

# Hydropower - Key to sustainable, socio-economic development of Bhutan

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**Abstract:** Hydro Power is the backbone of the Bhutanese economy. The rugged terrain, compounded by the fact that the Country is land locked does not provide much economic advantage to Bhutan. Transportation costs are high and unless Bhutan can think of certain niche products, her exports are not going to be competitive. The decision by the Royal Government to exploit its water resources for production of electricity has changed the economic scenario for Bhutan. The rapid altitudinal variations with swift flowing rivers has made Bhutan a natural haven for hydro power production. The close and friendly ties between Bhutan and India has provided the necessary political will and the market for Bhutan's power, as India has a huge power deficit.

While electricity has provided the much needed revenue, the Royal Government has also prioritized network expansion in the Country. It is expected that by 2020, the entire Country will have access to electricity. Industrial activities are expected to increase with the commissioning of Tala Hydroelectric Project. There is however, a need to ensure that internal electricity tariff is kept affordable so that it becomes the main source of energy in the Country and also to stimulate industrial activities.

This paper highlights the role and importance of hydropower for social and economic development of Bhutan and covers aspects related to planning and policy initiatives being pursued by the Hydropower sector to fulfill the national objectives. The introductory sections provide the baseline information on hydropower resources of Bhutan, development potential and existing situation in the supply and demand of hydroelectricity. Subsequent sections cover the planning and policy interventions that the Royal Government of Bhutan is undertaking in order to maximize on the benefits from hydropower development.

## 1 Introduction

The Kingdom of Bhutan, by virtue of its geographical location on the Southern slope of the Eastern Himalayas, is blessed by nature with altitudinal varying land mass with good vegetation cover, perennial flow of water in the swift flowing rivers and fair climatic conditions. Bhutan is a land-locked country bordering China in the North and India in the West, South and East. It covers an area of 38,394 square kilometers roughly measuring 140 km North to the South and 275 km East to West. It is estimated that over 72% of the land is under the vegetative cover with altitudes varying from 100 metres above sea level (masl) in the southern sub-tropical region to 7550 masl in the Northern alpine region. Bhutan receives fair amount of annual rainfall varying from 500 mm in the North to 5000 mm in the South. Thus, Bhutan is endowed with rich development potential for harnessing hydropower. Most of the schemes identified are run-of-the river types and they are found to be techno-economically least-cost and environment-friendly. Few reservoir schemes are also identified with limited and/or no environment impact in the Southern belt before the Bhutanese rivers fan-out and enter the Indian plains. Bhutan has an estimated hydropower potential of 30,000 MW and 120 TWh mean annual energy generation indicating an average development potential of 781 kW in a square kilometer of area of land (catchment). So far 23,760 MW has been identified and assessed to be technically feasible. Only 1.6% of the potential is harnessed so far.

Bhutan's ability to harness the hydropower resources has been made possible because of the close and friendly ties with its neighbour India. India has been the lead donor in providing both technical and financial assistance to develop the numerous hydro power projects in Bhutan. The relationship

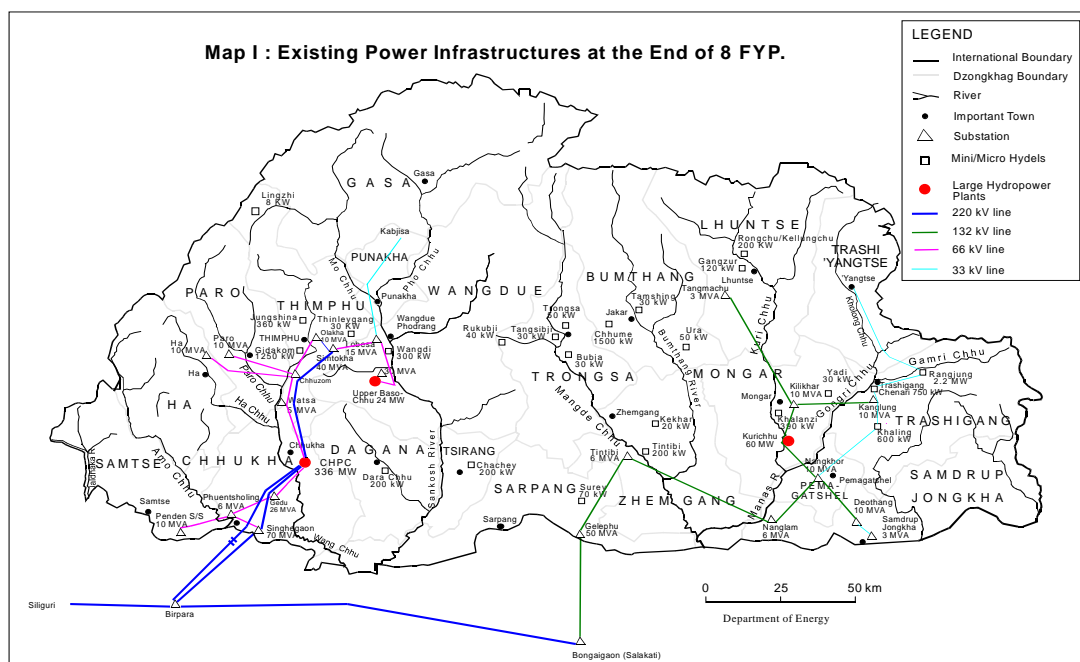
developed in the hydro power sector has been a win win situation for both the countries. India has a huge power shortage while Bhutan a large hydro power potential.

## 2 Situation of hydropower development

Electricity was introduced sometimes in the year 1966 when the first 256 kW diesel generating plant was installed to supply power to Phuentsholing, a border town in the Southwest and gateway to Bhutan. Bhutan's first hydroelectric plant of 360 kW installed capacity was commissioned in 1967 to supply power to the capital, Thimphu. Thereafter mini hydropower plants of sizes 300 kW to 1250 kW capacity were built in 5 districts' headquarters to supply electricity primarily for the lighting energy need by 1974. The development of first major hydroelectric project started in 1974 when a bilateral agreement was signed between India and Bhutan for the construction of 336 (4x84) MW Chukha hydel project (468 metres, Pelton turbine) across river Wangchu in Western Bhutan for meeting the internal power demand and export of the surplus electricity to India. The Project was commissioned in 1986-88.

During the period 1975-1990, twelve other off-grid micro/mini hydropower plants were constructed in potential sites with capacity varying from 20 kW to 1500kW to supply power to remote villages/hamlets situated nearby the National Highways. Two more off-grid plants were commissioned in 1996 and 2001. Some of the older plants were also rehabilitated during the period 1997-2002. During the 8<sup>th</sup> Plan (1997-2002), two medium sized hydropower projects namely the Kurichu project of 60 MW installed capacity (35 metres, Kaplan) and Basochu hydropower project of 24 MW capacity (336 metres, Pelton) were commissioned. During the month of September 2004, Basochu lower stage hydropower of 40 MW capacity (359 metres, Pelton) was commissioned. Today Bhutan has thus developed total hydropower potential of 468 MW. The existing power infrastructures is depicted in the map I. Tala hydroelectric project of 1020 MW installed capacity and 860 metres gross head is been under construction since 1997 and is scheduled for commissioning in the year 2005-06. Once this mega project is completed, Bhutan shall have developed 1488.68 MW, about 5% of its total hydropower potential.

Bhutan's electricity demand in the year 2003 was 105 MW, 664 GWh and 99.5% of the electricity was supplied from hydropower resources. About 40% of the Bhutanese population (in 40 towns and 822 villages) has electricity access. There are 45,743 electricity consumers. The surplus generation from hydropower plants is exported to India and fetches a substantial amount of revenue that helps to meet the budget deficit. About 300 MW power and 70% of the total hydroelectric energy generation was exported to India in 2003.



### **3 Role of Hydropower in the socio-economic development of Bhutan.**

While the micro/mini hydels contributed to the meet the primary electricity needs, the commissioning of the 336 MW Chukha hydropower in 1986-88 brought about the much needed revenue to support socio-economic development in the Country by exporting over 75% of the generation to India. Bhutan thus realized the potential of its hydropower resources as a key to achieving economic self reliance and for poverty alleviation.

From the time when the countries development activities were totally donor funded, Bhutan has since the 8<sup>th</sup> Plan (1997-2002) not only been able to finance its current expenditures but also part of the capital expenditure. This has been possible mainly because of the dominant role played by the hydropower sector from export of electricity to India. Direct sale of electricity contributed as high as about 45% of the gross national revenue during the 8<sup>th</sup> Plan, mainly from its export to India. Hydropower is hence recognized as the backbone of the Bhutanese economy.

Hydropower, as a clean renewable resource, has two important roles to play in the socio-economic development of Bhutan:

- 1) To provide safe, reliable, sufficient and affordable electricity for domestic consumption and industrial use.
- 2) As an industry for earning revenue from export of hydroelectricity thereby providing the much needed capital to finance social projects and achieve economic self reliance.

While in the past, primary focus had been to address the most urgent need of electricity services in schools, hospitals, district administration establishments and urban areas, development thrust is now being given to rural electrification. Bhutan's current target is to achieve "electricity for all" by 2020. To achieve this target, the Department of Energy is currently working on a Rural Electrification Master Plan – a road map of how to achieve the same. Rural Electrification (RE) is a challenging task as it is capital intensive in the first place, difficult especially in a land-locked mountainous country where transport is laborious and the population density is sparse and remote.

Today, about of 40% of the total Bhutanese population and about 30% of the rural people have access to electricity. The per capita consumption of electricity is 949 kWh per annum (2003 data). The rural electrification process has many positive impacts. Socio-economic impact study of RE project has shown that the electricity lighting has particularly improved the quality of lives of students, housewives (women) and the rural households and improved conditions in the quality of services of basic health units as well as other services like telephones. Once electricity service is made available to a rural home, it enhances their rural income activities. They find more productive time under better light. Rice cookers and water boilers have become very handy for mothers in the kitchen and overall exposure to health hazards from smoke created by fuel wood has been reduced. The quality of social life has also greatly improved once electricity is made available.

### **4. Planning and Policy Interventions in sustainable development of hydropower**

As per the 2020 Vision Document of the Royal Government of Bhutan, it is envisaged to add 1,000 MW of hydropower generation capacity by the year 2012 and another 2000 MW by the year 2017. Bhutan has therefore embarked upon the following approaches, methodologies, strategies and initiatives to achieve the national goals:

- a) Preparation of 20 Years' Power System Master Plan (PSMP) for sustainable hydropower development and Water Resources Management Plan on the basis of technical, economic, social and the environmental considerations.
- b) Preparation of Rural Electrification Master Plan for achieving 100% electricity access by 2020 and to fulfill the Millennium development goals of the Energy sector.

- c) Preparation of the Integrated Energy Management Plan for sustainable supply and demand management of energy resources for the economic development.
- d) Development of Legal and Policy frameworks for re-structuring and reforming the power sector.

#### **4.1 Water Resources Management Plan**

In the draft water policy, Bhutan has considered situations which may arise when water resources is not sufficient both in quantity and quality to meet every legitimate demand and especially the biological demand for survival of the living beings. In such situations, as per the draft policy, water for drinking and sanitation shall be the primary consideration. Water for irrigation, hydropower generation, industrial use and recreation is proposed to be considered based on national and local priorities. It is also recommended that water legislation and management practices allow flexibility for adopting practical local solutions. While hydropower development involves non-consumptive use of water, its diversion and damming can cause undesirable environmental and social impacts that shall be duly considered in the initial planning stage of development to avoid future conflicts and delays in implementation.

The Water Resources Management Plan formulated in 2003 provides the general assessment of water resources in the country and addresses its present and future supply and demand scenarios. Water related issues including conflicts of water use are highlighted and made aware in the Plan. Integrated water projects are also identified for possible sustainable development and demonstration.

#### **4.2 Power System Master Plan**

UNDP and NORAD/Norway had provided technical assistance for the preparation of Bhutan's first report on 20 Years Power System Master Plan study in the 1990s. This report was revised during 2001-2003 under NORAD's technical assistance to reflect more and detailed information and management issues on hydrology, environment and social aspects and to be more realistic, and synchronised with the requirements of the present and the future needs. The present report details the revised hydropower potential and availability of 23,760 MW from 76 sites of 10 MW and above capacity, in three regional river basins. The Report provides the ranking list of 6 major hydropower projects for possible development in the next 20 years including the national transmission grid development plan for supply of electricity in the Kingdom and export of surplus electricity to possible inter-connecting delivery points in India. The selection of projects for inclusion in the 20 Years' (2003-2022) Master Plan was done using Multi Criteria Analysis (MCA) on 11 top ranking projects with weightage/score points on the four thematic areas of consideration in hydropower development and based on the local Bhutanese perceived values and interests on various parameters as shown in Table 1.

It may be seen from Table 1 that most of the relevant issues were taken into account in the Master Plan and Preliminary design stage of the project while ranking and selecting the project for inclusion in the development list for the next 20 years. This was to ensure the sustainable development of the identified projects without any social & environment hindrance and hurdles, and to avoid delays in their implementation. As can be seen, the negative impact on socio-economic aspect including that on population displacement by the project and the environment impacts are assessed and the merits and demerits are considered in the ranking process. Table 2 shows the MCA % scores of the projects during the ranking and selection process.

**Table 1: Multi Analysis Criteria and Sub-criteria for ranking of the Hydropower Projects of development planning.**

Main Criteria	Technical –28%	Economic–42%	Social –15%	Environmental – 15%
Sub-criteria	Hydrological risk	Economic merit	Improved access	Intrusion into protected areas
	Geological risk	Finance-ability	Rural electrification	Loss of primary forest
	Dam cost risk		Employment benefits	Dewatering impacts (downstream)
	GLOF risk		Fishery potential	Access road erosion
	Site accessibility		Tourism	Fish migration
	Transmission line length		Balanced regional development	
	Reservoir sedimentation		Population displacement risk	

**Table 2: Final scores and ranking of 11 projects for inclusion in 20 years’ Power Master Plan**

Name of Scheme/ Project	Project Power & Energy capacity	Techno-economic	Socio-Environment	Overall score
		<b>70%</b>	<b>30%</b>	<b>100%</b>
Punatsangchhu-1	1000 MW, 4770 GWh	52%	15%	67%
Amochhu-2 *	500 MW, 2210 GWh	40%	25%	65%
Zhemgang (Digala) Project	670 MW, 3207 GWh	44%	18%	62%
Punatsangchhu-2	990 MW, 4667 GWh	40%	15%	55%
Kholongchhu (Gomkora)	485 MW, 2209 GWh	36%	18%	54%
Kheng (Shingkhar) project	570 MW, 2713 GWh	35%	18%	53%
Mangdechhu	670 MW, 2909 GWh	38%	14%	52%
Khomachhu	326 MW, 1507 GWh	29%	19%	48%
Nikachhu/Tangsebji	210 MW, 1042 GWh	34%	12%	46%
Kurichhu (Rothpashong)	401 MW, 1883 GWh	25%	14%	40%
Bunakha Reservoir scheme	180 MW, 893 GWh	27%	10%	38%

\* Based on desktop study

Table 3 below shows the list of 6 Hydropower projects listed in the 2003-2022 Power System Master Plan.

**Table 3: List of Projects scheduled for development in next 20 years.**

River Basin	Name of Project	Gross Head-metres	Installed capacity-MW	Mean annual energy – GWh	Plant capacity factor	Remarks Proposed for construction in:
Punatsangchhu	Punatsangchhu-I	286	1000	4770	0.54	2007-2012
Mangdechhu	Mangdechhu Hydel Project	719	670	2909	0.50	2009-14
Punatsangchhu	Punatsangchhu-II	267	990	4667	0.54	2012-2017
Bumthangchhu	Zhemgang/Digala	527	670	3207	0.55	2015-2020
Bumthangchhu	Kheng/Shingkhar	487	570	2713	0.54	2017-2022
Drangmechhu	Kholongchhu(Gomkora)	378	485	2209	0.52	2020-2025
<b>TOTAL</b>	<b>6 Projects</b>		<b>4385</b>	<b>20475</b>		

The average investment cost of these 6 projects is US\$ 0.835 million per MW and 17.88 US\$cents per Unit mean annual generation. The economic unit cost of Energy generation works out to 2.87 US\$Cents per Unit generation at 12% discount rate and 25 years of economic life at 2002 international price levels.

According to this 20 year Master Plan, Bhutan is proposing to develop on an average 220 MW incremental generation capacity per annum over the next twenty years which may appear to be ambitious for the size of the Bhutanese economy. However, given the pro-active development policy and sustained efforts of the Royal Government of Bhutan, this does not appear to be unrealistic given the huge power deficit in India and the excellent relationship that exist between Bhutan and India.

#### **4.3 Rural Electrification Master Plan to achieve 100% electrification by 2020.**

Study is being conducted for the preparation of the Rural Electrification(RE) Master Plan under JICA technical assistance. This RE plan will serve as the road map to not only meet the Millennium Development Goal of providing access to clean energy services to atleast 50% of the population by the year 2015 as part of the global poverty alleviation efforts but also to prepare action plans for a achieving the national target of 100% electrification by 2020. This dynamic master plan shall be updated every 5 years to account for effects of the population growth rate, the economic growth and the advancement in cost-effective technologies. Today only about 30% of the rural Bhutanese populations have access to electricity and the plan is to cross the 50% target of providing RE access to the Bhutanese households before the year 2012.

Rural electrification services will greatly enhance the quality of Bhutanese people to improve upon their socio-economic living conditions. It is an established fact that after provision of electricity supply, the quality and standard of education of rural students improve due to electric lighting and increased working hours. Similarly the health and hygiene of women and children improve due to improved electric lighting conditions and ready availability of energy for cooking, whereby their efforts to fetch firewood and dependency on kerosene lighting would decrease. More time is thus available to concentrate on income generating activities thereby enhancing the family income and contribution to the socio-economic growth of the society.

#### **4.4 Integrated Energy Management Master Plan**

This study is being conducted to prepare the baseline country status report on various forms of energy supply and demand situation including the energy balance table for the country. The study is expected to further make an assessment of various energy supply options based on sectoral needs (transport, electricity, industry etc) and prepare a energy demand forecast for the future. The study is expected to come out with a management strategy for sustainable development of indigenous resources (including hydropower) and import of other forms of energy (such as the fossil fuels) for sustainable supply of energy to the economy based on various demand forecasts and scenarios in the future.

#### **4.5 Sustainable tariff principles for socio-economic development**

In a developing country like Bhutan, the affordability of the consumers (citizens) to pay for the electricity charges has to be cautiously considered while deciding the power tariff. It is not an easy exercise where one can apply directly the principles of tariff setting. The concept of social justice and fair pricing is to be considered. If the energy price is kept high, there will be less incentive (motivation) for use of electricity, which has the potential to encourage income generating activities to contribute towards economic growth and reduction in poverty. In most least developed countries, less than 50% of the people have access to clean form of energy. Bhutan is no exception. Affordability is a major issue and therefore, while developing hydropower, the least cost projects with lowest economic unit cost of generation are chosen and their development phased. Bhutan is in a unique situation where major export is electricity and the export far outweighs domestic consumption and hence tariff for domestic supply is really not an issue. The hydropower planning

process has to always create “surplus” energy situation to ensure that the earnings from export of power continues to increase.

#### **4.6 Electricity Act 2001**

This act enacted in 2001 provides the legal framework for restructuring the power supply industry and provides mechanisms for licensing and regulating the operations of power companies and possible participation of the private sector. The Act enables the establishment of Bhutan Electricity Authority as an autonomous body mainly responsible for licensing and tariff regulation. At present, institutional capacity building of the BEA is taking place. Till June 2002, the hydropower planning, policy, regulatory and power utility function of transmission, distribution, supply and sale, had been looked after by the Department of Power under the Ministry of Trade and Industry. As part of the Reform process in July 2002, this Department had been broken up into three legal entities namely i) the Department of Energy as Planning and Policy arm of the Royal Government of Bhutan under the Ministry of Trade and Industry ii) the Bhutan Electricity Authority for regulating the electricity industry and iii) the Bhutan Power Corporation as a transmission, distribution and supply company. There are three large Govt owned generating companies namely the Chukha, Kurichu and Basochu Hydropower Corporations.

#### **5.0 Conclusions**

All these plans and policies in the hydropower sector are geared towards contributing to achieving economic self-reliance and overall socio-economic development of the country. The sustainable development strategies incorporating the social and environment concerns of hydropower development will lead to successful implementation of hydropower projects. Most of Bhutan’s hydropower plants (both already built and proposed to be built in future) are mainly run-of-the river schemes with no impact or minimal impact to the environment. Socially, these planned projects will have no negative impacts. The people will benefit from the project’s spin-off effects like the project road access, grid electricity, schools & hospitals built during project construction period and other income generating activities including some employment opportunities with the project. This is over and above the benefit to the national economy.

The sustained techno-economic cooperation with India where Bhutan’s export market lies is the key success factor for development of hydropower. India will benefit from Bhutan’s renewable hydroelectric energy resource to meet a part of its huge power demand while Bhutan will benefit from the revenues earned from the export of power.

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