sardarsarovardam.com
The Hindu: http://www.webpage.com/hindu
The Washington Post: http://www.washingtonpost.com
Union of concerned scientists: http://www.ucsusa.org
World Commission on Dams: http://www.dams.org

ENDNOTES

Introduction:

[1]Mufson, S. 'The Yangtze Dam: Feat or Folly?' *The Washington Post*, 09.11.1997.

[2]See comments by Steinberg, T. in the opening paragraph of an article on water control in 20th century America: 'Writer Wallace Stegner is not terribly fond of dams (...) But when he visited Hoover Dam in 1946 - then called Boulder - he had this to say: "Nobody can visit Boulder Dam without getting that World's Fair Felling. It is certainly one of the world's wonders, that sweeping cliff of concrete, those impetuous elevators, the labyrinth of tunnels, the huge power stations. Everything about the dam is marked by the immense smooth efficient beauty that seems peculiarly American". (Steinberg, 1993).

[3]According to a journalist of a South Asian magazine: 'The serious gap in scientific and economic tools for assessing dams has to be bridged. Only then the process of transparent research and policy reformulation will be able to replace the dual fundamentalism of the influential and arrogant construction lobbies as well as the campaigners for "no dams"'. (Bandyopadhyay, J. 'Dams for the Third Millennium', in *Himàl*, the South Asian Magazine, 11/3, March 1998, p.27).

[4]In its lead editorial of Saturday, November 12, 1998, the *New York Times* mentioned that 'The environmental hazards [of the Three Gorges Dam project] are so great that the US Export-Import Bank has refused to finance loans for the project, and the World Bank has declined to participate. But Beijing has managed to get private foreign financing for the dam through bonds issued by the State Development Bank of China.'

[5]It should nonetheless be noted that dam opponents often question developing countries' need for more energy. According to them, efficiency and conservation measures should be given priority. As R.Goodland notes: 'Dam opponents urge that most of the potential for demand-side management, energy efficiency and conservation be squeezed out of the sector before investing in new capacity.' (Goodland, R. 'Environmental Sustainability in the Hydro Industry: Disaggregating the Debate' in *Large Dams: Learning from the Past, Looking at the Future,* Workshop Proceedings, IUCN/World Bank, Gland, 1997, p.76). See also several comments in chapter 10 of this report taken from *Planning and Management in the African Power Sector*, AFREPEN, Zed Books, 1998.

Part I Chapter 1:

[6]Patrick McCully, Campaigns Director IRN, quoted from the World Commission on Dams information leaflet. See World Commission on dams web site: http://www.dams.org.

[7]David McDowell, Director General IUCN, quoted from the World Commission on Dams information leaflet. See World Commission on dams web site: http://www.dams.org.

[8]See editorial in *The Hindu* by journalist Kuldip Nayar, Saturday 26 September 1998, 'Damage from Big Dams'. The Hindu online: http://www.webpage.com/hindu/daily/98.0926.

Chapter 2:

[9]A useful list of sources on the impacts of hydropower dams is provided in Goodland, R. 'Environmental Sustainability in the Hydro Industry: Disaggregating the Debate' in *Large Dams: Learning from the Past, Looking at the Future*, Workshop Proceedings, IUCN/World Bank, Gland, Switzerland, 1997, p.98-101:

'Goodland and others (1978-1996) amplify hydro mitigation, as does Helland-Hansen et al. (1995). Pearce (1992) and Sklar and McCully (1994) provide useful details. Morse and Berger (1992) are the most thorough on the impacts of a single project (India's Narmada). The most recent is Biswas (1997).'
A checklist for key potential environmental and social impacts of large dams can also be found in Oud, E. & Muir, T.C. 'Engineering and Economic Aspects of Planning, Design, Construction and Operation of Large Dam Projects', in *Large Dams: Learning from the Past, Looking at the Future,* Workshop Proceedings, IUCN/World Bank, Gland, Switzerland, pp.37-39. See also Dynesius, M. & Nilsson, C. 'Fragmentation and Flow Regulation of River Systems in the Northern Third of the World', in *Science,* Vol.266, November 1994, pp.753-762, for an analysis of dam impacts on the river ecosystems and riverine species; and Ligon, F.K. Dietrich, W.E. & Trush W.J. 'Downstream Ecological Effects of Dams: a Geomorphic Perspective', in *BioScience*, Vol.45(3), 1995, pp.183-192.

[10]Inundation also includes: inundation of wildlife habitat, particularly habitat of threatened species with impacts of biological diversity; inundation of potentially valuable mineral resources; inundation of cultural/historic sites. See Dixon, J.A. *et al*. *Dams and the Environment: Considerations in World Bank Projects*, World Bank Technical Paper No.110, 1989, p.16.

[11]See Garzon, C.E. *Water Quality in Hydroelectric Projects*, World Bank Technical Paper No.20, The World Bank, Washington D.C., 1984.

[12]For example, see article on the impacts that dams may have on dolphins. Reeves, R.R. & Leatherwood, S. 'Dams and River Dolphins: Can They Co-exist?' In *Ambio*, Vol.23(3), May 1994, pp.172-175; and on fisheries in general: Mwalyosi, R.B. 'Management of the Mtera Reservoir in Tanzania', in *Ambio*,Vol.15(1), 1986, pp.30-33.

[13]See also article by Balon, E.K. 'Kariba: The Dubious Benefits of Large Dams', in *Ambio,* Vol.7(2), 1978 for a brief account of the dam's impacts on the region's ecosystem.

[14]For example, the Tehri dam in India 'is mainly opposed on the grounds that it could cause seismic activity in the Himalayan region, with disastrous consequences for the populous Gangetic plains below.' ('What Price Tehri Dam?' In *Ambio*, Vol.17(3), 1988, p.246).

[15] IRN web site: http://www.irn.org.

[16]Analysing the problems of land degradation in the Nile Valley, M.A.Kishk identifies several factors that contribute to the deterioration of soil fertility: 'the removal of large amounts of nutrients from the soil without systematic replacement, particularly under very intensive agriculture; the absence of annual deposition of Nile alluvium which previously was a good and continuous source of nutrients; (…) the expansion of agriculture in new, very poor land which was mainly sandy and/or calcareous and proved to be of limited capacity'. In conclusion, the construction of the Aswan Dam and related problems of desertification and wind erosion 'have threatened the fragile balance previously achieved in Egypt'. (Kishk, M.A. 'Land Degradation in the Nile Valley', in *Ambio*, Vol.15(4), 1986, pp.229). For further analysis of the impacts of Aswan Dam, see following articles: Abu-Zeid, M.A. & El-Shibini, F.Z. 'Egypt's High Aswan Dam', in *Water Resources Development*, 1997, pp.209-217; 'The Imperiled Nile Delta', in *National Geographic,* Vol.191(1), January 1997, pp.2-35.

[17]N.Hildyard also argues that small hydro 'is particularly well-suited to rural areas and remote settlements where electricity demand is relatively low and the costs for connecting villages to national distribution systems high (and of course where there are fast flowing, perennial rivers and streams).'
Hildyard, N. *High risk, Low Return?, ABB's Hydropower Strategy Under Review*, published by the Berne Declaration, 25 February 1998, p.17.

Part II:

[18]'Temples of Doom: The Human Consequences of Dams' is the title of chapter 3 of Patrick McCully's book, *Silenced Rivers: The Ecology and Politics of Large Dams*, Zed Books, 1996.
For historical accounts of dam building, see: McCully, P. *Silenced Rivers: The Ecology and Politics of Large Dams*, Zed Books 1996, chapter 1, pp.12-23; Petts, G.E. *Impounded Rivers: Perspectives for Ecological Management*, A Wiley-Interscience Publication 1988, chapter 1, pp.3-11; Smith, N.A. *History of Dams*, P. Davies, London, 1971.

[19]Many also point out that current dam-building is marked by a shift toward larger dams. 'In 1962, 60% of the dams being built were more than 30 meters high, compared with only 21% of existing dams in 1986. Construction of dams higher than 100 meters rose by some 27% between 1991 and 1993; half of these large structures were built by just three countries -Japan, china, and Turkey.' (Gardner, G. & Perry, J. 'Big Dam Construction is on the Rise', in *World Watch*, September/October 1995, p.36).

Chapter 3:

[20]Steinberg, T. 'That World's Fair Feeling: Control of Water in 20th-Century America', in *Technology and Culture*, The International Quarterly of the Society for the History of Technology, The University of Chicago Press, Vol.34(2), April 1993, p.405; and McCully, P. *Silenced Rivers: The Ecology and Politics of Large Dams*, Zed Books, 1996, chapter 1, p.1. When it was completed in 1935 the Hoover Dam was 221m high with an installed capacity of 2,451 megawatts. See Worster, D. 'The Hoover Dam: A study in Domination', in Goldsmith, E. & Hildyard, N. *The Social and Environmental Effects of Large Dams*, Vol.2, Wadebridge Ecological Centre, 1984, p.17 & 20.

[21]Clapp, G.R. 'The Experience of the Tennessee Valley Authority in the Comprehensive Development of a River Basin', in *Proceedings of the United Nations Scientific Conference on the Conservation and Utilization of Resources*, 17.08-06.09.49, Lake Success, New York, p.372.

[22]In 1957-58, an autonomous Corporation was set up on the model of the TVA in India for the construction of Damodar dam 'in the best interest of the nation'. Other examples include USSR (Volga River) and Australia.

[23]*Procès Verbaux et Rapports de la Réunion Technique tenue à Caracas du 3 au 9 sept.1952*, IUPN, 1954, p.176.

[24]See different technical and scientific conferences organised by IUPN in 1947, 1950, 1951 and 1954.

[25]*Procès Verbaux et Rapports de la Réunion Technique tenue à Caracas du 3 au 9 sept.1952*, IUPN, 1954, p.174.

[26]*Procès Verbaux et Rapports de la Réunion Technique tenue à Caracas du 3 au 9 septembre 1952*, IUPN, 1954, p.174.

[27]Smith, A.W. 'Hydro-Electric Power and Renewable Resource Conservation', in: *Hydro-electricity and the Protection of Nature*, IUPN, 1955, p.165.

[28]This does not entail, however, that local people were not displaced by the construction of early dams. TVA development meant the displacement of about 50,000 people from their land; the Dongpinghu Dam in China displaced 278,000 people in 1958; 120,000 people were displaced by Aswan Dam in Egypt (1970).

Chapter 4:

[29]11th International Congress on Large Dams, Madrid, cf. Cheret, 1973.

[30]Ward, J.V. & Stanford, J.A. (Ed). *The Ecology of Regulated Streams*, Plenum Press, New York, USA, 1979.

[31]Examples include lakes Volta and Kariba (see chapter 2, section 2.2.5). According to Goldsmith and Hildyard (1984) 'expansion in fish numbers, however, is likely to prove short-lived bonanza.'

[32]'In developing countries the most important diseases associated with water resource development are: malaria (264 million people are afflicted), schistosomiasis (200 million), lymphatic filariasis (90 million).' (Johansson, B. *et al*. *Renewable Energy: Sources for Fuel and Electricity*, 1993, p.105). See also article by S.Johnson for a discussion on the health impacts associated with the construction of the Volta Dam in Ghana. (Johnson, S. 'A Second Look at Volta Lake', in *The Ecologist*, Vol.1(17), 1971, pp.10-13).

[33]White, G. 'The Main Effects and Problems of Irrigation', in Worthington, E.B (ed), *Arid Land Irrigation in Developing Countries: Environmental Problems and Effects*, Pergamon, Oxford 1977, p.48.

[34]Colson, E. *The Social Consequences of Resettlement: The Impact of Kariba Resettlement upon the Gwembe Tonga*, Manchester University Press from Institute of African Studies, University of Zambia, 1971. Scudder, T. 'What it means to be dammed: the Anthropology of Large-Scale Development Projects in Tropics and Sub-Tropics', in *Engineering and Science*, 1985, 54(4). Scudder, T. 'A Sociological Framework for the Analysis of New Lands Settlements', in *Putting People First: Sociological Variables in Rural Development*, 1981.

[35]A study of 171 National Parks in India revealed that 1.6 million people who were living in 118 National Parks and 600,000 tribal people were displaced due to the creation of protected natural zones. (Kothari, A. Pande, P. Singh, S. & Variava, D. *Management of National Parks and Sanctuaries in India: A Status Report*, New Delhi, Indian Institute of Public Administration, 1989).

[36]*National Geographic*, Vol.192, No.3, September 1997, p.20.

[37]Speaking to the local regional assembly, Sudan's Southern Regional President, Abel Alier, expressed his view over the Jonglei scheme as follows: 'The people of the South cannot even have one full meal a day, and children of school cannot go to school because of our underdevelopment, backwardness and poverty. Yet we are asked to accept all this... and remain in a sort of human zoo for anthropologists, tourists, environmentalists and adventurers from developed countries of Europe to study us... I wish to say that although the Jonglei scheme is a Central Government Project, the Regional Government supports it and stands for it. If we had to drive our people to paradise with sticks, we will do so for their good and the good of those who come after us' (Hildyard and Goldsmith, 1984).

[38]'The planning procedure was to develop alternative technical solutions, to select the least-cost option and to mitigate the environmental and social impact of the plan or scenario to a minimum.' (Oud, E.& Muir, T.C. 'Engineering and Economic Aspects of Planning, Design, Construction and Operation of Large Dam Projects', in *Large Dams: Learning from the Past, Looking at the Future*, Workshop Proceedings, IUCN-World Bank, Gland, 1997, p.17).

[39]See article by Goodland, R. 'Environmental Sustainability in the Hydro Industry: Disaggregating the Debate' in *Large Dams: Learning from the Past, Looking at the Future*, Workshop Proceedings, IUCN/World Bank, Gland, 1997, pp.69-101. Figure 5 (p.77) shows that the design team evolved from engineers and economists for post-WW2 dam projects to comprising engineers, economists, environmentalists, sociologists, affected people and NGOs in the mid-1990s. Figure 6 (p.78) summarises the evolution of participation and consultation

issues from warning, consultation and participation to partnership. See also *Watershed* issue on the theme of participation: *Watershed*, 'Participation', Vol.2(3), March-June 1997.

Chapter 5:

[40]At a meeting of industry representatives in Frankfurt, I.M Sahai, who served from 1991 to 1995 as chairman and general manager of Power Finance Corporation Ltd. in India, said: 'The days of the big dams are over'. Anthony Churchill, former head of energy for the World Bank, insisted that he had considered naming his talk 'Can we save a dying industry?' but opted instead for 'How to make the bankers happy'. (*Risky Business*, World Rivers Review, January 1996).

[41]Conclusions and recommendations of the review were made public in *OED Précis,* World Bank, September 1996.

[42]The publication of the workshop proceedings includes a summary of the workshop discussion and recommendations and a series of overview papers commissioned for the workshop. It is entitled: *Large Dams: Learning from the Past, Looking at the Future,* Workshop Proceedings, IUCN/World Bank, Gland, Switzerland, 1997.

[43]For more information on World Bank policy on large-scale water projects, energy and water issues, see: *New Evaluation Procedures for a New Generation of Water Related Projects*, World Bank Technical Paper No.349, 1996; *Water Resources Management*, A World Bank Policy Paper, 1993; and *Energy Efficiency and Conservation in the Developing World*, A World Bank Policy Paper, 1993.

[44]Scudder quoting the Bank's Senior Environment Advisor in 'Social Impacts of Large Dam Projects', in *Large Dams: Learning from the Past, Looking at the Future*, Workshop Proceedings, IUCN-The World Bank, 10-11 April 1997, Gland, Switzerland, p.42.

[45]As of September 1994, the Manibelli Declaration had been endorsed by 2,154 groups, among them 326 NGOs, representing 44 countries. (*Manibeli Declaration: Calling for a Moratorium on World Bank Funding of Large Dams*, 1994.)

[46]See Goodland, R. *The World Bank's New Policy on the Environmental aspects of Dam and Reservoir Projects*, World Bank Reprint Series No.458.

[47]According to one participant of the hydropower industry meeting in Frankfurt, if the World Bank's involvement in hydropower continues at its current level, 'the Bank is likely to finance only some 5 per cent of the new hydroelectricity capacity in developing countries during the next decades' (IRN World Reviews, January 1996).

[48]See following article for an interesting discussion on social issues: Gyawali, D.'Water Planners Ignore Social Issues', in *Down To Earth*, 15 November 1994, pp.50-51.

[49]Documents on the Sardar Sarovar Project include: Alvares, C. & Billorey, R. 'Damning the Narmada: The Politics behind the Deconstruction', in *The Ecologist*, Vol.17(2/3), 1987, pp.62-74; Chitale, M.A. 'The Narmada Project', in *Water Resources Development*, Vol.13(2), 1997, pp169-179; 'Learning from Narmada', in *OED Précis*, No.88, May 1995; Shah, R.B.'Role of Major Dams in the Indian Economy', in *Water Resources Development*, Vol.9(3), 1993, pp.319-336. Web sites: International Rivers Network: http://www.irn.org; Sardar Sarovar Narmada Nigam ltd: http://www.sardarsarovardam.com.

[50]See following articles on Three Gorges Dam and China's energy policy: Qian, Z. *Water Resources Development in China*, China Water and Power Press, Beijing, 1994; Qing, D. *The River Dragon Has Come! The*

Three Gorges Dam and the Fate of China's Yangtze River and its People, New York, 1998; Hooper, J. 'China's Massive Three Gorges Project Presents Construction Challenges to Nordic Companies', in *Water and Waste Management International*, Vol.10(1), 1995, pp.20-22.

[51]See also summary of 'The General « Big Dams » Debate' in Goodland, R. 'Environmental Sustainability in the Hydro Industry: Disaggregating the Debate' in *Large Dams: Learning from the Past, Looking at the Future*, Workshop Proceedings, IUCN/World Bank, Gland, Switzerland, 1997, p.72.

Chapter 6:

[52]Beard, D. 'Remarks before the International Commission on Irrigation and Drainage, Varna, Bulgaria, May 18, 1994.

[53]Such statements should not hide the fact that the US government and many multinationals support dam building outside the US, whether financially or by providing technical expertise. See also chapter 7, section 7.3.

[54]See article by Chatterjee, P. 'Dam Busting', in *New Scientist*, 17.05.97, No.2082, p.34-37; and article in *The Economist*, 06.12.97, 'Victory for the fishes', p.54.

[55]The Romans were renowned for their aqueducts and water supply systems. Peter Gleick notes that 'The first of the Roman aqueducts was completed around 312 BC and by the height of the Empire, nine major aqueducts supplied Rome with as much water per capita as many parts of the industrialised world today.' (Gleick, P. 'Water and Energy', in *Water in Crisis: a Guide to the World's Freshwater Resources*, 1993, p.67).

[56]Remarks by D.P Beard at the International Dam Summit *"Creating a Vision of Rivers for the 21st Century"*, Nagaragwa, Japan, 14 September 1996.

[57]For general information on the global freshwater crisis, see: Clarke, R. *Water: The International Crisis*, Earthscan Publications, London, 1993.

[58]While oceans may seem unbounded, the amount of freshwater available to human beings is finite. Over 90 per cent of the total volume of water on earth is ocean water. Less than 0.0087 per cent exists as surface water in rivers, streams and natural lakes.

[59]B.Gujja notes in an article in *People and Planet* that 'Poorer countries using less of their water resources are home for much of the planet's remaining tropical forest and wildlife. The future of biodiversity in Africa clearly depends on how the continent uses its freshwater resources in the coming decades.' (Gujja, B. 'Use More, save More', *in People and Planet*, Vol.5(3), p.30).

[60]Alexandros, N. (ed). *World Agriculture: Towards 2010, An FAO Study*, 1995. According to the FAO model, even though growth rate of irrigated land is slowing down, more than half of the increase in global harvest will come from irrigated land between now and 2010.

[61]Eckholm, E.P. 'Salting the Earth', in *Environment*, Vol.17(7), October 1975, p.12: 'In India, almost 15 million acres, out of a total national irrigated area of about 99 million acres, have been severely damaged and in many cases rendered unusable by water logging and salinity'.

[62]These figures are global and there are of course significant variations between industrialised and developing nations. According to a VTZ report on *Renewable Energy Sources: Market Survey*, 1996,

‘Industrialized nations rely more heavily on fossil fuels (86 per cent of primary energy use) than do developing countries (58 per cent of primary energy use). Furthermore, the developing world as a whole relies heavily on biomass (35 per cent), though this varies significantly from country to country.’ (pp. 9-10). Notes on graph: primary electricity (nuclear hydro, geothermal) are converted assuming 33 per cent efficiency (10.909 PJ per Twh). Geothermal includes solar, wind, and wave. Biomass includes traditional (non-commercial) fuels such as fuelwood, bagasse, charcoal, animal wastes, and vegetal wastes.’

[63]According to *BP Statistical Review of World Energy 1997*, 1996 world average for energy consumption per capita is about 1.5 tonnes oil equivalent; the average per capita energy consumption for North America is 6.2 tonnes oil equi., 3.1 tonnes oil equi. for Europe and the Former Soviet Union, and 0.7 tonnes oil equivalent for all remaining countries.

[64]Goodland, R. ‘The Big Dams Debate: The Environmental Sustainability Challenge for Dam Engineers’, in *Civil Engineering Practice*, Spring-Summer 1997, p.11. This statement is also made in *World Resources 1996-1997*, p.275: ‘Although per capita use varies widely from nation to nation, on average, energy use per person is still more than nine times greater in developed countries than in developing countries’.

[65]Source: *World Resources, 1996-97*, table 12.2, pp.286-287.

[66]See comments by R.Goodland: ‘Most developing countries need prompt and major growth in energy and food supplies unless their people are to be shackled to a subsistence level of existence. Irrespective of affluence, just for subsistence everyone will need 1,000 to 2,000 calories of food (and energy to cook that food every day), as well as minimum clothing and shelter. Just this irreducible biophysical minimum to keep pace with rapid population growth will demand much energy and food’. (Goodland, R. 'The Big Dam Debate: The Environmental Sustainability Challenge for Dam Engineers’, in *Civil Engineering Practice,* Spring, Summer 1997, p.11).

[67]Demand side measures include for instance the promotion of energy saving lamps in the power sector. See further comments in section 10.4, chapter 10 of this report.

[68]Over the same period, world oil production rose from 2,940.2 million tons to 3,361.6 million tons.

[69]According to *The International Journal on Hydropower and Dams*: ‘Estimates have shown that hydropower, which supplies 20% of the world’s electricity, has reduced CO2 emissions by around 550 x 10^6 t.’ (*The International Journal on Hydropower & Dams*, Vol.5(1),1998, p.67).

[70]McCully, P. *Silenced Rivers*, pp.141-145; *Ambio*, Vol.2(8), December 1993, pp.568-570; Pearce, F. ‘Trouble bubbles for hydropower’, in *New Scientist*, No.2028, May 1996, pp.29-31. (See also chapter 2, section 2.6).

[71]Pearce, F. ‘Trouble Bubbles for Hydropower’, in *New Scientist*, No.2028, May 1996, pp.31. The mentioned rate of CO^2 emissions corresponds to an averaged rate of 50 years, i.e. the expected 50-year productive lifetime of a hydroelectric reservoir, as estimated by the Canadian government’s Freshwater Research Institute who undertook the study.

[72]Hildyard, N. *High Risk -Low Return? ABB’s Hydropower Strategy under Review*, published by the Berne Declaration, Switzerland, February 25, 1998, p.16: ‘If hydro is an appropriate technology both now and for the future, are there alternatives which offer a better investment opportunity, given the shift in energy priorities? The answer appears to be a clear ‘Yes’. The exciting new energy opportunities range from energy efficiency technologies, through high-efficiency gas energy generation to truly renewable technologies, such as wind and solar.’

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[73]Goodland, R. (Goodland, R. 'Environmental Sustainability in the Hydro Industry: Disaggregating the Debate' in *Large Dams: Learning from the Past, Looking at the Future*, Workshop Proceedings, IUCN/World Bank, Gland, Switzerland, 1997, p.78). One journalist also notes that: 'The question is whether the 'alternative' means (demand management, energy-saving, getting more out of existing capacities, extensive decentralised generation, non-conventional energy sources, etc.) can adequately meet the needs of the projected magnitude of population. I have seen assertion that they can, but not a definite establishment of the proposition.' (Iyer, R.R. 'Large Dams, Larger Issues', in *Himàl*, The South Asian Magazine, 11/3, March 1998, p.31).

[74]See Hildyard, N. *High Risk -Low Return? ABB's Hydropower Strategy under Review*, published by the Berne Declaration, Switzerland, February 25, 1998, p.16: 'Renewable methods of generating electricity have until recently been regarded by most mainstream economists and energy analysts as largely a passion of eco-freaks. But this is fast changing. A 1995 survey of 'the future energy' in the Economist states:
"Little noticed, the costs of many renewables have recently been tumbling. Fossil fuels are still almost always cheaper. But a battle has begun on the fringes of the mighty $1-trillion-a-year fossil-fuel industry that could force it into retreat early that coming century".

[75]In 1977, Hayes argued in a Worldwatch Paper on solar energy that: 'About one-fifth of all energy used around the world now comes from solar resources: wind power, water power, biomass, and direct sunlight. By the year 2000, such renewable energy sources could provide 40% of the global energy budget; by 2025, humanity could obtain 75% of its energy from solar resources. (...) Every essential feature of the proposed solar transition has already proven technically viable. (...) The kind of world that could develop around energy sources that are efficient, renewable, decentralised, simple, and safe cannot be fully visualised from our present vantage point. Indeed, one of the most attractive promises of such sources is a far greater flexibility in social design than is afforded by their alternatives. Although energy sources may not dictate the shape of society, they do limit its range of possibilities; and dispersed solar sources are more compatible than centralised technologies with social equity, freedom, and cultural pluralism. All in all, solar resources could power a rather attractive world.' (Hayes, D. 'Energy: The Solar Prospect', in *Worldwatch Paper* no.11, March 1977, pp.5-13).

[76]Goodland, R. 'Environmental Sustainability in the Hydro Industry: Disaggregating the Debate' in *Large Dams: Learning from the Past, Looking at the Future,* Workshop Proceedings, IUCN/World Bank, Gland, Switzerland, 1997, pp.78. See also table on 'Generalisations of the competition between hydropower and other renewable energy sources' in Goodland, R. 'The Big Dam Debate: The Environmental Sustainability Challenge for Dam Engineers', in *Civil Engineering Practice,* Spring, Summer 1997, p.27.

[77]Discussing the spread of 'green power' in the state of California, Dunn concludes that: 'Just how green California's electricity market will be in the future is uncertain. (...) While the share of those switching to green power is expected to be high in the long run, experts anticipate modest, but steady, growth of the green power market in its early years. As of May [1998], fewer than 100,000 electricity consumers had switched to electricity brokers, and only a fraction of those to green power.' (Dunn, S. 'Green Power Spreads to California', in *World Watch*, July/August 1998, p.7). According to the article, 32% of electricity in California comes from natural gas, 27% from hydropower, 16% from coal, 15% from nuclear and 9% from renewables.

Chapter 7:

[78]See: McCully, P. *Silenced Rivers: The Ecology and Politics of Large Dams*, pp 255-262; Sklar, L. & McCully, P. *Damming the Rivers: The World Bank's Lending for Large Dams,* IRN Working Paper No.5, November 1994, pp.12-14; 'The Politics of Aid', in *Watershed*, Vol.3(3), March-June 1998, pp.2-3.

[79]*Himàl*, The South Asian Magazine, 11/3, March 1998, p.19.

[80]Hildyard, N. *High Risk- Low Return? ABB's Hydropower Strategy under Review*, published by the Berne Declaration, 25 February 1998, p.9.

[81]For example, the World Bank agreed to lend $450 million for the Sardar Sarovar project in 1985. Seven years later, the World Bank decided to withdraw from the project due to heavy criticism of the project and World Bank involvement in it.

[82]See: - Sklar, L. & McCully, P. *Damming the Rivers: The World Bank's Lending for Large Dams*, IRN Working Paper no.5, November 1994, p.31; and - Briscoe, J. *The Financing of Hydropower, Irrigation and Water Supply Infrastructure in Developing Countries*, a background paper for the UN Commission on Sustainable Development, January 1998, p.2; 19-21.

[83]Quoted in Hildyard, N. *High Risk- Low Return? ABB's Hydropower Strategy under Review*, published by the Berne Declaration, 25 February 1998, from A.Churchill of the Washington Energy Group in Shaw, J. 'The Money Game', *International Water Power and Dam Construction*, December 1997.

[84]Churchill, A. 'Meeting Hydro's Financing and Development Challenges', in *Large Dams: Learning from the Past, Looking at the Future,* IUCN/World Bank Report, Gland, Switzerland, April 1997, pp.106-107. See example of the Xekaman 1 Project in Lao PDR, which was recently privatised. According to *Watershed*, the privatisation of the dam does not seem to have brought any changes regarding the adverse impacts of the hydro dam on fisheries, forest and local communities living along the Xekaman river. (*Watershed*, Vol.3(2), November 1997-February 1998, pp.45-49).

[85]Oud, E. & Muir, T.C. 'Engineering and Economic Aspects of Planning, Design, Construction and Operation of Large Dams', in Large *Dams: Learning from the Past, Looking at the Future,* IUCN/World Bank Report, Gland, Switzerland, April 1997, pp.21-22.

[86]See: Usher, D.A. 'Damming the Theun River: Nordic Companies in Laos', in *The Ecologist,* Vol.26, No.3, May/June 1996, p.85-86; and *Watershed*, 'The Politics of Power', Vol.2(2), November 1996-February 1997, pp.45-50.

[87]'Between 1990 and 1995 the Bank approved 12 hydropower projects, accounting for about $600 million a year of the total estimated investment in hydropower in developing countries of about $15 billion a year.' (Briscoe, J. *The Financing of Hydropower, Irrigation and Water Supply Infrastructure in Developing Countries*, a background paper for the UN Commission on Sustainable Development, January 1998, p.19).

[88]McCully, P. *Silenced Rivers: The Ecology and Politics of Large Dams*, Zed Books, 1996, p.260. See for example the role of Japanese ODA in the Mekong region: Nette, A. 'Japanese ODA: Moving into the Mekong', in *Watershed*, Vol.3(1), July-October 1997, pp.45-48).

[89]EDF web site: http://www.edf.org (section on large dams).

[90]For example, one of the major aims of the Bakun scheme apart from irrigation and electricity was the industrial development of Sarawak and Malaysia as defined by the authorities in the country's ambitious industrialisation campaign "Vision 2020". (See *Tomorrow*, Vol.7(1), February 1997, p.35 and Mohun, J. & Sattaur, O. 'The Drowning of a Culture', in *New Scientist*, No.1543, 15 January 1987, p.39).

[91]For example, India decided to go ahead with the construction of two 260 MW thermal power units in October 1997. The advantage of such a project (in terms of social, economic, financial and environmental costs and benefits) compared to the construction of another Hirakud dam (same rated capacity of 270 MW) is doubtful,

or at least disputable.

[92]On this subject, McCully, P. (1996) notes that 'an important consideration which should be taken into account when decisions are made about such massive and risky investments as dams is their opportunity cost - the cost of not using the money for other investment which may be more efficient and more socially beneficial.' Any compensation should only be for the opportunity cost compared to the next most acceptable option, and the accounting should consider the hidden costs dam builders normally ignore.

[93]As is noted in *World Resources 1992-93*, technically feasible hydropower potential 'refers to the energy that is exploitable under existing technical limitations and economic constraints' (p.334); it is therefore of a lower value than **gross theoretical hydropower potential** which assumes 100% efficiency. It also differs from the **economically feasible hydropower potential**, substantially smaller, which is calculated on the basis of detailed environmental, geological and other economic constraints. Any estimate of economic potential is clearly speculative, especially in the regions of greatest untapped potential. According to us, **technically exploitable potential** is the most reliable estimate of a country's hydro potential and it is this estimate of a country's hydro potential that is considered in this report.

[94]Note that large countries like Canada, Australia, China, etc. may be included in one of the categories although their actual hydro potential developed is often lower than the percentage range of this particular category. However, the size of these countries suggests that hydro potential developed is likely to remain low because of high exploitation costs, i.e. technical, physical and/or financial.

[95]According to Gardner and Perry, 'China accounts for more than one-fourth of the big dams under construction, while China, Japan, South Korea and India together account for more than half'. (Gardner, G. and Perry, J. 'Big Dam Construction is on the Rise', in *World Watch*, Sept/Oct.1995, p.36).

[96]Source: *BP Statistical Review of World Energy 1997*. Table lists consumption of primary energy by fuel. Data is given in million tonnes oil equivalent.

[97]The case of Australian corporations, the Tasmanian Hydroelectric Corporation and the Snowy Mountains Engineering Corporation, are classic examples of first world dam builders being shut out of their territory due to environmental restrictions then exporting their experience to developing nations, in particular in this case, Laos. See also chapter 7on privatisation and aid.

[98]In Asia for example, 'the potential for hydro-electricity generation in the region is huge: there are suitable sites for some 735,000MW of capacity, five times the capacity of existing dams plus those that are currently under construction'. ('A Dam Nuisance', in *The Economist*, 12.10.1996, p.74).

[99]Source: *World Atlas and Industry Guide, 1997*, The International Journal on Hydropower and Dams, International Hydropower Association, Sutton, UK.

[100]R. Goodland notes that 'China's Three Gorges multipurpose project is projected to generate 84,000 gigawatt hours of electricity, which is the equivalent of annually burning 40 million tons of local coal (based on 1 tonne equal to 2,100 kilowatt hours.' (Goodland, R. 'The Big Dams Debate: the Environmental Sustainability Challenge for Dam Engineers', in *Civil Engineering Practice*, Spring/Summer 1997, p.13).

[101]Source: *BP Statistical Review of World Energy 1997*. In 1996, consumption of oil was, in million tons equivalent, 172.5 for oil, 140.3 for coal and 15.9 for natural gas and hydroelectricity.

[102]China is planning to expand its installed capacity from the present 53Gw to 70Gw by the year 2000.

India has 10,000Mw under construction and a further 28,000 Mw planned while Brazil has more than 10Gw of hydro capacity under construction. (*World Atlas and Industry Guide 1997*, The International Hydropower Association, Sutton, UK, p.3).

[103]Based on data analysis and general observable trends, it was estimated that between 1995 and 2000, hydro production will increase by 10 per cent for Group 1, 40 per cent for Group 2 and 60 per cent for Group 3.

[104]*World Register of Dams*, ICOLD, 1998 (CD-Rom).

[105]North Africa and the Middle East, which account for only 5% of the world's population, imported about one fourth of total world grain imports in 1997. (Brown, L.R. & Halweil, B. 'China's Water Shortage Could Shake World Food Security', in *WorldWatch*, July/August 1998, p.20).

[106]International Energy Agency, web site data. http:/www.iea.org.

[107]According to the authors of *Planning and Management in the African Power Sector,* Ethiopia's hydropower is much in excess of the demand in both Ethiopia and Sudan. In fact, it is sufficient to meet the energy demand of all Nile riparian countries up to the year 2010 (p.212).

[108]It is estimated that, if industry in Ethiopia depended solely on electricity today, the power sector would have to install about 14 times its present generation capacity. (*Planning and Management in the African Power Sector*, AFREPEN, Zed books, Ltd, 1998, p.234).

[109]See section on Ethiopia in *Planning and Management in the African Power Sector*, AFREPEN, Zeb books, Ltd, 1998, p.232: 'In Ethiopia, the increased use of woody biomass in factories aggravates carbon dioxide emission by causing a reduction of CO2 sinks and promoting climate change'.

[110]According to G.Ledec, 'the amount of environmental and social damage from a proposed hydroelectric project is largely determined by the dam site (...) For hydroelectric projects the most effective environmental and social mitigation measure is good dam site selection.' (Ledec, G. *Good Dams, Bad Dams: Environmental and Social Criteria for choosing Hydroelectric Sites*, The World Bank, October 1997, p.17).

[111]Starr, C. & Milton, F., *Global Energy and Electricity Futures: Demand and Supply Alternatives*, Energy Systems and Policy, 1990.

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[112]ICOLD 1997 Annual Enquiry concerning the construction of new dams in its 80 member countries.

[113]After the demolition of Newport Number 11 in Vermont, USA, the United States government ordered on 25 November 1997 the removal of Edwards dam, on Maine's Kennebec river. Studies showed that it was less expensive for the private owner of the dam to remove the latter rather than add fish ladders to help fish migrations, a condition set by The Federal Energy Regulatory Commission (FERC) for the renewable of the owner's operating licence. ('Victory for the fishes', in *The Economist*, 06.12.97, p.54). See also article on the battle to restore Lake Pedder, a unique glacial lake in Tasmania, which was flooded as part of a massive hydroelectric project in 1972. (Anderson, I. 'Can Lake Pedder Resurface?' In *New Scientist*, No.1941, September 1994, pp.14-15). See also IRN web site on 'dam decommissioning': http://www.irn.org.

Chapter 12:

[114]World hydroelectric consumption was 2,460,000Gwh/y in 1995. If one cent is taxed per MWh produced, $24,600,000 would be available for an initial international fund. To give a better idea, one kWh consumption is equivalent to a 100 watt (bright) light bulb switched one for ten hours or an oven cooking

Sunday lunch and the dishwater washing up afterwards. In addition, one cent tax per MW corresponds to about 1/100 of what US citizens pay for 1 MWh of electricity consumption based on statistics from the international energy agency which indicate that the price for domestic electricity in the US is for the 4th quarter of 1996 $0.0824/kWh. (See IEA web site: http://www.iea.org/stats/).