ELSEVIER

Energy Policy 30 (2002) 1207–1213

ENERGY POLICY

www.elsevier.com/locate/enpol

Hydropower—the politics of water and energy: Introduction and overview

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Abstract

This special issue of Energy Policy is dedicated entirely to hydropower and this introductory article provides an overview of the contents. It is divided into three main subject areas: the present situation and history, the main policy issues, and the future of the hydropower industry. The first area covers the evolving context, the diversity, and the potential of the hydropower industry, and also reports on hydropower in China, the country with the largest remaining potential. The policy area covers the social and environmental effects, the regulatory framework and public acceptance issues. The discussion of the future describes the changes that are underway and still need to be made, to ensure that hydropower will continue to serve the needs of society for electricity and several other important services. Hydropower projects can yield large benefits to society, but they also entail costs, and well-informed decision-making processes are necessary to ensure the best outcomes for a region or a country. The authors who contributed to this special issue hope that their articles will provide some of the information needed for good decision making.

Keywords: Hydropower; Environment; Renewable

1. Introduction

The management of water resources has been one of the functions of government since the earliest civilizations arose in the Nile, Yellow, and Indus river valleys. Governments not only decided who would get how much irrigation water, but they also addressed the problems associated with flooding, in some cases regular annual floods such as in the Nile, and in other cases less predictable floods which destroyed lives and property. Some of the earliest public works projects were canals, dikes and aqueducts which used the water resources for the benefit of society and which protected the population from floods.

More than a hundred years ago, electric motors and light bulbs appeared in our societies, and electricity was needed to make them work. The first hydropower plants were constructed in the 1890s, and hydropower became an important new benefit that could be derived from a country's water resources. Governments were involved right from the start, they needed to adjust their water policies and regulations, so that this new use of water resources would fit in harmoniously with traditional users such as irrigation, shipping, fisheries, etc. Then as now, Governments had to ensure that the development of water resources was of overall benefit to society, and took account of the interests of all stakeholders.

Because hydropower has one foot planted in the area of water policy, and the other in the area of energy policy, the major hydro projects in the world have always been subject to government approval, and consequently to government policy and politics. A few of the major hydropower projects around the world were built in politically charged situations. The Tarbela dam in Pakistan was part of the Indus River Agreement intended to prevent resumption of open warfare between India and Pakistan. The Aswan High Dam in Egypt was built by Russia during the cold war, after the USA had declined to support the project. Most large hydro projects are built under less dramatic circumstances, but in all cases governments need to decide whether and under what conditions large hydro projects should be approved.

For any decision-making process, it is essential that all participants be well informed. For highly complex

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0301-4215/02/$ - see front matter
PII: S0301-4215(02)00081-2

decisions such as those involving hydropower projects this is doubly true. This special issue, devoted entirely to hydropower, attempts to clarify what hydropower is and does, and to set out some of the main policy questions that are the subject of current public debate.

This article will start with a description of the global importance of hydropower, and will then present an overview of all the articles in this special issue. The articles are organized into three main themes: basic information about hydropower, the main policy issues, and future development of hydropower. The first four articles following the present one will give some of the facts about hydropower, and the role it plays today in the power sector. This will then lead into a series of six articles on some of the main policy issues. The last two articles look to the future and provide some thoughts and guidelines about the role of hydro in the coming decades.

Many of the articles in this issue are based on the work of an International Energy Agency (IEA) working group on hydropower, known formally as the "IEA Implementing Agreements for Hydropower Technologies and Programmes". The Hydropower Implementing Agreement has recently completed a number of studies on the environmental and social impacts of hydropower, and their mitigation measures. The intention was to provide objective, balanced information on some of the controversial issues related to hydropower. Other articles in this special issue are by invited authors well known in the hydropower literature.

2. The global importance of hydropower

2.1. Size in energy and economic terms

In 1999, hydropower generated 2659 TWh of electricity (2659×10^9 kW h), which was 17.5% of the world's total electricity production, and 3.3% of global final energy consumption (IEA Energy Statistics, 1999). If the average wholesale price of electricity is taken to be about 3 cents (US) per kW h, then the annual 1999 production would be worth $ 79,8 billion. For comparison, the GNP of the Philippines, the 40th largest economy in the world, was US $ 78 billion in 1999 (IBRD, World Development Report, 1999). These figures demonstrate that hydropower is important at the level of the global macro-economy. At a national level, hydropower has a major macro-economic impact in the 65 countries where it supplies more than 50% of national electricity production, and even more so in the 32 countries where it supplies more than 80% (IHA et al., p. 1).

To illustrate the size of the global hydropower industry, it would have required 1595 million tons of coal to generate the same amount of electricity that was produced by hydropower in 1999.[1] This is equal to a coal unit train of 100 cars every 3 min, for 24 h/day and 365 days/yr.[2] If these unit trains were on the same track moving at a speed of 30 km/h, there would be no gaps between them, and they would become one infinite unit train.

The present size and revenues of the hydropower industry make it an important component of the total energy supply system. However, the future is even more impressive, because the remaining economic hydropower potential which could be developed is estimated at 5400 TWh/yr, or about twice the currently installed capacity (IHA et al., p. 1). This would be equivalent to revenues of more than $ 160 billion/yr.

3. Overview of articles in this special issue

3.1. The evolving context of hydropower development

The article by Engelbert Oud, which immediately follows the present one, will trace the evolution of the hydropower industry. Some readers may have recollections dating back to the 70s, when hydropower was generally considered to be a very good thing, and may be asking what has happened to hydropower during the past 20 yr? The answer is that social attitudes have changed, and technology has had to adapt to these changes. Technology is, after all, the application of science to the needs of society, and if the needs change, technology has to change with them.

The hydropower industry has been a first-hand witness to the fact that our value systems keep evolving over time. The increased awareness of environmental issues and an increased concern with the rights of minorities or small groups in society have led to important changes in how governments decide on large hydro projects, or, for that matter, on all large infrastructure projects. These same trends have also led to changes in the public's perception of hydro projects. Whereas in the post-war period almost every hydro project was considered a good project, and many governments nationalized the hydropower facilities in their country because of their benefit to the public, today perceptions are more differentiated, and it is more widely recognized that hydro projects have both advantages and disadvantages. Weighing the former against the latter, and then reaching a decision, is a challenging and complex task for the policy maker and the politician, because many factors entering into the

[1] Although the efficiency of coal generating plants varies widely, and different kinds of coal have different energy content, it is assumed that 0.6 kg of coal is required to generate 1 kW h of electricity.

[2] One wagon of a coal unit train holds about 90 Mt–CSXT Railcar Fleet Details, November 1999.

decision are not quantifiable and are not even comparable. The advantages of a hydro project might include not only a certain amount of renewable electricity produced with negligible amounts of noxious or greenhouse gas emissions, but also flood control, irrigation, urban water supply, improved navigation, and additional recreational facilities in the form of a new lake. The disadvantages might include negative environmental impacts on a river's ecosystem and disruption of communities in the area of the project. Putting these in the balance, and then deciding whether or not a project should go ahead, and under what conditions, is the very essence of policy and politics. There are no neat prescriptions and solutions, and there is no formula that can give an answer once the right numbers are plugged in. It is only possible to design a process, which will consider the important factors and the interests at stake, and arrive at compromises that will ultimately benefit our present and future generations. The article by Engelbert Oud traces how hydropower decision-making processes have evolved, and describes how these decisions are made today.

3.2. The diversity of hydropower projects

The diversity of hydropower projects in size and nature sets it apart from most other electricity production technologies. The article by Dominique Egre and Joseph Milewski will review the different categories, and will introduce a recurring theme throughout this special issue: "Not all hydro projects are the same—each hydro project should be judged on its own merits". There are, for example, many hydro projects known as "run-of-the-river" projects, which do not have a large dam. There are many other projects which do have a large dam but which are located in high mountain areas or in remote semi-desert areas, where there are no local populations and which do not have large effects on the ecosystem. In more populated areas, hydro projects are often multi-purpose projects in which irrigation, flood control, navigation or recreation may be more important objectives, and electricity generation is only a fifth or sixth priority. Finally, there are the more challenging projects, which involve inundation of highly valued land and the involuntary displacement of local populations. In these cases the weighing of benefits against costs becomes difficult and often controversial, and high levels of social, environmental, technical, and political skills are required to plan, construct, and operate the project. These projects are perhaps the most interesting from a policy perspective, but they are only one of the many different classes of hydro projects.

The article points out that it is simply not possible to make a general judgment about large hydro projects, either that they are generally beneficial and should be encouraged, or that they are generally problematic and should be avoided. Some projects represent clear benefits to society and to the environment, and should definitely proceed, whereas others may have environmental and social consequences, which a country is not willing to accept. This diversity among sites and projects adds another dimension to the political decision-making process, the specific local situation needs to be considered in each case.

3.3. Hydropower potential

The global importance of the hydropower industry derives as much from the future potential as it does from its present size. The third article by Alison Bartle presents a world overview of hydropower development and potential. It will show that much of the remaining potential is serendipitously located in those countries where demand is expected to grow most dramatically, i.e. in China, India, Brazil, and other Asian and Latin American developing countries. Projections by the IEA, the World Energy Council, and others foresee the largest growth in world electricity demand occurring in exactly these countries. By and large the resource potential exists where it is needed most.

3.4. Hydropower in China

The fourth article focuses on China, the country that not only has 21% of the world's population, but also 16% of its hydropower potential. Electricity demand in China will grow dramatically during the next decade, and during this time China will add more new hydropower capacity than any other country. The main generating options for China are hydropower and coal. The Government of China is faced with all the policy issues described in this Special Issue, and its decisions will affect not only the prosperity and quality of life of its own citizens, but also the global level of greenhouse gas emissions and consequently all the inhabitants of this planet.

4. The main policy issues—the positive and negative effects of hydropower on society and the environment

The main policy themes related to hydropower are the privatization of electricity markets, the social impacts of dam and reservoir projects, and the environmental impacts of hydropower. The latter two themes have had a strong effect on the public acceptance of large hydropower projects and were also the focus of the IEA Hydropower Agreement's work. For this reason, privatization will not be discussed, and the articles on policy issues will concentrate on the social and environmental effects.

4.1. Social effects of hydropower

Both the positive and the negative social effects of hydropower give rise to issues, which need to be addressed. On the positive side, a hydropower facility generates a lot of revenue from a natural resource, a river, and questions inevitably arise about the sharing of these revenues among the local communities, the government, and the investor in the plant (which is often a government corporation as well). In some countries, individuals and companies can own water rights, in other countries they are leased, and in yet other countries the government owns all the water rights. Independently of the legal provisions, the good will and cooperation of local communities in the project area are very important for its success, and the developer will usually work out arrangements to share some of its benefits with the local communities. This can take many forms including job creation, improvements of roads and other infrastructure, recreational facilities, sharing of revenues and payment of local taxes.

Aside from the revenues, the water resources themselves are often shared among irrigation, inland fisheries, flood control, navigation, recreation and tourism, etc. This need to share creates a fundamental need for sound water resources policies, on which processes can be constructed to arbitrate among competing claims and to manage the sharing arrangements on a day-to-day basis.

On the negative side, those hydro projects, which include a dam and a reservoir, will often necessitate the involuntary displacement of people from the area to be inundated. Throughout the world, expropriation has become increasingly difficult for all types of infrastructure projects, including hydropower projects. Unfortunately, the historic record is not unblemished, there are too many instances where displaced populations were not treated fairly or humanely. Today, there is greater public sympathy for such negatively affected groups, and modern communications have empowered civic society to make their voices heard. The solution is easy to say but difficult to do: make sure that affected people are better off after the project both in the short and the long term. Experience has been gained with the problems associated with resettlement, and there are now a number of "best practice" projects where this issue was handled successfully. The article entitled "Hydropower Projects: A Review of Most Effective Mitigation Measures" includes social mitigation measures, and discusses this question more extensively.

The question of fisheries is both an environmental and a social issue. The environmental aspect involves avoiding damage to habitats or compensating for them. The social aspects involve inland fisheries as a livelihood, a source of protein in the diet or a recreational resource. The article on mitigation measures will also elaborate on dealing with this issue.

Large-scale irrigation projects, which include many ditches with stagnant water, can lead to increases in water-borne diseases, especially in tropical areas. To a lesser extent, this can also occur in hydropower projects, and in temperate climates. Hydropower planners and operators have to be aware of these risks, and take appropriate measures to avoid them.

4.2. Environmental effects of hydropower

The article on the "Renewable and Sustainable Nature of Hydropower" discusses the main environmental advantages of hydropower, the fact that it is renewable and that it generally produces negligible emissions of greenhouse gases or other noxious emissions. At the same time, it recognizes that hydropower can have negative effects on aquatic and riparian ecosystems, and these disadvantages have to be weighed against the advantages. There are some widely held misconceptions on this subject, one is that "small hydro" is always more benign than "large hydro", and for this reason small hydro should be included in many countries' renewable energy programs, whereas large hydro should be excluded. In fact, one large hydro project can well be more benign than a hundred small ones, which generate the same amount of electricity. A second misconception is that large hydropower is renewable, but not "sustainable" because of its severe environmental impacts. A contributing factor to this misconception is exactly the variety and diversity of hydro projects, and consequently the variety of environmental impacts that may be encountered under different circumstances. For new projects, it is often possible to avoid or mitigate most of the impacts through good planning, design, and operation.

Energy policy makers have to make choices, all electricity generating options have environmental, social, and economic consequences, and the optimum decision has to be made in particular situations. The two articles on comparing electricity generation options give an excellent overview of the environmental impacts of generation options and how wind power could complement hydropower. In these comparisons of options, life cycle assessment attempts to quantify the main environmental impacts of a process, such as electricity generation, taking into account all contributing factors "from cradle to grave". On the whole, hydropower comes out very favorably in the comparison. Because of the diversity of hydro plants, it is usually not possible to assign a single numerical value to each environmental parameter, and instead a range of values is indicated. Life cycle assessment cannot provide complete answers to policy makers, because it is difficult to quantify some environmental impacts such as biodiversity, and almost

impossible to quantify social impacts. Similarly, it does not provide a way of balancing one kind of environmental benefit against another kind of environmental cost. For example, it may be possible to predict that a given project will save 100,000 tons of carbon dioxide per year, and also that a certain fish population is likely to decline by 2000 fish. We still do not have a methodology of balancing the one against the other. Life cycle assessment is a great help, but it cannot reduce all the complex factors involved to a simple decision-making formula.

4.3. The ethical and legal issues of hydropower development

In deciding on hydropower projects, Governments have to consider a whole range of important policy objectives which are not internalized in market prices, such as:

(a) Maintaining secure primary energy supplies.
(b) Reducing undue fluctuations in electricity prices, and maintaining an uninterrupted electricity supply.
(c) Protecting the lives and property of its citizens from floods.
(d) Maintaining the established rights of its citizens with respect to expropriation of land to be inundated.
(e) Maintaining or enhancing economic equity among its citizens.
(f) Improving air quality, especially in urban centers.
(g) Reducing greenhouse gas emissions.
(h) Protecting the environment on their land and in their waters.

Some or all of these competing, and sometimes conflicting, policy objectives inevitably bring major hydropower decisions into the political arena. The constituencies dedicated to supporting one or more of the above objectives will find themselves in conflictual situations, and a resolution has to be found. A priori, there is no obvious way to arbitrate among the claims of persons who are positively and negatively affected by hydro projects, and among the economic and environmental benefits of a project versus adverse social and environmental impacts.

A society codifies its value system in its legal and regulatory system. The two articles on "Ethical dilemmas and the decision-making process" and "The environmental legal and regulatory frameworks" compare the systems in place in several IEA member countries, and explain the reasons for their complexity. Hydropower affects both the power sector and water resources sector; each hydro project is highly site specific; and there are many different stakeholders in each project. The effectiveness and efficiency of the system itself have now become important issues. Effectiveness is defined as giving the right outcome: good projects are approved, mediocre ones are modified, and poor ones are disallowed. Efficiency is defined as using the minimum amount of time, human and financial resources to reach good decisions.

4.4. Public acceptance of hydropower

In most IEA countries, hydropower is not a high-profile issue in the eyes of the general public. Understandably, there are also significant variations among countries about the importance of hydropower. A large part of the world's hydropower plants are quietly and unobtrusively generating electricity (and revenues) while largely hidden from public view, either because the sites are remote or because the facilities are largely underground. Other hydro projects are in full public view, and produce other benefits such as flood control, irrigation, urban water supplies, improved navigation, fisheries, and recreational facilities which are enjoyed by large segments of the population. However, some activist groups in civil society are deeply concerned by some of the social and environmental issues related to hydropower, and a few of them focus most of their attention on opposing dams, reservoirs and hydro projects. The public image of the hydropower industry is affected by the criticisms of negative environmental impacts and of unfair treatment of persons who were involuntarily displaced or otherwise adversely affected. Large dams have become controversial and large amounts of information and misinformation about them has been widely disseminated. It has become more difficult to know where the truth lies and to form a balanced, objective opinion about these issues.

Few would deny that there are some poor dam projects when judged by their environmental impacts or by the way that the people affected by the project were treated. There are about 45,000 large dams in the world, and of necessity, the 50 or 100 least successful ones can be expected to have serious shortcomings. Somewhat surprisingly, the proportion of problem dams in the overall total is not well known. The main inventory of the world's large dams, the ICOLD database, is not intended to provide information on environmental and social parameters. In the absence of a complete study of all dams, or a statistically representative sample, most studies have selected a smaller or larger number of case studies, which are usually chosen precisely because they are controversial or have interesting problems. The literature dealing with problem dams is highly repetitive, the same cases are cited over and over again. This might indicate that the number of controversial dams is a relatively small percentage of the world total.

The issue of public acceptance has become a high priority for the hydropower industry. In some countries,

legislators and regulators have been affected by the advocacy efforts of opponents to hydropower and large dams, and the time and money required for the license approval process have increased substantially. At a more abstract level, good hydropower projects can make a large positive contribution to society and the environment, and persons in the industry want society to make the right decisions for its own benefit. Traditionally, the industry has not allocated many resources to its public image or to public relations, and government owned corporations are often constrained in this area. However, the general public deserves to have balanced, objective information on these issues, and efforts in this direction are now increasing within the IEA and other organizations.

4.5. Globalization of the hydropower debate

The debate about large dams has become globalized and opponents of a specific project or of hydropower in general have appealed to global public opinion. They have targeted international financial institutions such as the World Bank, and Export Financing Organizations in the industrialized countries. In response, the World Bank and the IUCN (International Union for the Conservancy of Nature) have jointly established a World Commission on Dams (WCD), which published its report in November 2000. The article entitled "Comparing recommendations from the World Commission on Dams and the I.E.A. Initiative on Hydropower" compares the principles, strategic priorities and detailed guidelines of the WCD with those produced by the IEA process.

One interesting question that arises from such a global debate is which issues are global, and the appropriate concern of the international community, and which issues are local and should be left to national authorities to decide. Among the environmental issues, the questions of greenhouse gases and biodiversity are widely recognized as being a global concern. Among the social issues, however, there is much less clarity, and the involuntary displacement of people is a particularly thorny question. Standards of compensation and notions of fairness vary widely from country to country. It would be difficult to formulate practical guidelines in this area, and even more difficult to apply them without infringing on the sovereignty of governments. The IEA report recommended that each country should make such decisions in accordance with its own developmental, economic, environmental and social priorities and taking into account its own culture and value system. The WCD advocated a set of international social and environmental standards, which would apply to all dam projects wherever they are.

5. The future of hydropower

The potential hydro sites in the world fall into the following three broad categories:

- sites which are economically viable and socially and environmentally acceptable;
- sites, which are presently not economically viable but are socially and environmentally acceptable;
- sites which are socially and environmentally controversial or unacceptable.

Policy makers and politicians will ultimately define what is socially and environmentally acceptable, and consequently which potential hydro sites in their countries fall into which category. Through electricity marketing policies, renewable energy subsidies, or carbon taxes, policy makers will also set the conditions which will make sites economically viable or not. Some countries (for example Norway and Sweden) have made very explicit master plans for all their large potential hydro sites and have decided which ones can or cannot be developed. Other countries are making these decisions on a case by case basis as development proposals are made. Some industrialized countries such as Canada, Finland, Norway, and Portugal are continuing to develop sites in the first category. Most industrialized countries have subsidies for small-scale hydro because it is perceived as environmentally and socially attractive. These subsidies move small-scale hydro from the second category to the first category. Depending on how "small-scale" is defined, and if fully developed, this could produce about 10% of the amount of electricity of large-scale projects.

The developing countries are of particular interest to the power sector and the hydropower industry. Both their populations and their economies are expected to show strong growth during the coming decades, and this will give rise to strong demand for electricity. In fact, the largest share of increased global demand for electricity is expected to be in the developing countries. In most cases, these countries will need to construct both coal and hydro generation plants. Because of climate change concerns, it is in the direct interest of the other countries of the world to have as large a share as possible for hydropower so that greenhouse gas emissions are minimized. In many cases this is also in the interest of the countries themselves because many of them are experiencing serious air pollution problems in their large cities.

Although the international debate on hydropower is not settled by any means, a consensus is gradually emerging that the question is not whether to construct hydropower and water resources projects, but how to construct them. The life cycle analysis results show that hydropower is the most environmentally friendly option

for power generation, and is the single best hope for reducing greenhouse gas emissions in the power sector. However, hydropower does affect aquatic and riparian ecosystems and the communities in the project area. How to avoid, minimize, mitigate or compensate for these adverse affects has become a central part of the planning and design of new projects. A large amount of expertise and experience has been acquired on these subjects and in most modern projects an important share of the project budget is allocated to addressing these concerns. Both the IEA and the WCD reports recognize that large dams will continue to be needed in our societies, and have formulated recommendations and guidelines for how such projects should be handled. There is agreement that the remaining potential should definitely be developed, but that does not mean that every proposal should be approved. It will all depend on how the project is structured and designed, and on the process that has been used to arrive at compromises on the environmental, social, and economic issues. The article entitled: "The ideal hydropower? Recommendations for development" elaborates on how these projects should be managed throughout their entire life cycle.

6. Conclusion

The continuing debate about large dams and reservoirs is increasingly focusing on the decision-making process for such projects. Both the IEA and WCD reports agree that public acceptance is one of the most important issues, and recommend that public participation must be a key element of the decision-making process, but not all countries agree on this point. As noted previously, there is also disagreement on which questions are the legitimate concerns of the international community, and which other questions are the business of national governments only. However the decision-making process is structured, it is essential that all parties operate on the basis of objective, balanced information on the likely economic, social, and environmental consequences of proposed projects. All the authors of this special issue hope that their articles will contribute to enabling energy policy makers to form such a balanced, objective view of the role of hydropower in our societies.

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