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Source: Mountain Research and Development, 21(1) : 4-9

Published By: International Mountain Society

URL: https://doi.org/10.1659/0276-4741(2001)021[0004:HFEIN]2.0.CO;2

Mountain Research and Development Vol 21 No 1 Feb 2001: 4–9

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An adequate and reliable supply of energy is a prerequisite for development. In Nepal, forests and water are the two major indigenous energy resources. Forests are being overexploited in many parts of the country, mainly for fuelwood, whereas water resources are underutilized with regard to their capacity to generate hydroelectricity. Nepal might be able to control forest degradation by adopting a differentiated approach to hydropower development. The prospects and the risks of such development are discussed here, and three scenarios that have received increasing attention in recent years are presented for implementation in a wider South Asian context.

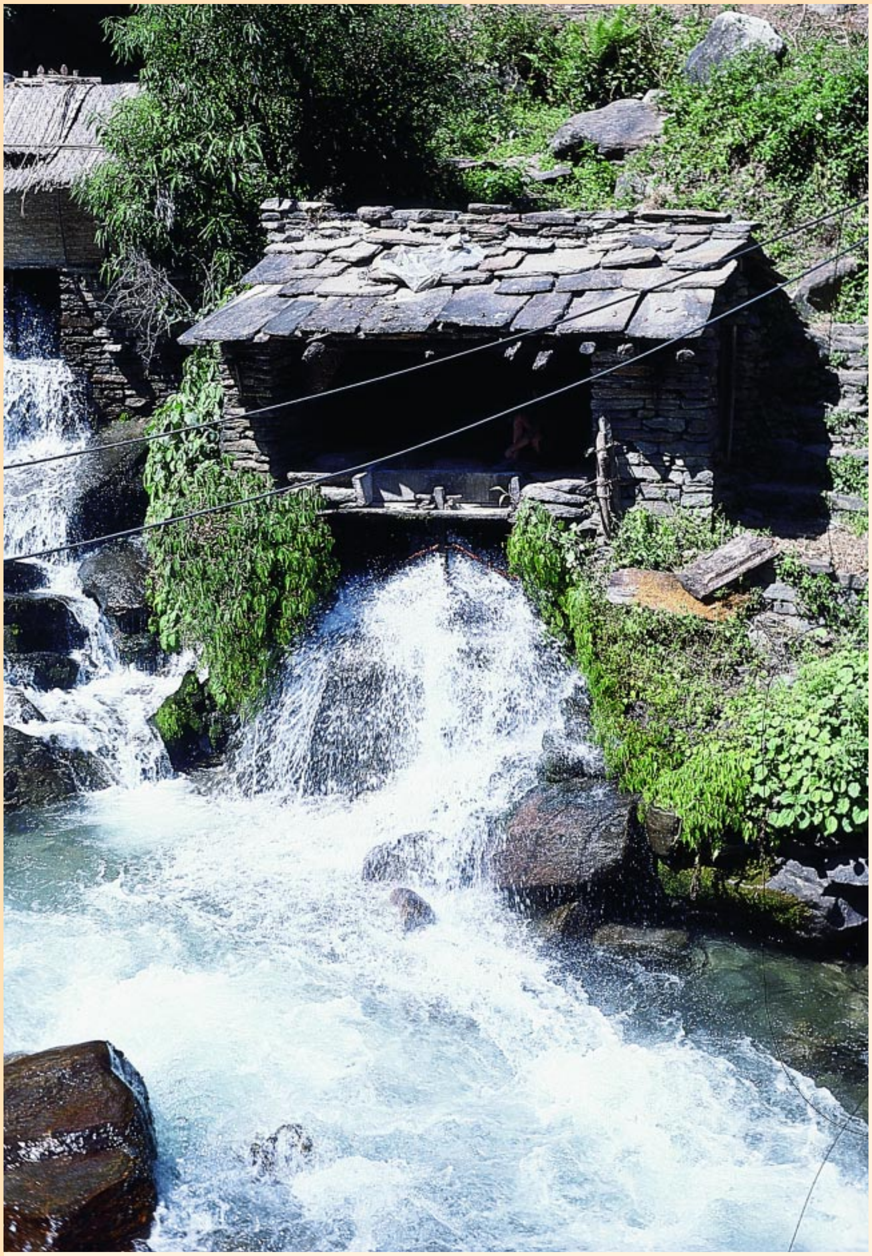

FIGURE 1 Nepal's rich mountain water resources make small hydels of this sort possible. Such plants are used to produce power in remote valleys for small-scale industry. (Photo by Susanne Wymann von Dach)

Developing hydropower to reduce dependency on forest resources and oil imports

Almost 80% of all household energy in Nepal is supplied by fuelwood, and demand is growing. Energy needs translate into demand for an estimated 14 million tons of wood annually. While Nepal's forests have a potential to supply 15 million tons of fuelwood annually on a sustainable basis, only half of this potential is actually used because of difficult terrain and accessibility, uneven population distribution, and varying levels of consumption. This implies that many forests are overused while others are used below capacity.

On the other hand, Nepal is richly endowed with water resources (Figure 1). The country is the major subbasin of the Ganges (Figure 2), to which it contributes about 220 billion cubic meters of water annually. This flow is almost half of the total annual flow in the Ganges. In the dry season, Nepalese rivers contribute almost 70% of the flow. The availability of a large volume of water combined with steep slopes offers the potential to develop more than 83,000 MW of hydroelectricity (Table 1). Therefore, a judicious exploitation of water resources could advance social and economic development in Nepal and help diminish pressure on the country's overexploited forest resources.

At present, Nepal's demand for electricity is just over 350 MW, while current capacity from hydropower stations is 250 MW—a mere 0.3% of the potential capacity mentioned above—and 51 MW from diesel units, thus totaling some 300 MW. Only about 15% of the population have access to electricity, and average per capita consumption is among the lowest in South Asia. The deficit in energy supply is met by importing petroleum

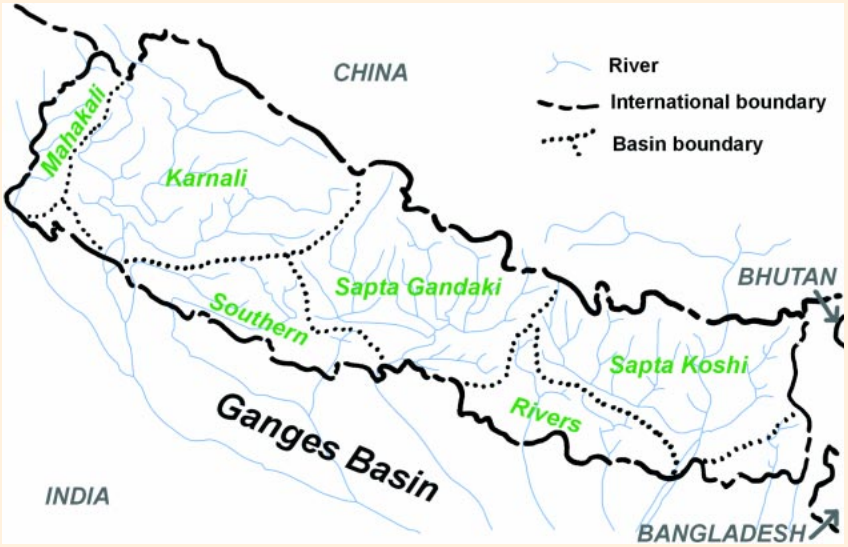

FIGURE 2 Map of Nepal's main rivers and basins (see also Table 1).

products for household and industrial consumption and power generation as well as clearing more forests and providing access to alternative sources such as solar power. However, imports of fuel have serious implications for government finances, society, and the environment at large. For example, in 1999/2000, the total bill for petroleum imports alone was just under 40% of total export earnings. Unless exports of goods can be increased substantially in the future, this percentage is likely to increase in the years to come. Nepal cannot sustain such a level of imports for long. Moreover, researchers see a clear link between the loss of forested area and increased incidence of landslides and soil erosion as well as declining crop productivity and a drop in the number of springs. These phenomena clearly indicate the need for a major change in Nepal's energy supply.

Policy interventions to promote hydropower development

The first comprehensive regulations on hydropower in Nepal were issued in the early 1990s, primarily to narrow the gap between supply and demand and to reduce forest degradation. Other aims included raising funds for development of infrastructure from the nonpublic sector and mobilizing internal financial resources for hydropower development. Various hydropower projects have been started or completed since that time (see Table 2) and three private-sector companies became involved for the first time with hydropower in Nepal. Although the participation of the private sector is laudable, the scale of public-sector hydropower development based on private-sector investment is unimpressive in relation to demand and economic growth.

The slower than anticipated pace of hydropower development is a clear blow to the expectations of planners, who believed that an appealing hydropower policy would attract new investment capital to Nepal. The present paper takes a three-pronged approach to hydropower development based on the author's discussions with various stakeholders and his own experience.

TABLE 1 Estimated hydropower potential.

Basin	Annual flow (in billions of m^3)	Catchment area (in km^2)	Potential (in MW)
Sapta Koshi	33	28,140	22,350
Sapta Gandaki	50	31,600	20,650
Karnali	42	41,890	32,010
Mahakali	7	5410	4160
Southern Rivers	42	40,141	4110
Total	174	147,181	83,280

TABLE 2 Hydropower projects under construction.

Project name	Capacity (MW)	Energy (GWH)	Investor	Year commissioned
Bhote Koshi	36.0	240	Private sector	2000
Indrawati	5.0	36	Private sector	2000
Khimti Khola	60.0	350	Private sector	2000
Modi Khola	14.0	91	NEA	2001
Kali Gandaki A	144.0	842	NEA	2001
Chilime	20.0	137	NEA subsidiary	2001
Puwa Khola	6.2	48	NEA	2002
Total	285.2	1744		

A decentralized approach for small-scale projects

Small rivers with catchment areas smaller than 300 km^2 are suitable for generating up to about 1 MW of hydropower, which could replace kerosene used for lighting and diesel used for processing agricultural products. Such small local plants, or hydels (Figure 1), which are already considerable in number, also stimulate other economic

FIGURE 3 Paper production made possible by a micro-hydel in Loding at the head of the Solu Valley, Nepal. (Photo by Susanne Wymann von Dach)

FIGURE 4 Electric power line crossing the Brahmaputra (Jamuna) River in Bangladesh. Such existing grids could be used to import hydropower from Nepal. (Photo by Thomas Hofer)

activity in rural areas, such as small-scale industry (Figure 3) and tourism. A hydropower project with a 100-kW capacity can potentially replace 100,000 L of kerosene annually if the electricity is used only for lighting. Inducing people to use electricity for cooking could reduce fuelwood consumption, and an additional effect would be gained from reducing smoke-related health problems. Due to small plant size, community participation in design and implementation is easier than with larger facilities and environmental aspects can more easily be incorporated. Guaranteeing sufficient low flow in the watercourse for downstream use and preserving resources such as fish are major concerns.

But such small-scale projects will never develop if they are put on an equal footing with large-scale projects, primarily because sites for smaller projects are located in remote rural areas and thus incur high transportation costs that place an additional burden on developers. The government should therefore absorb extra transportation costs. The government should also mobilize institutions such as the Department of Electricity Development for site identification and plant design. Involving cooperatives or local financing mechanisms could reduce the cost of site development. Local entrepreneurs must be involved so that the local economy can benefit from added value. Green Funds could be attracted from United Nations agencies, development banks, or donor countries for these types of subsidies. Such small-scale projects could also help develop the country's turbine and related equipment manufacturing industry, thus encouraging small-scale industrial development.

A centralized approach for medium-scale projects

Hydropower projects on medium-sized rivers with catchment areas between 300 and 1000 km^2 are suitable for both run-of-the-river and storage projects, which should be linked to the national electricity grid. The rationale for this approach is provided by the figures for energy demand and projections of supply.

The peak electricity demand forecast for Nepal for the year 2005 varies between 500 and 770 MW, depending on anticipated economic growth and development of transmission lines. The projected capacity of 660 MW for 2005 indicates that high economic growth could not be supported due to a lack of electricity needed by the industrial and service sectors—the fastest growing economic sectors in Nepal. Given a gestation period of 4 years and more for most hydropower projects in Nepal, an aggressive planning process might be necessary. Moreover, planners should also initiate programs that allow for a sufficient capacity margin, which could be around 20% for a growing economy such as Nepal. Greater capacity margins tie up investment unnecessarily, whereas lower margins curtail economic development. Given the figures on projected capacities and the above capacity margin, Nepal may face a shortage of hydroelectricity by 2005.

The availability of qualified human resources within the country is a prerequisite for achieving tangible results in centralized development of hydroelectricity. Government–university partnership is necessary to tackle this problem successfully. The government needs to adjust its education program in much the same way as Singapore has done, with a view to investing in a better future.

Staff management also needs to be improved. With almost 20 staff (70% nontechnical staff) per 1 MW generated and 80 per 1 MW of electricity leakage, the Nepal Electricity Authority (NEA), the country's only electric utility, is one of the most poorly managed and overstaffed electric utilities in the world. A few past attempts to reduce staff size were inappropriate and backfired. As long as the NEA is regarded as a government utility and as long as politicians and top-level management do not make impartial decisions, the situation will not improve. Other countries such as Thailand have tackled similar problems by breaking up electric utilities into separate entities in charge of generation, transmission, and distribution. The NEA is best suited for electricity generation and possibly for transmission as well but not for distribution, which should be made competitive by allowing private-sector participation. Making distribution systems competitive would

FIGURE 5 Flooded fields in the Brahmaputra/Jamuna flood plain in Bangladesh. Recent studies have shown that dams constructed in Nepal have little effect in preventing such floods. (Photo by Thomas Hofer)

also generate new markets for other electricity-generating utilities.

Theft of electricity is another serious problem. The NEA's attempt to reduce leakage, currently at a staggering 25%, by mobilizing motivated staff has failed because collecting arrears was more attractive to the staff than investigating the causes and mechanisms of theft. The NEA could easily monitor theft by metering its transformers and carrying out block electricity audits. However, there seems to be no motivation for such a move, although it would save a considerable amount of precious energy already generated.

An export-oriented approach for large-scale projects

Rivers with more than 1000 km^2 of catchment are suitable for large-scale storage and multipurpose projects geared to flood control, river navigation, irrigation, and hydropower generation. Such large-scale projects also create benefits for downstream countries, as the Columbia River project in the United States and Canada and the Mekong River Basin (cooperation/consultation between Cambodia, Laos, Thailand, and Vietnam) have shown. The most important lesson from the treaties that form the basis of such international basin development initiatives is that both the benefits and the costs of projects should be shared between riparian states. Large-scale multipurpose development projects in Nepal should focus on export of electricity since it could be a shared benefit.

Theoretically, electricity generated in Nepal could be transmitted to Bangladesh (Figure 4), Bhutan, India, Pakistan, and the Tibet region of China. Except for Tibet, however, electricity exports to other countries require strong technical and political backup from India since transmission lines to the other countries would have to cross Indian territory. Pakistan and Bhutan are themselves producers of surplus hydropower, and Bhutan has ambitious plans with regard to generation and export of hydropower, which adds an element of competition to Nepal's export plans. There are stringent climatic and terrain limitations on transmitting electricity to Tibet. Therefore, the only realistic option is export to India and Bangladesh, assuming that, as in Bhutan, India would support Nepal's effort to develop export-oriented projects.

The electricity market in Bangladesh

Existing electricity generation capacity in Bangladesh is 3000 MW, with a shortfall of about 300 MW during times of peak demand in Bangladesh. In order to fuel economic development, the government has adopted a policy of attracting nonpublic investment in electricity generation, mainly using natural gas reserves. Plans have been put forward to expand electricity generation by 2000 MW in the private sector and 1400 MW in the public sector. With its abundant natural gas reserves, Bangladesh might not be interested in purchasing electricity from other countries. But it might consider tackling water-related issues with its neighbors.

Water is an important issue in Bangladesh. More than 20% of Bangladesh is flooded in the monsoon season (Figure 5), although this figure varies extensively from year to year (eg, from 0.3% in 1994 to 67% in 1998). This widespread flooding is a recurrent problem for economic development, including food security. Water is often scarce in the dry season (Figure 6). Therefore, Bangladesh is interested in plans to construct high dams in Nepal to contain monsoon flow and increase dry-season discharge in the Ganges. However, recent research strongly suggests that Bangladeshi floods do not originate in the Himalayas but are the result of heavy rainfall within Bangladesh and neighboring areas in India and that dry-season discharge will not increase sub-

FIGURE 6 Very low discharge of the Brahmaputra/Jamuna River in the dry season leaves one channel of this mighty river almost entirely dry. It is hoped that dammed water resources in Nepal could supplement the periodically low water supplies in Bangladesh. (Photo by Thomas Hofer)

stantially by building dams as far away as Nepal. Of course electricity could still be supplied from such dams in order to allow Bangladesh to use its natural gas reserves for other purposes.

The electricity market in India

Of India's existing 90,000 MW capacity, 73% is based on coal and liquid fuel. India's supply capacity has grown by about 4% annually over the past decade, whereas demand during the same period increased by 9% annually. Since 1991, when the government amended The Electricity (Supply) Act of 1948 to allow private-sector participation in electricity production, it has received proposals from the private sector to develop 70,000 MW. The considerable deficit in electricity supply and the shortage of public funds are the main reasons for private-sector interest in energy production. With its large coal deposits, nuclear capability, and increasing private-sector participation, India may be able to meet the increasing electricity demand with its own resources. But India may also come to the conclusion that downstream benefits from the development of water resource projects in Nepal could outweigh the benefits of coal and nuclear power plants, both of which can pose social and environmental hazards and tend to deplete local resources.

Indian interest in developing hydropower in Nepal dates back to the early 1960s, when the 1-MW Phewa Dam project in western Nepal was commissioned. In 1972, another hydropower project with a capacity of 18 MW was commissioned with Indian cooperation. India had planned to develop much larger hydropower projects such as Karnali (Table 1) for imports of electricity into India, but the project was shelved due to political differences between Nepal and India and within India.

India is now developing a number of hydropower projects in Bhutan and importing most of the energy generated there. India may thus not be overly keen to buy electricity from Nepal at present. If Nepal wants to attract Indian interest in hydropower development, it should generate goodwill and be willing to share the downstream benefits of proposed facilities. Endorsement of the Integrated Mahakali Water Treaty in 1996 and the Power Exchange Treaty in 1997 between India and Nepal was an important step in this direction. A joint study group is now working on a detailed project report to implement the articles agreed upon in the Mahakali Treaty. This could signal a new beginning. As Bandyopadhyay (1995) points out, positive views of cooperation did not exist in the past mainly because water resources projects developed with Indian assistance failed to bring perceptible economic improvement in Nepal.

Towards a South Asian grid?

India is in the process of harmonizing its grid to transfer power from one region to another. This grid could be expanded and utilized to transfer power among the countries of South Asia. Grid integration could help India since India could use transmission lines in Bangladesh to transfer electricity to its northeastern states. Using the same grid would allow electricity produced in Nepal to be transferred to Bangladesh. Pooling surplus power through an integrated grid would create a smoother and more reliable supply of electricity and would make maintenance and rehabilitation of generating stations much easier in countries connected to the grid. Load shifting, which is possible thanks to the different time zones in South Asian countries, could help avoid the need for new facilities and also help to optimize the power operation system.

The potential for harmful impacts

Centralized projects, especially on a large scale, present greater challenges in mitigating environmental, social, and economic impacts than small, decentralized ones. These impacts include flooding and loss of valuable habitats, disruption of fish migration, a possible increase in the incidence of waterborne diseases, and the risk of devastating floods caused by landslides and seismic activities. Sedimentation of reservoirs may make the overall economic viability of a project questionable (Figure 7). Economic vulnerability and dependency are further risks in cases

FIGURE 7 A single 30-hour stormburst in July 1993 scoured sediment off upstream mountainsides and deposited it in the Kulekhani reservoir, leading to a one-tenth reduction of dam storage capacity. Kulekhani had a predicted life of 75 to 100 years after completion in 1981, but sediments could put the dam out of operation long before that. (Photo by Susanne Wymann von Dach)

where water and hydroelectricity from a few large facilities provide the bulk of a country's export earnings. Resettlement to make way for large reservoirs is another major issue. There are many cases all over the world where this issue has been handled to the detriment of those resettled. Thanks to the global debate on the pros and cons of large-scale hydropower development, these problems are now more widely acknowledged than before among developers, donors, and the general public. Therefore, careful planning will be required for all export-oriented facilities.

Conclusions

The three-pronged approach to hydropower described above could pave the way to a better future for Nepal in terms of meeting growing domestic energy demand and supporting economic development. Small-scale decentralized projects seem to be an appropriate solution to meeting growing energy demands in remote rural areas. Their installation will help stimulate the local economy, including tourism. The small scale of these projects will allow local conditions to be exploited optimally. Local stakeholders can participate in design and implementation, and their needs can more easily be incorporated than in the case of large-scale facilities. However, initial costs will be comparatively high due to remoteness of sites and difficult topography.

With regard to medium- and large-scale projects, Nepal has neither the capacity to cover investment costs nor to absorb all the electricity and other services generated by such projects. Liberalization of electricity markets in India and Bangladesh now provides export opportunities for Nepal; but both countries have developed aggressive programs of their own to attract investors in electricity production. Therefore, water resources in Nepal should be developed in partnership with coriparians. The joint communiqué issued by India and Nepal after an official visit of the Nepalese Prime Minister to India in August 2000 shows India's willingness to support Nepal's efforts to develop hydropower. But Nepal still needs to do its homework properly before the idea of riparian cooperation can fully materialize. This means tackling organizational and administrative bottlenecks in the energy sector. It also means preparing a comprehensive legal framework for mitigating the local and regional impacts of such a development.

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