



An Analysis of Growth and Stability of Solar Energy and Small Hydro Power Installation Capacity in Northeast India

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Abstract

Non-renewable energy sources are depleting fast. These non-renewable sources are also contributing in global warming and climate change. Hence, it is necessary to use the sources of renewable clean and abundant energy sources. Among various types of renewable energy sources, solar power and small hydro power are the two most important energy sources available in northeast India. Arunachal Pradesh has one of the highest small hydro power potential. Among all the states of northeast India, only Manipur has a solar policy. Despite having very high potential of these two sources, all the states are exploiting very insignificant proportion of these two clean energy potentials. Moreover, high instability is also observed in the use of these two potentials. On the basis of the findings, the study suggests greater efforts on the part of state governments and more spending on R&D.

Keywords: *Renewable Energy, Solar Power, Small Hydro Power, North East India*

1. Introduction

Energy is the driving force of any economy. Unlike fossil fuels, renewable energy is a more sustainable energy source which can immensely contribute to economic growth (Hieu and Mai, 2023, Obani, et al., 2024). As a country experiences rapid economic development, its focus shifts from the use of non-renewable energy sources to renewable energy sources. Renewable energy consumption is high for countries with higher GDP compared to lower ones (Ntanos *et al.*, 2018). Empirical studies showed positive influence of economic growth and renewable energy and a bi-directional causal relationship between energy consumption and economic growth (Belke *et al.*, 2011; Zhang 2011; Das *et al.*, 2012; Dantama *et al.*, 2012; Asiudu *et al.*, 2021). GDP per capita influenced energy consumption in short run and decline in GDP due to energy consumption in long run south Asian nations during 1971-2006 (Noor and Siddiqui 2010). Long run positive relationship is found between economic growth and the use of renewable energy in several studies (Madson and Hansen 2019; Kasperowicz *et al.*, 2020; Li *et al.*, 2021; Topcu and Dogan 2022; Gupta and Guha 2024; Bhavsar *et al.*, 2025).

There are several sources of renewable energy, viz., small hydro power, biomass power, power generated from waste to energy, solar power and large hydro power. If we consider northeast India, this region has a lot of potential in terms of renewable energy especially solar and small hydro power. The topography has blessed this region a hydro power potential of 66000 MW, which is approximately 40% of the national potential (Saikia, *et al.*, 2023). Arunachal Pradesh has the 3rd highest estimated potential of small hydro power among all states of India (www.pib.gov.in). Assam is leading with rooftops and village level mini grids. Meghalaya and Tripura are experiencing urban rooftop boom. The community owned and operated solar micro grids are providing reliable power in Arunachal Pradesh and Nagaland. Mizoram and Manipur are using solar irrigation pumps to enhance crop yields without negative environmental effects. Moreover, Manipur used to face acute power shortage. By the introduction of solar heaters with a capacity of around 100 liters per day has helped to cope with power shortage. In 2012, Tripura has provided solar energy to almost 700 hamlets and 50 villages, thereby benefitting more than 30000 families.

The estimated potential of all the sources of renewable energy in northeast India is 128962.49 MW. Out of which, only 4834.58 MW has been installed (www.pib.gov.in). Despite having huge potential for renewable energy, all the states of northeast are power deficient states. Among all these sources, wind power has not been developed in the northeastern states of India at all despite having a potential of 300 to 500 MW at even the low hub heights of 50 and 80 meters respectively (cdn.cseindia.org). Small hydro power constitutes 98% of installed renewable energy in northeast region (cdn.cseindia.org). It does not have the problems like displacement of people, submergence of land in catchment area, ecosystem damage, risk of dam malfunction like large hydropower projects and exempted from forest, free from public sitting, economical, have low gestation period, and are idle for powering villages and isolated areas (Doso and Gao, 2020). The solar power potential of northeast India is almost 62300 MW. Only Manipur has a solar policy. Among the northeastern states, the electricity sector is dominated by renewable energy sources like small and large hydro power. Meghalaya is the only state which has 70% of its electricity generation from large hydro power with no deficit or surplus in terms of availability and requirement of electricity (cdn.cseindia.org). All other states are heavily dependent on small hydro power generation. Other forms of renewable energy sources like biomass power, waste to energy are not developed in this region.

2. Objectives of the study

The paper intends to study the variance and stability in installed capacity of renewable energy sources in the states of India. Moreover, average installed capacity of renewable energy sources and their consistency in these states are also investigated.

3. Data and Methodology

3.1 Data

This study is based on secondary data. The major data source is Renewable Energy Statistics, different years and Handbook of Statistics on Indian Economy, different years published by Ministry of New and Renewable Energy, Govt of India and Reserve Bank of India respectively. The data is collected for the 17 years' time period 2007-08 to 2023-24 on the renewable energy installed capacity of the states of India.

3.2 Methodology

This section discusses the methodologies of investigating the mentioned objectives.

3.2.1 *Measurement of Instability*

We have used Cuddy-Della Valle (1978) index to measure stability in installation of solar power and small hydro power. The Cuddy-Della Valle index is defined as

$$I_x = CV^2$$

Where CV is the coefficient of variation and r^2 is the corrected or the adjusted coefficient of multiple determination of the trend function that best fits the series of data. If F test is significant at 5% level, the index is calculated by selecting the trend function (linear or log linear) having the highest r^2 . If $r^2 < 0$, then unadjusted R^2 is chosen.

Low instability will be there if the value of the index lies between 0-15. Instability will be medium if it ranges between 15-30 and if the value of the index is more than 30, then it shows high instability. This index is better than coefficient of variation. A rising trend shows high CV despite having small fluctuations in different years. Cuddy Della Valle index corrects this by removing the trend effect.

4. Results and Discussion

In this section, the estimated results of the study are discussed.

Table: 1 Annual growth rates of installed capacity of small hydro power (SHP) and solar power (SP) in all the states of northeast India

Year	Arunachal Pradesh		Assam		Manipur		Meghalaya		Mizoram		Nagaland		Sikkim		Tripura	
	SHP	SP	SHP	SP	SHP	SP	SHP	SP	SHP	SP	SHP	SP	SHP	SP	SHP	SP
2007-08	0	0	0	-	0	-	0	-	0.4	-	0	-	0.2	-	0	-
2008-09	0.36	0.5	0	-	0	-	0	-	0.5	-	0	-	0	-	0	-
2009-10	0.2	0	0	-	0	-	0	-	0.01	-	0	-	0.11	-	0	-
2010-11	0.1	0	0.2	-	0	-	0	-	-0.01	-	0	-	0	-	0	-
2011-12	0.01	0	0	-	0	-	0	-	0	-	0	-	0	-	0	-
2012-13	0.3	0	0	-	0	-	0	-	0	-	0.03	-	0	-	0	-
2013-14	0	0	0.1	-	0	-	0	-	0	-	0	-	0	-	0	-
2014-15	0.01	0	0	-	0	-	0	-	0	-	0.03	-	0	-	0	-
2015-16	0	8	0	-	0	-	0	-	0.1	0	0	-	0	-	0	0
2016-17	0	0	0	0.1	0	71.3	0		-0.1	0	0	-	0	-	0	0.02
2017-18	0.02	18.9	0	-0.02	0	-0.9	0	5	0	1	0	1	0	-	0	0
2018-19	0	0	0	0.8	0	56.3	0	-0.7	0	0	0	0	0	-1	0	0
2019-20	0	0	0	0.8	0	0.5	0.1	5	0	1.5	0	0	0	-	0	0
2020-21	0.22	0.04	0	0.04	0	0.2	0	0	0	2.04	0	0	0	6	0	0.8
2021-22	0	0	0	2.4	0	0.9	0	0	0.2	0.01	0.1	0	0.06	0	0	0.6
2022-23	0.02	1.1	0	0.1	0	0.1	0.7	33.6	0	17.3	0	2.04	0	6	0	0.2
2023-24	0	0.01	0	0.1	0	71.3	0	0.02	0.4	0.1	0	0.04	0.2	0.5	0	0.05

*Adapted from secondary data

Table: 1 shows that both SHP Installation and SP installation growth rates were very negligible during the entire study period. Before 2015-16, almost all the northeastern states had no installation of solar power. Highest growth rate in SP installation was found in 2017-18 in Arunachal Pradesh, while the same year showed negative growth in SP installation in Assam. The SHP Installation remained same in Manipur during the study period. In 2018-19, SP installation had negative growth rate in Meghalaya but it showed sharp increase in 2022-23. In this year, Mizoram too had highest growth in SP installation. The SHP installation remained stagnant from 2007-08 to 2023-24. In Tripura. Sikkim too demonstrated same results from 2010-11 to 2020-21. Hence, it can be concluded from the table that the annual growth rate in the installation of SHP and SP were very much insignificant during this 17yres period.

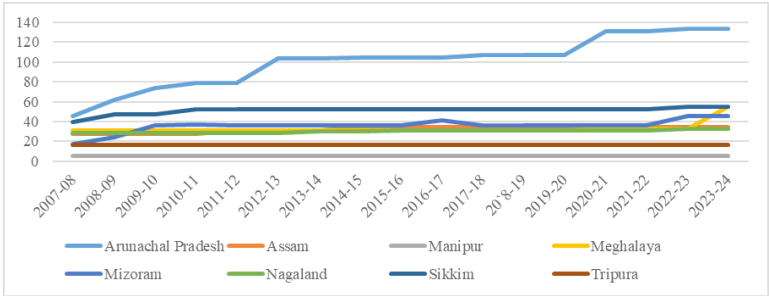


Figure:1 Trends in installation of SHP in all states of northeast India during 2007-08 to 2023-24

**Adapted from secondary data*

Figure:1 shows Arunachal Pradesh has seen a continuous growth but from 2011-12 to 2012-13, there was a sharp growth rate. From 2012-13 to 2019-20, small hydro power had a steady growth rate. Again, it showed a sharp rise. After that, it maintained a stable growth. Other states maintained a more or less stable growth during the study period. Tripura did not show any small fluctuation.

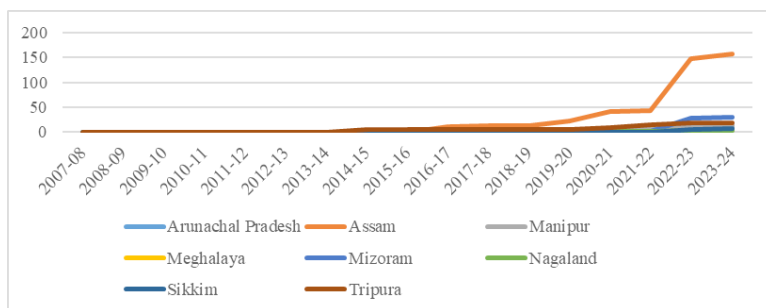


Figure:2 Trends in installation of SP in all states of northeast India during 2007-08 to 2023-24

**Adapted from secondary data*

Figure:2 shows Assam has experienced a continuous growth from 2016-17. From 2021-22 onwards, there was a sharp growth rate. Other states did not show much improvement. Only Mizoram showed small improvement from 2021-22.

Table: 2 Average installed capacity, estimated potential, coefficient of variation and stability (I_x) of SHP and SP in all northeastern states of India during 2007-08 to 2023-24

States	Small Hydro Power (SHP)					Solar Power (SP)				
	Mean	Estimated Potential*	CV	2	I_x	Mean	Estimated Potential*	CV	2	I_x
Arunachal Pradesh	100.6	2064.9	25.4	0.87	9.2	3.03	8650	134.9	0.72	71.4
Assam	31.9	201.9	9.3	0.73	4.8	26.3	13760	187.5	0.5	132.6
Manipur	5.45	99.9	0	0	0	2.5	10630	172.5	0.58	111.8
Meghalaya	32.7	230.1	17.6	0.16	16.1	0.5	5860	258.2	0.29	217.6
Mizoram	36	168.9	18.2	0.46	13.4	3.68	9090	261.1	0.3	218.6
Nagaland	30.1	182.2	4.4	0.84	1.8	0.7	7290	147.3	0.64	88.38
Sikkim	51.1	266.6	7.3	0.47	5.3	0.7	4940	284.3	0.26	244.6
Tripura	16.01	46.9	0	0	0	5.3	2080	117.6	0.78	55.2

*Researchers' own calculations based on secondary data

**Energy Statistics, different years, MoSPI, GOI

Table: 2 shows that the estimated potential of both SP and SHP are much higher than the average installed capacity of both the sources. Assam has the highest estimated SP potential among all states but only an average of 0.19 per cent has been installed. Manipur has the second highest estimated SP potential but only 0.02 per cent has been installed. The remaining states too have very low proportions of installed SP. Among all the states, average installed capacity of SP is highest in Assam and lowest in Meghalaya. The estimated potential of SHP in every state is quite high but only a small proportion has been utilized. Its potential is highest in Arunachal Pradesh followed by Sikkim. It is lowest in Manipur.

Among solar power and small hydro power, highest coefficient of variation is found in case of SP. Mizoram recorded highest coefficient of variation while Tripura registered lowest coefficient of variation in SP installation. In case of SHP installation, highest coefficient of variation is shown by Arunachal Pradesh and lowest variation is shown by Nagaland. Manipur and Tripura did not show any variation. This is because, throughout the study period, SHP installation remained almost stable in both the states.

The instability index for SHP is found to be lowest in case of Nagaland. Tripura and Manipur showed zero instability. On the contrary, the instability index for SP is found to be much higher than that of SHP. Among all the northeastern states, Sikkim has highest instability. None of the 8 states recorded low or medium instability in SP installation during the study period. The reason could be the less importance given to the installation of SP in all these states.

5. Conclusion and Policy Prescriptions

5.1 Conclusion

The paper looks into average installed capacity of the two most important sources of renewable power, viz., solar power and small hydro power and the variations in the installed capacity during the period from 2007-08 to 2023-24. Because of mountainous topography and perennial streams, northeast India has largest hydropower potential (Thakur, J. 2023). Arunachal Pradesh has adopted small hydro power policy to encourage private participation in small hydro power generation. Same

policy was adopted by Sikkim also. The central govt has granted Rs.22.5 million to all the states of northeast India for small hydro power projects (www.investindia.gov.in). Northeast India gets a healthy amount of 4-5 hours of daily peak sun for efficient and economical photovoltaic solar system. The use of urban rooftops in Guwahati, Shillong and Agartala, community micro-grids in Arunachal Pradesh, use of subsidized solar irrigation pumps in Mizoram, Manipur and Tripura are increasing (solarprabha.com). The Contribution of the present study is that it discusses whether the region is steadily increasing its installation capacity to meet its growing energy needs or not. Northeast India is facing certain challenges like heavy rainfall and humidity, weak transmission power lines, high initial costs, lack of awareness among local communities (solarprabha.com). In this study, most of the states showed high instability in the installation of solar power. On 31st March 2019, the Ministry of New and Renewable Energy has approved projects with capacities upwards of 55MWp in various northeastern states (www.investindia.gov.in).

The study helps to understand that over the years, a very insignificant proportion of both the energy sources have been utilized. For example, in 2009-10, per capita electricity consumption of Sikkim was 845.40 kWh (www.pib.gov.in). Again, the per capita electricity consumption in 2012-13 was 718.57 kWh in Arunachal Pradesh, 240.28 kWh in Assam, 352.86 kWh in Manipur, 690.20 kWh in Meghalaya, 469.38 kWh in Mizoram, 268.49 kWh in Nagaland, 296.05 kWh in Tripura. This was much lower than 914.41 kWh of India (Energy and energy access: northeast India, factsheet). But present analysis shows very insignificant contribution of both the clean energy sources to meet its energy needs. The empirical findings suggest that the estimated potential of both solar energy and small hydro power are much higher than the average installed capacity of solar energy and small hydro power. Both Assam and Manipur have highest estimated solar power potentials but none of the states of northeast India has installed its fullest potential. Similar results are also found in case of small hydro power installation also. Geographical disadvantage, tectonic problems, northeast being a part of Indo-Burma Hotspot with more than 1/3rd of country's total biodiversity, socio-economic challenges creating problems for the development of small hydro power in this

region (Saikia, *et al.*, 2023). In case of solar power, lower solar insulation, the output of solar power projects is less but the cost is high due to their remoteness, according to the Ministry of New and Renewable Energy.

Moreover, non-receipt of an adequate number of state govt proposals to set up grid connected solar projects (The Sentinel, 31st March, 2023, www.sentinelassam.com) shows lowest variation in installed capacity of solar energy is found in case of Tripura while it is highest in Mizoram. Assam showed high variation in installed capacity of solar energy. In case of small hydro power, Assam, Manipur and Tripura did not show any variation. The reason is all the three states recorded same amount of installed capacity of small hydro power installation. Highest instability in solar power installation capacity is registered by Meghalaya and Mizoram, while highest stability is found in case of Tripura and Assam. The instability index of small hydro power shows highest instability is found in Mizoram. If the CV and instability index of both the energy sources are compared, it is found that compared to solar power, the installation capacity of small hydro power showed greater stability with lesser variations.

5.2 Policy Prescriptions

The above analysis suggests that the state governments should increase their efforts to raise the installation capacity of these two largely untapped clean energy sources. The huge gap between the estimated potentials of solar energy and small hydro power and their installed capacity suggest more expenditures on R&D so that costs can be reduced and installation capacity can be increased.

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