Hydropower Development in Nepal

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Hydropower has been recognised as a sustainable source of energy with almost zero input cost. Its benefits are that it is non-polluting in the sense that it releases no heat or noxious gases, it has low operating and maintenance cost, its technology offers reliable and flexible operation, and hydropower stations have increased efficiencies along with long life. Nepal's huge potential in hydropower is still untapped. Though Nepal has not yet been able to tap even one percent of its potential electricity capacity and 60 percent of Nepal's population is still deprived of electricity, it is fascinating to note that Nepal's start in 1911 in the hydropower generation almost dates back to a century. As a cheap, renewable source of energy with negligible environmental impacts, small hydropower has an important role to play in Nepal's future energy supply. Accordingly, micro-hydro system is becoming increasingly popular as an energy source in rural Nepal. Use of environmentally-friendly technologies and implementation of sound legal and institutional issues are critical to improve the reach of the population to hydropower. To make the Plan targets in the power sector a reality, directing more resources to the power projects focusing on rural population remains the pre-requisite. The major strategies of the power sector have been appropriately identified as promoting private sector participation in power generation and distribution, integrating rural electrification with rural economic development programs, and strengthening power infrastructure. The immense role of the power sector in contributing to the generation of broad-based, sustainable and high level of economic growth as well as improving the relative competitiveness of the economy both on a regional and global basis makes it imperative that the programs and activities on power sector development as visualized in the plans and policies be given the utmost urgency, priority and focus.

I. INTRODUCTION

It is now not a new knowledge that flowing water creates energy that can be captured and turned into electricity called hydropower. Hydro comes from the Greek word 'hydra', meaning water. It is the electricity produced by the movement of fresh water from rivers and lakes. Also called hydropower, it is a renewable energy source dependent upon the hydrologic cycle of water, which involves evaporation, precipitation and the flow of

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water due to gravity. Gravity causes water to flow downwards and this downward motion of water contains kinetic energy that can be converted into mechanical energy, and then from mechanical energy into electrical energy. At a good site, hydropower can generate very cost effective electricity. The history of conversion of kinetic energy into mechanical energy dates back to two thousand years ago in ancient Greece when wooden waterwheels were used. Hydropower represents an important source of energy, accounting for one-fifth of the world's electricity supply. Most of the technically and economically feasible hydropower potential has been exploited in the developed countries and the developing countries, too, realizing the significance of this source of power for the higher sustained economic growth and development of their respective economies, have been embarking on the various phases of the hydropower development process.

Hydropower projects have a number of benefits. The prominent among them are that these projects have low energy production cost considering the long effective lifetime of the plants along with the low operation and maintenance cost, greater efficiency than of all the major types of plants using non-renewable and renewable energy resources, almost complete absence of greenhouse gas emission, possibility of multi-purpose water use and water management such as irrigation and regulation of river flows both during flood season and low flow periods, independence of fluctuating fuel prices and supply disruptions, efficient output regulation, rapid response capacity to variable energy demand, reliable, proven mature technology with known positive and negative influences, a renewable energy source, save consumption of fossil, fuel, or firewood which constitute classic energy sources that contribute to the greenhouse effects or atmospheric pollution as the hydropower plants make use of artificial fall of the river, the hydraulic conveyance circuit that can be integrated in other components for multiple purposes such as irrigation, water supply systems, fisheries, water-tourism, etc. The most important benefit is that hydropower plants produce electricity without consuming power.

Hydropower provides a reliable, efficient, safe and economic source of power for increasing effectiveness of the decentralized industries system. The use of water to produce hydropower has the advantage of absent of carbon-dioxide, sulphur-dioxide, nitrous-oxide and solid or liquid waste production. Thus, the water sources should contribute to a substantial reduction in emission of carbon-dioxide and other harmful gases responsible for greenhouse effects. The water will continue to fall downhill and will continue to be a resource for men and environment needs as a part of the natural hydrologic cycle. However, it has some disadvantages like high investment along with long lead-time for project realization, long gestation period, and environmental and social problems, mainly due to inundation of affected areas by large water reservoirs causing possible destruction of unique biotypes and endemic species. Some other disadvantages include, possible destruction of human habitat, high cost for the necessary resettlements and fallouts related to social and political implications.

Regarding the presentation of the analysis, this first section outlines the Introduction. The second section covers the History of the electricity development with reference to Nepal. The third section on Operations of Hydropower Stations and the fourth section on the Small Scale Hydropower describe, in short, the operational technicalities of the station operations. The fifth section on Development of Hydropower in Nepal describes the decadewise growth of hydropower and the sixth section on Small Hydroplants in Nepal analyses the distribution of smaller hydroplants. While the seventh section covers the Hydropower Policy, the eighth section deals with the Challenges before arriving at the Conclusion which is given in the last or the ninth section.

II. HISTORY

In the modern days, it was only in 1882 that the first hydropower plant was built in Wisconsin, USA. This plant made use of a fast flowing river as its source. Some years later, dams were constructed to create artificial water storage area at the most convenient locations. These dams also controlled the water flow rate to the power station turbines. In Nepal, the first hydropower plant was established at Pharping (500-KW) in 1911, 29 years after the world's first plant was established, during Prime Minister Chandra Shamsher Rana's time to meet the energy requirements of the members of the ruling class. Though some 60 percent of Nepal's population remains deprived of electricity while the capital city continues to thirst for drinking water and suffers from regular load-shedding even at the present, it is fascinating to note that Nepal had such an early start in the hydropower generation. The first hydropower plant in India was established in 1898 in Darjeeling and the first hydropower plant in China was established in 1912. Originally, hydropower stations were of a small size set up at waterfalls in the vicinity of towns because it was not possible at that time to transmit electrical energy over long distance. The main reason why there has been large-scale use of hydropower is because it can now be transmitted inexpensively over hundreds of kms. where it is required, making hydropower economically viable. Transmission over long distances is carried out by means of high voltage, overhead power lines called transmission lines. The electricity can be transmitted as either alternating current (AC) or direct current (DC). Unlike conventional power stations, which take hours to start up, hydropower stations can begin generating electricity very quickly. This makes them particularly useful for responding to sudden increases in demand for electricity by customers, i.e., peak demand. Hydro-stations need only a small staff to operate and maintain them. No fuel is needed to operate, as such; fuel prices do not become a problem. Also, a hydropower scheme uses a renewable source of energy that does not pollute the environment. However, the construction of dams to enable hydropower generation may cause significant environmental damage. In the world today, the highest producers of hydropower are Canada, United States, Brazil, China, Russia, and Norway. Among the various countries, Canada ranks first in the production of hydropower as it has abundant water resources and a geography that provides many opportunities to produce low-cost energy. In fact, accessing the energy from flowing water has played an important role in the economic and social development of Canada for the past three centuries.

BOX 1: Pharping Hydropower: Nepal's First Hydroplant

Pharping Hydropower Plant is one of the oldest hydropower plants of Asia and the first hydropower plant of Nepal. The construction of the plant commenced in 1907 and was commissioned in 1911. The plant was inaugurated by His Late Majesty King Prithvi Bir Bikram Shah on May 1911(Jestha 9, 1968 BS, Monday, at 6:30 PM). In total, 900,050 thousand man-days were required to complete the construction of the plant. The plant was equipped with two turbines each of 250 KW. The water for the generation was tapped from Satmule and Shesh Narayan laying steel pipeline with diameter of 44 inch from Satmule and diameters of 10 inch and 9 inch from Shesh Narayan. A reservoir with 200 ft. diametre and 18 ft. depth with the capacity of 528,733 cu. ft. was built. From the reservoir, riveted steel pipes of 20 inch diameter were used as penstock up to the bifurcation point. An overhead transmission line of 6 miles from the plant to the distribution sub-station at Tundikhel was constructed using steel and wooden poles. In the transmission line, there are two major crossings of 600 ft. and 900 ft. on Bagmati river. The equipment of this plant was a grant from the British Government and other expenditures were borne by Nepal Government. The total cost borne by Nepal Government was CRs. 713,273.82, out of which CRs. 367,984.00 was spent locally inside Nepal. The breakdown of the total cost (CRs. 713,273.82) was: Pipeline/Headwork/Reservoir CRs.196,324.84, Powerhouse/Colony/Tailrace and Widening of Bagmati River CRs. 156,778.31, Substation/Office/Store CRs. 36,175.80, Transmission Line/Street Light/Distribution Line and Telephone Line CRs.111,049.50, London to Kolkata Transportation/Packing/Commission to Agent CRs. 28,699.26, Kolkata to Bhimphedi Transportation CRs. 40,311.79, Bhimphedi to Site Transportation CRs. 40,372.32, and Salary/ Wages CRs. 103,565.00. The plant was constructed under the overall supervision and monitoring of General Padma Sumsher JBR. Executive Engineer Colonel Kishor Narsingh Rana was responsible for planning of the powerplant.

Salient Features of the Plant

1. Turbine	*: Pelton Turbine, 2 Nos.*
2. Governor	*: Milton Oil Governor*
3. Penstock	*: Riveted Steel pipes of 20" dia. (length 2,538 ft.)*
4. Reservoir	*: 200' dia. and 18' deep (capacity 528,733 cu. ft.)*
5. Conveyance System	*: Pipeline:- 44" dia. from Satmule 10" and 9" dia. from Shesh Narayan*
6. Water Pressure at Turbine	*: 288 lb/sq. inch*
7. Transmission Line	*: Length 6 miles, Support - Steel and Wooden Poles.*

Source: Nepal Electricity Authority, Aug.2005, Generation, Third Issue, Kathmandu, Nepal.

III. OPERATIONS OF HYDROPOWER STATIONS

The most common type of hydropower plant uses a dam on a river to store water in a reservoir. Water released from the reservoir flows through a turbine, spinning it, which, in turn, activates a generator to produce electricity. But hydropower doesn't necessarily require a large dam. Some hydropower plants just use a small canal to channel the river water through a turbine. Another type of hydropower plant—called a pumped storage plant—can even store power. The power is sent from a power grid into the electric generators. The generators then spin the turbines backward, which causes the turbines to pump water from a river or lower reservoir to an upper reservoir, where the power is stored. To use the power, the water is released from the upper reservoir back down into the river or lower reservoir. This spins the turbines forward, activating the generators to produce electricity.

Thus, the main components of a hydropower facility are the dam, the powerhouse that contains the mechanical and electrical equipment, and the waterways. Water is released from the dam to turn turbines. The turbines drive generators that produce electricity. The purpose of the dam is to create height for the water to fall and to provide storage. However, the dam must also be provided with a spillway that can accommodate and pass high flows or flood waters without overtopping the dam or reducing its safety. The flood water come from heavy rain or rapid snowmelt on the upstream part of the basin. If it is proposed to utilize not only the head at the dam but also the fall in the river downstream, a canal, penstock or tunnel are needed to carry the water to the powerhouse. A canal may also be needed to carry water from the powerhouse back to the river.

The amount of electrical energy that can be generated from a water source depends primarily on two things: the distance the water has to fall and the quantity of water flowing. Hydropower stations are, therefore, situated where they can take advantage of the greatest fall of a large quantity of water: at the bottom of a deep and steep-sided valley or gorge, or near the base of a dam. Water is collected and stored in the dam above the station for use when it is required. Some dams create big reservoirs to store water by raising the levels of rivers to increase their capacity. Other dams simply arrest the flow of rivers and divert the water down to the power station through pipelines. The amount of energy available from water depends on both the quantity of water available and its pressure at the turbine. The pressure is referred to the head, and is measured as the height that the surface of the water is above the turbine. The greater the height (or head) of the water above the turbine, the more energy each cubic metre of water can impart to spin a turbine which, in turn, drives a generator. The greater the quantity of water, the greater the number and size of turbines that may be spun, and the greater the power output of the generators. It may be relevant to mention that current hydropower technology, while essentially emission-free, can have undesirable environmental effects, such as fish injury and mortality from passage through turbines, as well as detrimental effects on the quality of downstream water. A variety of mitigation techniques are in use now, and environmentally friendly turbines are under development.

IV. SMALL SCALE HYDROPOWER

Hydropower is available in a range of sizes from a few hundred watts to over 10 GW. Facilities range in size from large power plants that supply many consumers with electricity to small and micro plants that local community operates for its own energy needs or power producers operate to sell power to the central grid authority. Small-scale hydropower plants (up to 1000 KW) play an immense role in meeting the energy needs and do not require huge investment and market requirements. Micro-hydro systems (up to 100 KW) operate by diverting part of the river flow through a penstock (or pipe) and a turbine, which drives a generator to produce electricity. The water then flows back into the river. Micro-hydro systems are mostly run-of-the-river systems, which allow the river flow to continue. This is preferable from an environmental point of view as seasonal river flow patterns downstream are not affected and there is no flooding of valleys upstream of the system. A further implication is that the power output of the system is not determined by controlling the flow of the river, but instead the turbine operates when there is water flow and at an output governed by the flow. This means that a complex mechanical governing system is not required, which reduces costs and maintenance requirements. The systems can be built locally at low cost, and the simplicity gives rise to better long-term reliability. However, the disadvantage is that water is not carried over from rainy to dry season. In addition, the excess power generated is wasted unless an electrical storage system is installed, or a suitable 'off-peak' use is found. There are two main types of turbines used in micro-hydro systems, depending on the flow and the head, namely, impulse turbines and reaction turbines. Typical impulse turbines are generally used for medium to high-head applications. Reaction turbines are generally used at low propeller turbine or medium head turbine. Electrical energy can be obtained from a micro-hydro system either instantaneously or through a storage system. In an instantaneous power demand system, the system provides 240V AC power to the load via-a turbine which must be sufficiently large to meet the peak power demand. These systems require a large head and/or flow. In a storage system, the micro-hydro generator provides a constant DC charge to a battery system, which then supplies power to the load via an inverter. The battery system must be sized to the daily electrical demand. However, the turbine is significantly smaller than for an instantaneous demand system, and it operates at a constant power output.

V. Development of Hydropower In Nepal

Nepal is rich in hydro-resources, with one of the highest per capita hydropower potentials in the world. The estimated theoretical power potential is approximately 83,000 MW. However, the economically feasible potential has been evaluated at approximately 43,000 MW. After the establishment of the first hydropower plant (500 MW) in 1911, the second hydropower plant (640 KW) was established at Sundarijal in 1936. Similarly the Morang Hydropower Company, established in 1939, built 677 KW Sikarbas Hydroplant at Chisang Khola in 1942 though this Plant was destroyed by landslide in the 1960s. The development of hydropower was institutionalized after the initiation of the development planning process. The First Five-year Plan (1956-61) targeted to add 20 MW of hydropower. However, the target was unmet. During the Second Three-year Plan (1962-65), some progress was achieved. Till 1962, the Electricity Department of HMG was responsible for the generation, transmission and distribution of electricity. In 1962, Nepal Electricity Corporation (NEC) was established and was given the responsibility of transmission and distribution of the electricity. The Electricity Department was responsible for the task of electricity generation. After a long gap since the establishment of the Chisang Hydroplant, the hydropower generation capacity of the country expanded with the construction of the Panauti Hydroplant (2400 KW) in 1965 and the Trishuli Hydroplant (21000 KW) in 1967. A series of hydropower projects then followed. The Eastern Electricity Corporation was established in 1974. In 1977, Small Hydropower Development Board was established. Institutional restructuring took place again in 1985, when the merging of the Electricity Department, Nepal Electricity Corporation and all the development boards (except the Marshyangdi Hydropower Development Board) resulted in the creation of Nepal Electricity Authority (NEA). Since this arrangement, the NEA has been responsible for the generation, transmission and distribution of electricity. Other public sector institutions involved in the hydropower sector include Water and Energy Commission and its Secretariat constituted in 1976, the policymaking body established in 1981, and the Department of Electricity Development. Of late, the private sector is also emerging as an important player in the hydropower development. Independent Power Producers (IPPs) have been the ongoing institutional innovations in the power sector of Nepal, with the IPPs signing power purchase agreements (PPA) with the NEA to sell electricity. At present, the total hydropower generation has reached 556.8 MW or just 0.7 percent of the potential. Of the total energy consumption in Nepal, traditional energy like fuel-wood, agriculture residues and animal dung comprises 88 percent and commercial energy like petroleum, hydropower and solar energy constitutes 12 percent. Hydropower accounts for 75 percent of the commercial energy supply in Nepal. The hydropower plants have mainly catered to the electricity needs in the urban and semi-urban areas. The highest growth of hydropower took place during 2001-2005 wherein 195.3 MW (35.1 percent of the total) was produced followed by the decades of 1981-90 and 1991-2000 decades which saw the production of 180.3 MW (32.4 percent of the total) and 125.9 MW (22.6 percent of the total) respectively. The period since 1981 produced 501.5 MW (90.1 percent of the total), implying that only 55.3 MW (9.9 percent of the total) was produced during the entire period of 1911-1980 (Table 1 and Figures 1-4).

TABLE 1. Decadewise Development of Hydropower

Decade	Generation		Cumulative	
	Mega Watts	% of Total	Mega Watts	% of Total
1911-1920	0.5	0.1	0.5	0.1
1921-1930	0.0	0.0	0.5	0.1
1931-1940	0.6	0.1	1.1	0.2
1941-1950	0.0	0.0	1.1	0.2
1951-1960	0.0	0.0	1.1	0.2
1961-1970	27.5	4.9	28.6	5.1
1971-1980	26.7	4.8	55.3	9.9
1981-1990	180.3	32.4	235.7	42.3
1991-2000	125.9	22.6	361.5	64.9
2001-2005	195.3	35.1	556.8	100.0
Total	556.8	100.0		

Source: Compilations from NEA Publications.

FIGURE 1: Decadewise Development of Hydropower Generation (MW)

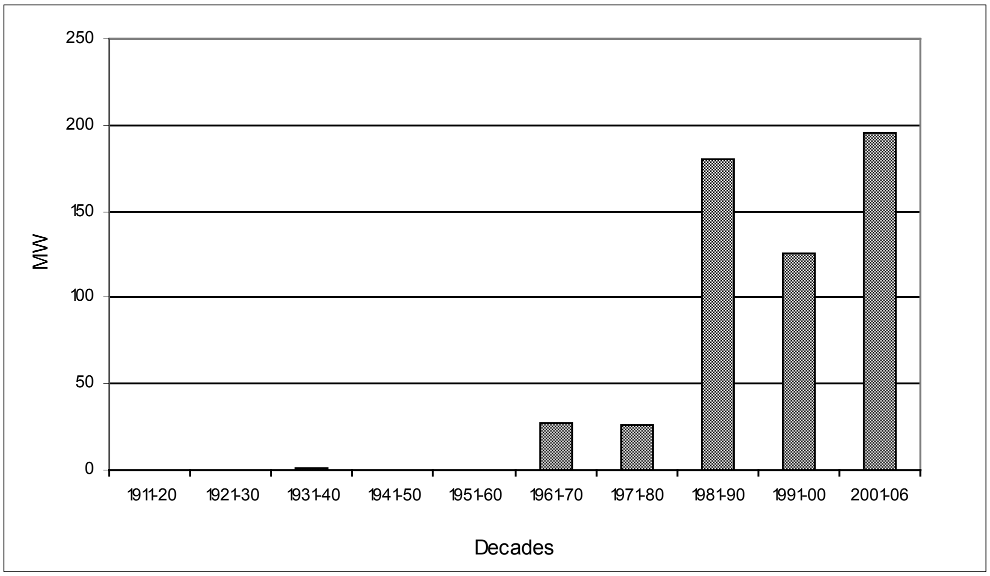


FIGURE 2 : Decadewise Development of Hydropower Generation (% of Total MW)

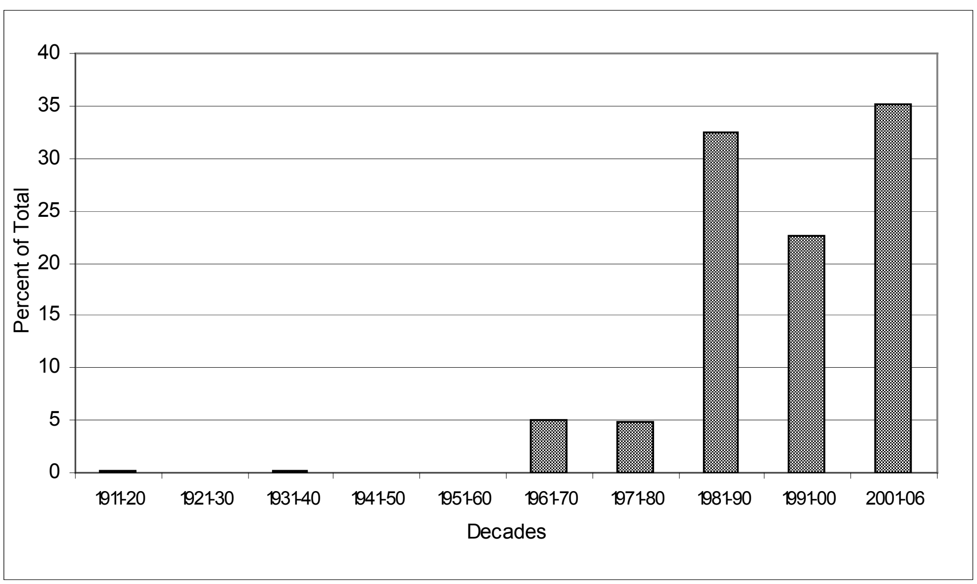


FIGURE 3 : Decadewise Cumulative Hydropower Development (MW)

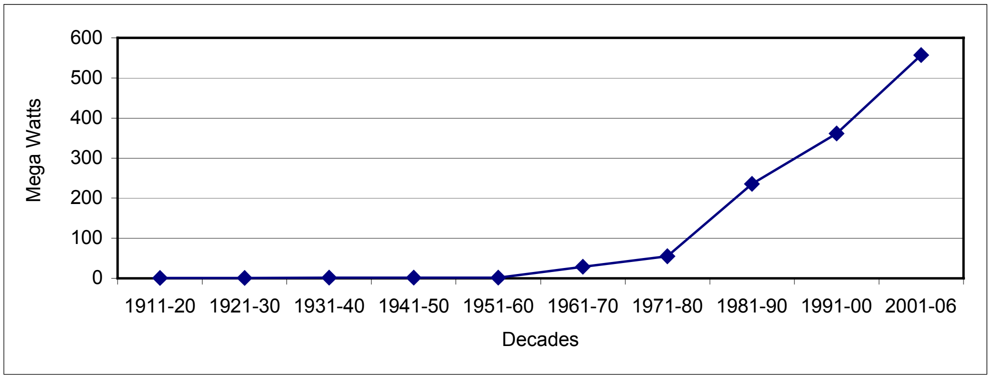
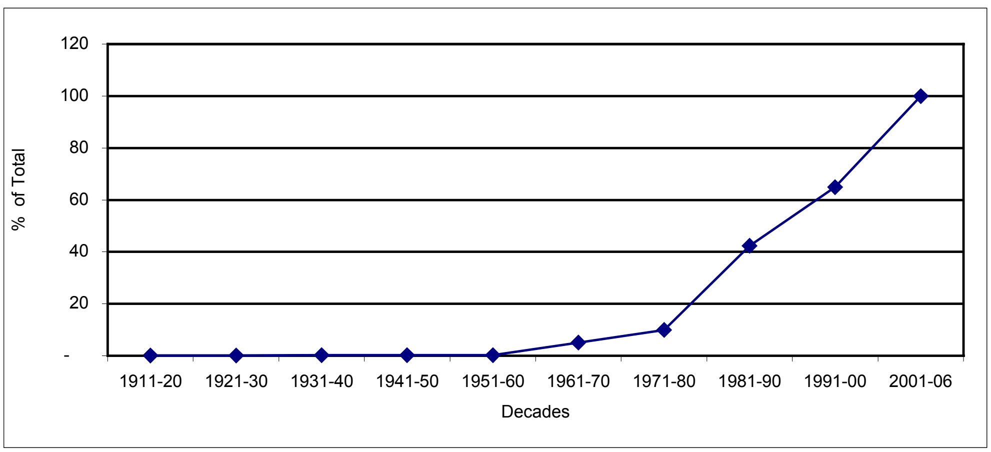


FIGURE 4 : Decadewise Cumulative Hydropower Development (% of Total)



VI. SMALL HYDROPLANTS IN NEPAL

Environmental problems with the dams such as inundation, siltation, negative impacts to river water quality, harm to riparian ecosystems, controversies over monopsony buyer, and the fact that the large projects rely on expensive foreign contracting firms have raised opposition against large-scale hydropower projects in Nepal. Although medium to large-scale hydropower (above 1000 KW) remains the likely choice for meeting Nepal's urban electricity demand, which is growing at an average annual rate of 15 percent, small hydropower is an attractive alternative to conventional power systems in rural and remote areas as a means of achieving rural electrification. As only 33 percent of the population has access to electricity from the national grid, there are many important micro-hydro schemes designed to meet the rural demands. Hence, as a cheap, renewable source of energy with negligible environmental impacts, small hydropower has an important role to play in Nepal's future energy supply. Accordingly, micro-hydro system is becoming increasingly popular as an energy source in rural areas, which are excluded from the energy grid that transmits power from the large hydropower stations to the major urban areas. In fact, micro-hydro power generation is only one component out of the four that include bio-gas generation, solar energy schemes and improved stoves to meet the local need for fuel. As an example of the micro-hydro project, the village of Ghandruk that lies in the Annapurna region is one of many villages in the region that is generating electricity from the Modi Khola river. The stream is no more than a metre wide in the dry season, but generates 50 KW of power: enough for electric lighting for every house in the village and for 20 percent of the village to cook with electricity. The thrust of the micro hydro projects of this nature is to develop hydropower potential in a sustainable and environmentally-friendly way, with a maximum use of the domestic resources and expertise. Of the total electricity generation, the small hydroplants (up to 1000 KW) generate 8.4 MW and medium-sized hydroplants (above 1000 KW) generate 548.4 MW, with the respective shares of 1.5 percent and 98.5 percent (Annexes I, II and III , with Annex IV giving the details of the hydropower projects under construction). The following tables (Table 2 &3) and figures 5,6,7 and 8 provide the distribution of small and medium-sized hydropower plants.

TABLE 2. Distribution of Small Hydroplants (up to 1000 KW)

Kilowatts	No. of Plants	% of Total
1 – 100	8	22.2
101 – 200	14	38.9
201 – 300	6	16.7
301 – 400	3	8.3
401 – 500	3	8.3
501 – 600	1	2.8
601 – 700	1	2.8
Total	36	100.0

Source: Compilation from NEA Publications

TABLE 3. Distribution of Medium-sized Hydroplants (more than 1 MW)

Megawatts	No. of Plants	% of Total
1 – 20	18	72.0
21 – 40	3	12.0
41 – 60	2	8.0
61 – 80	1	4.0
81 – 100	0	0.0
101 – 120	0	0.0
121 – 140	0	0.0
141 – 160	1	4.0
Total	25	100.0

Source: Compilation from NEA Publications

FIGURE 5 : Distribution of Small Hydroplants (Number)

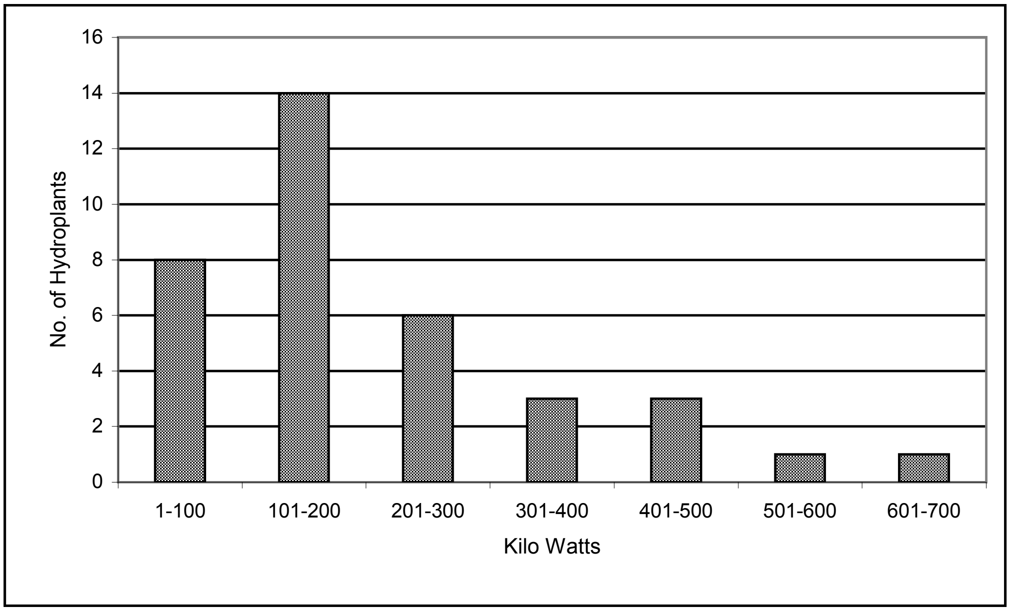


FIGURE 6 : Distribution of Medium-sized Hydroplants (Number)

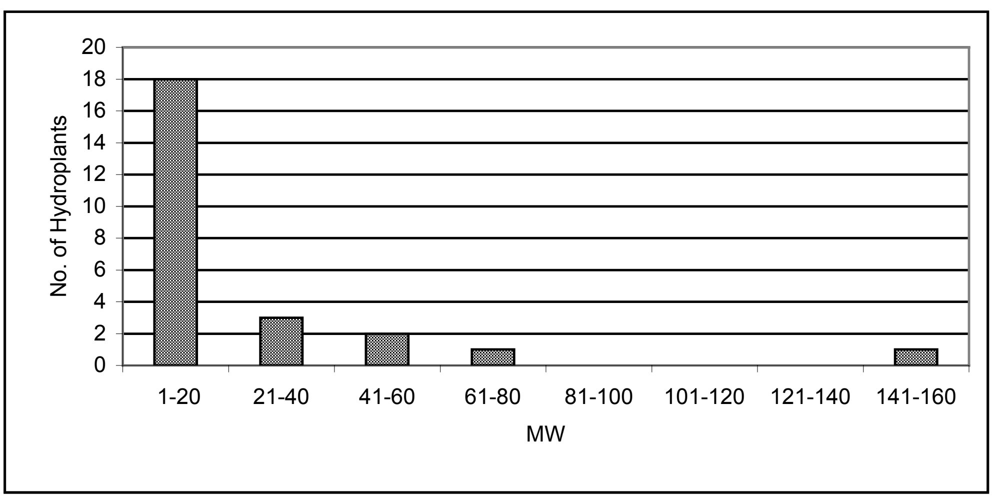


FIGURE 7: Contribution of Small and Medium-Sized

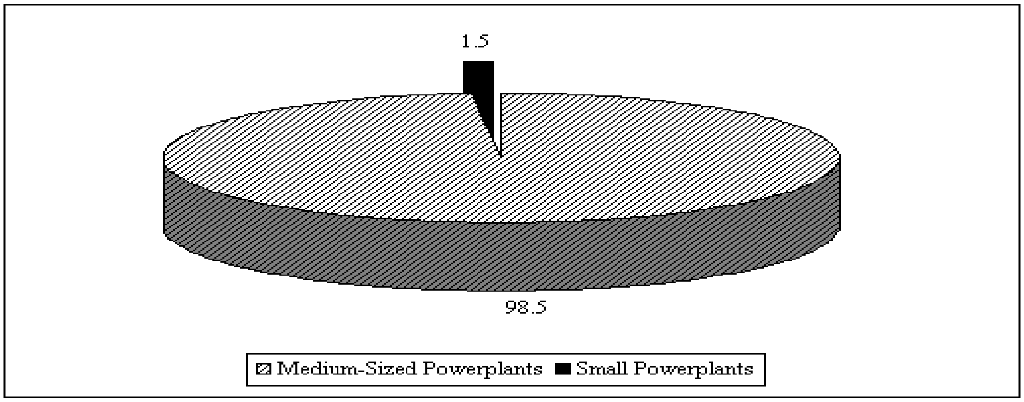
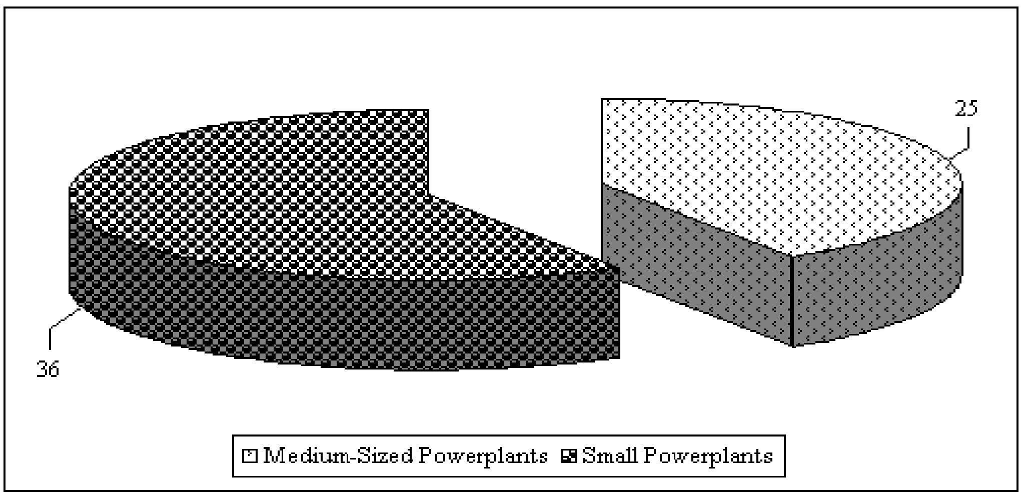


FIGURE 8 : Contribution of Small and Medium-Sized Powerplants (Number)



VII. HYDROPOWER POLICY

The Tenth Plan's (2002-07) key objectives in the power sector include expanding, in a sustainable and environmental-friendly manner, electricity coverage by generating low-cost power; accelerating rural electrification to promote economic growth and improve living standards, and to develop hydropower as an important export item. Rural electrification is particularly important in a rural-based economy of Nepal. It plays an important role in accelerating both agricultural and rural development. It could have a catalytic effect on agricultural growth, especially by accelerating shallow tubewell irrigation. In addition to supporting the development of agro-business, the extension of rural electrification would also help modernize cottage industries and improve the living standards of rural households. Accordingly, key programs are aimed at expanding grid-based rural electrification, promoting small projects where grid-based expansion is not possible, and enhancing the capacity of cooperatives for management at local levels. To achieve the objective of increasing rural coverage of electricity over the Plan period, the government's strategy envisages initiating an explicit subsidy policy for grid-based rural electrification.

Water Resources Strategy 2002 has formulated 10 different strategies, out of which the strategy for the hydropower development aims to achieve "cost-effective hydropower development in a sustainable manner". The strategy has prescribed short-term (5 years), medium-term (15 years) and long-term (25 years) strategic plan of hydropower development. The target of the strategy is: (a) by 2007, to develop hydropower capacity to meet projected demand of 700 MW, (b) by 2007, laws making national contractors/consultants' participation mandatory in all types of projects promulgated, (c) by 2017, 25 percent of households supplied with electricity, (d) by 2017, 2230 MW hydropower developed to meet projected demand including 400 MW for export, (e) by 2017, 38 percent of households supplied with electricity, (g) by 2027, 60 percent of households accessing the grid-supplied electricity, and (h) by 2027, Nepal exporting substantial amount of electricity.

The major strategies of the power sector include promoting private sector participation in power generation and distribution, unbundling the activities of the NEA as well as improving its financial viability, integrating rural electrification with rural economic development programs, and strengthening power infrastructure. The major initiatives/activities to be undertaken to improve power sector development include the establishment of a Power Development Fund (PDF); creation of an independent regulatory authority; initiation of an explicit subsidy policy for grid-based rural electrification; and promotion of small, medium and storage hydropower projects. Hydropower policy has been accordingly revised to allow the private sector entry into a full range of power sector activities, i.e., generation, transmission and distribution. Considerable private investments have already taken place in a number of power generation projects. But progress has been constrained by the insecurity caused by the civil disorder. The major outcomes expected are that the proportion of population having access to electricity will increase from 40 percent to 55 percent by the end of the Tenth Plan period, as stated above, and adequate power will be supplied as needed to support economic growth. To make this outcome a reality, directing more resources to the power projects focusing on rural population remains the pre-requisite.

In accordance with the priority accorded to this sector, HMG has spent substantial sums of money for the electricity development in Nepal. The actual capital outlays on electricity during FY 1998/99 through FY 2003/04 are: Rs. 2.3 billion in FY 1998/99, Rs. 2.5 billion in FY 1999/00, Rs. 2.8 billion in FY 2000/01, Rs. 2.5 billion in FY 2001/02, Rs. 2.2 billion in FY 2002/03 and Rs. 2.3 billion in FY 2003/04, representing 20.9 percent, 21.6 percent, 23.7 percent, 17.6 percent, 17.4 percent and 20.6 percent of the total capital outlay of HMG during these six years respectively. The average of these components works out at 20.4 percent. The Public Statement on Income and Expenditure of HMG for FY 2005/06 has termed roads, electricity and communications as the pre-requisite for economic growth. Accordingly, important programs have been outlined for the electricity development. To expedite the construction of the Middle Marshyangdi Hydro Project, Rs. 2.8 billion has been allocated. Rs. 1.5 billion has been allocated for the rural electrification program which includes handing over the electricity distribution responsibility to the consumer groups in 100 places. There is also a program to generate 2,075 KW electricity in different districts not accessed by the national grid. Necessary preparations will be made to initiate the construction of the 302-MW Upper Tamakoshi and 42-MW Upper Modi "A" under the joint investment of the NEA and the private sector. In order to address the rising demand for electricity by taking advantage of the lower interest rate prevailing in the financial system, the NEA will issue Power Bonds with maturity period of 20 to 30 years and invest them for the construction of new projects.

The immense role of the power sector in contributing to the generation of broad-based, sustainable and high level of economic growth makes it imperative that the programs and activities on power sector development as visualized in the plans, policies and the Annual Public Statement on Income and Expenditure of HMG be given the utmost urgency, priority and focus. The programs of the NEA also need to be completed timely and efficiently. It is very important to realize that, in the present global scenario where the oil prices are remaining higher and future provides an uncertain outlook with respect to oil, optimal utilization of the abundant natural endowment, viz., hydropower, would reduce Nepal's import cost substantially and contribute to improve the relative competitiveness of the economy both on a regional and global basis.

VIII. CHALLENGES

Conventional energy plays an important role in the energy sector of Nepal. The role of conventional energy is more significant in the rural areas where around 85 percent of the population resides. The fuel-wood supply is constrained because of environmental considerations and depleting forest resources. In contrast, the country's enormous hydropower potential is virtually untapped to meet its energy needs, creating a unique situation of a chronic imbalance between energy consumption and energy resource endowment. Large increase in population resulting in the big loss of per-capita land and the poor state of the development of other types of renewable energy have left Nepal no space except to rely on hydropower.

The consumption pattern of hydropower supply in Nepal displays a prominent share of industrial and domestic demand which together accounts for about 80 percent of the total use. Nepal's power supply and demand patterns have a noticeable seasonality characteristic of imbalance in the form of power shortages during dry-months (mid-December through mid-April) and surpluses during wet-months. Despite the introduction of some demand management measures to even them out, these imbalances are still very evident. According to demand supply projections concluded under Water Resources Strategy 2002, such imbalances are expected to persist in the years ahead and this presents an unique opportunity as well as challenge for evening-out the power imbalances on a long-term basis.

Hydropower projects are more capital intensive and most of the existing hydropower plants owned and operated by NEA have mainly come up through bilateral donor financing in combination with soft loan financing from multilateral development financing institutions. The low per-capita consumption of energy in Nepal is not attributed to lack of demand but to the supply bottleneck resulting from financial constraints and inherent delay in hydropower project development. The existing hydropower projects are expensive due to heavy reliance on bilateral and multilateral financing agencies, costly foreign consultants and contractors, limited manufacturing capability of power generation, transmission, and distribution-related equipment, inefficient management and high cost of preparatory works as well as unfavorable geological condition. High cost of project development together with initially expensive power purchase agreement with IPPs, transmission and distribution losses, non-payments or payments in arrears from the public sector consumers and wastage of surplus power contribute to high electricity tariffs, thereby making adverse impact on industrial use and export purposes.

For the implementation of plan and achieving the targets relating to the hydropower, development of cost effective small and medium-sized projects to meet domestic demand at affordable price, encouragement of private sectors investment in hydropower development and power distribution on competitive basis, acceleration of rural electrification attracting investment from community and private entrepreneurs, improvement in the integration of social and environment mechanism into power development process, encouragement of the power-based industries and transportation systems to create market for existing surplus energy and future energy growth are extremely important. Besides, facilitating the flow of funds from domestic financial sector to the hydropower sector and the institutional set-up for the power export, promoting hydropower research and development (R&D) center to assist in preparation of national power system and improve NEA as a commercially viable entity remain the other challenges.

Financing and cost considerations provide major challenges in the process of materializing the hydropower potential of Nepal. It is estimated that the government developed medium-sized hydropower cost an average of US$ 2,800/KW while private generators have been able to produce at US $ 1,000/KW. In this context, making the government-developed hydropower at a cheaper rate comparable to that of the private sector becomes an important challenge. To meet the existing gap in the supply of hydropower, new and cheap hydropower generation must come on national grid very fast. Producing hydropower in sufficient quantity and quality constitutes another challenge. Regional balance in production and distribution capacity needs to be maintained for both socio-political and techno-economic reasons. The people of Nepal from east to west must feel that they are part of the overall national development process, and this will occur if important symbols of development such as hydropower is available to them. Large-scale export potential should not be entertained without first achieving a strong domestic base because once Nepal's needs are adequately met from hydropower development efforts within Nepal, it will be in a more comfortable bargaining position then if it is in a situation where her internal demands have to be met, especially in border towns, with the generosity of the Bihar and the Uttar Pradesh Electricity Boards. So, there is a need for seriously pushing forward a strong hydropower development program that matches Nepal's own power demand growth. State monopoly with no contractual accountability to supply the consumers power of reliable quantity and quality needs to be discouraged at all costs. Hence, the challenge facing Nepal is to generate sufficient financial resources to develop its hydropower in an environmentally sustainable and socially acceptable manner to meet the needs of its people. This calls for least cost approach that makes power affordable to domestic consumers and competitiveness in the export markets of the neighbouring countries in the medium-term. In this context, it is interesting to observe that the hydropower development policy 2001 and the Tenth Plan has attempted to address these issues by way of power sector reform focusing on promotion of private investment, creation of competition through institutional restructuring and establishment of an independent regulatory authority though the reform is progressing very slowly.

IX. CONCLUSION

The hydropower potential of Nepal is huge and the sustainable hydropower development becomes the key to make Nepal's economic growth scenario brighter, gaining deep inroads into the national goal and priority of poverty reduction. Hydropower has a number of benefits: (a) it is a continuously renewable electrical energy source; (b) it is non-polluting, i.e., no heat or noxious gases are released; (c) it has no fuel cost and, with low operating and maintenance cost, is essentially inflation-proof; (d) hydropower technology is a proven technology that offers reliable and flexible operation, (e) hydropower stations have a long life and many existing stations have been in operation for more than half a century and are still operating efficiently; (f) hydropower station efficiencies of over 90 percent have been achieved making it the most efficient of the energy conversion technologies.

Hydropower offers a means of responding within seconds to changes in load demand. Fortunately, Nepal is rich in hydro-resources, with one of the highest per capita hydropower potentials in the world. However, at present, the total hydropower generation has been 556.8 MW, merely 0.7 percent of the potential, with connection to 40 percent of the people. It is notable to mention that, by the end of the Tenth Plan (2002-07), 55 percent of the population will have connection to the electricity. Use of environment-friendly technologies and implementation of sound legal and institutional issues are critical to improve the reach of the population to the hydropower. Putting into place a favorable environment for increasing investments in cost-effective projects would definitely contribute to make this target a reality. As a cheap, renewable source of energy with negligible environmental impacts, small hydropower has an important role to play in Nepal's future energy supply. Micro-hydro systems are particularly suitable for power supplies in rural and isolated communities, as an economic alternative to extending the electricity grid. These systems provide a source of cheap, independent and continuous power, without degrading the environment, so essential for a mountainous and environmentally fragile country like Nepal. To make this outcome a reality, directing more resources to the power projects focusing on rural population remains the pre-requisite. The Acts and regulations should be made to support the environment as well as the hydropower development efforts so that the environment and development go together, especially when it comes to the most important natural resource development endeavors of the nation. The major strategies of the power sector have been appropriately identified as promoting private sector participation in power generation and distribution, unbundling the activities of the NEA as well as improving its financial viability, integrating rural electrification with rural economic development programs, and strengthening power infrastructure. In the present global scenario where the oil prices are remaining higher and future provides an uncertain outlook with respect to oil, optimal utilization of the abundant natural endowment, viz., hydropower, would reduce Nepal's import cost substantially, contribute in improving the relative competitiveness of the economy both on a regional and global basis, and fulfill the desire of double-digit sustainable growth in the coming decades.

ANNEX 1: Development of Hydropower Projects in Nepal (1911-2005)*

S. No.	Hydropower Projects	Commissioned Year	Capacity (KW)	Cumulative Generation (KW)	Type	Located District	Grid Status	Ownership
1	Pharping **	1911	500	500	RoR	Kathmandu	Grid Connected	NEA
2	Sundarijal	1936	640	1,140	RoR	Kathmandu	Grid Connected	NEA
3	Panauti	1965	2,400	3,540	RoR	Kavre	Grid Connected	NEA
4	Phewa	1967	1,088	4,628	RoR	Kaski	Grid Connected	NEA
5	Trisuli	1967	24,000	28,628	RoR	Nuwakot	Grid Connected	NEA
6	Dhankuta	1971	240	28,868	RoR	Dhankuta	Isolated	NEA
7	Sunkosi	1972	10,050	38,918	RoR	Sindupalchowk	Grid Connected	NEA
8	Jhupra	1977	345	39,263	RoR	Surkhet	Isolated	NEA
9	Dhading	1978	32	39,295	RoR	Dhading	Isolated	NEA
10	Tinau	1978	1,024	40,319	RoR	Rupendehi	Grid Connected	NEA
11	Gandak	1979	15,000	55,319	RoR	Nawalparasi	Grid Connected	NEA
12	Baglung	1981	200	55,519	RoR	Baglung	Grid Connected	NEA
13	Doti	1981	200	55,719	RoR	Doti	Isolated	NEA
14	Phidim SHP	1981	240	55,959	RoR	Panchthar	Isolated	Leased
15	Gorkhe	1982	64	56,023	RoR	Ilam	Isolated	NEA
16	Jumla	1982	200	56,223	RoR	Jumla	Isolated	Leased
17	Jomsom	1982	240	56,463	RoR	Mustang	Grid Connected	Leased
18	Kulekhani 1	1982	60,000	116,463	Storage	Makwanpur	Grid Connected	NEA
19	Devighat	1983	14,100	130,563	RoR	Nuwakot	Grid Connected	NEA
20	Syangja	1984	80	130,643	RoR	Syangja	Isolated	NEA
21	Helambu	1985	50	130,693	RoR	Sindupalchowk	Isolated	NEA
22	Seti (Pokhara)	1985	1,500	132,193	RoR	Kaski	Grid Connected	NEA
23	Salleri	1986	400	132,593	RoR	Solukhumbu	Isolated	NEA
24	Kulekhani 2	1986	32,000	164,593	Storage	Makwanpur	Grid Connected	NEA
25	Chame	1987	45	164,638	RoR	Manang	Isolated	Leased
26	Manang	1988	80	164,718	RoR	Manang	Isolated	NEA
27	Tehrathum	1988	100	164,818	RoR	Tehrathum	Isolated	Leased
28	Taplejung	1988	125	164,943	RoR	Taplejung	Isolated	Leased
29	Chaurjhari	1989	150	165,093	RoR	Rukum	Isolated	Leased
30	Ramechhap	1989	150	165,243	RoR	Ramachhap	Isolated	NEA

S. No.	Hydropower Projects	Commissioned Year	Capacity (KW)	Cumulative Generation (KW)	Type	Located District	Grid Status	Ownership
31	Serpodaha	1989	200	165,443	RoR	Rukum	Isolated	Leased
32	Bajhang	1989	200	165,643	RoR	Bajhang	Isolated	Leased
33	Dolpa	1989	200	165,843	RoR	Dolpa	Isolated	NEA
34	Khandbari	1989	250	166,093	RoR	Sankhuwasabha	Isolated	Leased
35	Bhojpur	1989	250	166,343	RoR	Bhojpur	Isolated	Leased
36	Marsyangdi	1989	69,000	235,343	RoR	Lamjung	Grid Connected	NEA
37	Okhaldhunga	1990	125	235,468	RoR	Okhaldhunga	Isolated	NEA
38	Bajura	1990	200	235,668	RoR	Bajura	Isolated	NEA
39	Rupalgad	1991	100	235,768	RoR	Dadeldhura	Isolated	NEA
40	Arughat	1991	150	235,918	RoR	Gorkha	Isolated	NEA
41	Surnaiyagad	1991	200	236,118	RoR	Baitadi	Isolated	NEA
42	Tatopani 1 and 2	1991	2,000	238,118	RoR	Myagdi	Grid Connected	NEA
43	Andhi Khola (BPC)	1991	5,100	243,218	RoR	Sangja	Grid Connected	Pvt. Sector
44	Darchula	1992	300	243,518	RoR	Darchula	Isolated	NEA
45	Namche	1993	600	244,118	RoR	Solukhumbu	Isolated	NEA
46	Jhimruk (BPC)	1994	12,300	256,418	RoR	Pyuthan	Grid Connected	Pvt. Sector
47	Achham	1995	400	256,818	RoR	Achham	Isolated	NEA
48	Chatara	1996	3,200	260,018	RoR	Sindupalchowk	Grid Connected	NEA
49	Kalikot**	1999	500	260,518	RoR	Kalikot	Isolated	NEA
50	Puwa Khola	1999	6,200	266,718	RoR	Ilam	Grid Connected	NEA
51	Modi Khola	2000	14,800	281,518	RoR	Parbat	Grid Connected	NEA
52	Chilime (CPC)	2000	20,000	301,518	RoR	Rasuwa	Grid Connected	Pvt. Sector
53	Khimti Khola (HPL)	2000	60,000	361,518	RoR	Dolakha	Grid Connected	Pvt. Sector
54	Sange Khola (SHP)	2001	183	361,701	RoR	Lamjung	Grid Connected	Pvt. Sector
55	Bhotekosi (BKPC)	2001	36,000	397,701	RoR	Sindhupalchowk	Grid Connected	Pvt. Sector
56	Chaku Khola (APCO)	2002	1,500	399,201	RoR	Sindhupalchowk	Grid Connected	Pvt. Sector
57	Indrawati (NHPC)	2002	7,500	406,701	RoR	Sindhupalchowk	Grid Connected	Pvt. Sector
58	Kali Gandaki A	2002	144,000	550,701	RoR	Sangja	Grid Connected	NEA
59	Piluwa Khola (AVHP)	2003	3,000	553,701	RoR	Sankhuwasabha	Grid Connected	Pvt. Sector
60	Rairang (RHPD)	2004	500	554,201	RoR	Dhading	Grid Connected	Pvt. Sector
61	Sunkosi- Small (SHP)	2005	2,600	556,801	RoR	Sindhupalchowk	Grid Connected	Pvt. Sector
	Total		556,801					

* Hydropower Stations Producung Less than 100KW are excluded.

** Not in normal operation.

Source: NEA

ANNEX II: Small Hydropower Projects (up to 1000 KW)

S. No.	Hydropower Projects	Capacity (KW)	Type	Commissioned Year	Located District	Grid Status	Ownership
1	Dhading	32	RoR	1978	Dhading	Isolated	NEA
2	Chame	45	RoR	1987	Manang	Isolated	Leased
3	Helambu	50	RoR	1985	Sindupalchowk	Isolated	NEA
4	Gorkhe	64	RoR	1982	Ilam	Isolated	NEA
5	Sangja	80	RoR	1984	Sangja	Isolated	NEA
6	Manang	80	RoR	1988	Manang	Isolated	NEA
7	Tehrathum	100	RoR	1988	Tehrathum	Isolated	Leased
8	Rupalgad	100	RoR	1991	Dadeldhura	Isolated	NEA
9	Taplejung	125	RoR	1988	Taplejung	Isolated	Leased
10	Okhaldhunga	125	RoR	1990	Okhaldhunga	Isolated	NEA
11	Chaurjhari	150	RoR	1989	Rukum	Isolated	Leased
12	Ramechhap	150	RoR	1989	Ramachhap	Isolated	NEA
13	Arughat	150	RoR	1991	Gorkha	Isolated	NEA
14	Sange Khola	183	RoR	2001	Lamjung	Grid Connected	Private Sector
15	Baglung	200	RoR	1981	Baglung	Grid Connected	NEA
16	Doti	200	RoR	1981	Doti	Isolated	NEA
17	Jumla	200	RoR	1982	Jumla	Isolated	Leased
18	Serpodaha	200	RoR	1989	Rukum	Isolated	Leased
19	Bajhang	200	RoR	1989	Bajhang	Isolated	Leased
20	Dolpa	200	RoR	1989	Dolpa	Isolated	NEA
21	Bajura	200	RoR	1990	Bajura	Isolated	NEA
22	Surnaiyagad	200	RoR	1991	Baitadi	Isolated	NEA
23	Dhankuta	240	RoR	1971	Dhankuta	Isolated	NEA
24	Phidim SHP	240	RoR	1981	Panchthar	Isolated	Leased

S. No.	Hydropower Projects	Capacity (KW)	Type	Commissioned Year	Located District	Grid Status	Ownership
25	Jomsom	240	RoR	1982	Mustang	Grid Connected	Leased
26	Khandbari	250	RoR	1989	Sankhuwasabha	Isolated	Leased
27	Bhojpur	250	RoR	1989	Bhojpur	Isolated	Leased
28	Darchula	300	RoR	1992	Darchula	Isolated	NEA
29	Jhupra	345	RoR	1977	Surkhet	Isolated	NEA
30	Salleri	400	RoR	1986	Solukhumbu	Isolated	NEA
31	Achham	400	RoR	1995	Achham	Isolated	NEA
32	Pharping **	500	RoR	1911	Kathmandu	Grid Connected	NEA
33	Kalikot**	500	RoR	1999	Kalikot	Isolated	NEA
34	Rairang	500	RoR	2004	Dhading	Grid Connected	Private Sector
35	Namche	600	RoR	1993	Solukhumbu	Isolated	NEA
36	Sundarijal	640	RoR	1936	Kathamndu	Grid Connected	NEA
	TOTAL	8,439					

Source: NEA.

ANNEX III: Medium-Sized Hydropower Projects (more than 1000 KW)

S. No.	Hydropower Projects	Capaciy (KW)	Type	Commissioned Year	Located District	Grid Status	Ownership
1	Tinau	1,024	RoR	1978	Rupendehi	Grid Connected	NEA
2	Phewa	1,088	RoR	1967	Kaski	Grid Connected	NEA
3	Seti (Pokhara)	1,500	RoR	1985	Kaski	Grid Connected	NEA
4	Chaku Khola (APCO)	1,500	RoR	2002	Sindhupalchowk	Grid Connected	Private Sector
5	Tatopani 1 and 2	2,000	RoR	1991	Myagdi	Grid Connected	NEA
6	Panauti	2,400	RoR	1965	Kavre	Grid Connected	NEA
7	Sunkosi- Small (SHP)	2,600	RoR	2005	Sindhupalchowk	Grid Connected	Private Sector
8	Piluwa Khola (AVHP)	3,000	RoR	2003	Sankhuwasabha	Grid Connected	Private Sector
9	Chatara	3,200	RoR	1996	Sindupalchowk	Grid Connected	NEA
10	Andhi Khola (BPC)	5,100	RoR	1991	Sangja	Grid Connected	Private Sector
11	Puwa Khola	6,200	RoR	1999	Ilam	Grid Connected	NEA
12	Indrawati (NHPC)	7,500	RoR	2002	Sindhupalchowk	Grid Connected	Private Sector
13	Sunkosi	10,050	RoR	1972	Sindupalchowk	Grid Connected	NEA
14	Jhimruk (BPC)	12,300	RoR	1994	Pyuthan	Grid Connected	Private Sector
15	Devighat	14,100	RoR	1983	Nuwakot	Grid Connected	NEA
16	Modi Khola	14,800	RoR	2000	Parbat	Grid Connected	NEA
17	Gandak	15,000	RoR	1979	Nawalparasi	Grid Connected	NEA
18	Chilime (CPC)	20,000	RoR	2000	Rasuwa	Grid Connected	NEA & Private Sector
19	Trisuli	24,000	RoR	1967	Nuwakot	Grid Connected	NEA
20	Kulekhani 2	32,000	Storage	1986	Makwanpur	Grid Connected	NEA
21	Bhotekosi (BKPC)	36,000	RoR	2001	Sindhupalchowk	Grid Connected	Private Sector
22	Kulekhani 1	60,000	Storage	1982	Makwanpur	Grid Connected	NEA
23	Khimti Khola (HPL)	60,000	RoR	2000	Dolakha	Grid Connected	Private Sector
24	Marsyangdi	69,000	RoR	1989	Lamjung	Grid Connected	NEA
25	Kali Gandaki A	144,000	RoR	2002	Sangja	Grid Connected	NEA
	Total	548,362					

Source: Compilation of different publications of NEA.

ANNEX IV: Up-coming Hydropower Projects (Under-Construction)

S. No.	Hydropower Company	Name of River	Capacity (KW)	Located District
1	Gautam Buddha Hydro Power Company	Sisne Khola	750	Palpa
2	Unique Hydro Power Company	Baramchi Khola	999	Sindhupalchowk
3	Khudi Hydro Power	Khudi Khola	3,450	Lamjung
4	Lower Nyadi Hydroelectric Project	Lower Nyadi	4,500	Lamjung
5	Molnia Power Pvt. Ltd.	Mailung Khola	5,000	Rasuwa
6	Gitec. Nepal Pvt. Ltd.	Upper Modi Khola	14,000	Kaski
7	Kathmandu Small Hydro Power System	Sali Nadi	232	Kathmandu
8	NEA	Middle Marsyangdi	70,000	Lamjung
9	NEA	Chamelia	30,000	Darchula
10	NEA and Private Sector	Chilime	11,000	Rasuwa
11	NEA	Kulekhani III	14,000	Makawanpur
12	NEA	Gomgad	400	Mugu
13	NEA	Heldung	500	Humla
	Total		154,831	

ACRONYMS USED

AC	Alternating Current
CBIP	Central Board of Irrigation and Power, India
CBS	Central Bureau of Statistics
CRs.	Company Rupees.
DC	Direct Current
dia	Diameter
ft.	Feet
GW	Giga Watts
HMG	His Majesty's Government, Nepal
IPPs	Independent Power Producers
KW	Kilo Watts
lb.	Pounds
MW	Mega Watts
NEA	Nepal Electricity Authority
NEC	Nepal Electricity Corporation
PDF	Power Development Fund
PPA	Power Purchase Agreement
R&D	Research and Development
RoR	Run-of-River
sq.	Square
US$	United States Dollar
V	Volts

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