REVIEW ARTICLE

An Overview on the Solar Energy utilization in Bhutan

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ABSTRACT

The only Asian country to have surplus energy generation is Bhutan. Not only energy surplus, but also energy export to India forms an important part of the country’s economy accounting to 45% of the net national revenue and 19% of the GDP in 2012-13. 99% of the energy produced is from hydropower. It is of serious concern that for developing hydropower lot many considerations like environmental, economic etc. are to be made. Also there is reduction of about 300MW during the winter dry season and there is less possibility of energy export from India, which is Bhutan’s main energy partner. Therefore alternative energy sources are to be sorted out so that the energy sources will become diversified. Bhutan is looking for energy production from renewable resources like solar, wind and biomass and have programs for improving energy efficiency and also for using clean fuels for transportation. This paper looks into the current energy scenario of Bhutan to understand the solar energy potential of the country. The technologies which can be developed indigenously like solar collectors, solar dryers, and solar cookers were also explained. The methods to overcome the challenges for implementing solar based energy systems were also discussed.

Keywords: Bhutan, Energy scenario, Solar energy, Alternative energy, Energy potential.

1. INTRODUCTION

During the United Nations Climate Change Conference 2015, held in Paris, it was the highest greenhouse emitters who took the stage initially. At the end of the day, a small country with mountains, glaciers and forests took away the show, being a carbon negative country. A country sandwiched between two Asian giants China and India, Bhutan, has a population of approximately 745,000 people with an area of 38,394 km². The lowest point of the country is only 160 m above sea level and the highest part reaches to about 7000m with steep mountains crisscrossed by shift rivers born from the glaciers of the Himalayas in the north. This geographical diversity contributes to Bhutan’s beautiful and diverse biodiversity. Bhutan has 72% of the land under forest cover and intends to keep at least 60% of the land in forest cover all the time by constitutional law [1].

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Article 5 Section 3: Constitution of the Kingdom of Bhutan states that “The government shall ensure that, in order to conserve the country’s natural resources and to prevent degradation of ecosystem, a minimum of sixty percent of Bhutan’s total land shall be maintained under forest cover for all time.”

Biodiversity conservation is one of the main concerns of the Bhutan government and it houses rare species of animals, birds and flora. Bhutan forest absorbs nearly 3 times the CO₂ emitted by them making it not a carbon negative country but also a carbon sink. It is of much importance as its location is between China and India, which are the first and fourth largest CO₂ emitter respectively in the world.

Bhutan has committed to be carbon neutral since 2009 as being highly vulnerable to climate change as it have a very fragile mountainous environment [2]. High vulnerability is because 56.3% of the people
are engaged in agriculture and also the revenue from hydro power. Also the steep topography and geography of the country leads to natural disasters like flash floods, glacial lake outburst floods (GLOF), windstorms, forest fires and landslides. Indented Nationally Determined Contribution (INDC) submitted by the Kingdom of Bhutan to the UN climate change secretariat tells that “As a least-developed country, Bhutan has a development imperative and will pursue ecologically balanced sustainable development in line with our development philosophy of Gross National Happiness. To remain carbon neutral, growing emissions from economic development will need to be mitigated by pursuing low emission development pathways across all sectors” [3].

2. PRESENT ENERGY SCENARIO

Until the early 21st century, household energy requirements for heating and cooking accounted for about 70% of the energy requirements of the country and was met mostly with firewood. Bhutan has very less reserves of fossil fuels. The country has around 1.96 million tonnes of coal and the annual extraction is only 1000 tonnes only to meet domestic needs. It would last long till 2028 with an extraction rate of 4.6%. The kingdom has no natural oil or petroleum depositions. Bhutan imports around 1000 barrels of petroleum for automobile industry. Figure 1 shows the fuel mix in Bhutan (2015).

Adapted from [4]

Figure 1. Fuel mix in Bhutan (2015)

In early 1990s, Bhutan shifted its agriculture based economy to an energy based one by harnessing the energy from its fast flowing rivers, hence making energy an important aspect of Bhutan’s economic growth. Bhutan has a 30,000 MW potential of hydropower of which only 5% was extracted and it accounts to about 99% of the nation’s electricity production [5]. At present, it exports 75% of the hydropower produced to India accounting to 19% of its GDP [2]. In 2015, Bhutan exported 5,149.17 MU of electricity to India which is higher than in 2014 which is 4,991.89 MU. Bhutan formulated the rural electrification master plan for 100% electrification by 2020 which was further changed to 2013 [6]. With this scenario, electricity demand in Bhutan is expected to grow significantly and hence newer option of power generation needed to be found out with less harm to the environment as highlighted in Bhutan’s Gross National Happiness Policy (GHP). Bhutan successfully provided electricity to 95% of its households and is expected to reach 100% by 2015 with funding from Asian Development Bank and Japan International Cooperation Agency [7].

2.1. Alternative energy policy 2013

As Bhutan’s energy is completely dependent on rivers, its dependence for energy security is of much concern due to climatic changes, seasonal variations, natural disasters etc. [8]. Also there is reduction of 20% in energy production in winter dry seasons and hence a diversification in energy sources is required for energy security [7]. Therefore an alternative energy policy was formulated in 2013 to promote use of renewable energy resources for primary energy production [2]. “This Policy sets out a preliminary minimum target of 20 MW by 2025 through mix of renewable energy technologies”.

Specific targets include electricity generation of 5 MW each from solar, wind, biomass and energy generation of 3 MW equivalent each from biomass and solar thermal. It also involves fossil fuel substitution of 1000 kilolitres equivalent to 111,000 MWh in transport sector. By 2025, 20% of the state owned and 10 % of the private vehicles will be encouraged to use clean fuels. As to promote renewable energy usage, solar technologies (PV and thermal) will be implemented in government buildings, hospitals and other possible public buildings for electricity generation and also for heating. Also Decentralized Distributed Generation (DDG) or other such methods like smart grids etc. will be implemented to promote renewable power generation.

3. SOLAR ENERGY POTENTIAL IN BHUTAN
A study on the availability of solar energy was done by NREL and the Atmospheric Sciences Research Center (ASRC) at the State University of New York (SUNY), Albany in collaboration with Kingdom of Bhutan and was sponsored by United States Agency for International Development’s (USAID) South Asia Regional Initiative for Energy Cooperation and Development (SARI/Energy) [5]. The average annual global horizontal solar radiation of 4 – 5.5 KWh/m² are well suited for flat plate solar collectors. The northern parts have better potential but due to low population density and topographical limitations, it cannot be well utilized. Solar photovoltaic cells can be well utilized throughout the country where ever the grid is accessible. The scope for concentrated solar collectors are limited as the direct normal irradiance average values are from 2.5 – 5 KWh/m² (see figure A1).

An estimate of the electricity which can be developed from solar energy was made with the following assumptions [9], (i) Only 5% of the available land is productive, (ii) Only 30% of the productive land is available for developing solar plants. Therefore only 1.5% of the total land is available for solar power plant generation, (iii) Tilt angle is same as that of Equator, (iv) Panel efficiency of 10% at standard test condition of 1000 W/m². Under these assumptions, the land available was around 582km² and the total technical potential for DC current generation was roughly 58 TW. Even with this high potential many social, economic, environmental, political and other considerations are to be made before accepting such a potential assessment.

As a part of Asian Development bank project, a feasibility study on developing a 30 MW power plant in Shingkhar, Bumthang District was done which is funded by Norway. If it is completed, it will be first of the kind in Bhutan [10]. Solar Electric Light Fund (SELF), an organization working on electrification of rural areas using solar PV, in partnership with SELCO-India and Tshungmed Solar, came forward to provide better living condition to the villagers of Phobjikha valley. They provided solar PV based electricity to 151 houses and a health clinic. They also installed a 750 W solar PV system in Royal Society for the Protection of Nature, a NGO which gave ground support for the project. This initiative was a role model to larger developmental strategy of the country. It provided the people of Phobjikha valley with huge benefits like 24 hours health clinic, women could weave at night hence better income, children could study, escape from dull light and smoke from kerosene lamps etc. Under the rural electrification master plan 2005, 88% or 32,000 households would be served through extension of the national grid, and the remaining 12% or 4,400 households would be served by solar home systems and micro-hydropower systems [6]. Apart from this, very less literature and data are available about solar power utilization in Bhutan.

4. TECHNOLOGIES WHICH CAN BE DEVELOPED INDIGENOUSLY FOR SOLAR ENERGY UTILIZATION

Solar air heaters for space heating and drying options for building integration of solar air heaters on existing buildings and how can it be utilized without affecting ascetic value of Bhutanese architecture is summarised here.

4.1. Space/water heating

Residential sector is the largest energy consumer amounting to 44% which is mostly used for air conditioning. Around 90% of this energy is from firewood making Bhutan the largest per capita consumer of firewood in the world [6]. As there are strict restrictions for deforestation, firewood is becoming more expensive and also usage of kerosene and electricity has become prominent. But still these energy sources have their own drawbacks. Hence use of solar energy for space heating can be a better option in Bhutan as the country have normally cold days with clear skies. Both solar water and air heaters can be utilized for this. Solar water heaters can be used for hot water requirements and also space heating applications using a heat exchanger. Hot water storage can be used to store water at higher temperature and hence can be utilized at night for space heating also. Estimates show that by using a 15m² solar thermal system with storage was able to reduce the use of firewood by 50% in a rural settlement [11]. Solar air heaters can be used very directly for space heating applications as there will be lesser problems of storage and leakage in it. Also the maintenance of these systems are very less as there will be no problem of corrosion, freezing and other
related issues. One of the other advantage is that these solar air heaters can be manufactured using very easily available materials like wood, steel etc. It can also be integrated into the building walls, roofs, windows, and hence the space requirement can also be reduced. The cost of storage tanks and heat exchangers can also be reduced. The only disadvantage is that the solar air heaters cannot be used during night when heating is required more. Also storage using air heaters is not a feasible technology [12]. Hybrid systems like solar – biogas systems can be used as an alternative.

4.2. Food drying

One of the other major application of solar power is food drying. It has a huge potential in Bhutan as dried food is a major part of the Bhutanese food menu. Dried meat like pork (Shikam) and beef (Shakam) is a regular diet for northern Bhutanese people. Dried fish is also a popular food in Bhutan, which is usually imported from India and Thailand. Some of the fruits and vegetables are also preserved and served in dried form namely apple, persimmon, peach, pear, pumpkin, chilly, eggplant, crow’s beak, spinach (green leaves) and even the mushrooms. Currently for food drying, open sun drying and smoke drying is being used which is less effective. It comes with many disadvantages like contaminations, animal attack, rain attack etc. Unlike these methods solar drying can be done in a controlled manner in a very hygienic environment. There are different types of solar dryers like direct, indirect and greenhouse. The selection on the type of dryer can be done based on the product to be developed. There are numerous types of dryers developed throughout the world and was tested successfully. Economic feasibility study shows that not only it reduces the energy used for drying, as in the case of firewood or other fossil fuels, but can also reduce the food loss and can increase income to the farmers. Studies shows that the post-harvest food loss is more than 45% worldwide and that means around half of the food is lost before reaching the consumers. Therefore solar drying, which is a less energy intensive food processing method can help in reducing the food loss when the world is in hunger and also can generate revenue for the farmers [12].

4.3. Solar cooking

Solar cooking can be said a well suited application which can be implemented in a country like Bhutan, as it is a decentralized application which can be sized in any proportion. A single unit can be used to cook food for a family and a community based cooking can also be designed so that a small village can utilize it. Smaller units directly uses solar power whereas community based will be of steam generated type. The only drawback is that it can only be utilized during day. It may be coupled with biogas based systems so that it can used anytime.

5. CHALLENGES AND SOLUTIONS.

There are many challenges to be faced when thinking of utilizing solar power for electricity and heating. Some of them are listed below [11].

5.1. Capital investment

Technical feasibility of the solar energy utilization is very much high in Bhutan due to the high availability of solar irradiation and government policies for adapting alternative energy resources. But when it comes to implementation, economic feasibility is of major importance as it is very much evident that for the installation of solar power the initial investment is very high. The payback period will be more than 5 years and hence capital for the project will need to be outsourced from other resources. Economic challenges can be met by raising money for the investment though campaigning, public private partnerships, carbon trading etc. Carbon trading has a huge potential in this aspect as Bhutan is already a carbon negative country by absorbing three times the carbon produced. Also foreign investments can also be called for from carbon positive countries.

5.2. Land requirement

As said earlier, Bhutan will have a forest cover of 60% all the time and hence the land availability is more or less the same as today. With rapid growth in urban population, the land required for housing and other settlements will be increasing. Therefore large scale solar installations cannot be possible. Also even if the land is possible, there will be a serious problem of shadowing due to the steep topography and forest cover. Space limitations are of serious concern but roof tops and other
building parts can be well utilized for thermal application as it does not have shadowing problems like Solar PV.

5.3. Grid connectivity
Bhutan’s population is so much diversified with high density rural areas and low density northern regions and hence meeting sustainable economic growth with no parity among these is a major concern. As far as energy distribution and transmission is concerned, due to the high mountain terrains and lesser transmission lines, decentralized energy generation and distribution is to be considered. An extensive expansion in the transmission lines is crucial for the linking of the domestic transmission lines and also for the export lines to India which seeks huge investments [7]. National transmission grid master plan 2020 will be helpful in limiting this challenge, which tends to connect the northern parts of the country to the main grids (as shown in figure A2.) [4].

5.4. Availability of skilled personnel and awareness.
Technology awareness is very much required for the better safer utilization. Else the entire initiative will be a failure as in the case happened in 1980s on the biogas program and it took 20 years for it to come back again. Bhutan is still much dependent on foreign expertise and personnel and hence personnel’s should be trained for installation and maintenance of the solar power plants and devices [8]. Human resource for implanting these projects can be taught and trained by well-established international experts in the field. This can help in international exposure to the personnel’s and can generate more employment opportunities. Also awareness can be given through schools colleges and NGOs for promoting alternative energy sources.

6. CONCLUSION
Bhutan currently generates 99% of its energy from hydropower by utilizing only 5% of its total potential. But net utilization cannot be possible due the countries policy to keep the forest cover more than 60% all the time and also due to environmental and economic issues. Also dependence on a single source of power is not advised as it may lead to power insecurity at some times. Bhutan has the alternative energy policy to generate 25MW power from solar, wind and biofuels combined, to use energy efficient devices and products, to use clean fuels for transportation and also to adopt sustainable practices in construction and manufacturing. This helps in creating diversity in energy sources without hindering the Country’s Gross National Happiness (GHI) policy. Bhutan has a good potential for solar energy which was less utilized till now as compared to hydro energy. Rooftops can be utilized for solar electricity generation and also technologies like solar heating, solar cooking and solar drying can be well utilized for reducing the utilization of fire wood for heating and cooking. For implementing these, there are many challenges like capital cost, manpower, poor grid connectivity, land availability etc. Government should come up with initiatives to utilize this untapped source of energy in order to facilitate a sustainable development in the country.

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REFERENCES


APPENDIX

Adapted from [4]

Figure A1. Bhutan’s annual direct normal solar radiation

Adapted from [4]

Figure A2. National transmission grid master plan 2020 for Bhutan