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Review

An overview of small hydro power development in India

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Abstract: India is a developing nation with 1.35 billion populations living in varied strata of living standards. Therefore, the energy demand is constantly increasing in an effort to accelerate industrial activities and boost the economy. The country mostly meets its electricity demand from fossil fuel. It has large generation capacity but in some remote and rural areas only 53% of the villages get electric supply for less than 12 hours a day. This is because of hilly and mountainous terrains especially in the north and north-eastern regions of the country and absence of utility grid owing to economic reasons. It is estimated that about 15% of country's population do not have access to electricity. With huge hydro potential in the country, especially in the Himalayan States, hydropower generation may be emphasized and pressed in to augment ever increasing energy demand. The emphasis should be on small hydropower (SHP) as construction of large hydropower involves huge capital cost and they are associated with various techno-economic and social issues. The article aims to provide important information for appropriate policy making in developing small hydropower in India.

Keywords: small hydropower; renewable energy; economy; energy demand; India

1. Introduction

The economic development and societal progress is highly influenced by per capita energy consumption. In order to fulfil the energy requirements, more and more electricity generation is essential. Presently, 74.4% of the energy utilized in the world is obtained from fossil fuel based generating stations. But such generating stations are deterrent to cleanliness of environment. The worldwide energy generation from renewable energy sources stands at 26% as shown in Figure 3 [1]. The leading top 5 countries in hydropower generation are China, Brazil, United States, Canada and India which accounts for 53.4% of total installed capacity in the world. China has the highest hydropower installed capacity of 320 GW which stands at 27.2% of the total installed capacity followed by Brazil, United States, Canada and India at 8.04%, 7.9%, 6.2% and 3.86% respectively. Thus, many researchers are working on the prospects of harnessing biomass, hydro, solar and wind energy sources in order to produce clean energy and reduce the environmental damages. Hydropower is considered as leading renewable energy source and is gaining importance in the map of worldwide electricity generation [2–4]. Hydropower is "clean energy" as it comes naturally and is one of the most cost effective and sustainable energy. It can be replenished much faster than being consumed. According to report of International Hydropower Association, 26 PWh of electricity was generated in the year 2019 and Figure 4 shows the contribution of different source used for electricity generation. It shows that 16% of the total generation were from hydropower so, basically hydropower contribute the highest of approximate 62.10% of the total electricity produced by renewable energy source [1]. Contribution of Hydropower is very important in electricity generation for future and International Energy Association (IEA) stated that Hydropower will continue to become main energy source of renewable energy source in 2024 [5]. According to report of IEA 2019, the hydropower electricity generation attained nearly 4,200 terawatt hours (TWh) and an approximate hydropower of 23.8 gigawatts (GW) capacity was put into operation bringing the world's installed capacity to 1,292 gigawatts (GW). The East Asia and Pacific region shows the fastest growth with 9.2 GW of hydropower installed capacity added to it. The total installed capacity and generation by region are represented through Table 1 and Figure 1 represent the new installed capacity by region.

Many countries are also working to increase the hydropower capacity and in the year 2018 Forty eight countries added hydropower capacity among which China has the highest new installed capacity of 8,540 MW. Figure 2 shows the top 5 countries with highest new installed capacity [1].

Table 1. Total installed hydropower capacity and generation by region [1].

Sl No.	Region	Total Installed Capacity (MW)	Generation (TWh)
1	Africa	36,264	138
2	South and Central Asia	148,511	439
3	East Asia and Pacific	480,426	1,534
4	Europe	251,707	643
5	North and Central America	204,056	720
6	South America	170,792	726
Total		1,291,756	4200

Hydropower emits the lowest greenhouse gas; it is predictable and has high efficiency. Because of its flexibility and reliability, such generating stations can be integrated with any other emerging energy systems and hence, hydropower is implemented on large and small scale power generation. Large hydropower, however, is associated with displacement of people, submergence of land in the catchment area, risk of dam malfunction, damage to ecosystem, etc. These issues are usually absent in small hydropower and it is found to be extremely beneficial in supplying electricity, especially to remote and rural areas where grid accessibility is constrained [6,7]. Utilizing hydropower for electricity generation in place of coal prevents release of 148 million tonnes of particulate, 62 million tonnes of sulphur dioxide and 8 million tonnes of nitrogen oxide every year. India has abundant water resources that can be harnessed for electricity generation. Thus, the prospects of hydropower in India need to be relooked with greater zeal and scientific temper. This paper aims to present the status of the water resources focusing mainly on present conditions, various schemes and obstacles of small hydropower development in India and around the world.

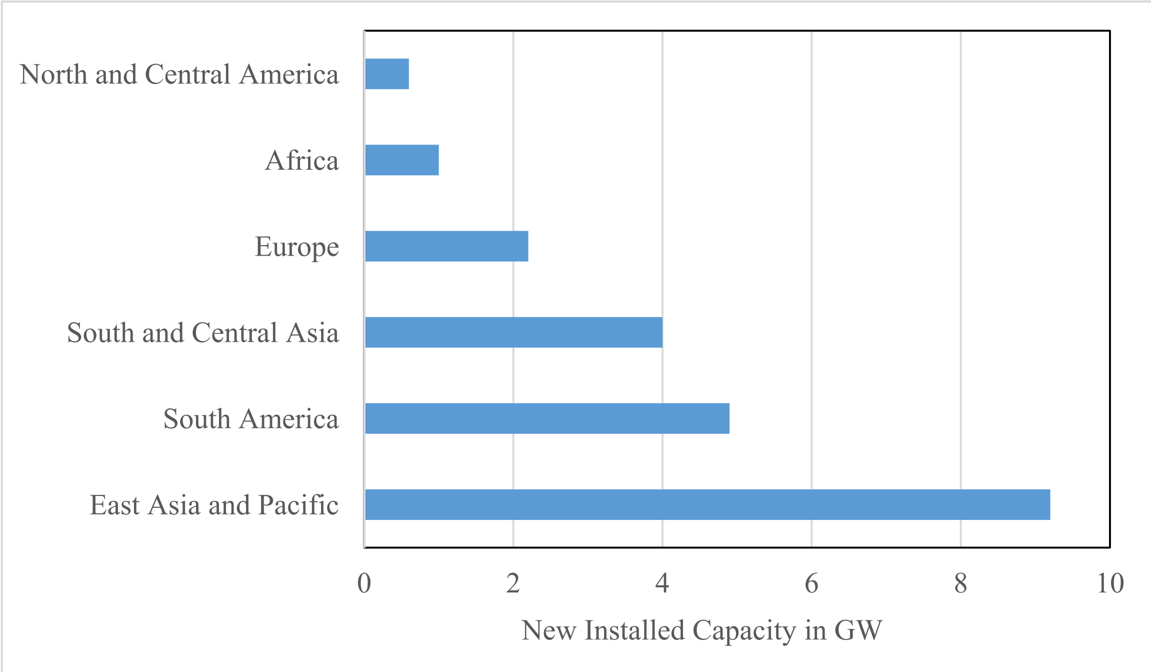

Figure 1. New installed hydropower capacity by region (GW) [1].

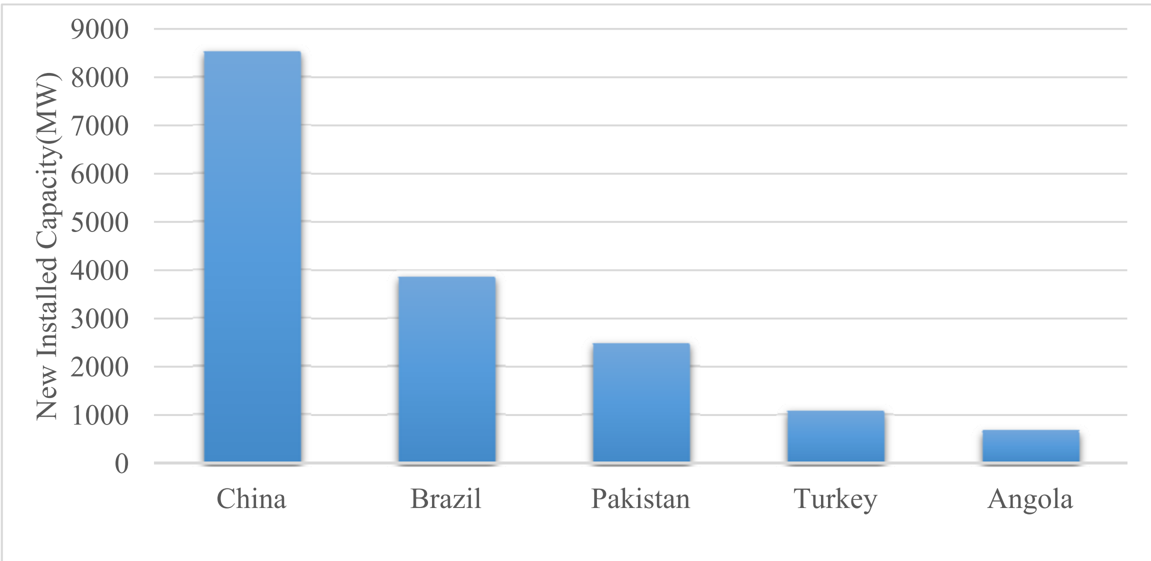

Figure 2. Leading top 5 countries in new installed hydropower capacity in 2018 [1].

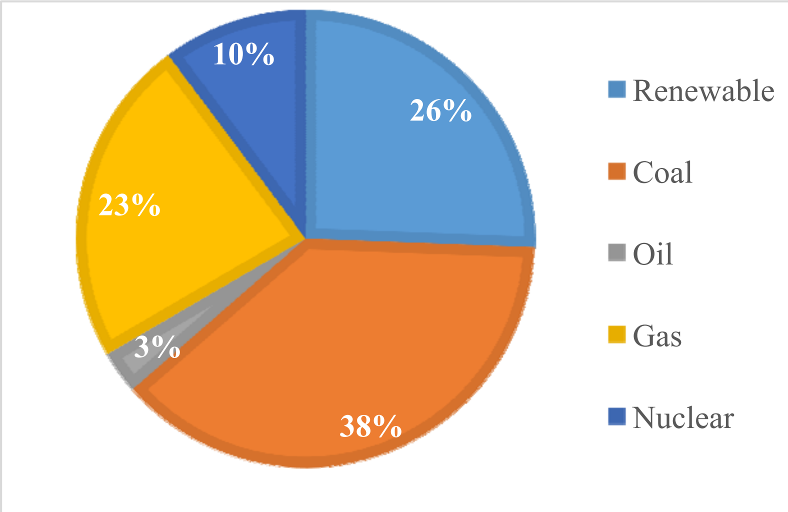

Figure 3. Total energy generation across the world [1].

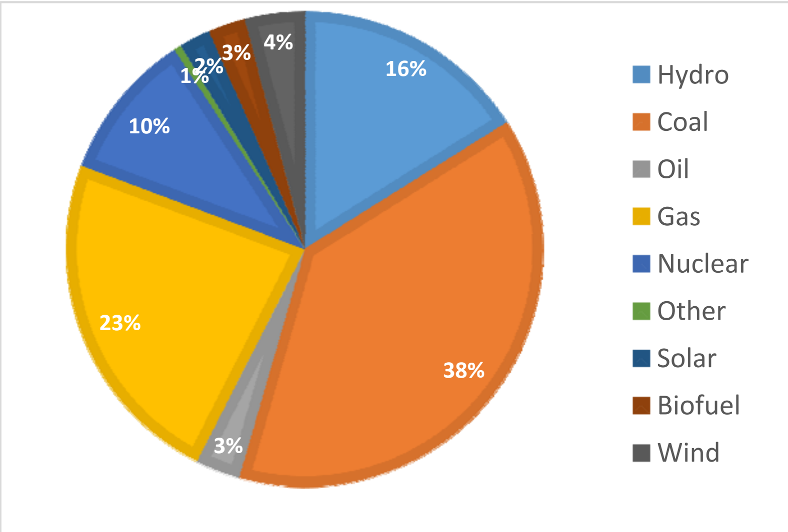

Figure 4. Electricity generation by source [1].

2. Methodology

This article is based on studies and analyses of latest scientific literatures presented in journals and conferences, data obtained from various ministries of the government of India and books related to hydropower development. Extensive literature review is carried out and eventually large and small hydropower is segregated and a detail discussion is presented against short hydropower in India category. The article is divided in 5 section which cover status of SHP in India, review of recent article on SHP in India, policies and schemes of SHP development, challenges of SHP development, areas of research in SHP and conclusion.

3. Small hydropower in India

India is a country with 1.35 billion population and third largest electricity energy consumer in the world after China and US. According to Key World Energy Statics 2019, India is the third largest producer of electricity in the world with the generation of 1,561 TWh. Although power generation has stretched more than 100 times since independence in 1947, the energy demand is ever increasing due to accelerating economic activities. In order to boost growth in primary sectors such as agriculture, industrial or manufacturing and service sectors abundant availability of electricity is inevitable. Electricity is one of the eight core industries of India and thus, it directly correlates electricity usage and economic development. By providing access to electricity, the country is putting all out efforts to reduce poverty. At present the total installed capacity of India is 370,106 MW and the contributions of various sources of electricity are presented in Figure 5. It can be seen that fossil fuel such as coal, natural gas, and oil contributes 62.7% of electricity generation [8]. It is anticipated that energy demand will be more than double by 2030, while electricity demand will be almost triple [9]. But studies have shown that most of the fossil fuels will be exhausted by 22nd century. Therefore, shifting attention to generation of electricity from renewable energy sources needs to be emphasized. Government of India has targeted increase in renewable generation up to 175 GW by 2022 [10]. Presently India is 5th largest producer of hydro power energy in the world with an installed capacity of 45,699 MW as on April 24, 2020 with more than 80% of the hydropower capacity being distributed among the Himalayan States. However, hydro power contributes only 12.4% of the total installed capacity in the country [9]. In India hydropower are commonly classified into small and large hydropower. The large hydropower is governed by Ministry of Power and small hydropower up to 25 MW is looked after by the Ministry of New and Renewable Energy [11]. The large hydropower is often opposed by societies, environmentalist and non-governmental organizations for fear of flooding, desertification, relocation issues, etc. Therefore, small hydropower can be envisaged as a better solution for electricity generation. Small hydropower is usually clean, sustainable and environmental friendly as most of the SHPs are canal based or run of river type which uses running water to drive the turbine. The weir or barrage is small and no water is stowed; it is free from problems such as relocation of local inhabitants or deforestation which are usually associated with large hydropower [12]. Because SHPs are sustainable, they are exempted from forest and land clearance and are free from public sitting/plenary inquiry in many countries including India [13,14]. SHPs are economically feasible and the gestation period is rather low [15]. SHPs are ideal for powering villages and far-flung or isolated areas. The accessibility of electricity in these areas will boost small scale industries and thereby improve the socio-economic status of the people [16,17]. SHP does not emit greenhouse gas; and lesser greenhouse gas means lesser carbon foot print thus, decreased CO_2 release [18]. The capacity of SHP is different in different countries; for instance, in China, capacity up to 50 MW is considered as SHP while in USA the capacity is up to 100 MW [12]. The classification of SHP in India is shown in Table 2 and Table 3 shows the attainment of small hydropower along with other renewable source in grid connected renewable power in the country [19].

From 7,133 odd sites situated in different parts of the country, the approximated potential of SHP in India is 21.13 GW out of which 1,127 SHP plants contributes to 4,671.55 MW installed capacity as recorded till December 31, 2019; another 109 SHP plants are in different phases of completion. SHPs are implemented by both public and private sectors or collaboration of both to enhance the contribution of SHP in the power market of India. The growth of SHP for the last three years is shown in Figure 6 [19–21]. Table 4 presents the potential and installed capacity of SHP in India.

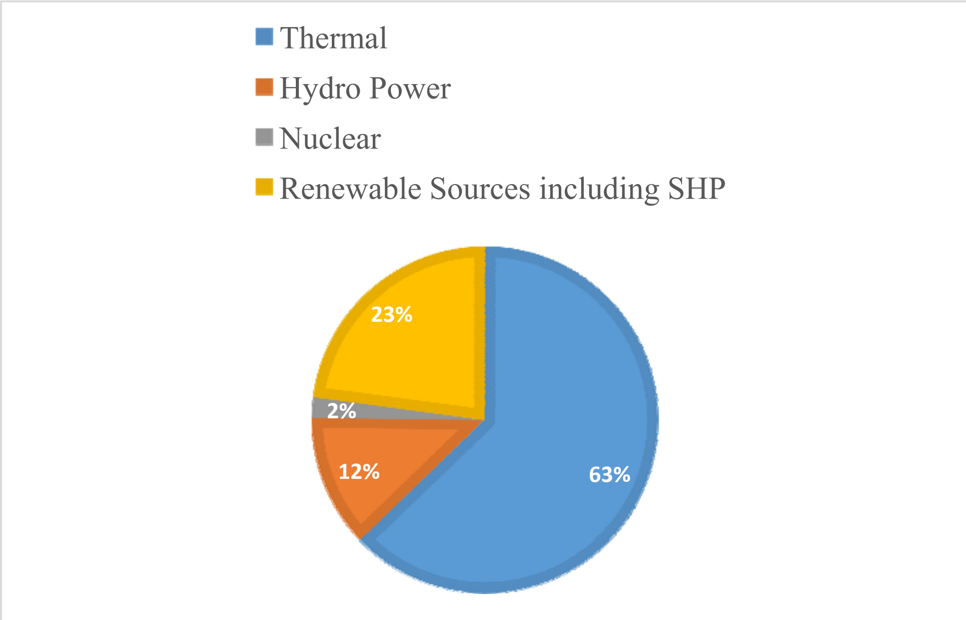

Figure 5. Total installed capacity in India [8].

Table 2. Classification of SHP.

Sl. No.	Plant Capacity	Type
1.	Up to 5 kW	Pico
2.	Up to 100 kW	Micro
3.	101–2000 kW	Mini
4.	2001–250000 kW	Small

Table 3. Attainment in grid connected renewable network [19].

Renewable Source	Attainment (MW) (April–Dec 2019)	Cumulative Attainment (MW) as on 31 December 2019
Bio Power	83.00	9861.31
Solar Power-Ground Mounted	5013.00	31379.30
SHP	78.40	4671.55
Solar Power-Roof Top	536.88	2333.23
Wind Power	1879.21	37505.18
Waste to Power	1.50	139.80
Total	7591.99	85908.37

From the Table 4, it can be seen that the State of Karnataka has the highest installed capacity followed by Himachal Pradesh and Maharashtra. The north and north eastern region of India has high potential of SHP; the north eastern part of India is often called 'Future Power House' of

India [22]. Table 5 details the tariff figures of SHP for the year 2019–20; it shows that the capital cost of the SHP plant is inversely proportional to plant size [23]. Government of India is promoting accelerated development of SHP and in the year 2019–20, 12 SHP projects were commissioned out of which 6 projects are in the State of Himachal Pradesh with generating capacity of 45.9 MW and is illustrated in Figure 7 [19].

Table 4. State wise details of SHP potential, installed capacity and under implementation [19].

	States	Potential		SHP Installed		SHP under execution	
		No.	Capacity (MW)	No.	Capacity (MW)	No.	Capacity (MW)
1.	Andhra Pradesh	359	409.32	44	162.110	0	0
2.	Arunachal Pradesh	800	2064.92	156	131.105	10	7.05
3.	Assam	106	201.99	6	34.110	1	2
4.	Bihar	139	526.98	29	70.700	0	0
5.	Chhattisgarh	199	1098.2	10	76.000	0	0
6.	Goa	7	4.7	1	0.050	0	0
7.	Gujarat	292	201.97	13	62.352	9	48.81
8.	Haryana	33	107.4	9	73.500	0	0
9.	Himachal Pradesh	1049	3460.34	195	906.510	18	179.60
10.	Jammu & Kashmir	302	1707.45	46	180.480	16	47.10
11.	Jharkhand	121	227.96	6	4.050	0	0
12.	Karnataka	618	3726.40	170	1280.73	3	13.000
13.	Kerala	238	647.15	34	222.02	8	80.500
14.	Madhya Pradesh	299	820.44	12	95.91	2	7.600
15.	Maharashtra	270	786.46	70	379.575	9	10.400
16.	Manipur	110	99.95	8	5.45	0	0.000
17.	Meghalaya	97	230.05	5	32.53	2	25.500
18.	Mizoram	72	168.9	18	36.47	4	8.700
19.	Nagaland	98	182.18	12	30.67	1	1.000
20.	Odisha	220	286.22	10	64.625	3	57.000
21.	Punjab	375	578.28	56	173.55	7	4.900
22.	Rajasthan	64	51.67	10	23.85	0	0
23.	Sikkim	88	266.64	17	52.11	1	3.000
24.	Tamil Nadu	191	604.46	21	123.05	0	0
25.	Telangana	94	102.25	30	90.87	0	0
26.	Tripura	13	46.86	3	16.01	0	0
27.	Andaman & Nicobar Islands	7	7.27	1	5.25	0	0
28.	Uttar Pradesh	251	460.75	9	25.1	2	25.500
29	Uttarakhand	442	1664.31	102	214.32	13	7.580
30	West Bengal	179	392.06	24	98.5	0	0
	Total	7133	21133.62	1127	4671.557	109	529.240

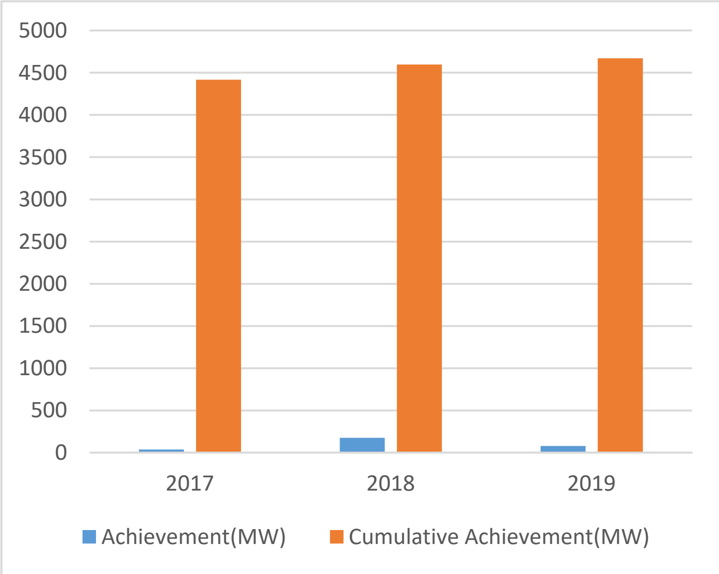

Figure 6. Growth of SHP in India [19–21].

Table 5. Tariff figures for 2019–20 for SHP [23].

Sl. No.	Region	SHP Size (MW)	Capital Cost	
			(INR Million/MW)	(USD Million/MW)
1.	Himachal Pradesh, Uttarakhand, West Bengal and North Eastern States	Less than 5	100	1.39
2.	Himachal Pradesh, Uttarakhand, West Bengal and North Eastern States	Between 5 to 25	90	1.25
3.	Other states	Less than 5	77.9	1.08
4	Other states	Between 5 to 25	70.7	0.98

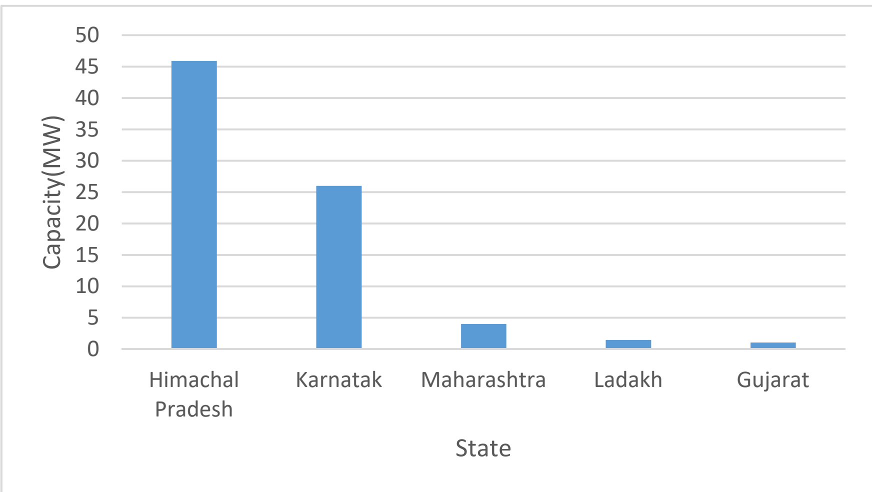

Figure 7. SHP commissioned between 2019 and 2020 [19].

4. Review of recent articles of small hydropower in India

In this section, recent articles published between 2015 and 2020 are exhaustively reviewed and it is found that most of the studies discusses the environmental impact of SHP while few literatures details technological interventions. Table 6 summarizes the outcome of various studies carried out on SHP in India.

Table 6. Summary of articles on SHP in India and their findings.

Year	Sl. No.	Authors	Remarks
2015	1.	Mishra, M. K. et al. [12]	(i) Almost 75% of SHP potential in remote and isolated part of India is not harnessed. (ii) MNRE is playing a vital role in the development, operation and dissemination of SHP. (iii) Delay in permission, approval and agreement retards the progress of SHP. (iv) Efforts should be made to increase penetration of SHP and aim to add power of 600 MW/year.
	2.	Khan, Rakshanda [24]	(i) SHP has both positive and negative aspects. (ii) SHP is not completely environmental friendly. It impacts the environment to some extent as it disturbs the river ecologies but produces no waste. (iii) SHP improves the socio-economic status for example, the villager get employed and reduced movement of people to cities results in setting up of schools, hospitals, etc. (iv) Social harmony should be established between the employees and the stakeholders to improve the performance of SHPs. (v) Foreign subsidies can help independent power producer with low interest rates and improve production services.
	3.	Gohil, Pankaj P. [25]	Hydraulic turbine corrosion due to cavitation causes loss to SHP.
	4.	Sachdev, Hira Singh et al. [26]	(i) SHP is solution for providing electricity to steep and mountainous areas where there is no grid connectivity. (ii) For precise computation of hydro potential, uncertainty in the systems should be considered and thus, mathematical modeling and simulations survey is encouraged in the subject of energy.
	5.	Sharma, Ameesh Kumar [27]	(i) Western Himalayan region has a large SHP potential. (ii) SHP can be the mainstay of power sector in the State of Jammu and Kashmir; however, the growth is rather slow. (iii) To prevent the delay in approval of new SHPs, the process

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Year	Sl. No.	Authors	Remarks
			should be fast tracked with time bound mechanism as practised in the State of Himachal Pradesh. (iv) The utilization of hydropower potential of Jammu and Kashmir is impacted by Indus Valley Water Treaty (IWT). (v) Environmental impact assessment (EIA), environmental management plan (EMP) and social impact assessment (SIA) reports are made compulsory for implementation of SHPs.
2016	1.	Sharma, Ameesh Kumar [28]	(i) Jammu and Kashmir, Himachal Pradesh, Uttarakhand and Arunachal Pradesh have huge hydropower potential. (ii) SHPs may play an important role for the development of the regions which are not grid connected. (iii) Private players attracted to build SHPs.
	2.	Diduck, Alan Paul [29]	(i) Marginalization of SHP has left a vital gap in India's environmental assessment regime. (ii) Improved project-level assessment and better mechanism to involve locals are required for successful implementation of SHP.
	3.	Kumar, Deepak [30]	(i) Environmental impact of SHPs is not little as ordinarily viewed. (ii) It is suggested that EIA report may be dispensed with for installed capacity up to 5 MW as against the existing 25 MW capacity for SHP. (iii) The local residents support installation of SHP. (iv) It is recommended that untouched rivers must not be used for installing SHP without Cumulative Environment Impact Assessment (CEIA).
	4.	Höffken, Johanna I. [31]	(i) The access to electricity is poor in India especially, in rural areas where extension of grid becomes expensive or not feasible. In such areas micro hydro plants are welcoming solutions. (ii) SHP can be made more viable by involving people in numerous aspects of the SHP and instil sense of community ownership.
2017	1.	Sharma, Ameesh Kumar [32]	(i) Often SHP causes long-standing unfavourable effects on the environment because of improper designing. (ii) In order to expedite induction of more SHPs in the State of Jammu and Kashmir proper planning is needed for their sustainability. (iii) Government agencies involved in implementing SHPs should educate local people about the benefits of such power projects.

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Year	Sl. No.	Authors	Remarks
			It should be emphasised how such projects can improve the socio-economic status apart from getting electricity at the door. (iv) More private developers should be involved.
	2.	Sharma, Ameesh Kumar [33]	(i) Invite more private investors or power developers so that full potential is harnessed in specified time frame. (ii) To accelerate speedy growth of SHP, a single window clearance method is suggested wherein common No Objection Certificate (NOC) is provided on account of other departments from where the acceptance/agreement is needed.
2018	1.	Singh, Vineet Kumar et al. [34]	Water discharge, available head, head loss, penstock diameter and length, effectiveness and running cost affects the performance of SHP.
	2.	Rana, Shilpesh [35]	Weighted product method (WPM) and TOPSIS method may be used to identify the best site for SHP.
2019	1.	Roy Sr, Neha Chhabra [36]	Effective risk management policies should be adopted in order to identify SHP potentials, weaknesses, opportunities and threats.
	2.	Kumar, Arun [37]	The accuracy of discharge measurement may be improved by properly defining an area where the flow is stable and debris free.
	3.	Raghuwanshi, Santosh Singh [38]	Owing to economic reasons Private power developers are showing interest in SHP projects.

5. Policies and schemes of SHP development

As per report of Mission Antyodaya about 53% of the villages in India receive electricity less than 12 hours a day [39]; it is also reported that about 15% population do not have access to electricity [40]. The economic development, therefore, is highly dispersed in the country. Currently, the GDP of the nation is about 4% only. In the backdrop of this kind of dismal economy, production of electricity utilizing renewable energy sources would be a welcome step. The advantages of harnessing renewable energy sources are manifold; these energy sources are inexhaustible, usually the gestation period is low, cost per unit energy is lower, etc. Thus, SHP presents a viable option as it is a clean source of energy and its peak power generation is in summer that coincides with the period when maximum power demand occur. As on date, many policies and schemes are in place to encourage the development of SHP projects in the country. The first SHP was installed before independence with a capacity of 130 kW in the hills of Darjeeling. Table 7 presents the chronology of SHP development along with the relevant policies and schemes in place in the country.

Table 8 shows recently commissioned SHPs in the country. Photographs of the power projects are also presented from Figure 8 to 10.

Table 7. SHP development along with the relevant policies and schemes.

Year	Activity
1887	First SHP was installed in India [12] with a capacity of 130 kW; capacity upgraded to 508 MW by 1947.
1982	Looking at the SHP potential Government of India established Alternative Hydro Energy Centre at IIT Roorkee [12].
1989	Hydro power projects upto capacities of 3 MW were placed under the Ministry of Non- conventional Energy Sources (MNES) [41].
1994	Invite and involve Private power developers in SHP development [41].
1999	Hydro power projects upto capacity of 25 MW were transferred to Ministry of New and Renewable Energy(MNRE), earlier known as MNES from Ministry of Power [42]
2003	Electricity Act 2003 [43] was promulgated which mandates the promotion of electricity generation from renewable energy sources by offering proper procedures for grid connection.
2005	National Electricity Policy 2005 [44] was adopted which stipulated that progressively the stake/segment of electricity from renewable energy required to be enhanced; the purchase by distributors/supply companies shall be done through competitive biddings.
2006	Adopted Traffic Policy 2006 [44]. It mandates each State Electricity Regulatory Commissions to agree Renewable energy Purchase Obligation by distribution licensees before deadline/specified time. The policy has facility for renewable endorsement as in provisions of section 86 (1) (e) of the Electricity Act 2003; an Appropriate Commission shall fix a minimum percentage for acquiring energy from renewable sources taking into account availability of such resources in the region and its impact on retail tariffs.
2008	National Action Plan on Climate Change [45] envisages increasing share of renewable energy into electricity production in order to control climate change.
2008	According to Policy on Hydro Power [46] soft loans were proposed to be given through Power Finance Corporation/ Indian Renewable Energy Development Agency Limited /Rural Electrification Corporation and other financial institutions.
2010	Renewable Energy Certificate [47] was initiated to permit the States of India to achieve Renewable Purchase Obligation targets.
2010	Ladakh Renewable Energy Initiative [48] was initiated to encourage and promote renewable energy include SHP in the Ladakh region.
2012	State Initiative [49,50] encourages SHP development. 23 States announced schemes for private sector involvement in order to boost the growth of SHP.
	Under various Financial schemes [51,52] the Indian Renewable Energy Development Agency (IREDA) under MNRE offers loans for SHP projects and provide special incentive package for the promotion of the SHP programme in the Northeast region of India.
2015	INR 23.5 billion and INR 20.0 billion were spent for renewable energy and SHP respectively under Development/Reconstruction package for Jammu and Kashmir [21].
2016	National Tariff Policy [53] envisages special attention on renewable energy to promote use of renewable energy.
2016	In Paris Climate Change summit [10], Government of India expressed its desire to meet the INDC (Intended Nationally Determined Contribution by generating about 40% of the country’s energy from renewable energy sources. Hydropower generation will help meet this target.

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Year	Activity
2017	To help the stressed and stalled projects, Government of India announced INR 160 billion bailout for the hydropower sector [54]. Set up Sediment Monitoring and Abrasion Testing Laboratory at AHEC, IIT Roorkee [21,55] to carry out study and research sediment components and its effect in hydropower.
2018	Set up Hydraulic Turbine Research and Development Laboratory at AHEC, IIT Roorkee [20,56] for developing expertise in SHP in respect of entrepreneurs, engineers, plant operators and researchers; also providing affordable facility to small hydro manufacturer for design verification.
2019	• Declaration of large hydropower with capacity above 25 MW as Renewable Energy Source [57]. • 1127 SHP projects with an approximate capacity of 4671.557 MW achieved as on 31.12.2019 [19].

Table 8. Recently commissioned SHPs.

Sl. No.	Year	Name of SHP	Capacity	Location
1.	2017	Biaras SHP [21]	1.3 MW	Drass, Kargil, Jammu and Kashmir
2.	2018	Zhangdongrong SHP [20]	1.0 MW	West Kameng, Arunachal Pradesh
3.	2019	Dikshi SHP [19]	24.0 MW	West Kameng, Arunachal Pradesh
4.	2019	Nuranang SHP [19]	1.0 MW	Tawang, Arunachal Pradesh

Figure 8. Biaras SHP [21].

Figure 9. Zhangdongrong SHP [20].

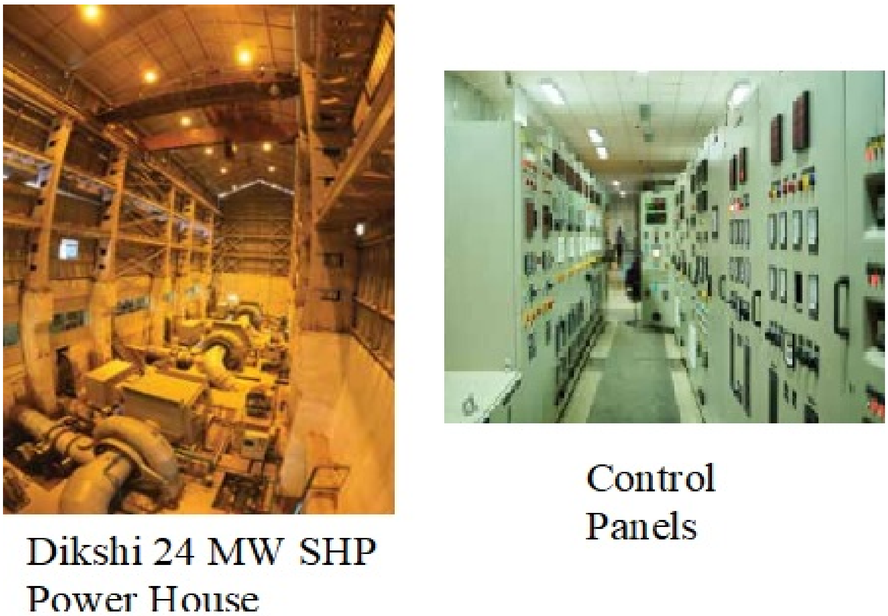

Figure 10. Dikshi SHP [19].

6. Challenges of small hydro power development

Various stages of implementation of SHP are presented in Table 9. SHP generation necessitates enthusiastic participation of three main stakeholders namely, the developer, the government departments and the project affected people. Non-cooperation amongst the stakeholders in the procedure might cause delay in SHP development resulting in cost escalation and gestation period.

Table 9. Steps for implementation of SHP.

Steps for implementation of SHP
1.Identification or selection of SHP site
2.Evaluation
3.Submission of pre-feasibility report
4.Obtaining no objection certificate or clearance certificate by the developer
5.Submission of detailed report
6.Grant of techno-economic clearance
7.Signing of implementation agreement
8.Signing of power purchase agreement
9.Funding arrangement
10.Arrangement of equipment and manpower
11.Construction
12.Completion and commission

Planning and development of SHP endures many hurdles. The datasheet of head and discharge is fundamental to proper design of an SHP. The river flow changes with season thus, measurement of flow rate should be carried out throughout the year in order to obtain proper discharge data, a minimum of 5 years data should be collected; the absence of genuine data causes improper estimate of the power potential [12]. Sedimentation is another issue that is often faced in developing hydropower projects. Absence of geological and sedimentation data has resulted in wrong design and caused closure of many hydropower projects [58]. Problems are faced in acquiring land due to delay in obtaining permission from community or from department like forest and environment [58,59]. Shortage of manpower for planning and developing results in slow progress of SHP [58]. Lack of participation from local community [31], non-compliance of Renewable Purchase Obligation by States [47], lack of knowledge about SHP, isolated land and very small size SHP sometimes adversely affect the plant economy [12]. Thus, developing an SHP involves complex procedures and requires meticulous steps to decide the site, unit size and generating equipment [60]. Many SHPs are scrapped due to low consumption of electricity and limited funding from the government in terms of maintenance cost. Usually the life span of SHP is 35–50 years but some SHPs are closed down even before the end of the expected life due to faults in design and construction, obsolete equipment or non-availability of grid extension which causes huge waste of resources [61]. Along with regular maintenance, SHPs require check on the possibility of breakdown [62]. Often environmentalists pose delay in implementation of SHP as the normal procedure is not all allowed. This is due to the popular belief that the movement of personnel and equipment during construction invade wildlife habitats; also the operations of turbines or generators create noise which affects the local community. It is considered that the transmission lines may causes adverse effect to the local birds due to corona and magnetic effects around the conductors. It is also believed that the water passing through the machinery equipment may pollute or change the character of the river, increase the water temperature and affects the lives of aquatic flora and fauna [32,63,64]. Marginalization and unequal distribution of benefits of SHP is another factor that may slow down the development as the local community feel deceived and does not participate while the ecosystem and water bodies are disturbed [65]. Dissatisfaction on land compensation amongst the land donors also results in slow down of the entire process as it involves long process of dialogue between the stakeholders [66,67]. The lack of information between the developers and local community may impede the growth of SHP [68,69].

7. Areas of research in small hydro power

There are many factors affecting successful implementation or operation of SHPs. Many of those problems are adequately addressed by the power developers however academics are still investigating all possible remedies to present the SHPs a better source of electricity generation. Table 10 illustrates some of the works carried out by researchers to make SHP more efficient, more economical and environment friendly.

Table 10. Research areas.

Sl. No.	Area of studies	Author (s)	Remarks
1.	Fish friendly turbine	Martinez, Jayson J [70] Vowels, Andrew S [71] Robb, Drew [72]	Focussed on minimizing the risk of injury or death to fish in the river.
2.	Location of hydro projects	Ioannidou [73]	Presents multi-objective optimization method with objectives of increasing hydropower production while reducing disturbance on river.
		Serpoush [74]	Suggests methods to locate best hydro project sites.
3.	Hydro abrasive erosion turbine	Sangal, Saurabh [75]	Presents methods for designing hydro-abrasive erosion free turbine to alleviate erosion.
4.	Materials	Ueda, T [76], Thapa, Biraj [77]	Study of new materials to increase life span of turbines while reducing the environmental damage is presented.
5.	Hydrokinetic turbine	Elbatran, A [78], Schleicher [79], Anyi, Martin [80], Riglin, Jacob [81]	Design of turbines for minimum initial and running cost is carried out.
		Hrvoje Dedić-Jandrek [82]	Focussed on achieving maximum efficiency based on inclination angle.
		Hosnar, Jernej [83]	Presents models for obtaining necessary data for evaluation of hydro energy projects.
		Berrada [84]	Presents optimization techniques for evaluating the system for increased benefit.
6.	Variable speed scheme	Breban, S [85]	Study of variable speed scheme is carried out which permit turbine speed to vary with the discharge.
7.	Sizing of plant	Anagnostopoulos [86], Punys, Petras [87], Berrada, Asmae [88]	Focus on optimization tools for sizing power plants.
8.	Sediment bypass tunnel	Sumi [89], Auel, Christian [90]	Aims to provide a sustainable solution in terms of sediment management.

8. Conclusions

The article presented that there are many places in India where hydropower remains as untapped resource and extensive literature review is carried out and the feasibility and challenges of implementing small hydropower projects are detailed. Small hydropower emits less greenhouse gas and can be replenished over a period of time and hence, it can certainly play a major role in the future energy generation. However, it is found that many potential SHP sites remain as untapped resource in India. Also it is found that the opinion of public/local people is very important for successful implementation and operation of SHPs. Therefore, emphasis may be given to increased involvement of community as well as research/science for developing innovative technologies in order to balance hydropower and river conservation.

Conflict of interest

The authors declare no conflict of interest.

Author contributions

1. Ms. Oying Doso- Contribute to the idea and research, collected the information and wrote the paper;
2. Prof. Sarsing Gao- Supervised the work, devised the ideas and proof outline and review the paper.

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