Chapter 6

Energy Resources

Introduction

The availability and use of energy is necessary for survival and prosperity. It is basic to any society's development and economic growth. Energy is used for many purposes in daily life and in the process of social and economic development, and the amount of energy consumed is an indicator of level of development and standard of living. Gross national income per capita is higher where per capita energy consumption is also higher. This indicates the link between prosperity and energy use in the present world—rich countries use a lot of energy. Nepal's per capita energy consumption is one of the lowest in the world as well as in South Asia, reflecting the low level of development and prosperity (Table 6.1).

Expanding economic activity and population growth are the two basic factors behind increases in energy consumption. In a country like Nepal, where economic growth is necessary and population growth is high, energy demand will continue to rise in the years to come. Energy consumption patterns and the rise in demand, their sources, and ways in which they are harnessed and utilized have implications for the environment and natural resources, which ultimately affect overall development.

Table 6.1: Energy Consumption and Per Capita Income

Category	GNI ($)	Energy Use Per Capita (kg oil equivalent)	Electric Power Consumption Per Capita (kWh)
World Average	5,120	1,686	2,159
South Asia Average	460	469	331
Countries in Different Income Groups			
Low Income	430	518	317
Middle Income	1,850	1,339	1,447
High Income	26,490	5,423	8,421
Selected Countries			
Norway	38,730	5,896	24,881
Switzerland	36,170	3,875	7,474
United States	35,400	7,996	11,714
Japan	34,010	4,099	7,237
United Kingdom	25,510	3,982	5,653
Singapore	20,690	7,058	7,178
China, People's Republic of	960	896	893
India	470	515	365
Bangladesh	380	153	94
Nepal	230	357	61

kg = kilogram, kWh = kilo watt-hour, GNI = gross national income
Note: GNI per capita is gross national product (GNP) divided by population.
Source: IBRD/WB (2004)

Sources and Consumption Patterns

Sources

Nepal's energy supply is primarily based on three sources.

Traditional (biomass). This includes fuelwood, agricultural residues, and animal waste. Biomass is the traditional source of energy in Nepalese society, which is predominantly rural and agricultural. People in rural areas do not have to pay for biomass—it is either available free from nature (fuelwood collected from a nearby forest) or is a byproduct of agricultural activities (agricultural residues and animal dung). In the past, there was an abundant supply of biomass from the forest and agricultural activities. The situation has been changing in recent times due to increases in population, long-term decline in forest areas (despite recent increases), and rising demand for energy. Biomass is becoming scarce and biomass sources are under increasing pressure, with potentially adverse consequences on agriculture and the environment. However, rural people continue to use biomass as an energy source because they have no other options and they do not have to pay for it.

Commercial. Commercial energy, also known as conventional energy, is traded in the market and in Nepal this comprises coal, electricity supplied through the national grid, and petroleum products. Hydropower is the main source of electricity in Nepal.

Definition, Forms, and Units

Energy is the capacity of matter to do work in relation to forces acting on it. Five forms of energy are often distinguished: (i) Mechanical, (ii) Electromagnetic, (iii) Thermal, (iv) Chemical, and (v) Nuclear. Energy conversion takes place among and within these forms in the process of human production and consumption, as well as in nature; for example burning fuels to produce heat converts chemical energy to thermal energy (i.e., burning wood releases stored chemical energy, but all is not converted to heat; if heat is the desired form of conversion, conversion to other forms are losses). The efficiency of conversion from one form to another depends on the extent to which unwanted dissipation can be avoided. Unwanted dissipation in the process of conversion and use is energy lost.

The most common energy sources are biomass, solar, fossil, hydropower, wind, and wave. The sources can be classified as renewable or nonrenewable depending on whether they can supply continuously or will be exhausted. The primary source of energy available to us is the sun. The concept of renewable and nonrenewable energy is a relative one—it is basically a distinction about time and space-scale.

Energy is measured and expressed in various ways. Joule (J) is the internationally recognized unit for energy. Energy production and use involves conversion of energy from one form to another: the rate of conversion (or rate of doing work) is defined as power, which is commonly measured in watt (W): 1 W is 1 J per second. Electrical appliances have power ratings quoted as W or kW, such as a 40-W electric bulb. Kilogram of oil equivalent is sometimes used to bring energy consumption from different sources to a single, common unit and to express it in an easily understandable manner.

Source: Blunden et al. (1991)

Alternative energy. Biogas, micro-hydro, solar, and wind energy come under this heading. Biogas is a more efficient way of utilizing some biomass (animal dung) as energy. Hydropower (including micro-hydro), biogas, solar, and wind energy are renewable; within their re-generation capacity, these can supply energy indefinitely.

Nepal's indigenous energy resources include biomass, hydroelectricity, solar, and wind. Coal and petroleum products are imported, as the country has no known economically exploitable fossil fuel reserves. The potential of known indigenous energy resources in Nepal is estimated to be 1,970 million gigajoule (GJ) annually on a sustainable basis (WECS 1996), which would be 15 times the estimated total consumption. This indicates that there is sufficient potential energy supply from indigenous sources. Of the total sustainable potential, water resources represent the largest fraction (75%), with forests contributing 12%, and the rest coming from other sources.

Consumption Patterns

In 2002, Nepal's total energy demand was 8,883 thousand tons of oil equivalent. Energy consumption increased at an average rate of 2.5% per annum between 1993 and 2002. The annual per capita energy consumption is 347 kg of oil equivalent (CBS 2004).

The energy consumption pattern by source between 1993/94 and 2002/03 is shown in Table 6.1. Energy consumption is dominated by traditional sources, which accounted for about 87% of the total energy consumption in 2002/03, although its percentage of total consumption has been slowly declining (Table 6.2). Of the traditional sources, fuelwood accounted for 89%, agricultural residues for 4%, and animal waste for 6%. Fuelwood contributed 75% of the total energy consumed in 2002/03. This indicates the pressure on the traditional sources, primarily on the forests.

The share of commercial and alternative sources has been increasing, although at a slow pace. From 1993/94 to 2002/2003, consumption of commercial energy increased from 7.5% to 12% of the total energy consumed, and the contribution of alternative energy increased from about 0.1% to 0.5%.

The energy consumption by sector is shown in Tables 6.3 and 6.4. The residential sector consumed 90.6% of all energy consumed in 2003, followed by transport (3.9%), industry (3.4%), commercial (1.2%), agriculture (0.8%), and others (0.1%). Although the amount of energy consumed has increased, the share of energy consumed by different sectors has remained more or less unchanged over the last decade.

The residential sector mainly consumes traditional fuels, whereas the "other" sector consumes commercial fuels. Residential consumption accounts for around 98% of the traditional fuels consumed in the country. Cooking is the main residential use of energy in rural areas, where the majority of people live, and fuelwood is the main source (household cooking consumes 65% of all rural energy). The residential sector consumes 99% of total fuelwood consumption. In urban areas, kerosene, liquefied petroleum gas (LPG), or electricity is used for cooking (MOPE 2003). Nepal imports all petroleum products and coal, most of which is consumed by automobiles and industries.

Nepal's energy supply and consumption patterns are overwhelmingly dominated by traditional biomass sources and residential uses, respectively. The principal use of biomass energy in

Table 6.2: Energy Consumption Pattern by Source 1993/94 –2002/03

Year	Energy Consumed ('000 toe)				Percentage of Energy Consumed			
	Traditional	Commercial	Other	Total	Traditional	Commercial	Other	Total
1993/94	5,933	483	6	6,422	92.4	7.5	0.1	100
1994/95	6,059	582	8	6,649	91.1	8.8	0.1	100
1995/96	6,185	651	11	6,847	90.3	9.5	0.2	100
1996/97	6,268	691	15	6,974	89.9	9.9	0.2	100
1997/98	6,403	769	21	7,193	89.0	10.7	0.3	100
1998/99	6,540	811	25	7,376	88.7	11.0	0.3	100
1999/00	6,681	1,044	29	7,754	86.1	13.5	0.4	100
2000/01	6,824	1,095	34	7,953	85.8	13.8	0.4	100
2001/02	6,996	1,169	39	8,204	85.3	14.2	0.5	100
2002/03	7,240	1,003	39	8,282	87.4	12.1	0.5	100

toe = tons of oil equivalent
Source: MoF (2003)

Table 6.3: Energy Consumption by Sector ('000 GJ)

Sector	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Residential	254,853	260,951	267,542	274,341	281,533	287,815	295,159	301,143	314,655	320,268
Industrial	9,231	11,084	11,771	6,417	6,921	7,522	15,717	12,998	12,537	11,969
Commercial	2,206	2,558	2,840	3,179	2,919	3,215	3,708	4,128	4,921	4,081
Transport	6,682	7,839	8,721	11,942	13,546	14,849	12,798	13,592	12,025	13,850
Agricultural	535	640	690	966	1,099	711	2,968	3,152	2,776	2,888
Other	206	243	262	293	322	342	355	409	454	484
Total	**273,712**	**283,315**	**291,827**	**297,139**	**306,339**	**314,454**	**330,706**	**335,421**	**347,369**	**353,541**

GJ = gigajoules
Source: Water and Energy Commission Secretariat, Kathmandu , 2005. Unpublished data file.

Table 6.4: Share of Energy Consumption by Sector

Sector	1994	2003
	%	%
Residential	93.1	90.6
Industrial	3.4	3.4
Commercial	0.8	1.2
Transport	2.4	3.9
Agricultural	0.2	0.8
Other	0.1	0.1
Total	**100.0**	**100.0**

Source: Water and Energy Com mission Secretariat, Kathmandu , 2005. Unpublished data file.

rural Nepal is burning in traditional cooking stoves or open fires. This is very inefficient, as most of the heat generated is lost. It is possible to increase the efficiency by introducing better technologies such as improved cooking stoves.

Hydropower

Nepal is rich in water resources. The gradient provided by the mountain topography, monsoon rain, and Himalayan-fed rivers offer great potential for hydropower development (Tables 6.5 and 6.6). The hydropower potential in Nepal is estimated to be 83,000 megawatts (MW), of which 42,000 MW is economically feasible at present. A substantial proportion of the potential is based on reservoir projects.

The National Water Plan (2002–2027) estimates that the maximum domestic demand for power by 2027 will be less than 7,000 MW even under a high-growth scenario—this is only about 17% of the economically feasible potential. This indicates that Nepal will have substantial surplus potential for the foreseeable future, and in theory the surplus could be exported to neighboring countries, particularly to India and Bangladesh where there are energy shortages.

Nepal has been keen to encourage hydropower development. The Water Resources ACT 1992, Hydropower Development Policy 1992 and 2001, Electricity Act 1992, and Environment Protection Act 1996 are milestones in this direction. However, despite the great potential and the Government's emphasis on developing hydropower, the

Table 6.5: Hydropower Potential

River Basin	Theoretical Potential		Economically Feasible	
	GW	%	GW	%
Sapta Koshi	22.35	27	10.86	26
Sapta Gandaki (Narayani)	20.65	25	5.27	13
Karnali and Mahakali	36.18	43	25.10	60
Southern Rivers	4.11	5	0.88	2
Total	**83.29**	**100**	**42.13**	**100**

GW = giga watt
Source: WECS (1995); USAID -SARI (2002)

Table 6.6: Summary of Hydroelectric Development Opportunities

Category	Number of Projects Identified	Total Capacity (MW)	Total Generation Potential (GWh/y)
10–100 MW (medium)	157	6,200	38,000
100–300 MW (medium)	47	7,815	42,056
300–1,000 MW (large)	20	9,437	45,723
> 1,000 MW (large)	5	19,463	50,985
Total	**229**	**42,915**	**176,764**

GWh/y = gigawatt -hour per year , MW = megawatt
Source: WECS (2002)

contribution of hydroelectricity to the overall energy production has so far been very small—only about 1% of the total energy need is met by hydropower. Power produced by the hydroelectric plants connected to the national grid mainly supply electricity to urban areas and their peripheries. At the end of the Ninth Plan (1997–2002), the national grid supplied electricity to an estimated 33% of Nepal's population, and an additional 7% had access to electricity generated from alternative energy sources like micro-hydro and solar (NPC 2002). A large part of the rural population is deprived of electricity.

Some of the factors contributing to the low level of hydropower development are lack of infrastructure and capital, high cost of technology, political instability, lower load factor due to low productive end-use of electricity, and high technical and non-technical losses. Despite its huge potential and acknowledged importance in national development, hydropower development has been lacking. The main concerns related to hydropower development in Nepal include the following.

High Tariff

Nepal's electricity tariff is comparatively high. In 2004, the average tariff in Nepal was NRs 6.7 per kilowatt-hour (kWh) ($0.091 per kWh), among the highest in the developing countries of Asia. The marginal rate for domestic energy consumption above 250 kWh/month is NRs 9.9 per kWh (US$0.134 cents per kWh), which is equivalent to or higher than the tariff in many developed countries (NEA 2005). The reasons for the high tariff include high production costs, high transmission and distribution losses due to technical losses and theft, inefficiency in management, and non-payment (or payment in arrears) from public sector customers. Further, the Nepal Electricity Authority (NEA) has been purchasing power from independent power producers at rates higher than its own current average cost of production. Power purchase agreements between independent power producers and NEA are on a ''take or pay" basis that requires NEA to pay for all energy produced in all seasons whether it is utilized or not, and the power purchase agreements are based on US dollar rates. The tariff is charged based on cost of production and with the intention of recovering costs, although Nepal received significant foreign finance as soft loans and grants. All of these factors result in high tariffs.

The cost of hydropower development in Nepal is high (typically NRs 5 per KWh for run-of-river plants), which is generally attributed to the fragile, unstable geology of hydropower sites (as well as remoteness of the sites which require building costly roads and infrastructure for access as part of the project cost), limited manufacturing capability related to hydropower plants (or grant or loan conditions tied to purchasing equipment from the country providing the grant), extensive employment of high-cost international contractors and consultants, and heavy reliance on bilateral and multilateral financing(WECS 2002, WECS 2004, USAID-SARI, 2002).

Slow Development

Although the first hydroelectric power plant in the country was established in 1911 at Pharping, by 2003 Nepal's total installed capacity had reached only 546 MW (about 1.3% of the feasible potential), which includes 144 MW hydropower produced by the eight independent power producers. In addition to hydropower, six thermal power plants owned by the NEA produce 57 MW. Thus total installed capacity in the country available in the integrated national power system is 603 MW.

NEA's monopoly until 1992 is cited as a reason for the slow development of hydropower in Nepal. Recent policies adopted following restoration of the multiparty system allow private sector development of hydropower, and since then several projects have been constructed by domestic and international private companies. Now some 21% of the installed capacity comes from the private sector. The Government's emphasis on large, export-oriented projects is another reason for the slow development of hydropower. In the past, the Government gave priority to mega-power projects such as the Karnali, Arun, and Pancheswor, with the aim of exporting power to India rather than meeting Nepal's own needs. However, development of these projects has been hampered because there was no ensured export market in the absence of a power purchase agreement with India. There appears to be a "buyers monopoly", as India is the only potential market and India has been unwilling to pay commercial rates for energy or to put an economic value to the other benefits, such as flood control, that India can derive from developing hydropower projects in Nepal.

Problems with Dams

Although much of the hydropower potential in the country can be exploited through run-of-the-river projects, a portion requires construction of dams. Development of dams is seen as a means to provide water for consumption, clean energy, and flood control. However, experience in the construction, operation, and maintenance of dams is in its infancy. Development of large hydro dams is complex in this geologically unstable area, and in light of the poor infrastructure in many mountain areas. Concerns are often voiced about the impact on local populations and the environment (see Energy and Environment section below). Small- and medium-scale dam projects of up to 100 MW are sometimes suggested as a more environmentally friendly alternative to large hydro projects (Gubhaju 1994; WCD 2001). This debate, and the complex construction requirements, have also slowed hydropower development in the country.

Inadequacy in Linking Hydropower Development with National Development

Hydropower is termed "white gold", and its development can play a vital role in the development of Nepal. Although hydropower's importance in national development is acknowledged by all, efforts to develop it appear to lack a long-term vision, plans, and strategy that clearly identify linkages with national development goals. As an example, hydropower development could be linked with industrial and electric transport development and development of rural areas. Much of the debate however, concentrates on issues of export versus domestic consumption, small versus big projects, and reservoir versus run-of-river projects rather than on how Nepal could best benefit from hydropower development. Project identification and development often take place in isolation, not as an integrated, coordinated plan to stimulate the national economy and social development. It is assumed that each individual project will automatically bring socioeconomic development, which is hardly the case.

Financial Constraints

NEA's hydropower production cost in Nepal is around $3,000 to $4,000 per kW constructed—two to four times more than the cost in the neighboring People's Republic of China, India, and Bhutan. But the private sector projects cost between $1,500 and $2,500 per kW constructed. Hydropower development requires high capital investment. Donor assistance and government funds have been the major source of finance for hydropower projects. In the past, as much as 80% of all investment requirements came from multilateral and bilateral donor assistance (USAID-SARI 2002). Private-sector investment in hydropower has gradually increased since 1992. This needs to be further promoted as the availability of donor funding is declining, and public funds are more needed by the social sector. The domestic and international private sector could be a greater source of investment if an appropriate and favorable environment for competition and cost reduction were created.

Building National Capacity

Nepal's hydropower development has relied largely on imported technology and expertise. This situation is obviously undesirable in the long run. Capability is needed in all fronts of hydropower development, including planning and design, construction and management, and manufacturing hydropower-related plants and accessories. Although national capability has been developing and smaller projects are now being constructed with experts and


Chilime Hydropower Company Ltd

Chilime Hydroelectric Plant Headworks

Chilime Hydroelectric Project: An Example of National Effort in Hydropower Development, Completed August 2003

The Chilime Hydroelectric Project (CHP) has an important place in the history of hydropower in Nepal. It is a medium size run-of-river scheme with a rated capacity of 22.56 MW. CHP is the first hydropower project of this size in Nepal that was planned, designed, financed, and constructed by the Nepalese themselves without outside technical assistance. Most of the components including surge tank, power house, transformer cavern, penstock shaft, and tunnel are underground. CHP is funded with a debt:equity ratio of 60:40. It received short-term and long-term loans from Nepalese financial institutions, mainly from Karmacari Sanchaya Kosh (Employees Provident Fund) and Nagarik Lagani Kosh (Citizens Investment Trust). Nepal Electricity Authority (NEA) holds 51% of the equity, while NEA employees hold 25% and the general public 24%.

Nepalese expertise, contractors, and manufacturers were utilized to the extent possible. Nepalese construction companies were employed for construction of the access road and camp infrastructure; the headwork structure including the diversion structure, the intake, gravel trap, approach canal, reservoir overflow spillway, and desander; and other surface structures such as the power canal, siphon, and pressure conduit. Underground civil structures were contracted to an Indian company; however, Nepalese companies, under subcontracts with the main contractor, carried out tunneling and other underground construction activities. Nepalese contractors and manufacturers completed hydro-mechanical works including gates and stop logs, as well as the steel siphon pipe structure. The supply and erection of electrical and mechanical equipment was done by a German company.

CHP consulted and involved project-affected people, local communities, and their representatives in the project from an early stage. A mechanism was formed to facilitate and ensure implementation of social and environmental measures to mitigate adverse impacts and to enhance project benefits to the locality.

With the experiences gained from CHP and other recent hydropower projects, there is confidence now that the Nepalese are competent to plan and develop run-of-river hydropower projects up to 100 MW. It took about 10 years for CHP to generate electricity commercially, including a three-year delay due to termination of the original contract with a Chinese contractor, and transport and other difficulties caused by political instability and others. Lessons from CHP and recent similar projects suggest that projects of this size could be completed in about 5 to 6 years if planned and managed properly. The total cost of CHP development was about NRs 2.45 billion (or about $35 million—$1,550 per kW). This is comparable to the cost of similar-size projects in the region including in India and Bhutan. The per unit cost could be further reduced if electrical and mechanical equipment manufacturing capacity were developed in the country.

Source: Bhattarai (2005) and personal communication.

technology largely available in Nepal, capacity is growing at a very slow pace and is still very limited and far less than necessary.

In light of the above concerns, hydropower development in Nepal should be guided by a broad perspective. Common recommendations made in this regard include the following (USAID-SARI 2002).

Improve power system planning. This may include selection of an optimal generation mix; introduction of storage projects to increase the system's capacity, optimization of installed capacity based on a "systems concept" rather than on an isolated project optimization basis, interconnection with India to take advantage of coordinated operation of hydropower and thermal dominated systems, implementation of demand-side management to improve the load factor and reduce high system losses, and use of investment planning tools suitable for hydro-dominated systems.

Increase access to electrification in rural areas. This may include: grid-based rural electrification, mini and small hydro-based local grids, and use of other renewable sources like solar, wind, and biogas.

Raise the needed investments for hydropower development. Hydropower development is very capital intensive. Government and donor funds are not enough. Hence, the investment requirements of the power sector have to come from the private sector.

Strengthen institutional and agency involvement in the power sector. The policy, regulatory, and operational functions of the organizations involved in the hydropower sector should be defined to eliminate overlap in their work. Institutional strengthening should also be geared towards development of multipurpose projects that can have benefits of cost sharing and optimum utilization of the available water resources.

Promote power exchange and export with neighboring countries, particularly with India. The Government should hold talks with concerned authorities in India to move this ahead and consider allowing independent power producers to negotiate power purchasing agreements directly with power purchasers in India without having to go through the Ministry of Water Resources of the Government of Nepal as is the current practice.

Reduce the cost of hydropower development. The cost of hydropower projects can be reduced significantly if the Department of Roads would coordinate with the NEA in aligning planned roads to provide close access to potential hydropower sites that have been identified by the NEA.

Alternative Energy

At present, alternative energy is the preferred choice for rural areas of Nepal for various reasons. However, this might change over time as the country develops and the national grid can supply electricity to remote rural areas at an affordable tariff. Some reasons for preferring alternative energy sources at present are discussed here. First, the excessive dependence on traditional biomass energy (fuelwood, agricultural residues, and animal waste) and their inefficient use has undesirable implications for the environment, health, and economy. Furthermore, commercial fuels are not easily available in remote areas (this might change with improvement in access). Most rural areas of Nepal do not receive electricity from the national grid, and the situation is unlikely to change in the near future because the integrated national power system is already overburdened, the terrain in the Himalayan mountains is difficult, and population density is low. The price of commercial energy (electricity from the national grid as well as kerosene and LPG), where available, is generally beyond rural people's purchasing capacity, whereas traditional biomass fuel is free of cost. Therefore, people continue to use the traditional energy even where commercial energy is available. Thus alternative energy can play a significant role in remote and rural areas.

Despite its importance and desirability, a major hurdle in promoting alternative energy is its high installation cost. Sustainability of alternative renewable energy is often questioned, as it cannot freely compete with grid electricity and petroleum fuels in the existing national and global market and energy systems. The market, however, is imperfect as it does not reflect environmental costs. Hence, there is a strong argument for a set of strategies, policies, and subsidies favoring alternative renewable energy. The Government has been providing subsidies to alternative energy since the Eighth Plan (1992–1997), which is the main promotion of alternative energy in Nepal. Major issues related to subsidies are that the policy has frequently changed or been inconsistent, causing difficulties and frustration to the stakeholders involved; subsidies have depended on donor assistance and continuity cannot be relied upon, as donor priorities can change; many of the benefits of subsidies go to suppliers rather than to people; and finally, subsidy schemes usually fail to consider operation and maintenance, and as a result a significant proportion of alternative energy technologies cease to function soon after being installed.


DHM

The highest micro-hydropower plant in Nepal at Tsho Rolpa (approx. 4,500 masl)

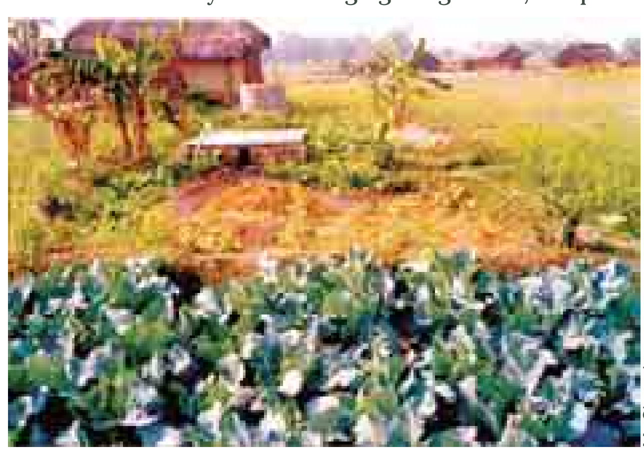
Micro-hydropower

Hydropower schemes in the range of 5 kW to 100 kW units are a suitable and common choice for the rural hilly areas of Nepal due to low capital investment, simple technology for which Nepal has in-country capacity, hilly topography, fairly high rainfall, numerous streams, and scattered rural settlements and communities.

Micro-hydro electrification started in the 1970s, and the Government began encouraging it in 1980 through a subsidy scheme. The installation of electrification schemes has been rising sharply since the mid-1990s following the inception of the Rural Energy Development Programme and establishment of the Alternate Energy Development Center. There are around 2,000 micro-hydropower plants in Nepal with a total capacity of about 12 MW—nearly 3% of the country's total hydroelectric power output (MOPE 2003; Basnyat 2004).

Despite its potential and advantages, there are constraints and obstacles to micro-hydro's widespread development.

The electricity generated from micro-hydro has been used mainly for evening lighting. Thus, the peak


M. Shrestha

Ghatta, a water-powered mill

load occurs from 6 pm to 9 pm with low utilization at other times. Low load-factor is a consistent problem for micro-hydro and affects the sustainability of micro-hydros schemes. There is a need to link micro-hydro with micro-enterprises in rural communities. Diesel and water mills are competitors of the micro-hydro plants.

Repair and maintenance is a major problem faced by micro-hydro plants installed by outside agencies. Operation, maintenance, and management are done locally, but there is general lack of technical skills and management capacity at the local level. As a result, a significant proportion of micro-hydro plants are non-functional.

Micro-hydro plants and civil structures are susceptible to damage by landslides and monsoon floods due to the mountain terrain and high rainfall.

A micro-hydro plant may require diversion of water used for irrigation and other purposes. As a result conflict may arise over water rights.

Peltric sets are also used to generate hydro-electricity. These are small units of vertically mounted impulse turbines coupled with induction generators that generate small amounts of power (less than 5 kW) and are suitable for providing electricity to a few households.

People in the hills of Nepal have traditionally used river water to run water mills (*ghattas*) that generate mechanical power used for agro-processing. These water mills are typically of less than 1 kW output capacity. It is estimated that there are over 25,000 ghattas in Nepal (MOPE 2003). Government agencies as well as several nongovernment organizations and private agencies are involved in improving these ghattas by replacing wooden water wheels with steel wheels and round buckets. Many of these improvements also include electricity generation during evening hours.

Biogas

Biogas, a methane-rich gas, is produced by anaerobic digestion of animal and human excreta. Livestock keeping is an important and integral part of Nepal's rural livelihood and farming system. Significant amounts of biogas can be produced using cattle and buffalo dung. The estimated potential for biogas production in Nepal is around 1,200 million cubic meters per year, which is equivalent to 29 million GJ (WECS 1999). By 2004, more than 120,000 plants had been installed in Nepal with support from the Biogas Support Program (BSP Nepal 2005). Various agencies such as NGOs are active in the promotion of biogas plants.

Biogas plants are particularly suitable in the Terai region where the climate is warm. As they require animal dung, rural households with livestock are the potential users, however, the poorest of the poor who have no livestock are unlikely to benefit. Biogas plants can also be attached to a toilet. The optimal temperature for biogas production is 35°C thus the high altitude mountain regions and winter season are unfavorable for gas production. It is estimated that a total of 1.9 million biogas plants can be installed in Nepal of which 57% would be in the Terai, 37% in Hill, and 6% in Mountain regions (BSP Nepal 2005). Special technical measures, such as heating the system by solar energy or biomass fuel, or using part of the gas produced for heating and using enzymes to digest the waste at low temperatures, may allow operation of biogas plants in colder conditions, but this will add to the cost and complicate operation and maintenance.

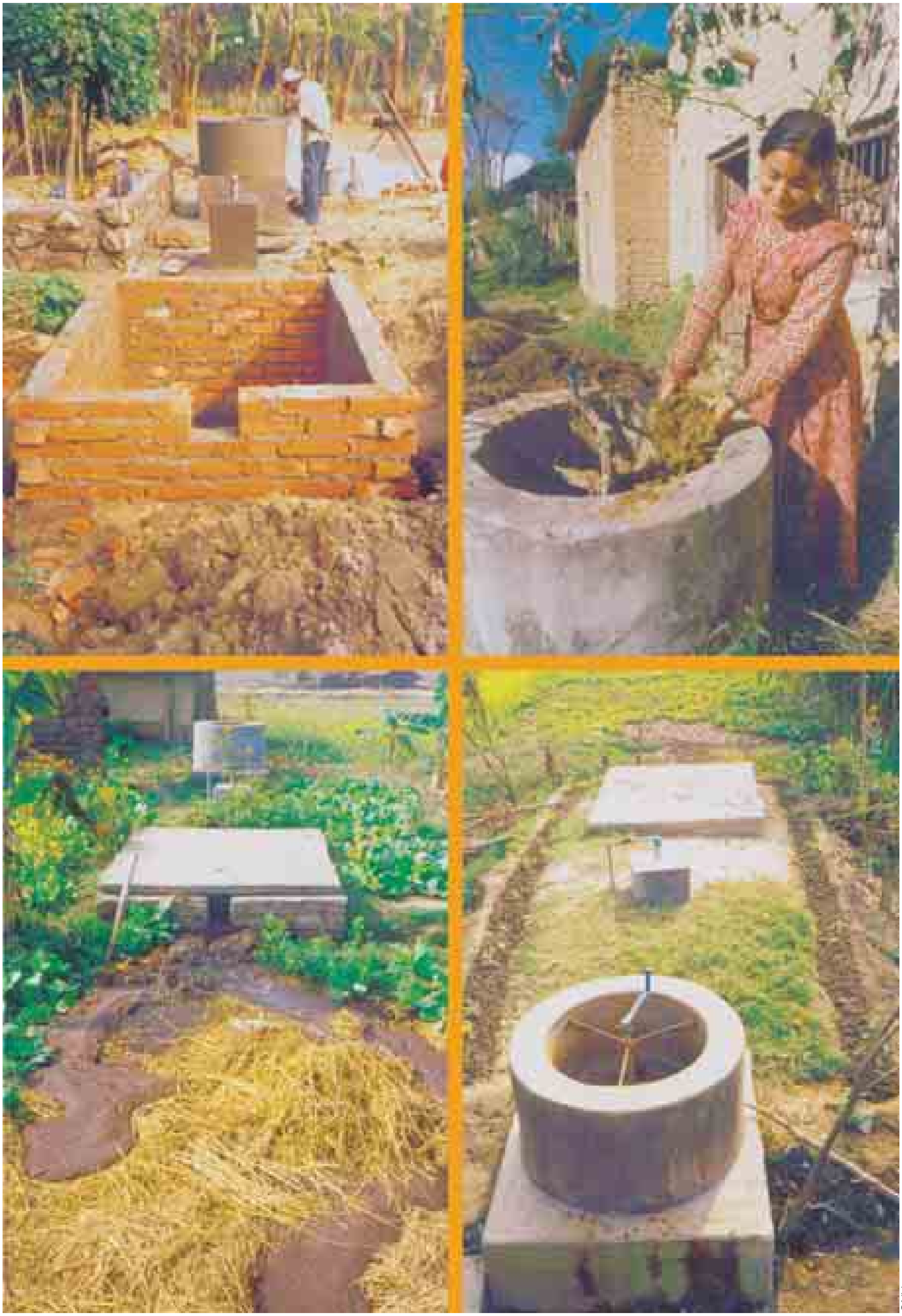
Solar

Solar energy has been used traditionally for drying crops, clothes, fuelwood, and others. Nepal has about 300 sunny days a year, and the average insolation lies between 4 and 5 kWh/m^2/day (WECS 1996; MOPE 2003). Nepal's solar energy potential is estimated to be about 26 million MW (WECS 1996). There are basically two methods of utilizing solar energy—solar thermal systems and solar photovoltaic systems. Solar thermal systems use solar radiation directly for heating, whereas solar photovoltaic systems generate electricity from solar radiation. An estimated 20,000 solar water heaters have been installed in Nepal (REDP 2002, cited in MOPE 2003). Nepal Telecommunications Corporation has installed more than 6,000 units of 50 W module solar photovoltaic systems; around 22,000 household solar photovoltaic systems have been installed, and the Nepal Electricity Authority has installed three 30–50 kW capacity solar photovoltaic stations at Simikot, Gamgadi, and Tatopani (MOPE 2003). The Mountains and Hills have a great solar energy potential, accounting for almost 94% of the total solar energy output in Nepal.

Solar home systems typically consist of a 32–36 watt solar panel, lead acid battery, charge controller, and energy-efficient lights. This is generally sufficient to operate three lights for approximately 4 hours per day. The solar home system is particularly suitable for remote rural areas where there is no other means of electricity supply. They are less likely to be destroyed by the monsoon floods and affected by temperature extremes.

Wind

Wind power development is still at an experimental stage, and no effort has yet been made to harness wind energy. Lack of wind data for proper



SNV

Biogas Installation for a Rural Household

assessment of wind energy and lack of technical expertise are the main obstacles to wind power development in Nepal. Although sufficient wind data are not available, a number of areas have constant high wind speed, such as several mountain ridges, the Mustang Valley, and the Khumbu region. A potential of 200 MW wind power in a 12 km corridor from Kagbeni to Chusung could generate about 500 gigawatt hour (GWh) (CBS 1998). Wind or wind/solar photovoltaic hybrid systems using small wind turbine technology currently available in the international market may well be feasible in some areas of Nepal. The nature of wind patterns indicates that small-scale (1–50 kW) wind generators may be feasible in remote and isolated places (MOPE 2003).

Energy and Environment

Energy and environment are related in complex ways. The production, distribution, and consumption of energy have direct and indirect environmental implications. Some of the environmental issues are global, like the greenhouse effect and climate change. However, Nepal's contribution to global environmental degradation is insignificant as Nepal's per capita annual energy consumption is one of the lowest in the world. Most environmental concerns related to energy sources and uses in Nepal are, therefore, related to national and local consequences.

Biomass Energy

The trend suggests that demand for biomass energy has been rising and will continue to rise. Low efficiency is a common feature in the traditional residential use of biomass energy. Environmental problems include the following.

Indoor air pollution. Inefficient burning of biomass coupled with poor ventilation is the principle cause of poor indoor air quality in rural Nepal (MOPE 2003). Indoor air pollution has detrimental health implications (see Chapter 7).

Pressure on forest. Fuelwood is the main source of energy in rural Nepal. This is putting significant pressure on the forest resources, even though this may not be the primary cause of deforestation in the country. As the human and livestock population continue to grow, demand for firewood will rise in the absence of other appropriate alternatives.

Impact on agriculture. As firewood becomes scarce, rural people are increasingly burning agricultural residues and cow or buffalo dung as domestic cooking and heating fuel. People in the densely populated Terai regions, and some mid-Hills areas, particularly rely on these sources. In Nepal's traditional farming system, agricultural residues and animal wastes are the main source of organic matter and nutrients for the soil. Burning these deprives the soil of organic matter and essential nutrients, affecting crop yield.

Fossil Fuels

The share of fossil fuels in Nepal's overall energy consumption is very small. However, consumption has been growing consistently (CBS 2004). Industries and automobiles are the main consumers of imported fossil fuels. Environmental concerns of fossil fuel consumption relate to emission-related air pollution, which is becoming a sensitive issue in urban and industrial areas, and their peripheries.

Hydropower

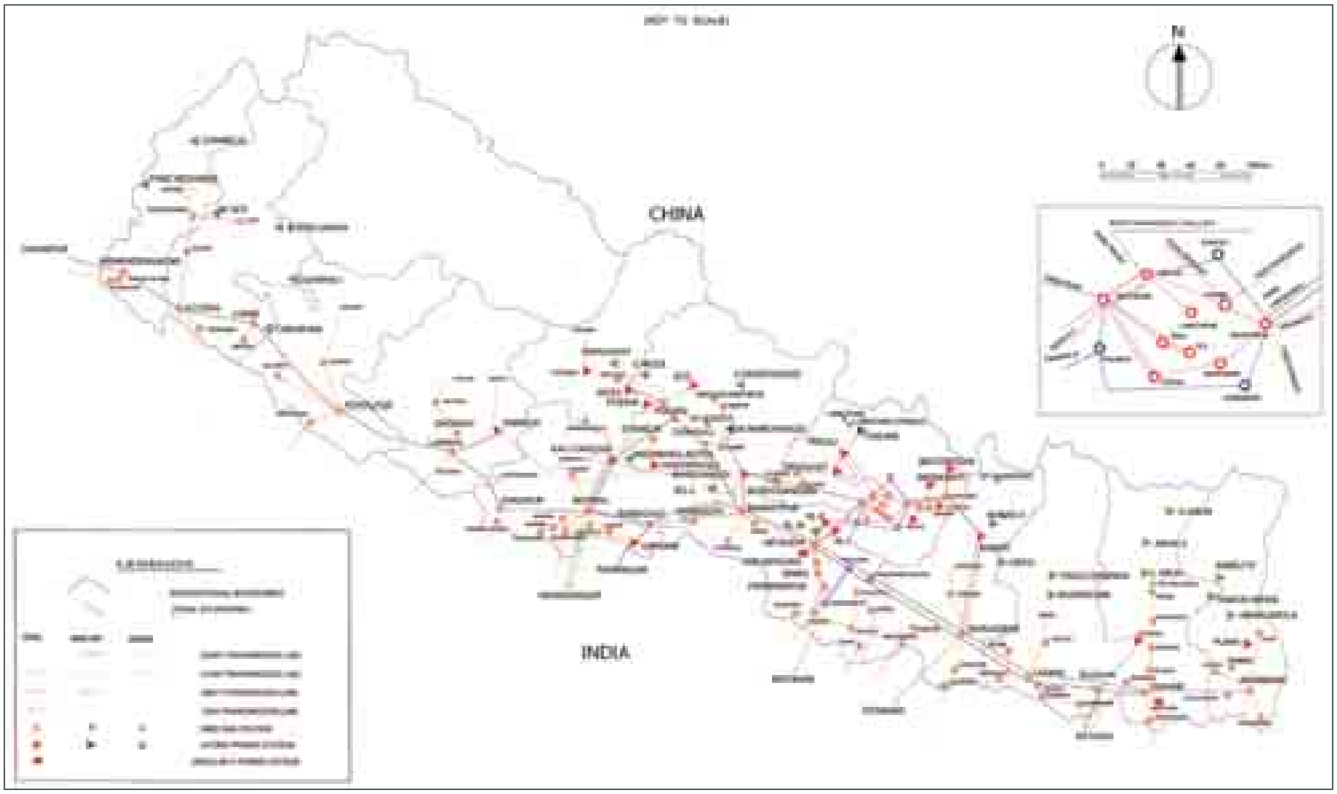
Hydropower is renewable clean energy. Therefore, environmental concerns of hydropower are related to development and production stages rather than consumption. The severity of these concerns depends on the size, type, and location of hydropower projects—the bigger the project, the greater the environmental impacts. Reservoir projects are likely to result in much higher environmental and social impacts than run-of-river projects. Many bigger hydropower projects around the world have become environmentally and socially contentious and many have encountered unanticipated difficulties in the course of development or operation. For example, the Arun III hydropower project in Nepal has been dropped following protracted environmental debate, and the Kulekhani reservoir project encountered a heavy siltation problem that was unsuspected during its planning and design. The main environmental concerns related to bigger hydropower projects include the following.

Impacts downstream. Water diversion can result in undesirable consequences downstream. These typically include, but are not limited to, depriving downstream users of water for irrigation and other traditional uses, degradation of water quality, and reduction in flows harming riparian ecosystems and aquatic life.

Inundation. Inundation upstream of dams can result in submergence of houses and settlements, fertile agricultural land, forest and other vegetation, and others.

Displacement. People can be displaced as direct or indirect consequences of a project, or livelihoods can be affected due to degradation or loss of private land and properties, resources, and local infrastructure and amenities. Quite often poor

Figure 6.1: Power Development Map of Nepal: Major Power Stations, Transmission lines, and Substations



Source: NEA (2005)

and marginal people are the worst affected. Most of the project beneficiaries live far from the project site while the people living around the project are adversely affected.

Physiographic risks. There is a high risk of damage to civil structures and plants by landslides as a result of the fragile physical setting of the Himalayan range and monsoon floods. Glacial lake outburst floods (GLOF) also pose a threat. These may not only damage the project but can also sweep away settlements, and destroy land and property downstream. The risk of reservoir siltation is also very high in the mountainous terrain of Nepal.

Impact on migratory fish. Hydropower dams can act as barriers to migration of fish, and projects can act as barriers to the movement of land animals or adversely affect their habitat.

It is now accepted that hydropower development needs to consider environmental and social consequences, and environmental assessment is now generally required to ensure this. Mitigation and compensation measures are part of the environmental assessment; measures such as compensation for loss of property, ensuring minimum downstream flow all the time, supporting the development of areas surrounding the project, and social upliftment programs in affected communities may be necessary. People should not be worse off due to a hydropower project, and project benefits should also go to those affected, adequately compensating the losses they incur.

Alternative Energy

Alternative energy such as from micro-hydro, biogas plants, or solar sources—as well as use of more efficient and environmentally sound technologies for biomass energy—has a number of environmental advantages over other energy sources available in Nepal.

Micro-hydro is a clean local source of energy suitable for hilly rural areas in Nepal. For rural communities, it can be an alternative to traditional biomass fuels and has a significant potential towards reducing the demand for traditional fuels (firewood) as well as imported fuel (kerosene).

Biogas is suitable for cooking and hence can substitute for firewood in rural areas, and reduce pressure on the forest. The Biogas Support Program estimates that 119,693 operating biogas plants save 239,386 tons of fuelwood, 3.83 million liters of kerosene, and 203,478 tons of bio-compost fertilizer in a year (BSP 2005). These savings would result in a positive carbon dioxide balance as well as carbon absorption. Use of biogas plants improves sanitary and hygienic conditions at the household level. The slurry produced by the biogas plants is rich in nutrients and can be used as manure. As biogas replaces firewood and kerosene, this helps improve

Review of Dams and Development by the World Commission on Dams

Conflicts over dams have heightened in the last two decades due largely to the social and environmental impacts. Social groups bearing the social and environmental costs and risks of large dams, especially the poor and vulnerable and future generations, are often not the same groups that receive the water and electricity services, nor the social and economic benefits from these. The debate is also related to many competing uses and needs of water—there is increasing concern about access, equity, and the response to growing needs. This could affect relations within and between nations; between rural and urban populations; between upstream and downstream interests; between agricultural, industrial and domestic sectors; and between human needs and the requirements of a healthy environment. These needs are intertwined. The debate about dams is a debate about the very meaning, purpose, and pathways for achieving development. Having conducted an independent, comprehensive, global review of dams and their contribution to development, the World Commission on Dams (WCD 2000) concluded the following:

- (i) Dams have made an important and significant contribution to human development, and the benefits derived from them have been considerable.
- (ii) In too many cases an unacceptable and often unnecessary price has been paid to secure those benefits, especially in social and environmental terms, by people displaced, by communities downstream, by taxpayers, and by the natural environment.
- (iii) Lack of equity in the distribution of benefits has called into question the value of many dams in meeting water and energy development needs when compared with alternatives.
- (iv Bringing to the table all those whose rights are involved and who bear the risks associated with different options for water and energy resources development creates conditions for a positive resolution of competing interests and conflicts.
- (v) Negotiating outcomes will greatly improve the development effectiveness of water and energy projects by eliminating unfavorable projects at an early stage, and by offering as a choice only those options that key stakeholders agree represent the best ones to meet the needs in question.

The commission recommends that it is necessary to break through the traditional boundaries of thinking and enshrine five core values in water and energy development: equity, efficiency, participatory decision-making, sustainability, and accountability. Decision-making needs to ensure: comprehensive approach to integrating social, environmental, and economic dimensions of development; greater levels of transparency and certainty for all involved; and increased levels of confidence in the ability of nations and communities to meet their future water and energy needs. The commission has proposed seven strategic priorities and related policy principles that water and energy resource projects should integrate in the planning and project cycles.

- (i) Gaining public acceptance: Acceptance emerges from recognizing rights, addressing risks, and safeguarding the entitlements of all groups of affected people, particularly indigenous and tribal peoples, women, and other vulnerable groups.
- (ii) Comprehensive options assessment: Alternatives to dams do often exist. The selection is based on a comprehensive and participatory assessment of the full range of options, and assessing social and environmental aspects at par with economic and financial factors.
- (iii) Addressing existing dams: Opportunities exist to optimize benefits from many existing dams, address outstanding social issues, and strengthen environmental mitigation and restoration measures.
- (iv) Sustaining rivers and livelihoods: Rivers, watersheds, and aquatic ecosystems are biological engines. Understanding, protecting, and restoring ecosystems at river basin level is essential to foster equitable human development and the welfare of all species.
- (v) Recognising entitlements and sharing benefits: Joint negotiations with adversely affected people result in mutually agreed and legally enforceable mitigation and development provisions.
- (vi) Ensuring compliance: Ensuring public trust and confidence requires that the governments, developers, regulators, and operators meet all commitments made for the planning, implementation, and operation of dams.
- (vii) Sharing rivers for peace, development, and security: Storage and diversion of water of transboundary rivers has been a source of considerable tension between countries and within countries. Dams require constructive cooperation.

indoor air quality, with a positive impact on human health.

Having micro-hydro or solar electricity is important for rural villagers. It provides light for students to study, and powers TVs and radios that bring news and can be an important means of family entertainment. Substituting traditional biomass fuels with electricity has a number of advantages: (i) Improvement in indoor air quality by reducing or eliminating smoke, (ii) Reducing pressure on forest and saving time spent collecting firewood, and (iii) Electric light allows household families additional working time.

Where electricity and biogas are not practical, technologies such as improved cooking stoves can be promoted in rural areas. This will not only increase efficiency and reduce firewood consumption, but also reduce indoor air pollution and lead to positive health impacts.

Energy Policy and Plan

The Tenth Plan (2002–2007), Hydropower Development Policy 2001, Renewable Energy Perspective Plan of Nepal 2000–2020, Perspective Energy Plan 1991–2017, Water Resources Act 1992, and Electricity Act 1992 are the main policy, planning, and legislative documents guiding the energy sector in Nepal. These policies aim to attract local and foreign private developers to the hydropower sector.

The Tenth Plan (NPC 2002) emphasizes rural electrification and has a target to increase national electricity coverage from 40% to 55% over the plan period. The major strategies to be followed are promoting private sector participation, institutional reforms, establishment of a Power Development Fund, initiating an explicit subsidy policy for grid-based rural electrification, and creation of an independent regulatory body in the power sector. The highlights are summarized below.

- (i) No license is required to generate hydropower up to 1 MW capacity, but projects must be registered with the District Water Resources Committee, and the Department of Electricity Development has to be informed.
- (ii) A 35-year license will be provided for hydropower production for domestic consumption; 30 years for export.
- (iii) Royalty rates will be based on project capacity and be higher for export-oriented projects than for domestic uses.
- (iv) Institutional reforms will allow operating the generation, transmission, and distribution systems separately through autonomous public institutions, local bodies, and the private sector.
- (v) A rural electrification fund to promote and develop rural electrification will be established, using a portion of royalties received from hydropower projects.
- (vi) Various subsidy and incentive schemes will be established for alternative energy development, including micro-hydro, biogas plants, and solar-based electricity.

The Way Forward

Energy affects livelihood, wellbeing, and development in multiple ways. As population increases and the economy expands, people need energy in increasing amounts. How the present and future energy needs are met affects not only the environment but also overall development. Energy policy and strategy are linked with sustainable development approaches and environmental strategies.

The industrial world has already shown that its traditional mode of industrial development and energy consumption is not sustainable. Indiscriminate use of fossil fuel is leading to global environmental threats such as global warming and climate change. Industrialized nations need to change current practices to those using energy from cleaner and sustainable sources, and more efficiently than in the past. This shift will be difficult, costly, and painful for them as their current industries, economies, and lifestyle depend heavily on the use of fossil fuels.

Nepal is at a low level of industrialization. This provides an opportunity to learn from the already industrialized countries and to pursue a path that utilizes cleaner energy in an efficient manner. This should not be as difficult for Nepal as it would be for already industrialized countries, as Nepal does not need to shift from an already existing system to a new one, but to choose a more sustainable and benign path. Nepal therefore needs to pursue an energy policy and strategy that can supply energy for present and future use from sources that are dependable, affordable, safe, and environmentally sound. Nepal's energy development should therefore be guided by the following three basic principles.

Self-reliance in Energy and Promotion of Indigenous Renewable Sources

A massive promotion of indigenous renewable energy sources will be necessary. Nepal's indigenous energy resources—hydro, biomass, solar, and wind—are renewable, and their combined potential exceeds current demand as well as demand for the foreseeable future. In theory, therefore, energy shortages should not be a problem for Nepal, and

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Rural energy past and future: clockwise from top-collecting firewood for cooking (top); a simple peltric set can provide electricity for lighting in remote villages; improved cooking stoves reduce firewood use

renewable energy sources could contribute substantially to self-sufficiency. In reality, however, Nepal has not been able to harness its indigenous sources adequately and cost-effectively with two undesirable results—the energy available in the market is costly, and rural and poor people continue to depend on traditional biomass sources.

Relying more on indigenous renewable energy sources has a number of advantages. In addition to environmental benefits, such sources are less susceptible than imported fossil fuels to price fluctuations and foreign exchange rates, and their use means minimizing the risk of supply interruption due to external factors. But their development and use are constrained by the lack of national priority as well as inadequate national capacity in terms of finance, technologies, and institutions. Renewable energy sources (hydro, biomass, solar, and wind) require a much higher priority in national energy programs.

Having an Appropriate Mix of Energy Sources

Each energy source has desirable and undesirable environmental, economic, technical, and social dimensions. No single source is likely to satisfy all types of energy needs for all groups of users at all locations. Therefore, dependence on one source alone is not sustainable in the long run. Energy needs, availability, and costs can change over time. The long-term strategy, therefore, should encourage a suitable mix of sources, including hydropower, improved biomass use, solar, and other sources, that satisfies current and emerging demand and includes the necessary flexibility to respond to changing contexts. The energy mix desirable today could change over time with changing needs and advances in technology.

Reducing Consumption through Increasing Efficiency

Current energy consumption in Nepal is heavily dependant on biomass. Two issues related to this are first that biomass is used in a wasteful and inefficient manner that affects the health of consumers, and second, that although biomass is a renewable source, its supply is limited and cannot continue to meet growing demand without adverse impacts on the environment, economy, and health. The consumption and demand of non-biomass, commercial energy such as electricity and petroleum have been gradually increasing and this has been met by a corresponding increase in supplies, but efficiency in end-use has hardly received consideration.

Efficient use of energy is probably more important in the long run than increasing supplies. Promotion of energy efficiency in the production, supply, and consumption stages will not only reduce or check increases in demand, but will also have positive impacts on environment and health. Energy efficiency should be an integral part of national energy development and environmental policies.

One constraint to promoting energy saving and efficient use is the cost of energy conservation technologies and end-use devices that, most commonly, have to be imported. Investment in energy conservation and improved technologies and measures can save money over time because there will be reductions in the investment to increase supply. Improving efficiency can be less costly than investing in new projects to supply increasing energy demand.

Many energy efficiency measures, however, may cost little or nothing to implement—quite often energy can be saved simply by demand-side management. For example, differential pricing for use of electricity during peak and off-peak hours or during the monsoon when hydropower supply is greatest and winter when it is limited can promote more rational consumption behavior. Improved cooking stoves can substantially reduce fuelwood consumption in rural areas in addition to their benefiting health. These principles, however, should be applied in such a way as not to impede development.

Constraints. Pursuing the sustainable and environmentally sound energy path that enshrines these principles is not easy in the present national and global economic structure. This will require clarity as to how such an energy policy can be linked with sustainable development. For example, transport and industry are important for national development and are the major consumers of petroleum and coal, which are not only imported but also environmentally undesirable. With the right policy, transport can be promoted in a way that consumes energy from indigenous renewable sources like hydroelectricity.

Availability of funds and national willpower to implement the policy is another basic requirement. Most of the technologies will have to be purchased from more developed countries, which will be a major constraint for a country like Nepal. Initially, foreign assistance may be mobilized. Building national capacity in renewable energy technologies and manufacturing energy-efficient devices should be at the top of the energy development agenda.

Energy price. Price at the consumption point is probably the most important factor influencing energy consumption behavior. Pricing policy should therefore reflect the three guiding principles discussed above: (i) Promotion of indigenous renewable energy sources, (ii) Appropriate mixes of energy sources, and (iii) Increasing efficiency. A well-devised system of subsidies, taxes, levies, and incentives is necessary for this to be realized. They should favor efficiency measures as well as environmentally sound energy production—pricing of energy could utilize the "polluter pays" principle and reflect external damage costs to health, property, and the environment. The demand for imported fossil fuels could be lowered through levies and changes in energy subsidies, energy efficiency in industries could be promoted through tax rebates for adopting energy-efficient technologies, and so on.

Energy should be available to all users at an affordable price. Scarcity of money is the immediate problem for the poor and this is frequently a greater concern for them than the shortage of energy, so cost is a major barrier to adoption of energy-efficient devices by the poor. The poor are forced to use inefficient end-use devices and fuels that are available free or cheaply because they lack money to purchase better choices, although at the end of the day, if all the direct and indirect costs are accounted for properly, they may be paying more per unit of delivered energy-services.

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