



Scope for feed-in tariff in a hydro-rich energy market—a case of Bhutan

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Abstract

To promote the use of renewable energy (RE), several types of RE policies have been implemented globally. Among these, feed-in tariff (FiT) is one of the most accepted mechanisms of pricing policy. However, choosing the best policy for a market with a high RE penetration is a challenge. A case of Bhutan is considered in this paper as the source of electrical energy is predominantly hydropower. Additionally, a generous subsidy is provided by the government to keep the electricity tariff to a minimum. Recently, there has been an increase in the advocacy and motivation for other forms of RE sources (RES) to supplement hydropower and increase energy security in Bhutan. Bhutan aims to achieve a total of 20 MW of non-hydro RES by 2025 as per the RE policy of Bhutan. However, Bhutan still does not have an RE pricing policy, and therefore, there is a need to institute a suitable pricing mechanism to accommodate the penetration of the planned non-hydro RES. This paper discusses the challenges in introducing FiT for non-hydro RES in an electricity market dominated by hydropower in Bhutan. Subsequently, recommendations are made in the wake of subsidised electricity tariff, which is the lowest in the region at 0.0171 USD/kWh for low voltage customers. FiTs for solar photovoltaic based on different categories of customers have been computed and proposed.

Keywords Deregulation · Renewable energy · Feed-in tariff · Electricity pricing · Electricity market

Introduction

Globally, there has been an increase in the use of renewable energy sources (RES) primarily to discourage the use of fossil-fuelled energy generation, reduce greenhouse gas emissions and increase energy security. Policy schemes such as feed-in tariff (FiT), net-metering and other mechanisms have been instituted to promote the use of RES. However, in regions where the share of RE is dominant, designing and implementing RE policy becomes a challenge. One such region is Bhutan, where the source of electricity is predominantly hydropower and a policy to provide incentives for the installation of RE is yet to be instituted.

Bhutan is blessed with a huge hydropower potential of 36,900 MW with annual production capacity of 154,000 GWh [1]. Chukha Hydropower Plant, the country's first hydropower plant (HP) was established in 1986–88. Since then, there has been a considerable progress in the

development of HPs in Bhutan. The total installed capacity of hydropower in Bhutan today stands at 2335 MW [1], which is 6.32% of the total potential. About 70% of the total generation is exported and sold to India [2], Bhutan's closest neighbour and ally because of which there has been a surge in the country's economy. The electricity exported to India topped 4,465 MU fetching Indian Rupees (Rs.) 10,080 million (~USD 136 million) in 2020, and the revenue from hydropower is approximately 7.5% of the country's gross domestic product (GDP) [2].

In addition, Bhutan had set up an ambitious target of providing 100% electricity coverage to all households by 2020, but this target was brought forward, to be achieved by the year 2013 [3]. In May 2008, Bhutan and India signed the *Protocol to the 2006 Agreement concerning Cooperation in the Field of Hydroelectric Power* and agreed to achieve a total generation of 10,000 MW by the year 2020 in Bhutan [4]. However, considering the current pace of development and complexities involved in the construction of HPs and the fact that excessive dependence on a single resource for electricity would imperil the country's energy security, the country has recently started identifying RES that would be most appropriate for Bhutan. Wind power and solar

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power are the front runners among others in Bhutan. The theoretical solar potential in Bhutan is estimated at 6 TW, while the restricted technical potential is estimated at 12 GW [5]. As per [5], the wind energy potential is estimated at around 760 MW, mostly in the northern region of Bhutan, with Wangduephodrang district in the north accounting for around 19% of the total potential. The two districts in southern Bhutan; Chukha has 12% and Dagana, 10% of the total wind power potential [5]. Other renewable technologies such as biomass and biogas are mainly limited to cooking purposes in rural areas. RE policy has not been implemented yet in Bhutan and there are no private generation companies (GenCos). As the country look towards diversifying the sources of energy in Bhutan, there is a need to institute an appropriate RE pricing scheme. Among the existing RE policies, FiT is considered the most effective and widely implemented RE policy in the world [6],[6]. This paper discusses the challenges in introducing FiT in Bhutan and subsequently proposes recommendations in the wake of subsidised electricity tariff and a non-liberalised market dominated by hydropower.

Methodology

Energy sector in Bhutan

The energy sector in Bhutan has been restructured to address the need of the changing market scenario and to keep pace with the global change. The restructuring of the energy sector in Bhutan has not been long. It was only in 2002, when

the energy sector, which was fully state-owned was restructured to derive maximum benefits for the country and the consumers.

Bhutan Power Corporation Limited (BPC), established on July 1, 2002, serves as the system operator for Bhutan and is responsible for both transmission and distribution of electricity in the country. In addition, BPC also looks after the Bhutan Power System Operator (BPSO), small/micro HPs and wind power plant comprised of two wind power generators of 2×300 kW in Rubessa, Wangduephodrang. Therefore, the role of BPC is comparatively unique from that of a conventional system operator elsewhere. Besides providing electricity services to the nation, BPC as one of the companies of Druk Holding and Investments (DHI) is also mandated to generate revenue for the company. Figure 1 shows the overall structure of energy sector in Bhutan. In general, the power and energy sector in Bhutan is comprised of only government entities and currently, there are no private GenCos, except as end-user consumers.

Renewable energy in Bhutan

Driven by the increasing domestic demand, risks due to reliance on a single source of electricity and the need to harness other forms of clean energy, the Ministry of Economic Affairs of Bhutan (MoEA) had come up with a draft RE policy in 2011, which was finalised and released as the ‘Alternative Renewable Energy Policy 2013 (AREP)’, the first edition of the renewable energy policy in Bhutan. Bhutan shall strive to generate 20 MW by 2025 through a mix

- **MoEA** = Ministry of Economic Affairs
- **DHPS** = Department of Hydropower System
- **DRE** = Department of Renewable Energy
- **DHMS** = Department of Hydromet Services
- **DoT** = Department of Trade
- **HPP** = Hydro Power Plants
- **MoF** = Ministry of Finance
- **DHI** = Druk Holdings & Investments
- **DGPC** = Druk Green Power Corporation Limited
- **BPC** = Bhutan Power Corporation Limited
- **RGoB** = Royal Government of Bhutan

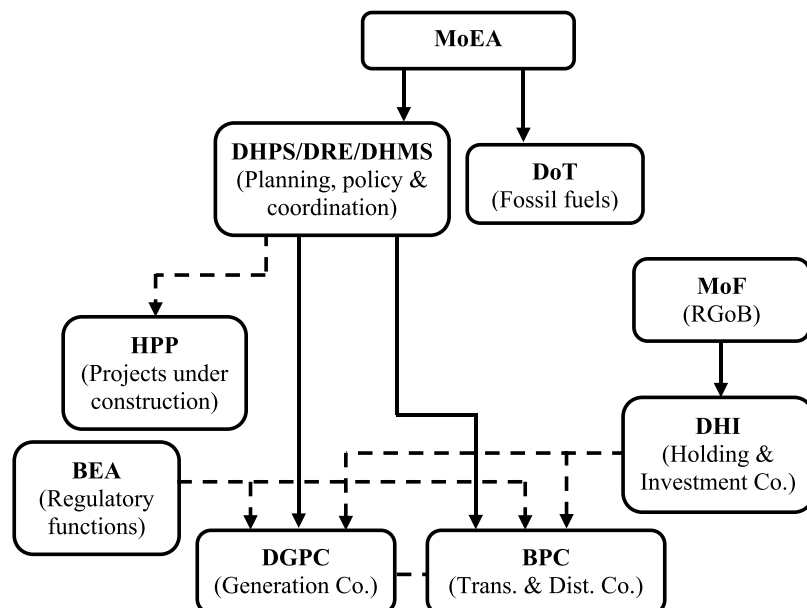


Fig. 1 Structure of energy sector in Bhutan



of renewable technologies such as solar power, wind power, biomass, and others [8]. However, the targets set in AREP [8] as shown in Table 1 are comparatively lower than what is available [5].

Although focus on small hydropower has been made in [8], no specific target has been set for small hydropower less than 25 MW.

In Bhutan, the development and implementation of wind power and solar photovoltaic (PV) and their integration into the national grid is prioritised over other non-hydro RES [9]. The current priorities are small hydropower, wind power and solar PV as they seem most appropriate and viable considering the rugged mountain terrains of Bhutan [8]. In a country where hydropower is the main source of electricity and that major portion of the country's economy depends on hydropower, penetration of other sources of renewable energy is seen as a challenge, primarily due to the overall costs and associated turnover. Keeping in view the challenges associated with hydropower generation, the threat to energy security due to reliance on a single source of electricity, and the increasing imports of fossil fuels, Bhutan has started diversification of its energy resources [8]. As per [9], major activities have been planned to promote RE and include the following types of RES:

- (i) Wind power
- (ii) Solar PV
- (iii) Biomass, and
- (iv) Small hydropower.

In 2014, two wind electric generators were installed in Rubessa, Wangduephodrang. The 2×300 kW wind power plant was established mainly to reduce the import of electricity during the lean period, increase sale during summer and diversify energy resources in the country. Although non-hydro RES for the generation of electricity (RES-E) has penetrated the market, BPC does not levy a separate tariff to its customers.

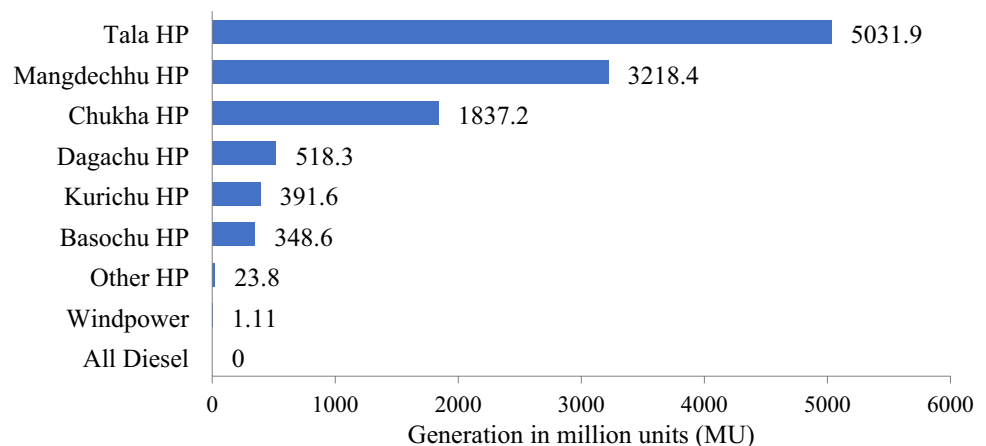
BPC is responsible for the transmission and distribution of electricity to residential, commercial, and industrial customers irrespective of the type of source of electricity. However, with the increase in the percentage of RE penetration, there will be a need to appropriately design and implement a pricing mechanism to suitably benefit investors as well as meet the objectives of the government. Additionally, the RE policy of Bhutan also indicates a FiT scheme to be introduced [8]. At the moment, non-hydro RES penetration has remained insignificant and therefore, the electricity pricing modality and the tariff thereof continue to remain unchanged. The electricity generation from various sources in 2020 is shown in Fig. 2. [10].

Electricity generation from non-hydro RES-E will grow and the share of these RES-E is expected to reach 20 MW by 2025. The DRE had planned to install three major renewable power plants: A 30 MW solar power plant at Shingkhar, Bumthang, a 17 MW solar power plant at Sephu, Wangduephodrang and a 23 MW wind power plant at Gaselo, Wangduephodrang [11]. The planned solar power plants will be the first of their kind and the largest solar power plants in the country. While the plan to install the 17 MW Solar PV plant in Sephu is in progress, the 30 MW solar PV plant in Shingkhar has been suspended due to community issues.

Table 1 Renewable energy scenarios proposed in Bhutan by 2025 [5, 8]

Source	Capacity by 2025 (MW)			
	AREP target	Low case	Base case	High case
Small Hydro	–	37.2	67.5	110
Wind	5	2.4	5.1	7.8
Solar PV	5	2	6.1	11.9
Biomass	5	0.6	1	8.1
Others	5	–	–	–
Total	20	42.2	79.7	137.8

Fig. 2 Electricity generation from various sources in 2020



Additionally, a utility scale 180 kW grid-tied ground mounted solar power plant was inaugurated on October 4, 2021, in Rubessa, Wangduephodrang as a pilot project. The solar power plant is expected to provide electricity to around 90 households in the locality through the grid. Therefore, FiT, or other pricing mechanisms will have to be carefully planned to suit the needs of the country in view of the increase in non-hydro RES-E.

Feed-in tariff

Feed-in tariff in general is a government driven policy to promote and support investments in renewable power generation. FiT scheme enables the RE GenCos, such as solar, wind or small hydropower to receive an incentive for electricity generation.

As per [7], there are two types of FiT models: (i) Market-dependent or Feed-in Premium (FiP) model and (ii) Market-independent or Fixed Price model, where the main distinction is the dependency on the actual electricity market price. While the market-dependent model is associated with an additional premium on top of the market price, the market-independent model offers a guaranteed minimum payment for every unit of electricity injected into the grid. FiTs facilitate long-term financial incentive to those who participate as GenCos and contribute electricity to the grid. Unlike the current system of unit-based pricing, the pricing is based on the conditions of the FiT contract with the utility company. A well-planned FiT can create a robust market for RE and encourage increased participation of RES-E. In addition to FiT, the following types of regulatory instruments in the promotion of RE are implemented:

- (i) Feed-in Premium
- (ii) Auction
- (iii) Quota
- (iv) Certificate system
- (v) Net-metering
- (vi) Mandate, and
- (vii) Registry

Fiscal incentives and other benefits such as grid access, access to finance and socio-economic benefits are also being implemented in the promotion of RE technologies. FiT schemes have been conducive to RE development since the early 2010's, however the focus has now shifted from FiTs to competitive tendering schemes such as auctions [12]. In [13], they have carried out an analysis to determine the effectiveness of the FiT policy and conclude that there are multiple avenues that can be leveraged to achieve a larger representation of RE. There is a preference for auctioning, net-metering and mini-grids as alternative mechanisms to

FiT policies. It is reported that the implementation of these options should be done effectively to avoid challenges faced with the FiT policy [13]. In Malaysia, successful utilisation of RES for electricity generation and the global implementation of FiT has encouraged the implementation of FiT. Although FiT can be conveniently implemented for biomass, biogas and solid waste energy, FiT has not attracted expected investment in solar and wind RES due to their requirement of higher FiTs [14]. In Taiwan, the government has adopted FiTs coupled with a bidding process to determine subsidised tariffs due to difficulties in setting tariff each year and because FiTs often cannot catch up with the market and technology-varying conditions [15]. Several nations have introduced technology-specific FiTs combined with net-metering scheme.

Although FiT is an effective RE policy, it is interesting to note that several countries have either revised or discontinued their FiT policy. In few cases, due to reduction in the solar PV costs, FiTs were replaced by combined policies and to prevent over-subsidisation in the markets [16]. More number of countries have opted auctions modality over FiTs as their renewable energy pricing policy [17]. The number of countries following FiT and Auction modality from the year 2014 to 2016 is shown in Fig. 3 [17]. As seen from the trend, by the end of 2016, more than 70 countries had adopted auctions as opposed to FiT. A substantial increase in the number of countries adopting auctions is noted as opposed to FiT, mostly due to their flexibility of design and because they can be made country specific.

Results and discussions

Feed-in tariff in Bhutan

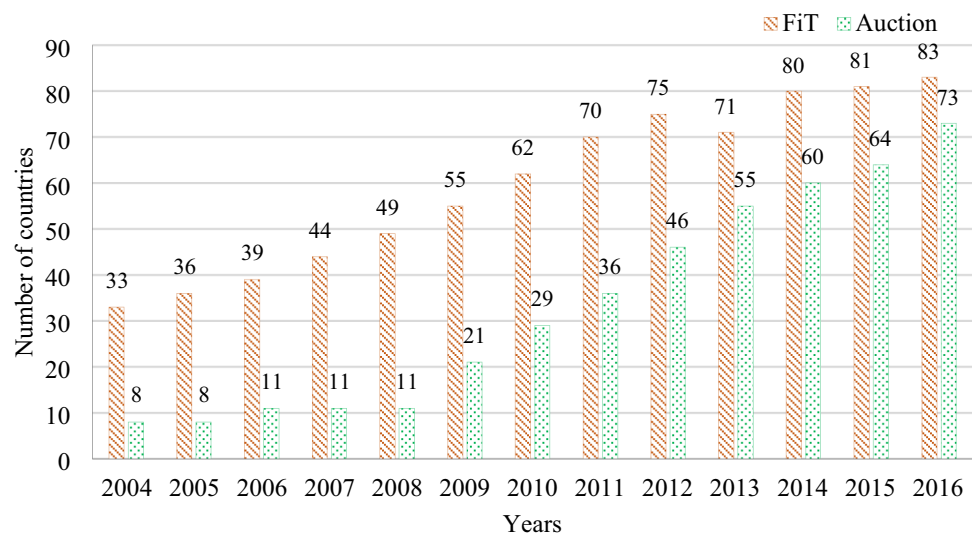
At the moment, there is a lack of FiT and other incentive schemes for RES in Bhutan. It would require a robust enabling policy environment for Bhutan to achieve a total of 20 MW of alternative RE generation by 2025 as planned. To enable a promising policy environment for alternate RE resources in Bhutan, the following are considered the highest priorities [18]:

- (i) formulation of renewable energy master plan to identify, assess, and forecast the resources,
- (ii) formulation of feed-in tariff framework, and
- (iii) preparation of implementation rules and guidelines of the alternative renewable energy policy.

With a feed-in policy in place, regulatory agencies such as the Bhutan Electricity Authority (BEA) and the DRE could initiate the development, implementation, and monitoring of the FiT programme. Further, the lack of private



Fig. 3 Number of countries adopting FiT and Auction [17]



GenCos in Bhutan has not conditioned the government to pursue such feed-in policies. Further, in a study conducted by [19], it has been opinioned that there is a barrier to promoting non-hydro RES due to the absence of a FiT policy in Bhutan. Based on the nature of the feed-in policy (feed-in tariff or feed-in premium), several types of incentives can be developed. As per [8], BEA shall design and develop the following:

- (i) feed-in tariff as per the principles contained in the policy, and
- (ii) norms related to grid connectivity/interfacing and load dispatch, etc.

Considering all circumstances, the current choice of RE pricing policy in Bhutan is FiT [8].

Electricity pricing in Bhutan

Bhutan's current electricity market structure is unique as all components of the power sector (generation, transmission, and distribution) operate under one entity, the DHI, which is the largest and only government-owned holding company in Bhutan. To encourage additional participants in the electricity market, the government will have to devise various strategies, and this will necessitate a major reform in the electricity market structure. Further, Bhutan currently exports electricity to only a single customer, which is India. To benefit more customers, enhance cross-border energy trade, and increase energy security, Bhutan will have to continue exploring opportunities to export energy to other neighbouring countries such as Bangladesh, Nepal, and Myanmar. Additionally, Bhutan's dependency on energy export from hydropower,

a single source of energy comes with a challenge to its energy security.

The electricity pricing in general is determined by the generation cost, transmission cost, distribution cost, interests and depreciation of assets, salaries of employees, and profit. These costs further depend on numerous factors, such as connected load, load conditions, demand factor, load factor, diversity factor, plant capacity factor, etc., which makes the fixation of tariff in an electricity market rigorous. BPC as the state-owned system operator, levies electricity costs on customers and these prices are regulated by BEA. The past and current end-user tariff is shown in Table 2 [20, 21].

Over the years, there has been a steady rise in the domestic electricity tariff based on numerous factors. Although small, the rise has been steady, and an extrapolation of the tariff gives an average annual increase of 1.8%. The variation in the tariff for low voltage (LV) customers from 2017 to 2022 (projected) is shown in Fig. 4. It can be concluded that the rise over the years is held minimum due to subsidies provided by the government.

The electricity prices in Bhutan are determined by the BEA and fixed in accordance with the *Tariff Determination Regulation 2016* of Bhutan. The regulation provides for the electricity prices in accordance with the *Electricity Act of Bhutan 2001* and the *Domestic Electricity Tariff Policy 2016*. These prices apply to all licensees including the following [22]:

- (i) Generation licensee.
- (ii) Transmission licensee.
- (iii) Distribution and supply licensee.
- (iv) System operation licensee.

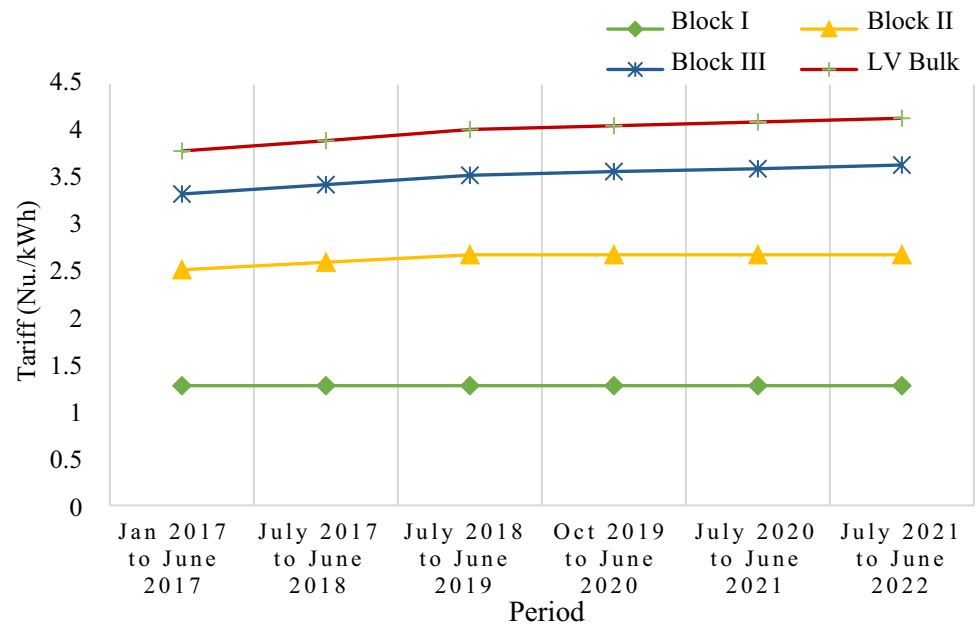


Table 2 Electricity tariff in Bhutan

Tariff Structure	Unit**	1/1/2017 – 30/6/2017	1/7/2017 – 30/6/2018	1/7/2018 – 30/6/2019	1/10/2019 – 30/6/2020	1/7/2020 – 30/6/2021	1/7/2021 – 30/6/2022
<i>Low Voltage (LV)</i>							
LV Block I (Rural) 0–100 kWh	Nu./kWh	0	0	0	0	0	0
LV Block I (Highlanders) 0–200 kWh	Nu./kWh	–	–	–	0	0	0
LV Block I (Others) 0–100 kWh	Nu./kWh	1.28	1.28	1.28	1.28	1.28	1.28
LV Block II (All) 101–500 kWh*	Nu./kWh	2.52	2.60	2.68	2.68	2.68	2.68
LV Block III (All) > 500 kWh*	Nu./kWh	3.33	3.43	3.53	3.57	3.60	3.64
LV Bulk	Nu./kWh	3.79	3.90	4.02	4.06	4.10	4.14
<i>Medium Voltage (MV)</i>							
Energy Charge	Nu./kWh	2.00	2.07	2.16	2.24	2.45	2.65
Demand Charge	Nu./kWh	250	275	300	325	325	325
<i>High Voltage (HV)</i>							
Energy Charge	Nu./kWh	1.59	1.59	1.59	1.50	1.50	1.50
Demand Charge	Nu./kVA/Month	262	262	262	292	292	292
Wheeling	Nu./kWh	0.195	0.195	0.195	0.27	0.27	0.27

*For 2017–2018, it is only up to 300 kWh instead of 500 kWh

**Conversion rate as of Feb 2022 is approximately, USD 1 = Nu. 74.8

Fig. 4 Increase in the LV tariff from 2017 to 2022

Further, all electricity tariffs for the sale of electricity must comply with the terms of the regulation, except for the following [22]:

- (i) import of electricity from other countries,
- (ii) export of electricity to other countries, and
- (iii) sale of electricity from generators under *Power Purchase Agreements* (PPA).



The existing low tariff has enabled significant success in the overall socio-economic growth in Bhutan. There has also been an increase in the small, medium, and large energy intensive industries due to the access to reliable and affordable electricity. This is evident from the government's initiative of establishing various special economic zones in the country [7], where citizens are encouraged to establish various industries through government-led schemes. However, hydropower projects have their own share of shortfalls. Environmentalists continue to question whether hydropower projects in Bhutan can really be considered as 'clean' sources of electricity.

In addition, there have been bottlenecks in the construction of hydropower projects, such as the construction of the 1200 MW Punatshangchhu-I which began in 2008 and was scheduled to be completed in 2016, but the completion date has been further delayed. The project has been facing serious challenges due to geological conditions in the construction of the dam. The delay in the completion of the project has caused serious financial and resource implications to the government.

Considering all circumstances, the government has now started embracing other forms of RE. Several projects are in the pipeline and constructions will begin soon. A pricing modality needs to be developed to encourage the establishment of non-hydro RES-E projects in the country. As per [8], all RE projects for electricity generation except for mini, micro, and small hydropower are to be developed under Build, Own, Operate (BOO) model.

Electricity tariff computation

The electricity tariff payable to BPC is derived as follows [23]:

$$E_T = CoS - S_R (\text{USD/kWh}) \quad (1)$$

where $CoS = G_C + N_C$.

The cost of supply CoS is the sum of generation cost G_C from DGPC and network cost N_C (transmission and distribution) from BPC. CoS includes the allowances for operation and maintenance costs, depreciation, return on fixed assets, i.e., including an allowance for company taxation, cost of working capital and any regulatory fees, duties, or levies that the licensee is liable to pay.

The network cost N_C , includes the operation and maintenance costs, depreciation, return on fixed assets i.e., including an allowance for company taxation, cost of working capital and any regulatory fees, duties, or levies that the licensee is liable to pay, cost of losses to transmit, distribute and supply electricity to the customers. S_R is the subsidy granted by the royal government of Bhutan (RGoB) to BPC to keep the MV and LV customer tariffs lower than the CoS .

The end-user tariff for LV, MV and HV works out as shown in Table 3 for the tariff sample of 2017 [23]. From the table, we see that the unit price of LV for all levels of block is Nu. 5.81 (USD 0.0776). The subsidy provided by the government ranges from 0 to 5.81 Nu./kWh (0 to 0.0776 USD/kWh), based on the customer type and consumption. For the LV customers, it ranges from 1.91 to 5.81 Nu./kWh (0.0255

Table 3 Computation of end-user tariff [23]

Customer group	Generation cost, DGPC (Nu/kWh) G_C	Network cost, BPC (Nu/kWh) N_C	Total COS (Nu/kWh) CoS	Subsidy (Nu/kWh) S_R	Tariff (Nu.) E_T
<i>LV Consumers (230/415 V)</i>					
Block I (Rural Domestic) ≤ 100 kWh				5.81	0.00/kWh
Block I (Others) ≤ 100 kWh				4.53	1.28/kWh
Block II ≥ 101 kWh to ≤ 300 kWh	1.59	4.22	5.81	3.21	2.60/kWh
Block III ≥ 301 kWh				2.38	3.43/kWh
LV Bulk				1.91	3.90/kWh
<i>MV Consumers (6.6/11/33 kV)</i>					
Demand charge	1.59	3.79	5.38	1.53	275/kVA/month
Energy charge					2.07/kWh
<i>HV Consumers (66 kV and above)</i>					
Demand charge	1.59	0.64	2.23	0	262/kVA/month
Energy charge				0	1.59/kWh



to 0.0776 USD/kWh), which works out to a minimum of 32.87% to a maximum of 100% for LV customers. Likewise, subsidy is also provided to MV customers. Therefore, it is evident from Table 3 that the government provides electricity subsidy based on different category of customers, mainly supporting those in rural areas.

In Bhutan, all generation plants fully owned by the RGoB must provide 15% of the annual generation as royalty energy to the government free of charge [24]. This enables the government to grant significant subsidies so that the domestic tariff is kept at minimum. To ascertain the impact of the subsidy provided by the government which eventually benefits the end-user customers in Bhutan, electricity pricing in the South Asian region is compared.

Table 4 gives a comparison of the average electricity pricing across South Asian countries and Fig. 5 compares the average electricity price for household customers as of

October 2015 [24]. From the comparisons, it is evident that Bhutan has the lowest unit price for household customers among the South Asian countries, while Sri Lanka has the highest unit price with a monthly consumption of 600 kWh. The comparison also indicates that the average unit prices of household customers as well as that for commercial and industrial customers are the lowest in Bhutan. Unfortunately, these lead to bigger challenges for those wishing to venture into non-hydro RES-E in Bhutan. Consequently, designing a renewable pricing policy becomes a bigger challenge.

Pricing mechanism

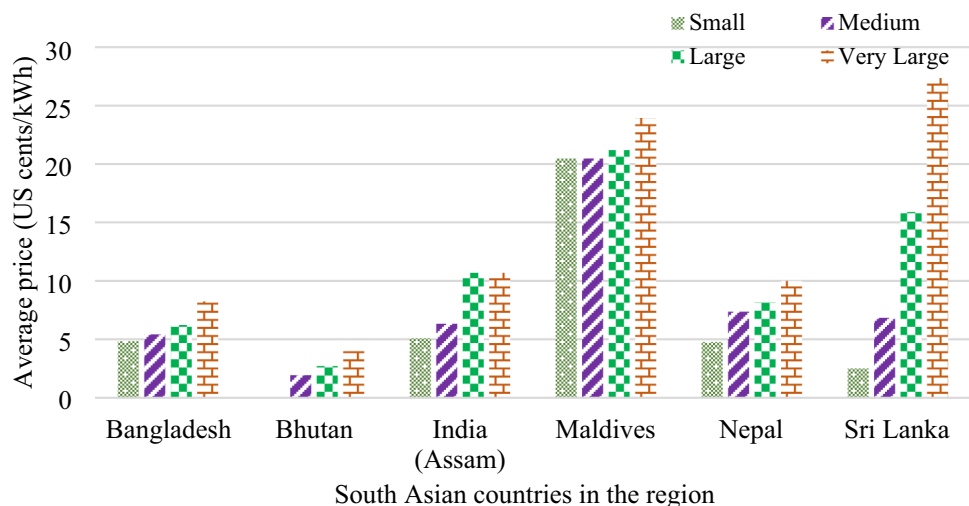
In the context of the current discussion, the following two objectives among others given in [25] are relevant and important:

Table 4 Average electricity price in South Asian countries in US cents/kWh at unity power factor [24]

Customer category	Class	Electricity use (kWh/month)	Max. demand (kW)	Bangladesh	Bhutan	India (Assam)	Maldives	Nepal	Sri Lanka
Household	Small	30	–	4.82	0.00	5.09	20.47	4.76	2.50
	Medium	90	–	5.42	1.92	6.32	20.47	7.35	6.84
	Large	180	–	6.21	2.70	10.68	21.18	8.16	15.89
	Very Large	600	–	8.24	3.97	10.68	23.93	9.99	27.35
Commercial	Small	1000	–	12.76	5.53	12.15	30.99	9.82	15.52
	Medium	58,000	180	9.97	4.74	12.18	34.05	9.46	17.99
	Large	600,000	1500	9.83	3.62	12.18	34.11	9.46	16.90
Industrial	Small	5000	–	10.07	5.53	8.05	33.49	7.83	8.71
	Medium	65,000	180	9.97	4.63	10.51	34.06	7.39	11.30
	Large	270,000	600	9.84	3.54	11.48	34.10	6.65	10.86
	Very Large	1,050,000	2250	9.83	3.52	11.48	34.11	6.31	10.85

USD conversion rate as of Oct 31, 2015: USD 1.00 = Nu. 65.40

Fig. 5 Comparison of average electricity price for household customers in South Asian countries



- (i) to promote a safe and reliable supply of electricity throughout the country (leading to increased energy security), and
- (ii) to promote development of renewable energy resources.

It has been established that a well-designed FiT scheme offer multiple benefits to all stakeholders as the tariff can be both cost-effective and cost-efficient. However, in a RE-rich market with subsidised electricity prices, designing an effective FiT scheme will demand careful analysis and planning. Additionally, once these subsidies are withdrawn, private players may see promising prospects while the general population may end up paying an increased tariff. Further, the introduction of a FiT without careful analysis may drive the existing electricity tariff to rise considerably. This may put economic pressure on the general mass, while only a handful of private participants operating as GenCos may benefit financially. Currently, there is a lack of standard for private sectors to participate in RE generation and the rate of subsidy provided by the government makes it difficult for private individuals and business entities to participate in RE business in Bhutan. This also poses one of the biggest challenges in implementing a FiT policy, aggravated by the lack of adequate grid infrastructure to support such schemes. As the overall design of FiT scheme is also influenced by the market design and the availability of resources, the FiT scheme may not allow an effective market integration of RE. FiT in a non-liberalised, monopolised electricity market is not encouraging, perhaps only when there are adequate number of private participations. Further, as recommended by [26], FiT policies must be kept transparent, less complex and consider local conditions such as RES-E potential.

This work proposes FiT scheme taking into consideration the following factors:

- (i) Energy is almost entirely hydropower based.
- (ii) Subsidy is provided by the government that results in a lower tariff for end-users.
- (iii) Lack of private participation and knowledge of the benefits of investing in RES.

Globally, favourable policies such as FiTs, renewable portfolio standards, tenders, and tax incentives have contributed to the growth in RES-E although these were aimed at overcoming initial barrier to the development of RES-E when compared to the costs related to conventional sources of generation [27]. Further, increase in the RES-E penetration could impact electricity prices and consequently, the revenue opportunities for RES-E plants. It will be a challenge to maintain rapid RES-E supply growth against decreasing costs and technical and market operation

challenges associated with high penetration levels of RES-E [27]. In the case of Bhutan, where such initiatives are yet to take place, modifications in the FiTs will have to be made to address the required needs of the investors and the government in future.

The levelised cost of energy (LCOE), which serves as a cost indicator for various RE technologies has an influence on the design of pricing strategies for RES-E. LCOE will continue to decrease for solar PV and wind power, while for hydropower, it will increase, primarily due to inflation and labour cost [28–30]. Therefore, it is more viable to opt for non-hydro RES-E, especially solar PV.

In terms of evolution in the incentive schemes, [31] gives a historical perspective of the introduction of the Grid Feed-in Law in 1990 in Germany, which was replaced by the Renewable Energy Sources Act (EEG 2000) based FiT scheme in 2000. They further give the underlying reasons for moving from fixed FiT scheme to auctions since 2016, although exceptions have been made for smaller-sized installations of less than 750 kW where these installations continue to receive FiTs. In Germany, solar PV investors between 300 to 750 kW are provided with the following two options [32]:

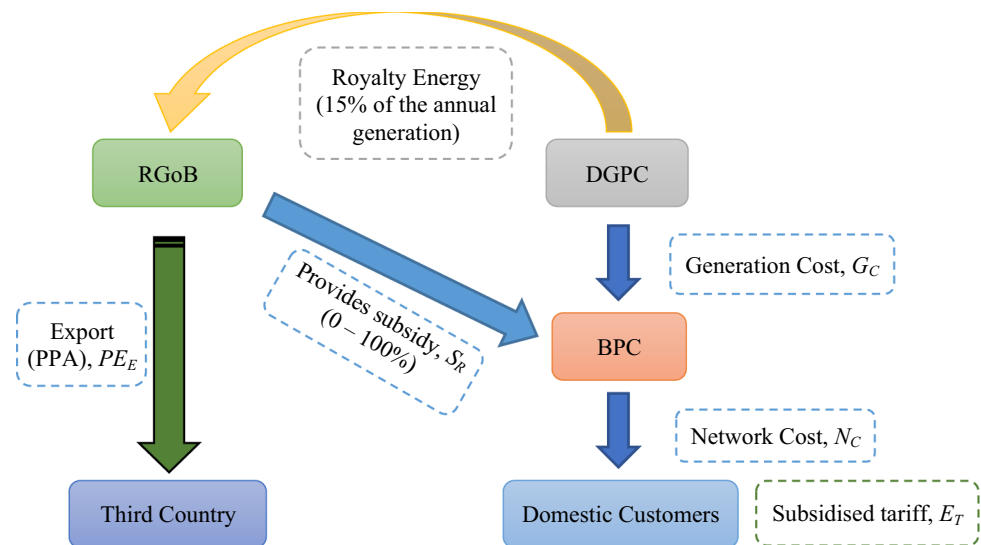
- (i) Tender scheme for utility scale PV without self-consumption, and
- (ii) FiT, halved compared to smaller systems, allowing self-consumption is allowed.

For the existing market in Bhutan, subsidy provided by the government is based on ‘blocks’ of consumers. Currently, there are no grid regulations and no incentives for private participants. Therefore, to determine FiT for effective implementation, the following components of the FiT pricing as per the traditional definition of FiT will need to be considered:

- (i) Generation tariff – where the generator is paid for every kWh of electricity generated.
- (ii) Export tariff – where the generator is paid for every kWh injected into the grid.
- (iii) Rate of own usage – rate at which deficit energy is bought from the grid.

The existing pricing modality in Bhutan is shown in Fig. 6. Customers pay subsidised electricity tariff E_T and the rate at which power is exported to the third country PE_E is based on the power purchase agreement (PPA) signed with the third country. In absence of fossil-fuelled energy sources in the country, and the existence of a well-established energy sector with hydropower as the primary source, support for other forms of RE is not well pronounced. Further, as per the energy policy, there is a cap of 25 MW of total generation



Fig. 6 Existing pricing mechanism

from non-hydro RES-E by 2025. Therefore, based on the prioritised non-hydro RES-E in [8], a suitable FiT scheme needs to be designed for solar power and wind power.

While designing the scheme, it must be noted that the non-hydro RES-E investors do not suffer any losses. FiT is based on several economic and cost aspects, including LCOE for various RE technologies. The LCOE of residential PV systems in 2019 was between 0.063 USD/kWh and 0.265 USD/kWh [33]. India and China had the lowest country/market average LCOE for commercial PV up to 500 kW. Further, for onshore wind, the global weighted-average LCOE in 2019 was 0.053 USD/kWh. The most competitive weighted average LCOE below 0.050 USD/kWh was observed in India and China and the LCOE is expected to further reduce [33].

While information on LCOE for different RE technologies in Bhutan would be ideal for this study, reliable information and data is not available. Therefore, data from India, 0.063 USD/kWh is used instead, owing to the proximity, and having a similar market scenario. The average residential load is assumed to be 5 kW.

To assess LCOE since it has an influence on the pricing strategy, LCOE in select countries have been reviewed. Table 5 shows the LCOE for residential solar PV and onshore wind power in various countries. Further, the lifetime of solar PV is between 20 and 35 years [33]. Therefore, it is safe to assume the project lifetime n of solar PV to be 25 years in the current work. For wind power plants, [34] has concluded that the useful life of wind power plant has changed over time and today it stands at an average of 30 years.

An investor or a homeowner will only opt for non-hydro RES-E if it offers an undue advantage over that from the grid. If TC_{RES-E} is the total cost in its lifetime n with electricity from non-hydro RES-E and TC_{grid} is the total earnings in its lifetime n with energy into the grid, the following preliminary condition for an investor to invest in RES-E must be satisfied:

$$TC_{RES-E} < TC_{grid} \quad (2)$$

The total costs TC_{RES-E} and TC_{grid} are given by,

$$TC_{RES-E} = nE_g LCOE \quad (3)$$

$$TC_{grid} = nmE_i E_T (1 + r)^{n-1} \quad (4)$$

where E_g is the total energy generation in n number of years and m is the number of months in a year, E_i is the kWh injected into the grid, and E_T is the retail LV tariff with an annual increase r at 1.8% per year as indicated in Fig. 4. The simplest forms of determining the total costs are considered in Eq. (3) and it does not account for taxes, discount rates and other associated costs pertaining to Bhutan.

Results

Considering the current market scenario, it is proposed that the FiT is pegged with the block-wise subsidy to enable each category of customer to make net savings for injecting equivalent kWh into the grid. FiT is computed based on the maximum

Table 5 LCOE (USD/kWh) for residential solar PV & onshore wind power in various countries in 2019 [33]

RES-E		India	Japan	China	USA	Germany
Wind	USD/ kWh	0.049	0.113	0.047	0.046	0.068
PV		0.063	0.163	0.067	0.171	0.138



subsidy S_{R_max} and electricity tariff E_T for each category of LV customer. As a sample, FiT for LV Block-I (others) FiT_{LVB1_o} is fixed as given below:

$$FiT_{LVB1_o} = S_{R_max} - E_{T_LVB1_0} \quad (5)$$

$FiT_{LVB1_o} = 5.81 - 1.28 = 4.53$ Nu./kWh = 0.0606 USD/kWh, and LCOE is 0.063 USD/kWh. The proposed FiTs with net savings that each category of customer/investor can make, considering a plant life of 25 years with 1.8% annual increase in the retail tariff have been computed and shown in Table 6.

The preliminary condition for an investor to opt for non-hydro RES-E based on Eq. (2) is shown in Fig. 7.

The following conclusions can be drawn from Table 6 and Fig. 7:

- (i) The proposed FiT will not be effective for LV customers in rural, highland areas, Block I (others) and Block II (all) as they receive subsidies of 0.0777, 0.0777, 0.0606 and 0.0418 USD/kWh respectively.
- (ii) Only LV Block III and LV Bulk customers with net injection of 500 and 1000 kWh per month respectively will be able to make savings if they opt for RES-E (solar PV). The proposed FiTs are 0.0290 and 0.0223 USD/kWh respectively, when export tariff component is pegged with the subsidy.

- (iii) To encourage maximum number of participants in the RE market, a generation tariff pegged with the lowest tariff (0.0171 USD/kWh) can also be provided in addition to the export tariff. This will result in a higher net savings for all categories of LV customers, including rural and highlanders.

Further, FiTs for different countries in the region and other areas where it has gained significant success are shown in Table 7 for the purpose of drawing comparison with the proposed FiT.

For the purpose of drawing comparison between the proposed FiT and the FiTs given in Table 7, the lowest values of FiTs in these respective countries are considered. The comparative analysis is drawn and shown in Fig. 8. From the comparative analysis, it can be concluded that the proposed FiT in Bhutan remains the lowest for all categories of customers, as it is pegged with the rate of subsidy provided by the government. This will not be encouraging for the private investors who wish to participate in FiT scheme in Bhutan, and therefore, a more rigorous scheme will have to be instituted to encourage private investors.

To encourage private participants to invest in non-hydro RES-E in a country with high ratio of RE (hydropower) and to achieve reasonable return on investment, the following recommendations are made:

Table 6 Comparison of costs and the proposed FiT

Category of Customer	kWh injected into grid/ month, E_i	Retail electricity tariff, E_T	Proposed FiT (USD/kWh)	Total earnings from grid, TC_{grid} (USD)	Total cost for RES-E, TC_{RES-E} (USD)	Net savings (USD/kWh)
LV Block I (Rural)	100	0.0000	0.0777	0	1890	-1890
LV Block I (Highlanders)	200	0.0000	0.0777	0	3780	-3780
LV Block I (Others)	100	0.0171	0.0606	788	1890	-1102
LV Block II (All)	500	0.0358	0.0418	8247	9450	-1203
LV Block III* (All)	1000	0.0487	0.0290	22,401	18,900	3501
LV Bulk*	5000	0.0553	0.0223	127,390	94,500	32,890

*The upper limits have been suitably assumed for the purpose of the study

Fig. 7 Condition for investors to opt for RES-E

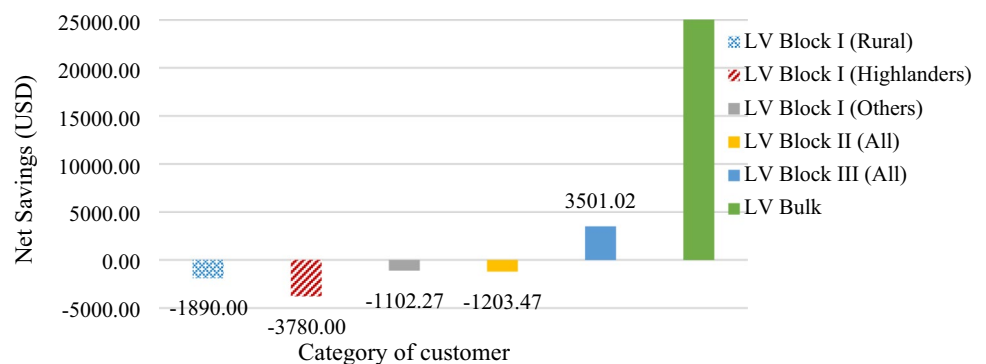


Table 7 FiTs (USD/kWh) in select countries for solar PV

India ^a	Japan ^b	China ^c	USA ^d	Germany ^e
~0.0405/kWh (1–5 MW)	~0.19/kWh (< 10 kW) ~0.12/kWh (10–50 kW)~0.11/kWh (50 to 250 kW) Tender > 250 kW	~0.0757 (region I) ~0.0908 (region II)~0.1059 (region III)	~0.1450 (30–500 kW) ~0.1300 (> 500 kW–3 MW)~0.1350 (> 3 MW)	~0.1220 (0–10 kW) ~0.1187 (10–40 kW)~0.1061 (40–100 kW)

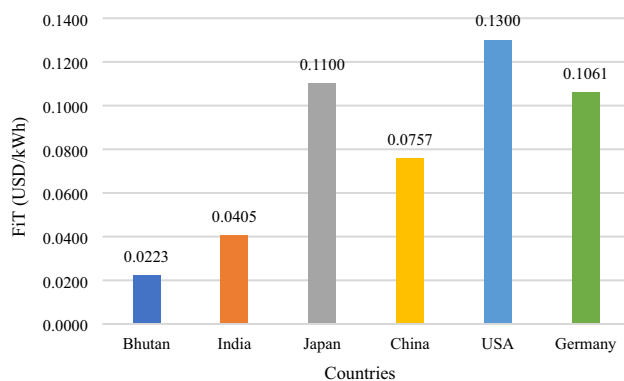
^aBased on [35] since it is the closest Indian state to Bhutan. Although competitive bidding is largely followed, the proposed FiT for 1 MW to 5 MW solar PV in 2021 was 3 Rs./kWh (0.0405 USD/kWh)[35]

^bProvisional solar PV FiTs for the fiscal year April 2020–March 2021 in Japan based on the Ministry of Economy, Trade and Industry (METI) [36]

^cFiT is based on large PV projects in three different regions in China [37]

^dFit for Los Angeles Department of Water & Power [38]

^eFiT in Germany [39]

**Fig. 8** Proposed FiT and FiTs in countries where it has been successfully implemented

- (i) For a system with block rate tariff, FiTs can be fixed based on the ‘blocks’ of kWh injected into the grid.
- (ii) Export tariff component of FiT can be pegged with the block rate tariff. LV customers will continue to draw benefits for their investment in non-hydro RES-E. Any sale of electricity after n years can be considered as ‘profit.’
- (iii) The generation tariff (FiT) can be pegged to the lowest subsidy rate. However, for the government to make marginal profit, the FiT remains lower or equal to the power export tariff (PE_E) based on the power purchase agreement, which may also include

framework for future bilateral cooperation in the field of energy between two nations.

- (iv) In place of ‘generation tariff,’ a tax credit can also be provided. As the percentage of non-hydro RES-E installation is going to be minimal due to the 25 MW cap on the installation of RES-E, this will not have any major financial constraints on the government. This strategy will encourage a greater number of participants.

The above analysis pertains to a rooftop solar PV, however, LCOE is technology-based and to make the proposal generic, pricing modality is proposed as shown in Table 8 for both wind and solar PV for a period of 25 years.

It must be noted that the retail tariff as well as the power export tariff keeps varying based on the market scenario and PPA, respectively. These variations must be taken into consideration while designing FiT so that the government nor the investor incurs loss. Although many RE-matured countries like United Kingdom and Germany are moving towards tendering scheme, for Bhutan, where there is lack of i) deregulated market ii) RE pricing modality, and iii) private participants, the pricing modality can be initiated with FiT scheme as proposed. With experience and increase in the number of participants, the following alternatives as shown in Table 9 can be proposed in place of FiT.

Table 8 Proposal for FiT scheme

Option	FiT	Benefit to the investor/generator	Benefit to the government
A	Generation tariff+Export tariff	Yes	Yes
B	Export tariff	Yes, but only to higher category of customers	Yes, more than Option A



Table 9 Alternatives to FiT scheme

1. Net-metering	There is no time-bound obligation or project time-period Additional design complications, such as those related to block rate tariff, project cost, LCOE will be minimised Allows investors to sell or use the units generated at any time without a specific contract
2. Auction	As the bid is evaluated by the government, it offers flexibility to make appropriate decisions Creates a competitive electricity market

Limitations and future work

The proposed schemes are based on a simplified method where assumptions are made on the LCOE of the two variable renewable energy (VRE) sources due to lack of data specific to Bhutan. Recommendations made in this paper would serve as a guideline for decision making, planning, and instituting a more robust system to introduce RE policy for non-hydro RES-E. As it would be a challenge to introduce an RE policy in Bhutan primarily due to the source of electricity being hydropower and generous subsidies provided by the government, it would necessitate the cooperation of all players: MoEA, BEA and DHI (BPC & DGPC) to work on a suitable RE policy. One of the immediate research works would be to determine LCOE for various RE technologies in Bhutan, in particular wind power and solar PV. Thereafter, we draw comparisons on different RE policies suitable for Bhutan's unique energy market on the basis of LCOE and subsidies provided by the government.

Conclusion

In a market with high share of RE, promotion and investment in additional RES-E is seen as a challenge. With the increase in the share of RE installations globally, several countries have started moving away from the traditional FiT scheme into tendering and other revised schemes. In the case of Bhutan, it is a challenge to promote and invest in non-hydro RES-E since the electricity tariff is the lowest in the South Asian region. However, apart from the financial aspects, there is a need to consider energy security and related challenges, such as dependency on a single source of energy in the country. Therefore, as Bhutan gradually begins diversifying its energy resources, suitable RE policy will need to be instituted.

Two RE technologies, solar power and wind power are considered in this paper. FiT for solar power has been computed and proposed for different blocks of customers. The analysis indicates that LV Block I customers would not benefit from the FiT scheme as they receive subsidies ranging from 0.0418 to 0.0777 USD/kWh/month. Only two categories of customers, LV Block III and LV Bulk, are able to make savings if they opt for the FiT scheme of 0.0290

and 0.0223 USD/kWh respectively. Further, two favourable alternatives, (i) net-metering and (ii) auction have been proposed. However, these recommendations are subject to change based on the market scenario and the government policies. A more robust RE policy will need to be instituted to benefit all players.

Data availability All data generated or analysed during this study are included in this published article.

Declarations

Conflict of interest The author has no conflict of interest to declare.

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