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POWER SECTOR PROSPECTS AND POLICIES OF RURAL ELECTRIFICATION IN BHUTAN

Received: 2 April 2019
Revised: 22 April 2019
Accepted: 4 September 2019

Kezang Lhazom[1] and Prapita Thanarak[1*]
[1]School of Renewable Energy and Smart Grid Technology, Naresuan University, Phitsanulok 65000, Thailand
[*]Corresponding author e-mail: prapitat@nu.ac.th

Abstract

Bhutan's electricity access rate has increased from 61 percent in 2006 to 100 percent in 2016, ahead of the country's initial 2020 goal. On-grid hydropower is Bhutan's main energy source and the main driver behind its rapid expansion of electricity access. The country's mountainous terrain makes grid extension difficult in the remote rural areas where around 4,000 households are located. In order to explore the prospects and policies of the power sector in Bhutan, this paper discusses the responsibility organizations, electricity demand, and supply, laws, and policies as well as the power sector development strategy in Bhutan. The interview data was from related organizations. The secondary was collected from relevant government and public agencies and published reports. As a result, the government has made off-grid renewable energy projects a significant development effort under the nation's five-year plans, providing around 2,000 rural households with solar home systems and repairing an additional 1,000. Related donor-assisted grant projects have filled the rest of the country's electricity gap. Although the government of Bhutan achieved the remarkable feat of 100 percent electricity access, it lacks the resources and workforce to sustain these projects on its own. The country's mountainous terrain makes remote areas difficult for government workers to access. Communities will ultimately need the training to install and repair systems themselves, a strategy that would also lead to more jobs in remote, off-grid

areas. A few pilot community-based projects exist, but Bhutan's remote rural areas need more.

Keywords: Renewable Energy, Electrification, Decentralization, Off-grid PV Systems, Remote Settlement

Introduction

Bhutan is a small, landlocked and mostly mountainous kingdom in the eastern Himalayas, bordered by China and India. It has an area of 38,394 km², 71% of which is covered by forests and it is presently a net carbon sink, with the forests absorbing more CO_2 than that released by the greenhouse gas producing activities. The 2017 Population and Housing Census of Bhutan indicate that 62.2% of the total population of 727,147 is rural and there are 163,001 regular households in Bhutan. The economic data of Bhutan is as the following Table 1.

Table 1 Economic data of Bhutan in the year 2017

Economic indicator	Value
GDP per Capita	US$ 3,438.16
GDP Growth rate	4.63%
Population Poverty Rate	8.2%
General Literacy Rate	71.4%
Youth Literacy Rate	93.1%
Household with Improved Sanitation Facilities	74.8%
Disability Prevalence Rate	2.1%
Population Access to Improved Water Sources	98.6%

Source: Ministry of Economic Affairs, 2019

Over 99.97% of Bhutanese households have access to electricity, and it is the primary energy source of lighting in 96.6% of the households. About 1.2% of the rural households use solar energy and another 1.2% use kerosene for

their lighting. While the nation has almost achieved its goal to provide electricity access to all, more than 30% of its rural population continues to depend on firewood for either cooking or heating or both. 95.2% of households use electricity, and 69.0% of households use LPG for cooking.

Bhutan has significant natural energy resources, including hydropower, solar, wind, vast forest cover and mineral resources. So far only about 6% of techno-economically feasible hydropower potential of 23,769 MW is developed, with an additional 3,658 MW under construction. As domestic electricity consumption is around 30% only, the surplus power is exported to India. However, from late November to March, hydropower output is low in contrast to domestic energy demand which is at its peak due to the requirement for constant heating during these cold winter months. Therefore, during the lean season for hydropower production, electricity is imported from India to meet the increased demand. Bhutan recognizes the risks involved in total dependence on hydropower resource for electricity generation and the vulnerability from an adverse change in the hydrological regime fueled by impending impacts of climate change. In addition, driven by population and economic growth, domestic energy demand is steadily rising. Thus, it is important to pursue and develop alternative energy resources such as the solar, biomass, biogas and wind energy, mainly to meet primary energy requirements of the off-grid villages, to address the energy security concerns and to improve the livelihood of the rural population.

Owing to the remoteness of the villages and highly dispersed nature of settlements, grid connection to provide reliable electricity to some of these far-flung villages is found to be impracticable and expensive as huge investment in long transmission lines, poles, transformers, and other infrastructure are required. Transportation of heavy materials and equipment in the mountainous terrains becomes inconvenient and difficult. Furthermore, some of these villages lie in the protected areas and obtaining forestry, and environmental clearances is another major bottleneck to connect them to the electricity grid. Most of these village households have been provided with solar home lighting systems but still, lack electricity for cooking or any other income generating activities.

Thus, these rural populations do not have clean cooking energy, and they rely on firewood and fossil fuel (kerosene, liquefied petroleum gas), which consume much of their time in collecting firewood and other chores related to cooking with firewood. Apart from the adverse effects of fossil fuel usage on the climatic conditions and environment, Bhutan does not have oil refineries and import fossil fuels which are subject to market volatility. Application of electric cooking has a huge added value as it saves many hours in biomass/firewood collection and also does away with the negative effect of smoke on health. The study aims to explore the prospects and policies of the power sector to supply electricity to remote off-grid areas in Bhutan.

Methodology

The objective of this paper is to observe the various organizations and policies in the power sector for rural electrification point of view in Bhutan. The methodology of this research consists of a literature review which primary and secondary data are collected. The authors interviewed 20 people related officers in related power sector organizations in Bhutan. The secondary data were collected from relevant government and public agencies and published reports. By using the qualitative method, all data were analyzed by the Context Analysis Method in order to indicate the possible scenarios for 100% rural electrification of Bhutan.

Results and Discussion

The rate of electrification in Bhutan is above 99.97%. Electricity is used in 96.6% of households for lighting and 95% for cooking, while 69.0% of households also extensively use LPG for cooking (PHCB, 2017). Electricity generation is almost entirely sourced from hydropower plants which are run-of-the-river types, with marginal generation from diesel generators power. The total installed capacity of 1,622.74MW includes 1,614.1MW of hydropower plants, 8MW of diesel generators and 0.6MW of the wind power plant. Solar power system deployment is also negligible with an estimated installation of less than 0.5MW.

According to the World Bank, Afghanistan, Nepal, and Bhutan are the three countries with the highest increases in national electricity access rates from 2006 to 2016. While grid-connected renewables have played a significant role in increasing access in these three countries, off-grid renewables have been pivotal in electrifying rural, remote areas where grid extension is not feasible.

1. Key Institutions and Organizations in Bhutanese Power Sector

The power sector in Bhutan saw a significant reform in 2002 when it was restructured to remove the conflict of interest and reconcile commercial, social and policy objectives by separating commercial management from the ownership of the government. Since then the Ministry of Economic Affairs (MoEA) is the policy-making body on power in Bhutan. It is responsible for policy formulation, planning, coordination and implementation of both conventional and renewable energy generation, consumption and exports as well as the import of fossil fuel. The agencies responsible for planning, coordination, and implementation of electricity-related policies and programmes in Bhutan (in Figure 1) are as follows:

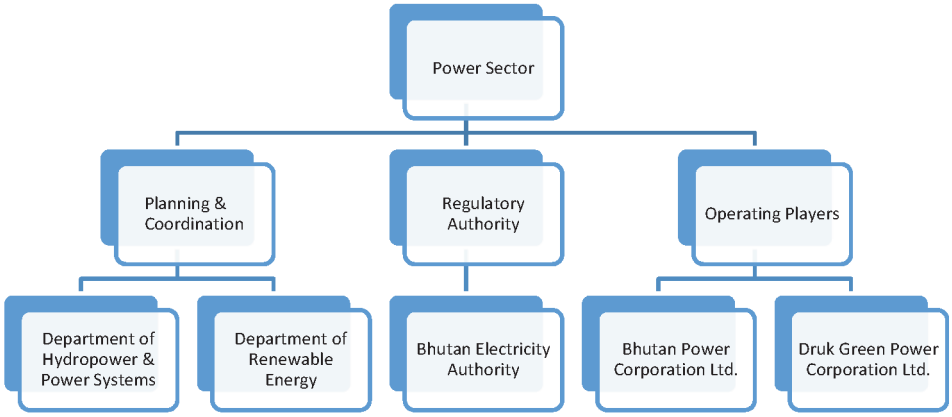

Figure 1 Key Institutions & Organizations related to Power Sector in Bhutan

1.1 Department of Hydropower and Power Systems (DHPS)

The DHPS is mainly responsible for policy and planning of hydropower generation, and the various roles of the department are to:

1) Obtain approval from the Royal Government of Bhutan (RGoB) for the hydropower projects being planned.
2) Facilitate support to consultants involved in the preparation of Detailed Project Reports (DPRs) for hydropower projects.
3) Coordinate all activities about registering hydropower projects under the CDM mechanism and also follow up on obtaining carbon credits for the RGoB.
4) Liaise with the National Environmental Commission Secretariat (NEC) until the formation of an independent Hydropower Authority on matters related to obtaining environmental clearance from NEC.
5) Organize a stakeholder discussion on the draft EIA with all the relevant line departments in order to collect inputs prior to its finalization.
6) Advise on environmental and social (E&S) issues in the context of policy formulation and coordination as and when required.
7) Support the hydropower authorities on any issues that may require resolution at higher levels within the RGoB.

1.2 Department of Renewable Energy (DRE)

This department is responsible for policy, planning, and assessment of renewable energy in Bhutan. DRE was established in December 2011 with the mandate to serve as the central coordination agency and the focal point of RGoB on all matters related to Renewable Energy (RE) development and Energy Efficiency and Conservation (EE&C) initiatives in the country. Functions of DRE are as follows:

1) To implement policy regulations related to RE and is responsible for the investigation, identification, design, and planning of RE systems covering solar, wind, biofuels, fuel cells, geothermal and small hydropower plants. It also implements pilot/demonstration RE projects and manages

the tendering of all reconnaissance, pre-feasibility, feasibility and DPR studies for RE projects.

2) To plan and coordinate programmes and initiatives for RE projects and Energy Efficiency measures; to administer and implement subsidy programmes and initiatives on RE projects and EE&C measures.
3) To collect and analyze energy data; provide techno-economic clearances and technical sanctions for RE projects.
4) To carry out applied research and development in RE & EE technologies and promote the use of energy efficient processes, equipment, devices, and systems; to promote innovative financing of EE projects and prepare educational contents on efficient use of energy and energy conservation.
5) To develop testing and certification procedures and testing facilities, including the development of minimum energy performance standards and labeling design for equipment and appliances.

1.3 Bhutan Electricity Authority (BEA)

BEA oversees the regulation of electricity generation and distribution in the country and is the power sector regulator responsible for setting tariffs, establishing and enforcing technical, safety, and operational standards, issuing licenses and monitoring other regulatory functions. While the BEA regulates the electricity prices on a cost-reflective tariff structure, actual retail prices are cross-subsidized in the value chain of the power sector. Prior to exporting power to India, DGPC provides 15% of its power generation as an energy royalty to the government, which sells it to BPC at subsidized prices. BPC distributes electricity to domestic consumers at reasonable tariffs that are substantially cross-subsidized by power exports.

1.4 Bhutan Power Corporation Limited (BPC)

BPC was launched as a public utility in July 2002 with the mandates to distribute electricity throughout the country and to provide

transmission access for generating stations for domestic supply as well as export. It was formed so that the corporatization of the utility functions would lead to greater efficiency and better delivery of electricity supply services in the power sector. Since the establishment of Druk Holding and Investment Limited (DHI), the commercial arm of the Royal Government of Bhutan in 2007, BPC and DGPC are under the ownership of DHI.

1.5 Druk Green Power Corporation Limited (DGPC)

DGPC was established in 2008 by merging the three hydropower corporations of Bashochhu Chhukha and Kurichhu with the vision to promote, harness and sustain Bhutan's hydropower resources. It operates and maintain all the existing large hydropower assets in Bhutan and is responsible for power generation.

2. Electricity demand and supply

Bhutan has net surplus electricity as the installed generation capacity is more than the total domestic demand and therefore surplus electricity is exported to India. In 2017, the domestic peak demand was 362.09MW only, and the surplus power of about 69% of the electricity generated was exported to India that year.

Figure 2 Generation from large hydropower plants (in MU)
(Bhutan Power Corporation, 2018)

Bhutan has an enormous hydropower potential of nearly 30,000MW but presently only 5% of the total potential has been developed, and 3,658MW of large hydropower projects are under various stages of construction. As all of the existing hydropower plants are run-of-the-river types, due to low water levels in the rivers during dry winter months from December to March, the whole generation drops considerably to below 20%. The power generation during the winter season is not able to meet peak system demand, and thus in addition to curtailing industrial loads, power has to be imported from India during the lean, dry season. The government planned to develop at least 10,000MW of hydropower capacity by 2020, mainly for exports to earn revenues and also help meet its domestic demand in winter months.

Due to the abundance of relatively low-cost hydropower, subsidized energy tariffs and the relatively high cost of renewable energy (RE) technologies, development of solar and wind energy systems in Bhutan has been marginal. Notwithstanding these challenges, Bhutan recognizes the risks involved in total dependence on hydropower for electricity generation, the vulnerability from an adverse change in hydrological regime fueled by impending impacts of climate change and the seasonal availability of sufficient water flows in the rivers. Thus, the importance to promote and develop alternative energy resources such as solar, biomass, biogas and wind energy is already realized.

2.1 Hydropower development

Bhutan exports around 70% of the total annual hydropower generated to India and the earnings from hydropower constitutes about 27% of revenues to the exchequer and contributes about 13% of Bhutan's gross domestic product. Therefore, hydropower development and its exports have contributed to the economy's rapid growth and generated government resources for social and other investments. Clean energy development for power exports will improve energy efficiency and foster economic cooperation in the region. Currently, five hydropower projects, as shown in Table 2 below, are under construction.

Table 2 Details of hydropower projects under construction

Parameter	PHEP I	PHEP II	MHEP	KHEP	NHPP
Installed Capacity (MW)	6 x 200 = 1,200	6 x 170 = 1,020	4 x 180 = 720	4 x 150 = 600	2 x 59 = 118
Annual Generation (GWh)	5,670	4,357	2,923	2,568.88	516.40
Type	Run-of-the-river				
Scheduled Completion	2023	2021	2019		

PHEP I – Punatsangchhu–I Hydroelectric Project

PHEP II - Punatsangchhu–I Hydroelectric Project

MHEP – Mangdechhu Hydroelectric Project

KHEP – Kholongchhu Hydroelectric Project

NHPP – Nikachhu Hydropower Project

Hydropower and renewable energy development are realized to be very important to stimulate economic growth and to mitigate climate change by increasing hydropower exports. The clean power Bhutan exports help reduce greenhouse gas emissions as electricity generation using fossil fuels in India can be reduced. Policies have been formulated to attract investments to the hydropower sector in environmentally sustainable energy development. Apart from the hydropower projects under development through bilateral arrangements with India, a few are developed or being developed with financing mechanisms for HP development through public-private partnerships (PPP), particularly for medium-sized and small projects. The 126MW Dagachhu hydropower project was the first PPP infrastructure project in Bhutan and was financed by ADB. The project involved a joint venture between DGPC and India's Tata Power Company, and it was the first cross-border project registered under the United Nations Clean Development Mechanism. As the next step in hydropower development, DHPS intends to promote investments by independent power producers (IPPs) as well as PPP after the formulation of the necessary IPP rules and guidelines.

Figure 3 The 336MW Chhukha Hydropower Plant

Figure 4 Dam site of 720MW MHEP
(DrukGreen, 2019)

2.2 Transmission

To evacuate power from new power plants to India and to connect them to BPC's national transmission network, huge investments will be needed in high-voltage power transmission. BPC will also need to improve its operational control to ensure system reliability.

2.3 Rural electrification

Despite having surplus electricity and being net power exporter, Bhutan has faced difficulties in extending grid electricity to remote settlements in mountainous terrain and thus limit access to clean energy in the rural areas

where 62.2% of Bhutanese people live. Traditional fuels such as firewood and kerosene are still used which cause indoor pollution and negatively affect health of rural population, particularly women and children. Since the late 1980s, the government launched large scale rural electrification projects and made it a key development effort to alleviate poverty and stimulate economic development. As of 2017 end, Bhutan had provided electricity to 99.97% of its households. This figure is expected to reach 100% marginally on completion of ongoing projects supported by ADB and the Japan International Cooperation Agency, scheduled for 2019. Households in remote villages where on-grid rural electrification is not technically or economically feasible are provided with electricity from other clean sources, mainly stand-alone home solar systems.

Figure 5 A remote off-grid village in Bhutan

2.4 Alternative renewable energy development

The Alternative Renewable Energy Policy (AREP) 2013 was formulated to improve national energy security by promoting alternative renewable energy sources other than large hydropower and diversifying the energy supply base through the use of wind, solar, biomass, and small and micro-hydropower systems. Wind power technologies have the potential to generate clean energy in the dry winters, thereby augmenting the reduced hydropower supply during these months and relieving seasonal power shortages. In 2016, a pilot wind power project of 600kW was successfully commissioned. Bhutan also has the potential to develop and promote the use of biogas as an

alternative to wood for cooking fuel in the rural households which rely heavily on fuelwood for cooking and heating and suffer from the indoor air pollutants and health hazards as a result.

Figure 6 The 600kW Wind Power Plant at Rubesa, Wangdue

3. Laws and Policies Pertaining to Power Sector

The key laws and policies related to the development of the power sector in Bhutan are:

1) Electricity Act of Bhutan 2001
2) Bhutan Sustainable Hydropower Development Policy 2008
3) Foreign Direct Investment Policy 2010
4) The Economic Development Policy of the Kingdom of Bhutan 2010
5) Alternative Renewable Energy Policy 2013

The Electricity Act of Bhutan 2001 provides the framework for the institutional governance of the electricity sector in the country. Some of the provisions of the Act have been superseded by the creation of new institutions.

The Bhutan Sustainable Hydropower Development Policy provides the framework and guidelines for accelerated hydropower development in Bhutan; and it permits the RGoB to develop hydropower projects with public,

private or public-private-participation further and in collaboration with other development partner countries, mainly India. The policy acknowledges the need to have RE policy to advance the exploration and exploitation of RE sources thereby ensuring national energy security through a diversified energy mix.

The Foreign Direct Investment Policy also supports private sector participation in the development of medium and large hydropower projects and other RE projects. It also provides incentives for foreign entities to invest in Bhutan's energy sector.

The Alternative Renewable Energy Policy (AREP) is formulated to promote and develop the RE sector in Bhutan to help meet its objectives to remain a net carbon sink, improve energy security, reduce dependence on imported fuels, and be prepared to meet possible adverse environmental conditions which may impact the country's hydroelectric generation capacity. The Policy provides the framework to address critical issues relating to the promotion of RE systems and public and private sector participation in the development of RE projects. The policy recognizes the growing energy sector challenges of Bhutan, in the form of increased reliance on a single source of electric power, dependence on imported fossil fuels for transport facilities against the threat of climate change, and proposes the exploration of untapped and salient Renewable Energy resources of Bhutan to increase the nation's energy security. This policy aims to promote the following clean Renewable Energy technologies: solar (both PV and thermal), wind, pico/micro/mini/small, bio-energy and geothermal, hydro, and waste to energy (WTE).

The Policy gives indicative target figures to be achieved by 2025 and includes

1) electricity generation from solar (5MW), wind (5MW), biomass (5MW);
2) energy generation from biomass energy system (3MW equivalent), solar thermal system (3MW equivalent) and
3) fossil fuel energy substitution in transport sector worth 1,000 kl of oil equivalent to be replaced by 111MU and 20% of the state-

owned and 10% of the private vehicle fleet to be encouraged to run on clean and green fuels.

The AREP also recommends the formulation of a Renewable Energy Master Plan by 2016, which shall direct the actual renewable energy target figures. However, presently, the master plan is still being drafted.

4. Power Sector Development Strategy

Bhutan's development strategy aims for power sector development to be a key player in increasing (i) all-encompassing economic development, with geographically balanced growth through electrification of rural communities; (ii) fiscal revenues though power exports; and (iii) industrial investments, based on a reliable supply of electricity. Rural electrification has long been a vital part of Bhutan's development strategy since 1988, as it helps poverty alleviation and improves the quality of life for the rural population. It has also been the government's strategy to use a mix of renewable energy including large hydropower/micro/mini hydro plants, solar energy, and wind power to electrify rural households. The solar home lighting systems have been used for remote rural households. In order to sustain economic growth, export-oriented hydropower development is essential. Therefore, a memorandum of understanding for cooperation was signed between the governments of Bhutan and India in 2006 to promote hydropower exports to India, and therein it was agreed to develop 10GW of generation capacity through 10 large hydropower projects under bilateral financing from the government and joint ventures with Indian public sector enterprises. The main objectives the AREP 2013 are to diversify the energy resource mix to enhance long-term energy security, reduce the need for fossil fuel imports, reduce greenhouse gas emissions, and stimulate social and economic development through effective renewable energy interventions and private sector participation for renewable energy resource development.

Conclusion and Way Forward

Some important issues should be strongly emphasized in for rural electrification in Bhutan, i.e., good governance, standard technical specifications, strong regulatory environment including penalties, reducing the subsidies and organizational structure to develop the market. It was observed that the majority of the economic viability studies carried out about the small solar home system of PV size between 40-120 Wp or to larger microgrid systems which served densely populated settlements or villages. Bhutan has restricted development solar and wind power potentials of 12.02GW and 0.761GW respectively. While the policies on the renewable energy are already in place, only 600kW wind and less than 500kW of solar home lighting systems are implemented so far. So there is a need for Bhutan has to prioritize and focus on the development of its other alternative renewable energy resources if the indicative targets set in AREP 2013 are to be met by 2025. The renewable energy produced by grid-connected solar, wind, and biomass generation may be used either domestically or exported.

Bhutan is excellent examples of how renewable energy potential combined with government support can result in successful electricity solutions. While they still face some financial, regulatory and technical challenges to long-term sustainability, their approaches so far can serve as models for other countries with a high elevation and mountainous terrains, such as Rwanda, Burundi, Lesotho, Peru, and Mongolia, are all places where off-grid renewables could be a more viable way of improving energy access than extending the electricity grid.

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