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Trends in Development and Recent progress of Small Hydropower Projects in India

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ABSTRACT

Energy is now one of the most essential elements in a nation's development process. At a 60% load factor, India's hydropower potential is estimated to be at 125,570 MW. In addition, small, mini, and micro-hydro generators have a potential of 6,740 MW, and there are 56 sites for pumped storage schemes with a total installed capacity of 94,000 MW. Hydropower projects up to 25 MW are classified as SHP projects in India. Hydropower plants are built with the ability to start, halt, and change loads instantly. The country's limited hydropower potential has been assessed at 15,384 MW, with just 3252 MW having been used thus far. The current study seeks to examine the literature on topics related to the development of SHP plants, particularly the financial/cost analysis. The study delves into the details of SHP planning and development, including the current state, difficulties, and potential solutions for SHP plant development, as well as cost analysis tools and methodologies utilized in SHP planning. A cost analysis approach can be used to find a sustainable solution by examining the costs and benefits to both the developer and society at large.

Keywords: SHP, Renewable energy, development, hydropower, solutions, economics

INTRODUCTION

Energy demand is increasing at an exponential rate due to economic and population growth, especially in developing countries. India, with a population of 1.35 billion, is the world's third largest energy consumer, after China and the United States. According to World Key Energy Statistics 2019, India is the third largest energy consumer in the world.

For a sustainable energy future, all energy production, transmission, distribution and consumption must be transformed under this scenario. This is necessary to lift living standards, give access to trendy energy services, use energy additional with efficiency, defend the world atmosphere and supply reliable energy supplies.Per capita energyConsumption has a hugeimpact on economic growth and social progress.

Hydroelectricity is an important renewable energy source that is rapidly gaining ground on the global power generation map. Hydroelectricity is inherently “clean energy” and one of the cost-effective, long-term energy sources. According to the International Energy Association (IEA), hydroelectricity will remain the main source of renewable energy in 2024. According to the 2019 IEA report, hydroelectricity production will reach about 4,200 terawatt hours (TWh) and 23.8 gigawatts. (GW) of hydropower capacity was added, bringing the global installed capacity to 1,292 gigawatts (GW).

India has abundant water resources that can be exploited to produce electricity. Therefore, the prospect of hydropower in India needs to be reexamined with more enthusiasm and science. The total installed capacity and generation by region are represented through Table 1.

Table 1. Total installed hydropower capacity and generation by region

S.No.	Region	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

As of 31 December 2021, the total installed capacity for renewable energy in India is 151.4 GW.
Based on capacity, the SHP are classified as various categories:

Hydro Category	Power Range	No. of Homes Powered
Pico	0 kW – 5 kW	0 – 5
Micro	5 kW – 100 kW	5 – 100
Mini	100 kW – 1 MW	100 – 1,000
Small	1 MW – 20 MW	1,000 – 20,000

As a result, the goals of this study are to:

(a) Review existing trends and challenges in the worldwide growth of SHP.,

(b) Examine SHP's competitiveness and long-term viability, and

(c) Investigate viable techniques and solutions to boost its long-term viability.

SMALL HYDROPOWER IN INDIA

India has a population of 1.35 billion people and is the world's third largest electricity user after China and the United States. According to Key World Energy Statistics 2019, India is the world's third largest power producer, producing 1,561 TWh. Even though electricity output has increased by more than 100 times since 1947, energy consumption continues to rise owing to increased economic activity. Electricity must be abundant in order to encourage growth in primary sectors such as agriculture, industrial or manufacturing, and service sectors. Electricity is one of India's eight essential sectors, and its use and economic development are inextricably linked.The nation is making every attempt to decrease poverty by giving access to power. India's total installed capacity is now 370,106 MW, with contributions from various sources of power. Coal, natural gas, and oil are responsible for 62.7 percent of electrical generation.

Energy consumption is expected to more than double by 2030, while electricity demand is expected to almost treble. However, research predict that most fossil fuels will be depleted by the 22nd century. As a result, the need of focusing on the generation of power from renewable energy sources must be stressed. By 2022, the Indian government wants to raise renewable energy output to 175 GW. India is now the world's fifth largest producer of hydroelectric energy, with an installed capacity of 45,699 MW as of April 24, 2020, with more than 80 percent of the hydropower capacity split across Himalayan states. However, hydropower accounts for just 12.4% of total installed capacity in the nation. Hydropower is typically characterised in India as little or big hydropower. The Ministry of Power oversees major hydropower, whereas the Ministry of New and Renewable Energy oversees minor hydropower up to 25 MW. Large hydropower is frequently opposed by society, environmentalists, and nongovernmental groups because to concerns about floods, desertification, and relocation challenges, among other things. As a result, modest hydropower can be envisioned as a superior method for generating electricity.Small hydropower is typically clean, sustainable, and ecologically friendly because many SHPs are canal-based or runof-river systems that use moving water to propel the turbine. The weir or barrage is small, and no water is collected; it is devoid of difficulties connected with significant hydropower, such as resettlement of local residents or deforestation.

SHPs are completely immune from forest and land clearance and public sitting/plenary enquiry in several countries, including India, since they are sustainable. SHPs are economically practical, with a relatively short gestation period. SHPs are suitable for powering settlements as well as remote or isolated places. Access to power in these locations will support small-scale industries and thereby enhance people's socioeconomic standing. SHP does not emit greenhouse gases, and lower greenhouse gas emissions imply a lower carbon footprint, and so lower CO2 emissions. The classification of SHP in India is shown in Table 2 and Table 3 shows the State wise details of SHP potential.

Table 2. Classification of SHP

S.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

From the Table 3, Karnataka is the state with the most installed capacity, followed by Himachal Pradesh and Maharashtra. The north and north-eastern regions of India have a great potential for SHP; the northeastern area of India is sometimes referred to as India's "Future Powerhouse."

Table 3. State wise details of SHP Potential

Region/State	Small hydro power projects
Jammu & Kashmir and Ladakh	1707.45
Himachal Pradesh	3460.34
Punjab	578.28
Haryana	107.24
Rajasthan	51.64
Uttarakhand	1664.31
Uttar Pradesh	460.75
Madhya Pradesh	820.44
Chhattisgarh	1098.20
Gujarat	201.97
Maharashtra	786.46
Goa	4.70
Andhra Pradesh	409.32
Telangana	102.25
Karnataka	3726.59
Kerala	647.15
Tamil Nadu	604.46
A&N Islands	7.27
Jharkhand	227.96
Bihar	526.98
Odisha	286.22
West Bengal	392.06
Sikkim	266.64
Meghalaya	230.05
Tripura	46.86
Manipur	99.95
Assam	201.99
Nagaland	182.18
Arunachal Pradesh	2064.92
Mizoram	168.99
Sub Total	2994.94
All India	**21133.62**

A total capacity of 4,647 MW (21.98 % total potential) has been built in the small hydro sector.

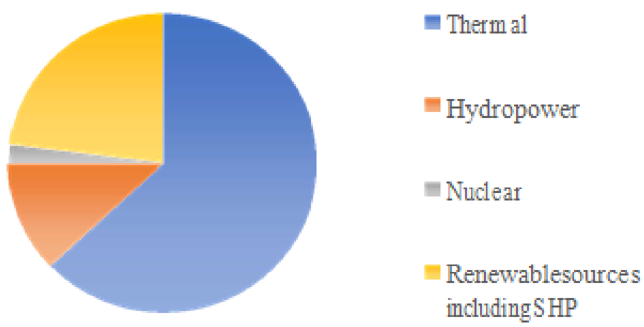
CURRENT TRENDS, CHALLENGES, AND RECOMMENDATIONS

Energy sector is one of the most critical areas confronting economic, environmental, and development challenges. The generation of renewableenergy and the deployment of new facilities are critical factors in meeting global power consumption. Concerns about climate change and greenhousegas (GHG) emissions fromconventional fossil fuels are growing, and a paradigm shift to green and ecologically friendly energy sources is urgently needed. Such circumstances highlight the importance of diversification and traditional energy independence. In 2018, the global installed hydropower capacity was 1.3 TW, with 4.2 TW of electricity generated. Hydroelectric power plants, on the other hand, require appropriate design and planning to mitigate negative environmental consequences and ensure long-term operation. SHP is a proven and flexible technology that is critical developing countries, particularlyrural regions, to have access to ecologically benign energy. With the development of SHP, a number of countries have made or are about to take steps to reduce poverty and enhance access to energy. SHP helps developed nations meet their goals for increasing renewable energy consumption and reducing greenhouse gas emissions. Current trends in the growth of the small hydro sector, issues facing the industry, and potential solutions for mitigating these challenges are examined in this section.

SHP accounts for 1.5 percent of the installed capacity, 4.5 percent of renewable energy, and 7.5 percent of global hydropower capacity. Asia-Pacific holds the largest share of the global SHP market. Regional statistics show that the Pacific region has the smallest share of SHP input capacity, while Asia has the largest share. Asia and the Pacific make up 65 percent of the global SHP volume included. Japan and India have implemented a SHP volume of 35% and 18% of their maximum capabilities, respectively. India is expected to see the growth of the SHP as a result government programs such as Rajiv Gandhi Grameen Vidyuti Karan Yojana and the Hydro Small Energy Program run by the Department of Renewable Energy. Rajiv Gandhi Grameen Vidyuti Karan Yojana India aims to electrify rural areas and supports the use of alternative and clean energy sources such as SHP, solar, and other mini-grid applications with or without projects, partnerships private, or private, while equally emphasized on grid connected and spatially integrated systems. Several SHP projects were operating or under construction in remote and isolated areas, particularly in the Indian Himalayan and Western Ghat regions. Despite the fact that these projects are being developed by various national government departments responsible for green energy, themanagement and maintenance of these projects is usually done in India by entrepreneurs or by donations from local communities / Gram Panchayat / tea garden owners / owners. In

Total installed capacity in India

4. Major problems for the Development of SHP



One of the most important issues in implementing SHP projects is the high cost. However, this disadvantage is measured in terms of the long-term benefits that can be achieved. SHP is an environmentally friendly renewable energy source that can operate both off-grid and grid modes while staying clean, efficient, and safe. It not only strengthens local finances, but also provides a higher rate of energy efficiency tax. Citizens who are currently a small group, geographically segregated and dispersed, using self-regulating electricity and strong grid infrastructure will be able to achieve long-term social and economic development.

Electricity is generated by diesel in several countries, including small island republics. As a result, they are facing rising fuel prices and a shortage of trade. In addition to improving energy independence and economic stability, switching to renewable energy (SHP) helps to reduce climate change. Energy independence, energy diversity, and renewable energy goals can all be achieved through SHP even in countries with full electricity. The following are some of the key barriers to SHP growth that nations around the world face:

(a) A common obstacle to the private sector's interest in growing the SHP sector in the emerging economy is the lack of accurate and up-to-date data on the potential of the SHP. Wherever they are made available, in developed and developing countries, the statistics provided in the SHP strength test are shown based on outdated research that fails to account for modern policy frameworks, technological advances, and strengths resulting from ancient regeneration. areas or development of existing canals and dams.

(b) The development of renewable energy focuses on the development of solar and wind energy in a number of countries. Solar and wind energy systems are the focus of government regulations and monetary compensation, and often do not work on other renewable energy sources, including small hydroelectric power. Most government regulations and subsidies are designed taking into account solar and wind energy, and do not apply to other renewable energy sources, for example small hydroelectric power needs to be addressed independently. Even today, private investors, especially in developing countries, view SHP growth as a high risk, whether they offer medium to long-term benefits over the main disadvantages of large-scale water generation, which is capital expenditure. As a result, SHP programs in developing countries are often implemented with funding or soft loans from international financial institutions or industrialized countries, which do not represent the paradigm of long-term funding.

(c) Countries with renewable energy goals, such as specific hydropower development objectives, often do not have clear and effective plans to achieve those goals.

(d) Many countries need to use clear motives for promoting renewable energy, especially public housing. Promotion and support programs must be tailored to the unique needs of the public and private housing industry. Otherwise, it may hinder the development of public housing projects. In many developing economies, incentives are used as part of energy exchange policies or to promote the spread of renewable energy in order to achieve renewable energy goals.

(e) As SHP tends to specify location, its development is highly dependent on local knowledge and knowledge. The vision, design, and operation should all be in harmony with local circumstances. Many of these considerations point to the development of unique skills and skilled workers, which will increase the cost burden of the SHP industry in terms of imports, taxes, and taxes.

(f) Due to the fact that most of the existing SHP areas are located in hilly and semi-arid and isolated areas, various conditions result in the unavailability of the power grid. It is up to the government to enact laws that promote the integration of the SHP grid, either through grid expansion or financial assistance; otherwise, most of the usable energy is not used or overcharged by developers.

(g) In many developed countries, new environmental protection frameworks have imposed a number of potential effects on SHP sites that may be developed, which require additional costs, make projects less financially viable, or hinder full development.

POSSIBLE SOLUTIONS FOR IMPROVEMENT OF CHALLENGES

The many benefits of sustainable energy reduction strategies, which include improved public health as a result of reduced emissions, higher reliability and resilience, and the creation of new employment opportunities, encourage the use of these forms of energy. However, the scope and depth of the renewable energy policy frameworks vary widely, which is why many renewable energy systems miss the mark of what is needed to meet global climate objectives. Policymakers may make significant changes in this area in the growth of the SHP sector, the following proposals, although broad and inclusive, may be evaluated in this regard in order to exceed the above-mentioned limitations in the previous section.

(a) Emerging nations should conduct an in depth study of their perceived capabilities and make a detailed project report public in order to reduce development costs and attract private partnerships to SHP development. Developed nations should undertake the expected re-evaluation of designated areas and evaluate new sites based on current SHP technologies, changing environmental conditions, laws and regulations, and so on. Transformation of existing infrastructure and rehabilitation of old areas to improve energy efficiency can also be considered.

(b) For SHP engineers, one of the most important setbacks is the complex and highly advanced process of obtaining the necessary permits from various government agencies and regulatory agencies. A unique window cleaning method should be designed to overcome this problem. In addition to the establishment of clearly stated objectives for SHP growth, current policies and financial rewards that highlight green energy technologies should be extended to SHP.

(c) The estimated financial risk is one of the major barriers to private sector involvement in the development of SHP. In order for developers to successfully fund a project, a smooth, improved access process must be implemented. A program like this can reduce financial risk for investors. One way to achieve this is to raise awareness of SHP among local financial institutions in order to improve risk measurement and secure favorable lending principles. In addition, skills development centers should be established to train and produce local skilled workers to perform various activities related to SHP development, such as before, during, and after the implementation of SHP projects, and their performance and maintenance. A framework like this can improve independence.

(d) Governments should establish norms to encourage the establishment of enterprises that will provide the equipment needed for the building, operation, and maintenance of SHP plants using indigenous technology. In the event of countries lacking in technology, facilities should be established to allow foreign countries free access to acquire and import equipment, as well as lower customs and taxes on such imports.

(e) Several studies, particularly in developing countries, demonstrate that SHP has grid access concerns, with the closest grid available location in some cases being several miles distant. This increases the cost and time complexity of construction, which must be borne by the operator or the administration, or both in some cases. Furthermore, even when grid connectivity is accessible, the grid operator's capacity or limits make SHP integration problematic. A robust grid with the capacity to accept newly formed SHP as well as the operational and functional gets about through them should be built to tempt private sector investment and help in the development of the SHP sector. Micro and mini-grids, which provide energy access and aid in economic growth in remote and isolated places far from the grid and which can provide enough base load, will be an attractive and cost-effective choice for rural electrification.

(f) In order for SHP to be favored as a renewable energy source, national and international stakeholders responsible for its development must work together urgently. This will increase public knowledge and information sharing on new technologies, techno-economically viable sustainable models, ownership issues, rules and regulations, benefits, and incentives that support SHP development and mitigate climate change's negative effects.

RECOMMENDATIONS FOR SHP DEVELOPMENT AND COST REDUCTION

This section examines the financial and economic factors behind the lack of interest in the development of SHP. The following are the approaches offered in the literature to increase the performance of the SHP plant while lowering the total cost of ownership.

a. The number of generators should be limited to 2–3 to save money on civil works, hydrokinetic equipment, control system redundancy, and cabling, among other things.

b. Instead of a full Kaplan, a semi-Kaplan can be used, where the guide vanes are adjusted, and fluctuations in the flow of water are achieved using runner blades. This also helps in the use of unobtrusive water level controls.

c. The height and size of the power house can be further reduced by placing control panels and fittings under the mezzanine, reducing the cost of public works. A reduced structure can be obtained, which allows a complete channel to be incorporated into the underground configuration.

d. Capacity measurement should be done carefully, taking into account all sub-systems, so that the system is not too expensive. Input generators are more popular than economically compatible generators with all related subsystems.

e. Setting up a turbine design, keeping in mind the potential for mass production of parts and services, is important in reducing costs. Allows multiple applications to be integrated with a small number of device designs. A typical turbine design may or may not always fit well with the parameters, although a close-capacity turbine may be made available.

CONCLUSIONS

The current study seeøks to examine the literature on topics related to the development of SHP plants, particularly the financial/cost analysis. The study looks into the specifics of SHP planning and development, including the current state, obstacles, and potential solutions for SHP plant development, as well as cost analysis tools and methodologies utilized in SHP planning. The cost analysis methodologies examined are helpful in determining the entire cost of the SHP over its lifetime and in making informed decisions. Several methodologies used by governments around the world in SHP planning and development revealed that some fundamental difficulties always exist in some manner. In this context, meeting all of the constraints that come with SHP planning and growth becomes a difficult undertaking.

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