

The Hydro-Electrical Power Sector in Bhutan: An Economic Assessment

by

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1986 – Chukha Hydropower Project, Bhutan

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Abstract

For the Kingdom of Bhutan energy has become the most favorable element in the nation's economic growth; for example, hydropower contributes about 45% of the national revenue and constitutes about 19% of the country's GDP (Ministry of Economic Affairs of Bhutan (MoEA), 2013). However, given the rising energy demand in high and medium voltage industry sectors, and the risk of reliance on a single electricity source, the Royal Government of Bhutan recognizes the need for energy efficiency through demand side management, and development of alternative energy sources. In addition, concern exists that the potential for hydro-generation might be impaired by the adverse effects of climate change.

The Druk Green Power Corporation (DGPC) has reported that water levels in rivers have been declining in recent years due to changes in monsoon patterns, thus leading to less hydropower production (MERCADOS Energy Markets International (EMI), 2013). A significant impact of climate change in Bhutan is the formation of supra-glacial lakes due to the accelerated retreat of glaciers with increasing temperatures. The risk of potential disasters inflicted by Glacial Lakes Outburst Floods (GLOFs), which pose new threats to lives, livelihoods and development, is mounting as the water levels in several glacier lakes approach critical geostatic thresholds (Yee, 2011). The Kingdom has experienced low river flows, thus constraining hydropower generation. Smart Grid and Smart Metering reduces the need for wasteful capacity, while enhancing the integration of renewable energy sources such as wind and solar that are prone to erratic spikes and dips in generation (Solanki et al., 2011). Load control or demand side management within the smart grid could potentially solve the problem of supply-demand of electricity in winter when the demand is at its maximum and the supply is limited.

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Introduction

The Kingdom of Bhutan – a small landlocked country with the population of 716, 896 people¹ is located to the eastern side of the Himalayas at 27°28.0'N and 89°38.5'E in South Asia. It borders China (to the north) and India (to the east, west and south).

Among the primary exports are electricity (to India), cardamom, gypsum, timber, handicrafts, cement, fruit, precious stones, and spices.

Bhutan began modernizing in the 1950s and has developed ten consecutive five- year plans starting in 1961 to coordinate development efforts.

Previously, there were no paved roads, most homes were built from mud and grass, literacy was low, and the death rates were high (Herrera, 2005). The country has made significant progress in extending access to safe drinking water and sanitation, protecting and managing the country's natural resources, providing basic health care and increasing access to primary education. This has been reflected in a steady increase of the Human Development Index (HDI) from 0.325 in 1984 to 0.583 in 2003 (Santos, 2013). By 2005 the literacy rate was almost 50 percent, whereas in the early 1990s it ranked the lowest among the least-developed countries. The country's first university opened its doors in 2003. Technology use has increased; according to World Bank figures (Herrera, 2005), over the period from 1999 to 2003 the number of fixed-line and mobile-phone subscribers jumped from 18 to 45 per 1,000 people and personal-computer ownership nearly tripled from 5 to 14 per 1,000 people. The progress Bhutan has made so far is remarkable. The previous king, who came to the throne in 1974, invested the country's meager finances in an airport, an east-



¹ http://www.indexmundi.com/bhutan/demographics_profile.html

west road, bridges, national education, health care, and select energy-producing technologies like hydropower, which provides almost all the country's electricity (Herrera, 2005).

Bhutan's economy is one of the world's smallest and least developed and is based on agriculture, forestry, and hydroelectricity. Rugged terrain makes it difficult to develop roads and other infrastructure. Despite this constraint, hydroelectricity and construction continue to be the two major industries of growth for the country. Being committed to a strategy of "Gross National Happiness," – pursuit of *sustainable development, preservation of cultural values, conservation of the environment* and good *governance* (Commission for Gross National Happiness (CGNH), 2010) – the government of Bhutan has undertaken a number of measures to ensure a diverse economy and prosperity for the rural dwellers in remote areas. One such measure is the Rural Electrification (RE) program which aims at achieving 100% rural electrification by end of 2013.

In 2010 Bhutan was ranked by the Transparency International Corruption Perception as the least corrupt country in South Asia (The World Bank Group (WBG), 2010). The country has low levels of corruption, robust institutions, a well-educated and dedicated civil service, and visionary leadership.

With its abundant hydro resources Bhutan has a total techno-economically exploitable capacity of 23,760 MW (Energy Sector Management Assistance Program (ESMAP), 2007). However, the currently installed capacity is 1,490 MW, approximately 6% of the potential total.



There are four major rivers in Bhutan: the Torsa which is the shortest, Sunkosh – the longest, Wangchu, and the Manas. In addition there are other smaller rivers which originate in the Middle Hills. The Middle Hills have no permanent snow or ice but receive heavy rainfalls

during the monsoon season. During the winter these rivers run almost dry but attain very high flow rates in monsoons (Dhakal, 1990).

The economic growth is largely driven by the export of surplus electricity to India. In the last few years the country's hydropower export levels decreased due to increasing domestic demand and seasonal declines in generation. This caused Bhutan to import energy from India to cover the gap.

In view of the growing domestic demand, seasonality in generation and the adverse effects of Climate Change, there is need for the Royal Government of Bhutan to focus on optimized utilization of energy resources.

Objective and Scope of Study

The objective of this study is to examine the electricity sector in the Kingdom of Bhutan, and analyze the historical evolution of electricity demand and supply, export and import, as well as the energy load profiles of high-voltage and medium-voltage industries. The goal of the research is to identify opportunities for energy efficiency and use of smart grids on Demand Side Management (DSM) and peak load management for industrial customers in order to sustain adequate internal supply and sufficient export even in winter.

The scope of this study is to: (i) review previous energy studies in Bhutan and understand the current developments in the energy sector and hydropower; (ii) analyze the annual and quarterly reports of the National Load Dispatch Center of the Bhutan Power Corporation, as well as the industry load profiles for the period 2010-2012; (iii) determine from the published literature the implications of energy efficiency and demand side management on industrial peak load and consumption; and (iv) provide recommendations on the implementation of renewable energy and/or energy efficiency projects to address the problem of seasonal energy shortages and to sustain energy sales during winter. It is expected that the results of this study which is, at this time a "*Preliminary Report*," will provide a basis for comparison of Bhutan industrial and commercial load profiles, as well as explore the possibility of demand side management for retaining Bhutan's energy sales year-round.

Methodology

The study focused on hydroelectric energy supply, demand, consumption, export and import, and of major hydropower generation plants in Bhutan.

A literature review of previous studies of the regulatory and institutional papers of the energy sector in Bhutan was done in order to become familiar with the baseline situation on macro- and micro- level electricity demand and supply. A thorough review of scientific journal articles and periodicals as well as case studies was accomplished in order to familiarize with the concepts, history and future perspectives of the issue.

In cooperation with the Bhutan Power Corporation Limited the data on electricity generation, demand, sales, export and import was collected and organized. I developed a questionnaire to collect and compile energy data for the period 2007-2012. Apart from primary data, secondary data (relevant existing studies, survey reports) were also collected for the purpose of the study. Data on demographics and socio-economic indicators of the Kingdom of Bhutan were extracted from the World Economic Outlook and International Monetary Fund (IMF) public databases (International Monetary Fund (IMF), 2004 - 2012). The data were then matched in their measurement units and analyzed in Excel for quantitative analysis of the seasonal variations in peak loads of the 24 hour data on daily load profile. The average annual growth rates (AAGR) were identified using the following formulae:

$$PR = \frac{\left(\frac{(V_{present} - V_{past})}{V_{past}} * 100 \right)}{N}$$

Where PR is the percent rate of annual average growth, $V_{present}$ is the Present Value, and V_{past} is the Past Value. Data are often collected on an hourly basis, but can also be collected at 15- or 30-minute intervals. For most facilities, energy use varies by the hour and by the day of the week, as well as by season. To understand seasonal load variations, a typical summer and winter day of electricity use for a facility in Thimphu, Bhutan, was plotted in Excel and analyzed.

Hydropower and Economic Growth

There are five major hydroelectric facilities in Bhutan, and several small and mini hydroelectric generators that serve remotely located households and communities, both off- and on-grid. In addition, a number of construction projects are underway that are expected to increase Bhutan's hydropower generation capacity to 10,000 MW by 2020.

Since 2003 hydropower development has been contributing to a significant growth of the Kingdom's GDP. According to the data from the World Economic Outlook, International Monetary Fund, over the period from 2003 to 2012 years² the average annual GDP growth rate (AAGR) is approximately 14.5 percent (Figure 1). The red line shows the annual GDP growth rate or the annual percentage change over the period from 2003 to 2012. In 2011, hydropower sales accounted for the largest share of the country's GDP (MoEA, 2013).

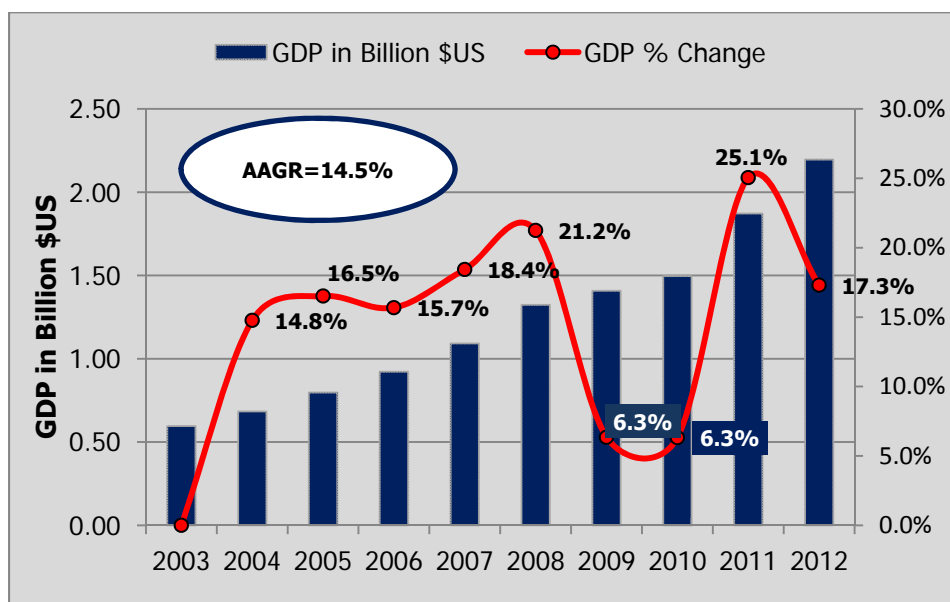


Figure 1: Nominal GDP Growth Rate, Bhutan. Source: World Economic Outlook, IMF

There is an important impact of GDP growth on electricity consumption. A positive relationship was found between the GDP growth and the household energy in developing countries (Wolfram et al., 2012). This is explained by the fact that most energy-using assets are hardly affordable for low-income households and the developing world's markets are usually credit-constrained. Thus,

² For the purpose of consistency all socio-economic data are taken from the same source: <http://www.quandl.com/search/electricity%20consumption%20bhutan>

as the households rise out of poverty they tend to purchase goods that consume a substantial amount of energy. Acquisition of appliances, such as refrigerators, televisions, and air conditioners, typically reflect a change from low-income to middle-income status (Wolfram et al., 2012). The energy needed to manufacture and use these assets for the new consumers is also likely to affect the demand for energy and form a large portion of the energy consumption.

With higher levels of income people are more willing to improve their living conditions, construct new houses, and make refurbishments and upgrades to their homes. This in turn will lead to increased energy demand, particularly of medium and high voltage industries.

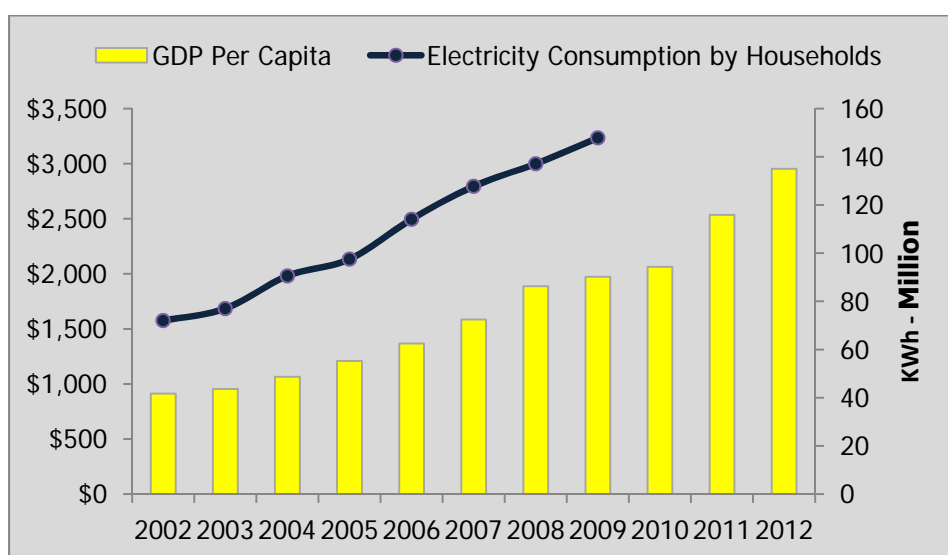


Figure 2: Per Capita GDP and Electricity Consumption. Source: World Economy Outlook, IMF.

Figure 2 shows a steadily upward curve for Bhutanese households' electricity consumption³ alongside the rising rates of per capita GDP over the period from 2002 to 2009. The economic growth of Bhutan is explained by the expanded hydropower industry with the construction of new hydropower plants and the development of closer ties to the Indian market. The country has established new special economic zones for manufacturing and processing industries and completed its rural electrification program embedded in its five-year plans. It is thus assumed that the steady increase in GDP and completion of the rural electrification program will further encourage growth in domestic electricity demand.

³ The data on electricity consumption was available only through 2009.

In 2005, nearly two thirds of the households in Bhutan did not have access to electricity (Herrera, 2005). In 2012 the rural electrical connectivity ratio reached 89% (Bhutan Power Corporation (BPC) Limited, 2012) . The RGoB pursues a goal of “electricity for all” by 2013 and within this agenda there has been a continuous upgrade in transmission system and development of new transmission lines in rural and urban areas of Bhutan. Figures 3 and 4 compare the number of customers and relative sales levels over a time series of 8 years.

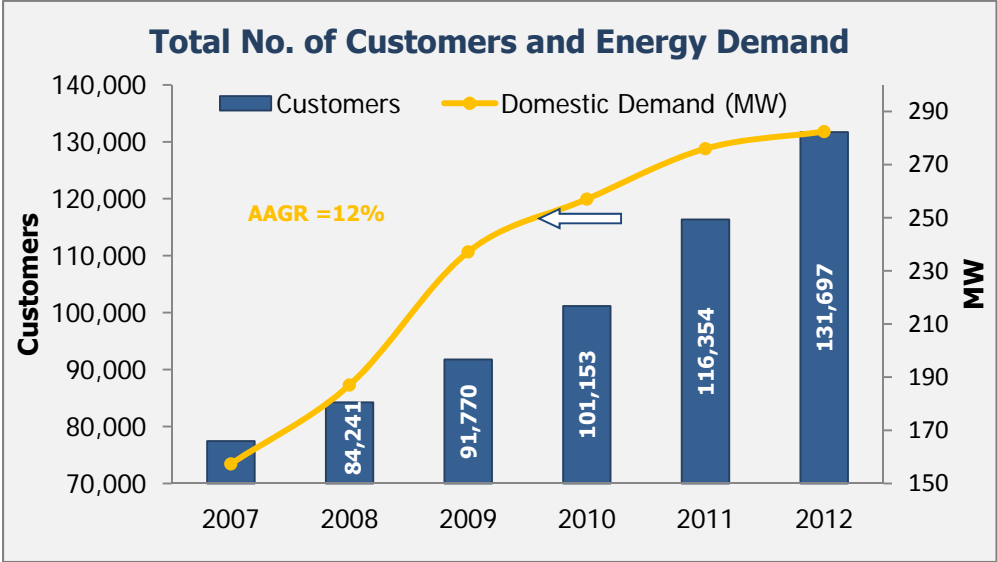


Figure 3: BPC customer base and energy demand. Source: Power Data Book 2009-2012, BPC Limited

With the increasing national income, unchecked rural-to-urban migration, and higher population density in the towns and cities, the energy sales to urban consumers in Bhutan are rising rapidly. There is a positive relation between the growth of nominal GDP and energy sales to urban customers (Figure 5). Both curves have upward trends and a similar AAGR. Thus, over the period of 8 years the Kingdom’s GDP has been growing at 12 percent AAGR, while the level of energy sales to urban customers has been growing at AAGR of 10 per cent over the same period (Figure 4). The trend is also explained by the substantial growth in rural and urban electric connectivity (BPC Limited, 2012).

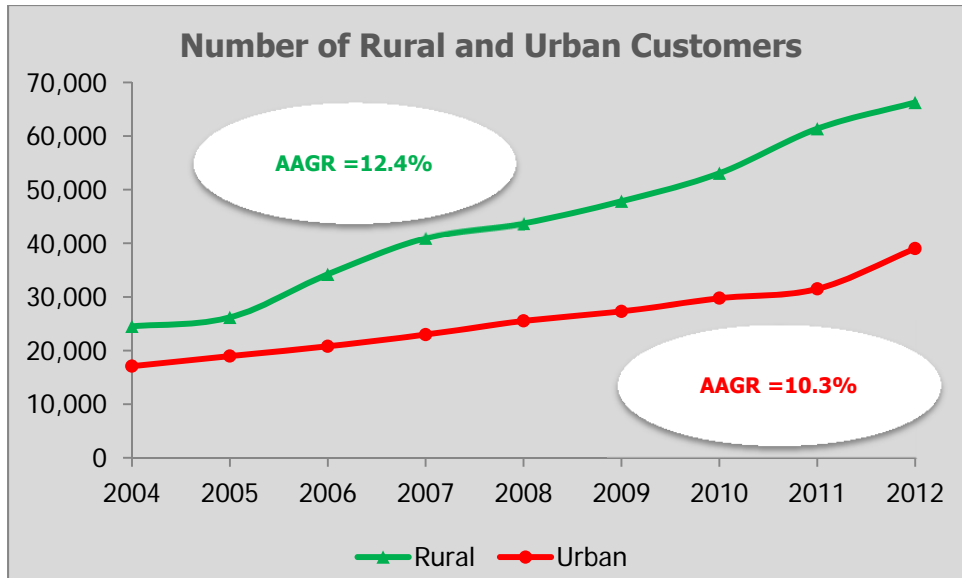


Figure 4: Number of rural and urban customers, BPC Power Data Book 2009-2012

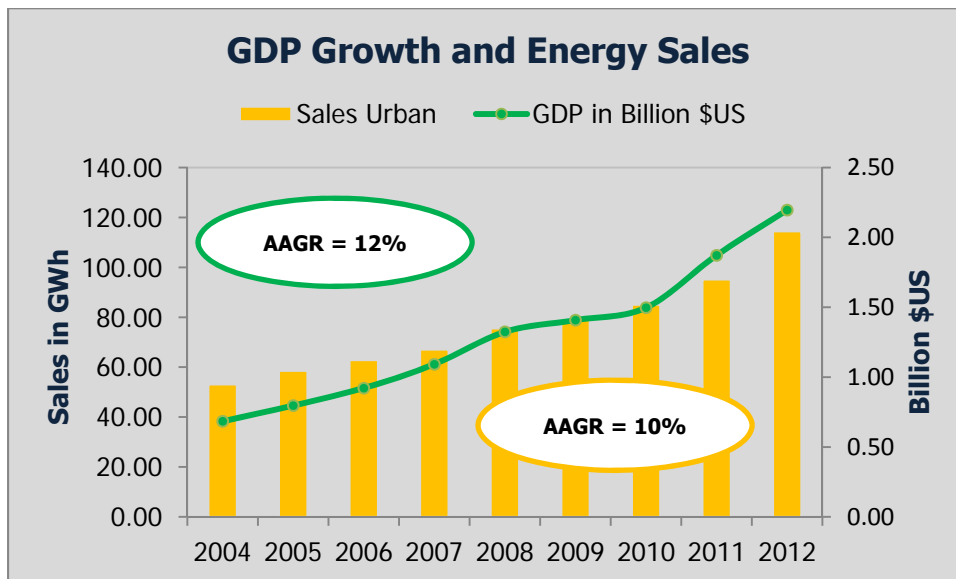


Figure 5: GDP vs. Sales to Urban. Source: Power Data Book 2009-2012, BPC Limited

Despite the fact that the number of rural customers is close to 2 times of that of the urban customers, the urban per capita electricity consumption is almost 3 times that of the rural per capita consumption⁴ (Figure 6).

⁴ The per capita electricity consumption rates are calculated through a ratio of the categorical energy sales (rural/urban) by the number of customers of the relevant category.

With improved access to electricity and affordability of electrical appliances due to increased GDP and per capita income and based on the trends observed, it is expected that the per capital electricity consumption will continue to grow. Such growth in domestic electricity consumption and can affect the country’s ability to collect revenues from the export of hydro-electricity, as has happened in the last years.

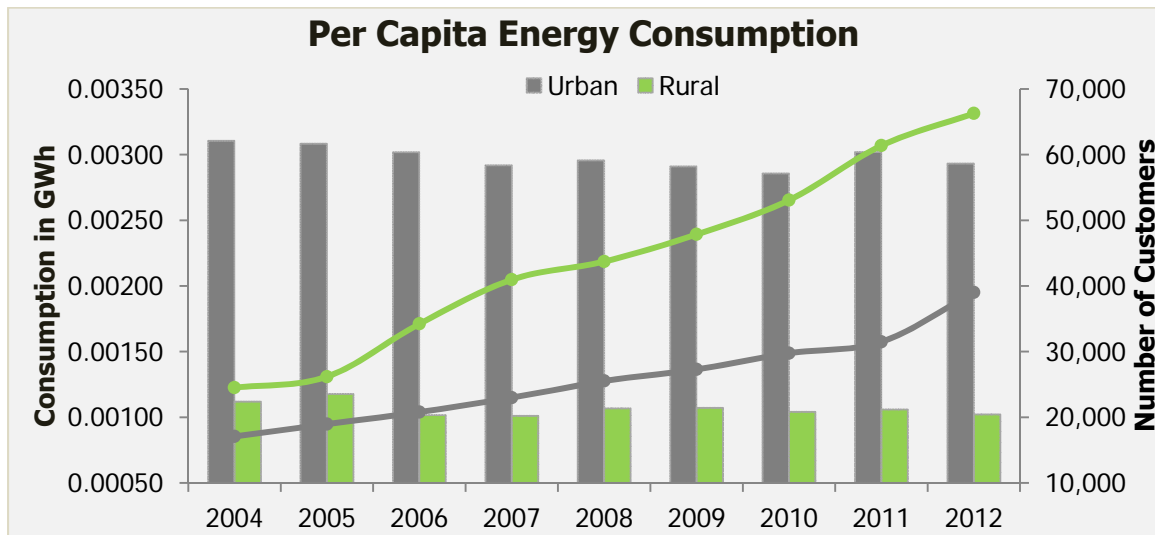


Figure 6: Number of Customers (lines) vs. Consumption (bars). Source: Power Data Book 2009-2012, BPC Limited

Supply and Demand

Bhutan's hydropower industry is relatively young and has recently become one of the priority areas of the RGoB agenda. The Kingdom of Bhutan has become the major electricity exporter to India since the commissioning of the first major hydropower plants under the Chhukha Hydro Projects in 1986 and 1998, and later since the construction of additional hydropower facilities.

Currently there are five major hydropower plants that supply hydropower for export after meeting the domestic electricity demand. The total generation capacity as of the year 2012 is 1,480 MW⁵ (Table 1).

No.	Hydropower Plant (HPP) Name	Year of Committed	Installed Capacity MW
1	Basochhu I (BHP)	1999	2 * 12 = 24
2	Basochhu II (BHP)	2004	2 * 20 = 40
3	Chhukha (CHP)	1986 – 1988	4 * 84 = 336
4	Kurichu (KHP)	2000 – 2001	4 * 15 = 60
5	Tala (THP)	2006 – 2007	6 * 170 = 1,020

Table 1: Currently Operating HPPs in Bhutan

Starting from 2007 there was a major increase in the generation of electricity, approximately 92 per cent compared to the previous year 2006 (Figure 7). Domestic consumption also significantly increased by 37 percent in 2007 compared to 2006.

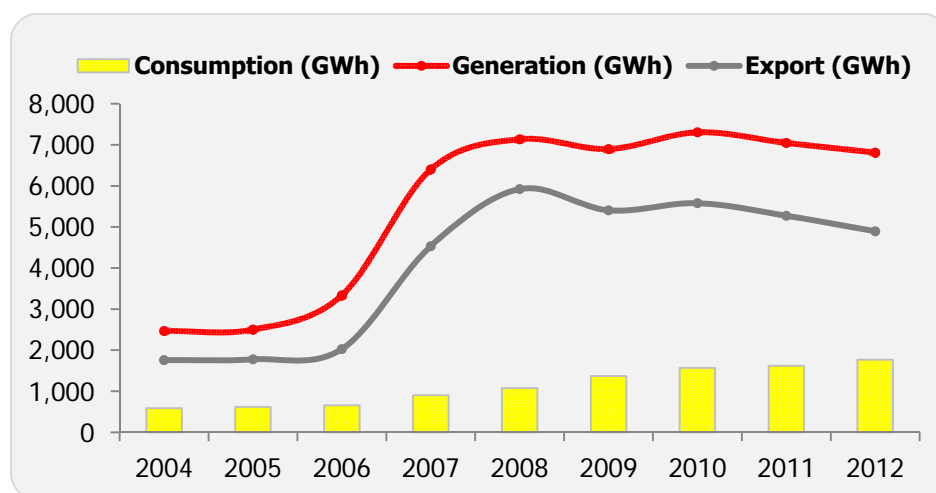


Figure 7: Generation, Consumption, Export. Source: Power Data Book 2012

⁵ Information on HPPs' generation capacities is obtained from the BPC Power Data Book 2012, page 21.

The sharp increase in generation in 2007 is due to the commissioning of the Tala Hydroelectricity project which added a total capacity of 1,020 MW. This additional capacity allowed exporting an average of over 73% of the electricity generated to India. In 2007 the BPC recorded an increase rate of 124% compared to the previous year in revenue from wheeled energy charges (i.e., exported energy; BPC Limited, 2007). The maximum export level was recorded in 2008 at 5,922 GW at an annual growth rate of 83%. However, electricity generation declined in 2009 by approximately 3.3% and has resulted in a significant reduction in electricity export to India. The export level has dropped by 8.7%. A similar trend is observed in years 2011 and 2012. Figure 8⁶ illustrates the 3-year time period where generation is declining and domestic electricity demand is increasing.

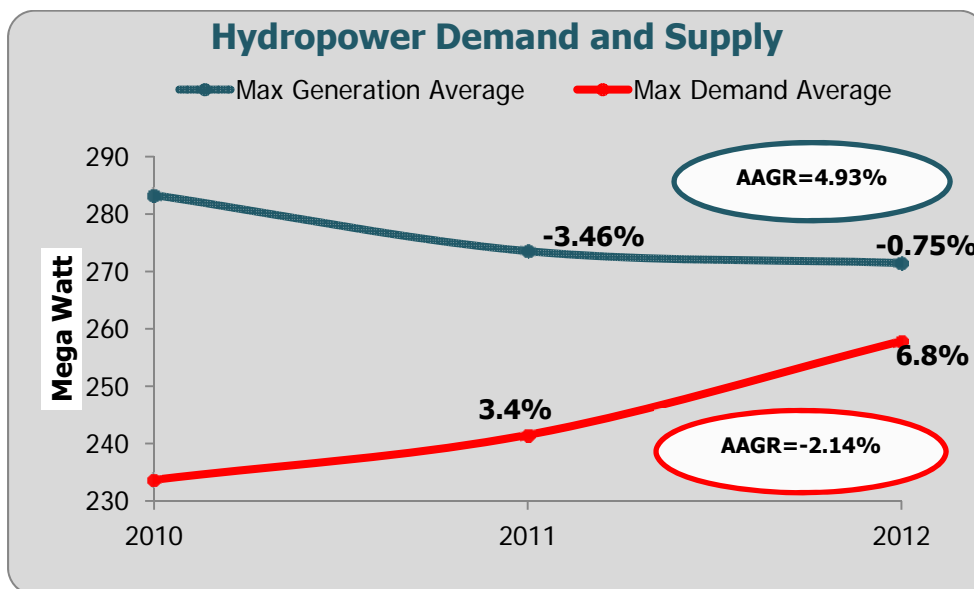


Figure 8: Generation vs. Demand, Power Data Book 2009-2012

This relationship is partly explained by the continual increase in electricity demand⁷ in Bhutan and reliance on a single particular energy resource. In addition, seasonal river flow reductions compared to the previous years were noted in the literature (MoEA, 2013). Losses were also due to some technical failure of the generators in September 2011.

⁶ This graph shows the average of maximum generation based on the maximum values of monthly generation and demand from the Quarterly Report 2009-2012.

⁷This is reflected in the BPC performance reports 2010, 2011 and 2012.

Any kind of fluctuation in electricity generation will affect the electricity export levels to India. According to the quarterly report data between 2010 and 2012 the national demand for hydropower has grown by an average annual rate of 4.93 per cent, while generation levels have decreased by an average of 2.14 per cent per year. The challenge that BPC is likely to face is to match the supply and demand of electricity in view of the lean flow generation constraints in winter when the demand is at its maximum (BPC Limited, 2009).

Energy Demand and Consumption by Categories

The customer base of the BPC has been growing continuously at AAGR at 11 per cent a year over the last five years. The total number of customers has risen from 77,433 to 131,697 people, i.e. by 70 per cent, over the period of five years from 2007 to 2012 (Figure 3).

The largest increase in the number of new customers percentage-wise is observed in the category of High Voltage (HV) industries with an AAGR of 28 per cent. The second-most growing category is Low Voltage (LV⁸) consumers with an AAGR of 11 per cent, which include residential, commercial, institutional buildings, as well as agriculture. The growth in Medium Voltage (MV) industries growth is 11 per cent a year.

Hydropower is as a low-cost energy source to support capital-intensive industries in Bhutan, such as forestry, mining, and cement and calcium carbide production. The RGoB has been following a policy of encouraging power-intensive industries by keeping industrial tariff rates low. This has encouraged industrial activity in Bhutan and thus diversified its economic activities, while ensuring reliable demand for its power in the long term (ESMAP, 2007). Figure 9 depicts BPC customer growth by categories over a time series of 5 years from 2007 to 2012.

⁸ LV total includes: commercial, industrial, agriculture, institutions, street lighting, power house auxiliaries, and temporary connections.

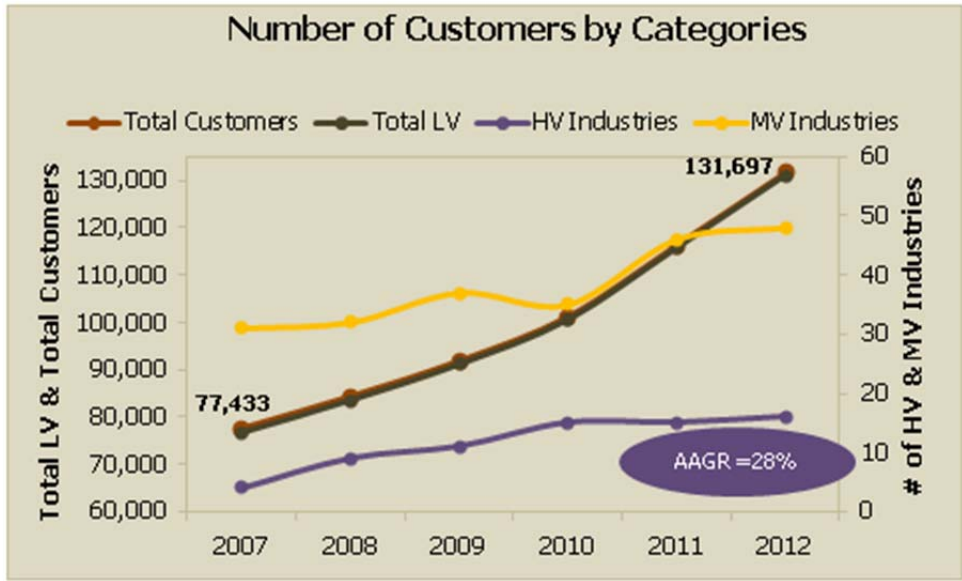


Figure 9: BPC customer base, Power Data Book 2012

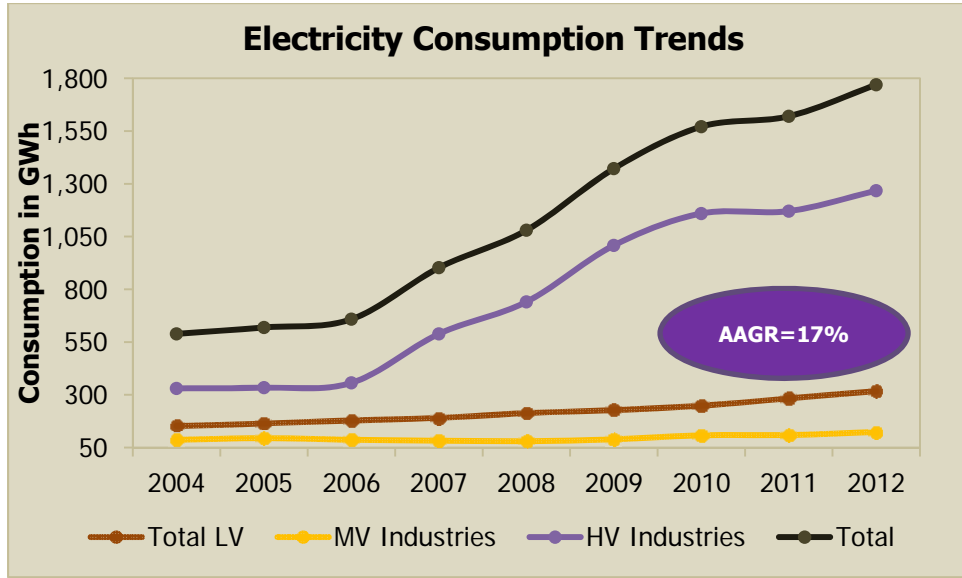
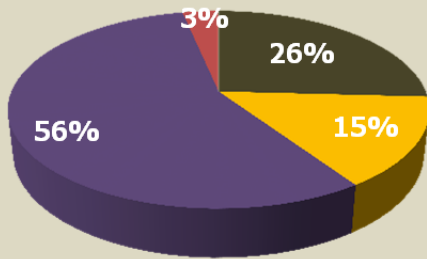


Figure 10: Generation vs. Demand, Power Data Book 2009-2012

The curve for energy sales to HV industries stands out with an AAGR of 17% over the period from 2004 to 2012 (Figure 10). During the year 2012 the total energy sales to customers was 1,769.59 GWh of which 21% was to LV customers, 7% to MV industries, and 72% to HV industries with an increase in overall energy sales growth to 9.24 per cent as against 3.13 percent in the previous year (Figure 12). Electrical energy consumption in high voltage industries are one of the major energy-intensive consumption areas (Figures 11 and 12).

Sales 2004

■ Total LV ■ MV ■ HV ■ LV Bulk

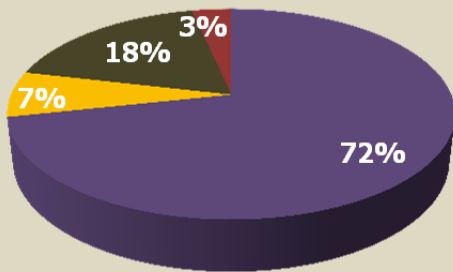


In 2004, the largest electricity consumption share was by HV industries which accounted for 56 per cent of total sales. The second largest share of electricity consumption belonged to LV customers including residential, institutional, agriculture and auxiliary buildings.

Figure 11: Energy Sales 2004, Power Data Book 2012

Sales 2012

■ HV ■ MV ■ LV Total ■ LV Bulk



There is a significant increase in HV industries sales between 2004 and 2012 and it still remains the largest electricity consumer. HV industries' electricity consumption has been continuously growing with the share of 65% in 2007; 74% in 2010, and 72% in 2011 and 2012. In year 2012, MV and HV industries together accounted for 79% out of the total hydro electricity consumed in Bhutan.

Figure 12: Energy Sales 2012, Power Data Book 2012

Climate Change & Hydropower

Currently, hydropower accounts for nearly 16% of the world's total power supply and is the world's most dominant (86%) source of renewable electrical energy (Killingtveit, 2012). Asia alone possesses a technically feasible potential of 6,800 TWh/y and a total capacity potential of 1,928,286 MW (Killingtveit, 2012). A feasible potential for global hydropower is 2 to 3 times higher than the current generation, and much of its potential is still underdeveloped in countries of Africa, Asia, and Latin America. However, there is an uncertainty brought by global climate change which poses some risk for the hydropower generation sector. Climatic changes are

causing changes in runoff and increasing retreat/melting of glaciers and the formation of glacial lakes, The Himalayan region is in a very active seismic zone, thus it is possible that earthquakes may trigger outburst of glacial lakes. Studies involving mathematical models, geographic information system and remote sensing are being undertaken by scientist to assess basins and areas most susceptible to damage (Padmanabhan et al., 2008).

Bhutan has been experiencing reduced and volatile hydropower generation from run-of-the-river facilities due to changed monsoon patterns and the consequent low river flows. As a result, hydroelectric energy is readily available during the months of monsoon rains, and is less available during non-monsoon months, particularly in winter when demand is high and supply is constrained (Figures 13 and 14).

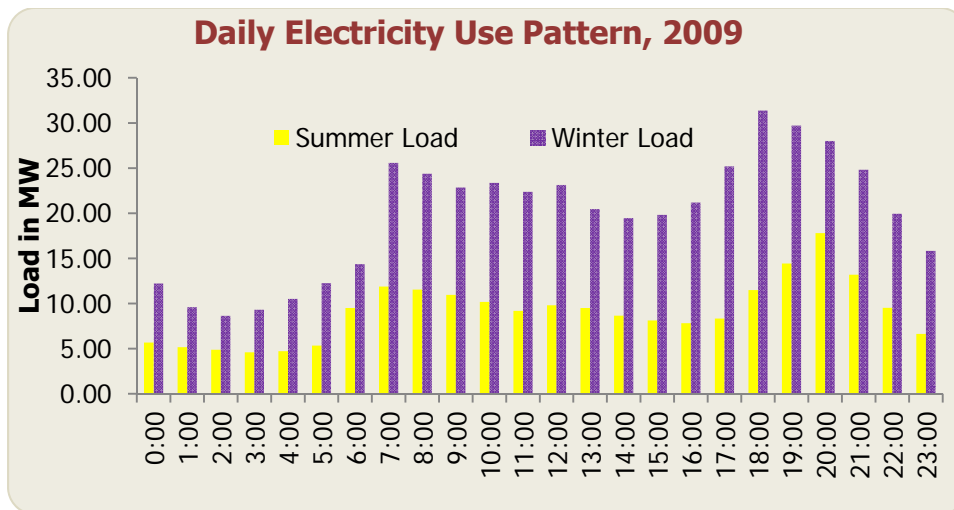


Figure 13: Daily Load Profile 2004, Power Data Book 2012

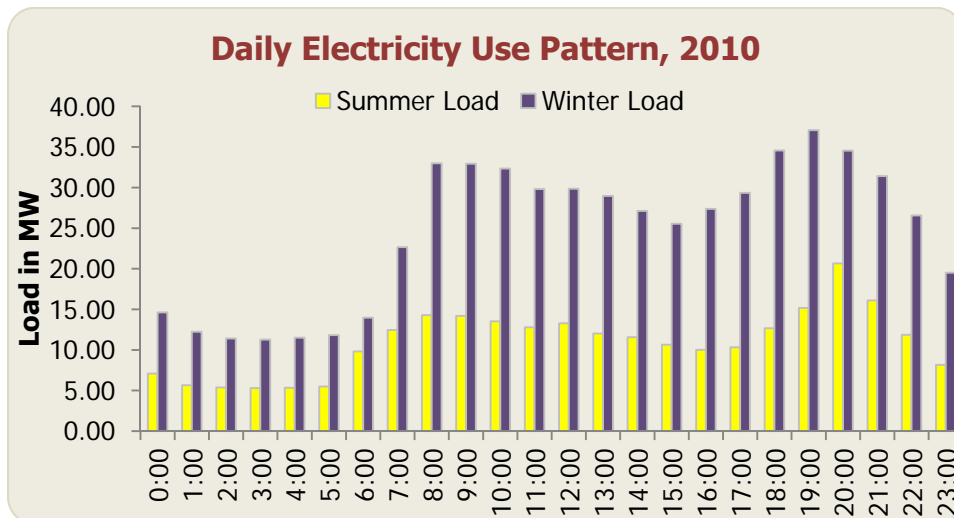


Figure 14: Daily Load Profile 2010, Power Data Book 2012

Over two decades ago there were no major expectation of Bhutanese industrial expansion and increased domestic electricity consumption (Dhakal, 1990), whereas, today the seasonal power shortages constrain the supply to meet the industrial electricity needs. Temperature and rainfall vary seasonally in Bhutan (Figure 15).

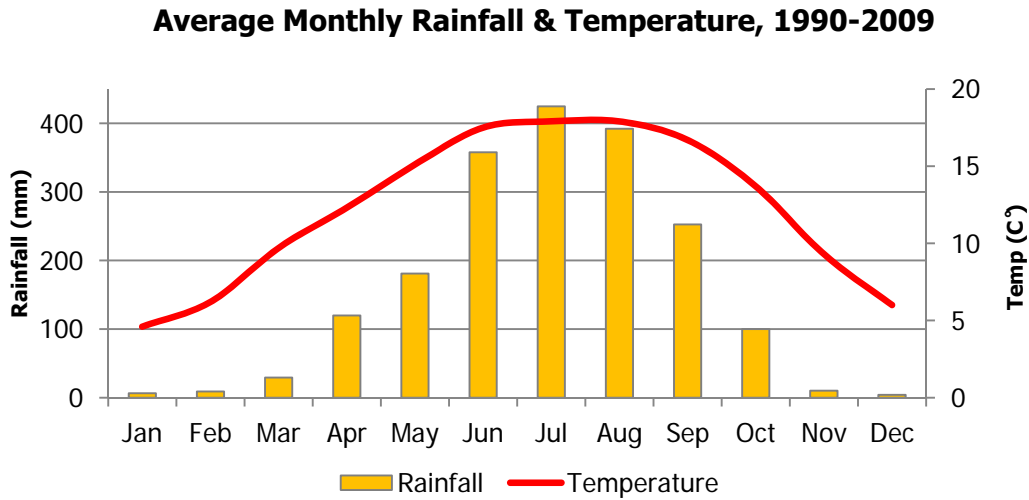


Figure15: Bhutan Average Monthly Rainfall and Temperature, Climate Change Knowledge Portal, World Bank

The power shortages in the dry winter periods were recorded when hydropower generation is reduced due to low river flows. Consequently, the existing generation systems have been unable to meet the recent fast-growing demand for electricity during the dry winter peak periods (Figure 16).

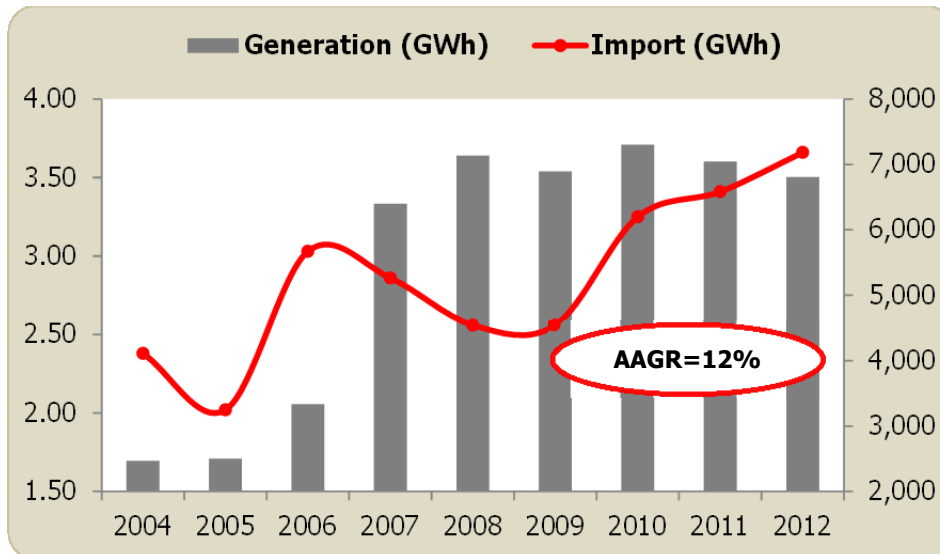


Figure 16: Generation vs. Import, Power Data Book 2012

There has been a rapid jump in import levels starting from year 2009 (Figure 16). Importation of electricity has been growing annually at 5 per cent in over the last eight years 2004-2012, whereas the AAGR over the last three years 2009-2012 has been 12 per cent. The BPC has confirmed that during the last three years they were obliged to increase re-import power from India during the winter months to meet the domestic demand.

In addition to the changing patterns of monsoons, there is more significant impact of climate change in Bhutan and that is the formation of supra-glacial lakes due to the accelerated retreat of glaciers with increasing temperatures. The risk of potential disasters inflicted by Glacial Lakes Outburst Floods (GLOFs), which pose new threats to lives, livelihoods and development, is mounting as the water levels in several glacier lakes approach critical geostatic thresholds⁹ (Figure 17). Bhutan's entire northern region has glacier/snow-fed lakes near its mountaintops. With a majority of Bhutan's population and infrastructure development concentrated in large river valleys, climate-induced GLOFs could cause significant human and economic devastation. Rising mean temperature attributed to climate change is the main cause of glacial retreat and melt rates¹⁰.



Figure 17: Thorthormi Glacial Lake

Thorthormi and Raphstreng glacial lakes require immediate attention¹¹. The combined volume of water from these two lakes is projected to be 53 million cubic metres. If melt rates create a glacial lake outburst flood, the ensuing damage is estimated to be three times more powerful than the 1994 flood in Punakha (BBS, 2012).

⁹ <http://www.undp-alm.org/partners/bhutan-department-hydro-meteorological-service-dhms>

¹⁰ <http://www.undp-alm.org/explore/bhutan>

¹¹ <http://www.bbs.bt/news/?p=10702>

Bhutan Energy Sector Institutions and Current Energy Policies

The primary institutional players in energy management in Bhutan are described here.

Department of Energy (DOE): The DOE is responsible for policy formulation, planning, and coordination of activities for the energy sector as well as the overall responsibility for implementing the government's ambitious rural electrification program and developing the new export-oriented HPPs.

Bhutan Electricity Authority (BEA), a regulatory body under the DOE: Acts as an entrusted body for the economic and technical regulation of power sector entities, including tariff setting and licensing.

Druk Green Power Corporation is a holding company that is responsible for harnessing and sustaining Bhutan's renewable energy resources. It controls the four major hydropower projects including Chukha HPP, Basochhu HPP, Kurichhu HPP, and Tala HPP.

Bhutan Power Corporation Limited (BPC) was established as a public utility on 1 July 2002 with the mandate of distributing electricity throughout the country and also providing transmission access for generating stations for domestic supply as well as export.

The BPC Distribution & Customer Services Department (DCSD) is responsible for providing adequate, reliable, good quality, safe and affordable electricity in a customer friendly and efficient manner. It consists of 21 smaller divisions.

The Renewable Energy Division (RED) under DOE oversees the implementation of alternative renewable energy development projects, as well as the construction of MV and LV lines and substations. The current mandate of the RED is expansion of the distribution infrastructure to achieve the Royal Government's goal of 'Electricity for All by the year 2013'.

RGoB Policy Overview

The government's energy development strategy during 1994–2009 recognized the central role of the power sector in promoting economic development and poverty alleviation. It also pursued the balanced regional growth through access to electricity for rural communities, and encouraged industrial investments based on the cheap and reliable supply of electricity.

The development of untapped hydropower potential is outlined in the 10th Five Year Plan. Hydropower provides the country with strong socio-economic and environmental advantage, however, given the rising energy demand in the industry sector and the risk of reliance on a single electricity source, the government of Bhutan recognizes the need for an Alternative Renewable Energy (RE) Policy. Provision of adequate energy services to the rural inhabitants while promoting dispersed energy generation options for urbanized inhabitants is in the vision of the royal government. The application of solar heaters, solar rooftop systems, and other standalone solar technologies are strongly encouraged and supported by the RGoB (Hydropower Policy, 2008). The RGoB foresees the acquisition of 20 MW generation capacity through a mix of renewable energy technologies as a minimum target. It welcomes developers and manufacturers of RE projects by offering beneficial tax exemptions, such as exemption from corporate or business income taxes for 10 years, and an additional 5 year exemption for the developers of projects in remote locations of the Kingdom (MoEA, 2013). Management of energy demand is noted as a separate priority in RGoB policy papers and is to be addressed in the coming Energy Efficiency Policy.

This way the RGoB aims at fostering sustainable development, climate change mitigation, energy and economic security, and conservation of environment in the Kingdom.

Smart Grid and Demand Side Management (DSM)

The concept of the **Smart Grid** is based on the application of digital technology in the electricity network in order to supply electricity consumers via two-way communication¹². Such systems monitor and analyze the energy use and help improve energy efficiency, as well as ensure transparency and reliability of the energy supply chain. In Europe, for example, energy efficiency is a key element of programs to meet the target of 20% reduction in energy demand by 2020. Energy efficiency is seen as one of the most cost-effective ways to reduce carbon emissions and improve security of energy supply (European Commission (EC), 2011). Smart energy enabled by 'information and communication technologies' (ICTs) can allow consumers to closely monitor their consumption and energy suppliers to more efficiently meet the demand.

¹² http://en.wikipedia.org/wiki/Smart_grid

Smart energy response and management technologies provide utilities with tools to streamline and target **Demand Side Management (DSM)** and potential reduction opportunities.

The U.S. Department of Energy defines DSM as: *"Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized"* (Hedrick, 2011).

The scientific literature defines DSM as *"the planning, implementation, and monitoring of those utility activities designed to influence customer use of electricity in ways that will produce desired changes in the utility's load shape, i.e., changes in the time pattern and magnitude of a utility's load"* (Solanki et al., 2011).

However, for implementing smart metering and automated energy management systems (AEMS), a sophisticated cost-effective infrastructure is essential. Introduction of ICT in electrical sector infrastructure and acquisition of Internet-based information networks for fast and secure data exchange are necessary to develop AEMS. In a smart grid the service pools are interconnected with end-user interfaces, thus standardization of power interfaces and ICT hardware and protocol are the important elements for putting advance metering system into practice (Solanki et al., 2011).

With increasing national income, improved electrical connectivity, and higher population density in the towns and cities, Bhutan's domestic energy load is projected to increase. The number of capital-intensive high voltage industries in Bhutan, such as forestry, mining, cement and calcium carbide production, has increased at an average annual rate of 28 percent over the last 8 years. Energy sales to medium and high voltage industries, the largest consumers of hydroelectric energy (BPC Limited, 2012), have grown by 13 percent a year during the same period. During the period 2009-2012 the BPC was obliged to increase its power re-import from India during the winter months to meet the domestic demand. The BPC reported that even with additional generation from commissioning of the Punatsangchu- I hydropower plant by 2015, demand side management is recommended, unless other supply side augmentation initiatives are put in place on time (BPC Annual Report, 2009).

In order to meet supply-demand, installed generation of the system must be able to cope with the peak load and unexpected rises in demand. Thus reduction of peak demand through adjusting the

daily energy use patterns, particularly for MV and HV industries, would be an appropriate solution to keep the supply and demand balanced.

The Royal Government of Bhutan recognizes the need to develop a policy and regulatory framework that promotes and enhances optimization of energy use through demand side management measures.

ICT Development in Bhutan

There have been many significant advances in the development of ICT in Bhutan, and these include:

- Evaluation of various bill payment options for the consumers through internet, SMS.
- Improvement of the metering efficiency and monitoring with the introduction of Automatic Meter Reading (AMR) on a pilot basis for the industrial customers.
- Live-line replacement of conventional ground wire systems with Optical Power Ground Wire (OPGW) on transmission lines and live-line installation of All Dielectric Self Supporting (ADSS) Optical Fibers on BPC distribution Poles.

The National ICT Broadband Master Plan of Bhutan envisages optical fiber connectivity to all the 20 District Headquarters and 205 Gewogs¹³. So far Bhutan Power Corporation Ltd. has successfully implemented 86km of OPGW on 220kV from Thimphu to Phuentsholing and 396km of OPGW on 132kV and 66kV transmission lines. With completion of those projects, optical fiber has now reached in 17 Dzongkhags¹⁴ as of December 2011. All ADSS Optical Fiber cable connectivity is taken up from the high voltage substations to the District Headquarters and Gewog centers (BPC Limited, 2012). All the testing and commissioning of the ADSS optical fibers (Phase-I) were completed in the year 2012. The survey and installation of the ADSS optical fibers (Phase-II) have started in a few Dzongkhags during the same year.

¹³ Gewog is a term for a group of villages in Bhutan. There are 205 gewogs, which cover an area of 230 km² in average.

¹⁴ Dzongkhag is an administrative and judicial district of Bhutan. There are 20 dzongkhags which are further divided into 205 gewogs.

Conclusions & Recommendations

The royal government of Bhutan is pursuing opportunities for the enlargement of hydropower capacities, which currently makes only 6 per cent of the 23,760 MW technically exploitable electrical power potential (ESMAP, 2007). Several hydropower projects are underway, which are expected to generate a total of 10,000 MW by 2020. Nevertheless, there is a risk of dependency on the sales of a single commodity to a single market – India. In addition, there are risks from natural disasters, such as earthquakes, as Bhutan is located between the Indian and



Asian tectonic plates. Climate change effects including glacial melts, landslides and monsoons may also pose a severe risk to the infrastructure. Now that climate change has become one of the most severe threats to development, thorough evaluation and research of the environmental factors and potential adverse effects should take place before implementing massive hydropower projects.

Harnessing other forms of clean/renewable energy to supplement the electricity generation in the low river flow months is strongly promoted by the RGoB. Application of hybrid energy systems should be explored for use in peak load periods. However, development of a comprehensive alternative renewable energy program would require feasibility studies and comprehensive environmental and climatic data acquisition. It is therefore recommended that the Kingdom of Bhutan collects and maintain accurate and up-to-date environmental data, including rainfall, wind speed, sediment load, glacial melt rates and movements, and hydrological monitoring in order to support the research and development processes.

In view of the observed low river flow seasons, the BPC is challenged with the constrained generation and the problem of supply-demand of electricity in winter when the demand is at its maximum. The country is currently exploring opportunities for re-import of power from India especially to meet the winter peaking shortages is being explored (BPC Limited, 2010).

Although this problem is expected to be solved with the additional generation from

commissioning of new hydropower projects, energy efficiency remains a key driver for energy security and sustainable development. By integrating energy efficiency and smart grid technologies into current voltage management, load control, and energy efficiency programs, BPC can realize significant savings by reliably flattening the peak demand, thereby leaving more energy surpluses for export and sustainable revenues. The customers, in this case the HV and MV industries will benefit from these programs through cost savings from reduced energy consumption and power quality improvements. However, a more detailed analysis of the industries' daily, weekly and monthly load curves will show what specific energy efficiency measures and DSM strategies would be most cost-effective and promising.

Works Cited

- BBS. (2012, March 15). *Only 2 lakes dangerous, not 25, new study reveals*. Retrieved from BBS: The Bhutanese Expression: <http://www.bbs.bt/news/?p=10702>
- Bhutan Power Corporation (BPC) Limited. (2007). *Annual Report*. Thimphu: Bhutan Power Corporation Limited.
- Bhutan Power Corporation (BPC) Limited. (2009). *Annual Report*. Thimphu: BPC Limited.
- Bhutan Power Corporation (BPC) Limited. (2010). *Annual Report*. Thimphu: Bhutan Power Corporation Limited.
- Bhutan Power Corporation (BPC) Limited. (2012). *Power Data Book*. Thimphu: Bhutan Power Corporation Limited.
- Catherine Wolfram, O. S. (2012). How Will Energy Demand Develop in the Developing World. *Journal of Economic Perspectives*, pp. 119 – 138.
- Commission for Gross National Happiness (CGNH). (2010). *Population Perspective Plan*. Thimphu: Commission for Gross National Happiness, Government of Bhutan.
- Dhakal, D. (1990). Hydropower in Bhutan: A Long-Term Development Perspective. *Mountain Research & Development*, 291 - 300.
- Douglas F. Barnes and Willem M. Floor. (1996, November). Rural Energy in Developing Countries: A Challenge for Economic Development. *Annual Review of Energy and the Environment*, pp. 497-530.
- Energy Sector Management Assistance Program (ESMAP). (2007). *Bhutan Hydropower Sector Study: Opportunities & Strategic Options*. Washington: The World Bank Group.
- European Commission (EC). (2011, March). *The Contribution of ICT to Energy Efficiency: Local and Regional Initiatives*. Belgium: European Commission Information Society and Media.
- G. Padmanabhan, S. L. (2008). GLOF Risk Mitigation - Key Issues, Challenges and Approaches. *Solution Exchange for the Disaster Management Community*, (pp. 1 - 17). Thimphu.
- Happy and You Know It. Bhutan at the Polls. (2013, July 6th). 408(8843).

- Hedrick, K. (2011). Demand Side Management: Why utility-directed load management programs make more sense than ever before. *White Paper*.
- Herrera, S. (2005). Healthy, Wealthy and Wise. *Technology Review*, 60 - 63.
- International Monetary Fund (IMF). (2004 - 2012). *World Economic Outlook: Nominal GDP - Bhutan*. Retrieved from Bhutan - All Economic Indicators:
<http://www.quandl.com/economics/bhutan-all-economic-indicators>
- International Panel for Climate Change (IPCC). (2007). *Synthesis Report*.
- Killingveit, B. H. (2012). Assessing Climate Change Impacts on Global Hydropower. *Energies*, 305-322.
- MERCADOS Energy Markets International (EMI). (2013). *Key Issues in the Power Sector in South Asian Countries*.
- Ministry of Economic Affairs of Bhutan (MoEA). (2013, April). *Alternative RE Policy*. Retrieved 2013, from Ministry of Economic Affairs, Royal Government of Bhutan:
<http://www.moea.gov.bt/>
- Parmal Singh Solanki, Venkateswara Sarma Mallela, Malcolm Allan, Chengke Zhou. (2011, April). Benefits, Barriers and Challenges of Demand Side Management: a Review of Electrical Systems in Oman. *International Review on Modelling and Simulations*, 784 - 794.
- Santos, M. E. (2013). Tracking Poverty Reduction in Bhutan: Income Deprivation Alongside Deprivation in Other Sources of Happiness . *Springer Science*, 259-290.
- Sioshansi, F. P. (2012). *Smart Grid: Integrating Renewable, Distributed & Efficient Energy*. Waltham: Elsevier Inc.
- The World Bank Group (WBG). (2010, October 27). *Country Partnership Strategy for the Kingdom of Bhutan*. Retrieved from <http://www.worldbank.org/>
- The World Bank Group. (2011). *ICT Sector Strategy Approach Paper*. Retrieved from The World Bank Group: www.worldbank.org
- UNICEF. (2010). *Bhutan Multiple Indicator Survey (MICS)*. UNICEF.
- Yee, A. (2011). Working in the Himalayas to Prevent Disastrous Flooding. *New York Times*, 1 - 4.