



Identification of barriers to the development of hydro power in Uttarakhand

*¹ BCK Mishra, ² HSS Santosh Kumar, ³ Atri Nautiyal, ⁴ Dayanand Pandey, ⁵ Anil Kumar, ⁶ Mohammed Yaqoot

¹ Uttarakhand Power Corporation Limited, Dehradun, Uttarakhand, India

²⁻⁶ University of Petroleum and Energy Studies, Dehradun, Uttarakhand, India

Abstract

Uttarakhand is endowed with perennial rivers and large network of both rain fed and ice fed rivers that provide immense scope for development of Hydro Power in the State. Hydro power is the clean energy which generates electricity at zero fuel cost. Regulatory issues, Transmission /Power evacuation issues, Environmental concerns, Inter-state perspectives, Law and order issues, Dearth of good contractors, Natural effects, Political issues, Land acquisition problem, Resettlement and Rehabilitation issues, Locational disadvantages, Budgetary requirements, Private sector involvement and Longer gestation period are some of the obstructions which are hindering the development of hydro power plants. This paper reviews the available literature to identify several barriers affecting the development of Hydro Power in Uttarakhand.

Keywords: hydro power, advantages, barriers, Uttarakhand

Introduction

India has recorded remarkable economic growth during last decade or so [1, 2, 3, 4]. Access to reliable and affordable electricity is considered as one of the major input factors to the economic development [5]. As economy grows demand of quality, reliable and affordable energy increases [6]. Thus, in supporting to the accelerated economic development, India's power sector has also experienced accelerated growth trajectory during the phase [7]. Capacity-wise, India has 5th largest electricity generating capacity in the world with a reported installed capacity of 330.86 GW as on 30th November 2017 [8]. Fuel-wise, thermal (coal, gas, diesel) and hydropower contribute 66 % and 14 % to India's power generation capacity and the rest is contributed from energy sources namely solar, wind, small hydro, biomass and nuclear (Table 1). As evident in Table 1, the fuel-mix clearly indicates the dominance of coal in India's power. This pattern of energy mix is highly problematic for the country [9]. As a responsible nation with respect to the global concerns for sustainable development, India has to focus mainly on Green Energy which generates electricity through renewable sources [10, 11, 12].

Table 1: ALL India Installed Capacity (IN MW) of Power Stations.

Source	Installed Capacity	Percentage in Energy Mix
Thermal (Coal, Gas, Diesel)	219414.51	66.25%
Nuclear	6780	2%
Hydro	44765.42	13.5%
Renewable Energy Sources	60157.66	18.25%

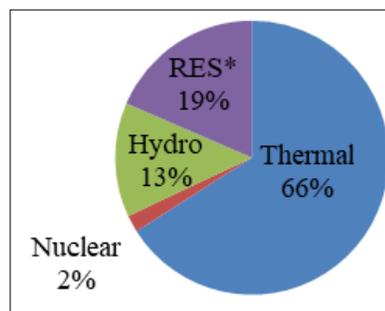


Fig 1: India's primary energy mix- fuel type [8]

Renewable energy technology exists in many forms like Solar, Wind, Biomass and Hydro [8, 9, 11, 13]. Yet the largest source of renewable energy comes from proven technology, Hydro Power [12]. Hydro Power plants are the renewable/clean sources of energy due to their emission/radiation free operation and generation of power at zero fuel cost [12, 17]. Hydro Power is considered as the fundamental instrument for reasonable advancement and sustainable development [17, 27]. India has about 150GW of hydro power potential, yet the nation has tapped under 45GW of this and contributing just 15% of the total energy mix [28, 8, 29]. Hydro power stations also allow us to reap the benefits of the economies of scale [30]. Due to its large scale (economy of scale) and zero fuel-cost based operation, hydropower is the cheapest source to generate electricity [13, 14, 25, 30, 36]. Once a dam has been constructed and the hydro power equipment installed, the energy source (i.e. water) is free that is renewed yearly by snow and rainfall [37, 38].

Advantages of Hydro power generation

A comprehensive snapshot of the advantages of hydro powered electricity is as follows

1. It is a clean source of energy [12, 39, 41]
2. In many cases development of Hydropower is associated with irrigation, drinking water, flood control and tourism benefits [42, 18, 19].
3. Ideally suits for meeting the peak demand as it has the inherent capability of quick start, stop, load variations etc., [42, 18, 43, 44, 19, 45]
4. The cost of generation is not only inflation free but it also reduces with time [42, 19, 35, 46, 16, 24].
5. Once the Hydro Power project is constructed, it can generate power at constant rate [43, 47, 19]
6. Hydropower projects emit very less green house gases when compared with other large scale energy options [18, 43, 19, 27, 41, 39, 20].
7. Dams are designed and constructed to last many decades which further contribute for the generation of power for decades [43, 18, 33].
8. Run-of-River (ROR) projects have comparatively low environmental damage [19, 20].
9. Hydropower provides quality power and high level of service to power system (reliability, flexibility, efficiency) [19, 48, 22]
10. Operating costs are very low and only fewer personnel are required on site during normal operation which further reduces the operating cost [33, 13, 26, 12, 14, 32, 18, 31, 49].
11. Remote area get developed and the rural people can be benefitted with proper and better connectivity, job opportunities, education, health care facilities and infrastructure [20].
12. Hydroelectricity makes it feasible to utilize other renewable sources [14]. At very low costs they can be modified to allow pumped storage [11, 13]. It is possible with most of the existing hydropower plants, to make use of them as ideal storage for wind and solar power which are intermittent in nature [33].

The advantages make Hydro power more desirable in the Energy Mix of India’s installed capacity. The total hydro potential assessed by CEA is approximately 1,48,701 MW, where as the installed capacity is only 44,765.42 MW [20, 29]. Despite of several advantages and available hydro potential, its contribution is only 13.5% of the total energy mix. Availability of such large potential indicates huge opportunity for India to generate cheap and clean electricity through large scale Hydro power development.

Utilization of Hydro Power potential in Uttarakhand

The Himalayan glaciers feed the perennial rivers of the Himalayan states and make them suitable for the development of Hydro Power projects [9, 11, 19, 21, 23, 49, 54]. Hydropower potential wise Arunachal Pradesh, Himachal Pradesh and Uttarakhand are the top three states in India with Hydropower potential of 50,328 MW, 18,820 MW and 18,175 MW respectively [42, 55]. Arunachal Pradesh has around 93.4% of its hydro potential unutilized whereas Himachal Pradesh and Uttarakhand have 37.84% and 71.85% potential lying

unutilized [42].

Arunachal Pradesh is in north-eastern part of India that faces law and order issues and thus large scale hydropower development in that state may not be feasible [55, 49]. Average unutilized hydropower potential of 92.81% for north-eastern states is indicative of the law and order challenges and subsequent feasibility issues for hydropower development in the region [42]. After Arunachal Pradesh, Uttarakhand positions next with substantial unutilized hydropower capability of around 12,932 MW [42]. As Uttarakhand is a peaceful state with negligible law and order problem compared to north-eastern part of India, the probability of development of unutilized hydropower potential is higher. Thus, the study focuses on hydropower development in the state of Uttarakhand.

In Uttarakhand, out of the total hydropower potential of 18,175 MW, only 3,426.35 MW capacity has been developed and 1,640 MW capacity is under construction phase [42, 56, 11, 57]. Including small hydro the total developed potential in Uttarakhand is 3988.05 MW. (UJVNL)

However due to urbanization and economic growth, demand for electricity has been growing in the state. During the initial years after formation of the state of Uttarakhand in the year 2001, it was an energy surplus state and over the years due to its increase in demand and slow pace of capacity addition, it has become an energy deficit state since 2006 [58]. With the state facing power shortages and with significant unutilized hydropower potential, policymakers of the state need to promote hydropower development for electricity generation through cheap and clean source of energy leading to sustainable development of the state.

Growth of Hydropower in Uttarakhand

It is evident from Table 3 and Figure 2 that during last few years, the growth in development of hydropower in Uttarakhand has been sluggish. The sluggish growth is depicted by the flattening of the growth curve of hydropower in Uttarakhand since 2010 (Figure 2).

Table 2: Growth of hydropower in Uttarakhand (UJVNL)

Year	Installed capacity	Annual Growth in %
2001	1112.90	-
2002	1117.00	0.37
2003	1117.00	0.00
2004	1123.50	0.58
2005	1408.50	25.36
2006	1808.85	28.43
2007	2813.85	55.56
2008	3123.85	11.02
2009	3164.35	1.30
2010	3164.35	0
2011	3614.50	14.23
2012	3614.50	0
2013	3614.50	0
2014	3637.90	0.65
2015	3967.90	9.07
2016	3988.05	0.51
2017	3988.05	0

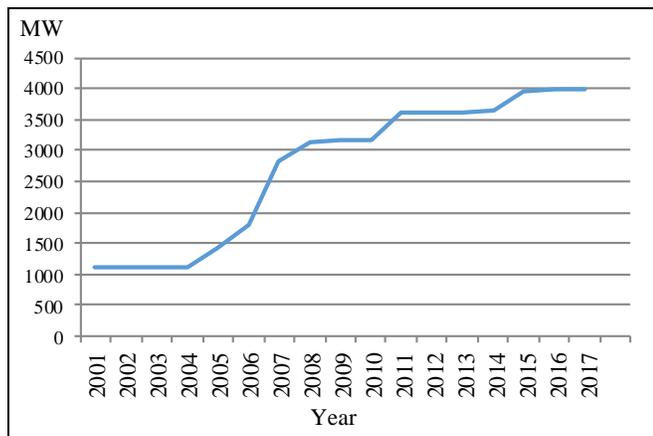


Fig 2: Growth of hydropower capacity in Uttarakhand (UJVNL)

The sluggish growth in the development of hydropower in Uttarakhand indicates presence of barriers and subsequent risks that hinder its development. Low hydropower capacity utilization in other hydropower potential rich states such as Arunachal Pradesh point that they may also be facing similar barriers. This research aims to study the barriers and risks associated with hydropower development in India, with special focus on Uttarakhand.

Identification of Barriers to the development of Hydro Power in Uttarakhand

A barrier to the development of Hydro power may be defined as a factor that negatively affects its adoption and subsequent utilization which hampers its widespread diffusion [59]. In Uttarakhand, private sector participation in the hydro power sector is noticeably absent [54, 15]. Due to frequent damage of Transmission lines, lack of availability of skilled labour in the remote areas, inaccessible locations are some of the factors that make an extremely unfavorable condition for the development of Hydro power in the state [54, 60, 24, 15, 61, 12]. Identified barriers for the development of Hydro power in India are as follows:

Longer gestation period and allocation of funds

Hydro Power projects entails long gestation period, due to unavailability of geological, seismological and hydrological records, delays in land acquisitions, resettlement and rehabilitation issues, law and order problems and poor connectivity [62, 63]. Whereas Thermal projects have short gestation period and get priority in fund allotments with a view to get early benefits [11, 64, 61].

Land acquisition problems

Due to land acquisition problem many of the Hydropower projects faced prolonged project implementation and schedule delays [49, 19, 20, 24, 31, 35, 36, 41, 42, 42, 51, 53, 63, 70]. This problem can be minimized with co-operation of concerned state governments [71]. Thein Dam, Doyang, Ghatgar pumped storage plants are some of the projects affected in the past due to this problem [42]. Problems arises in acquiring private land [35].

Geological Surprises

As the Hydropower projects being site specific, they rely on geography, geology and hydrology at the site [12, 13, 19, 20, 25, 26, 42, 42, 69, 72, 73]. Geological survey should be done and analysed before starting any project [49, 51]. Even with proper geological survey with technical advancements, a component of vulnerability stays in the sub-surface geography and the topographical amazements amid genuine development can't be precluded [49, 51]. This in turn prolong the time and cost leading to constructional risks.

Hydrological Challenges

River discharge observations are made available to the developers on pretext of confidentiality to the concerned government department only after the approval of the Ministry of Water Resources, GoI [15, 20]. Considerable time is lost in getting the approvals and the data [19].

Location Disadvantage

The Hydro power projects are site specific [12, 13, 19, 20, 25, 26, 42, 73]. Majority of Hydropower projects are constructed in remote locations and at high altitudes [36, 70, 73, 75]. Proper connectivity to the site, transportation of machinery, lack of power evacuation infrastructure and adverse weather conditions, construction of these projects get delayed [76, 64, 19, 54].

Lack of Political Commitment

In theory, India is endowed with economically exploitable and viable hydro-potential assessed to be about 1, 48, 700MW at 60% load factor [42, 67]. This potential cannot be exploited without clear political vision with efficient scientific and technological support [61]. Political instability, government intervention in domestic markets, corruption and lack of civil society are major barriers [9, 61].

Lack of Public Awareness

Negative perception in public regarding safety and environmental damage due to hydropower projects, there is inadequate public involvement during the project planning stage [19, 20, 42, 75, 77, 78]. And also no effort is taken to gain public acceptance through public involvement and transparency by the Government Agencies [19, 20, 42, 75, 77, 78].

Lack of Private Sector Interest

In the perspective of payback period, lack of availability of data, construction risks, regulatory and political issues, private sector is not showing interest for investing in Hydropower projects [27, 39, 51, 60, 61].

Environmental and Forest Clearances

Due to several concerns on deforestation, submergence, monuments, seismicity, ecology, flora, fauna, wildlife protection and catchment area treatment getting Environmental and Forest clearances became a major issue in the development of Hydro power projects [1, 31, 49, 62, 67, 70, 71, 78, 79]. Tehri is the best example of this issue as it took more than 36 years to start after conceptualization of the Project, this has delayed the Project and in turn realization of energy [42].

Public and Political Hesitations

Intermittent stoppage of projects due to local and political hesitations and frequent bandhs against the projects will take much time in completing the project [20]. Sometimes the project may also have a difficulty in even getting clearances due to this regard [19, 57].

Financial Constraints

High costs are involved. As many of these projects are located in remote locations and connectivity is an issue, costs incurred in developing the transport infrastructures (roads, protective measures for roads), bridges, housing infrastructure, royalties, custom duties, etc., [36, 70]

Power Evacuation and Transmission Facilities

Hydropower projects are majorly built up in the hilly areas and remote locations where there is no transmission facility available, developing proper transmission facilities for evacuation of power will take very long time which further delays the schedule of the project [19, 20, 35, 42, 46, 49, 54, 75, 80]. Also there is a difficulty in getting power for auxiliary consumption at the time of construction.

Equity of State Governments

Many hydropower projects are constructed or developed as Joint Ventures between private sector and State Governments [75]. In many cases due to negligence or not contributing in equity funding by the state governments, private partner needs to contribute 100% of the project funds and the projects get delayed due to this lack of funds by states [75]. Equity contribution and commitment from all the partners is necessary in completing the project as per the schedule [75].

DPR Preparation

There is lengthy and time consuming process for preparation of DPR and clearances having uncertainty of time line and shortage of people with clearing agencies e.g. forest and wild life clearances, environmental clearances, availability of land and hydrology records etc. [19, 20, 62, 70].

Resettlement and Rehabilitation Issues

As this is public related and sensitive issue, implementation of resettlement and rehabilitation for the project affected people is difficult [11, 42, 64, 71]. It is one of the main reasons for the delay in the project execution, resulting in time and cost overruns. Several projects like Tehri, SardarSarovar, Indira sagar are affected due to R&R issues, where the opposition came from the environmentalists and the surrounding people [42, 69]. Hydroelectric power projects in India's mountainous north and northeast regions have been slowed down by rehabilitation controversies, coupled with political interventions and public interest litigations. [61, 24, 19, 23, 81, 11, 31, 39, 42, 65, 66, 69].

Law and Order Problems

Lack of support of Concerned State government in ensuring proper law and order situation in the local and downstream areas of project location and due to lack of commitment in augmenting the required resources, especially in the projects

located at inter-state boundaries are the reasons hampering the project activities [19, 20, 36, 41, 42, 42, 49, 65, 69, 71, 75].

Regulatory and Policy Issues

Frequent changes in policy/norms by the central and state government, delay in getting environmental and forest clearances, delay in getting NOC from local village level institutions and government departments [53]. It is a major barrier because, the projects can be developed or operated only if there is a proper regulatory/permitting frameworks [64, 62, 27, 39, 51, 60, 61].

Lack of Local Infrastructure

Infrastructure here comprehensively allude to not just physical transmission facilities and distribution networks but also necessary equipment and services for the development of project [61]. Absence/very bad quality of access roads and/or bridges, delay in grid extension or absence of grid to match with commissioning of projects, absence/poor communication facilities (mobile, internet etc.) at the project sites are the major infrastructural barriers affecting the development of HPPs [53].

Non-standard Designs and Manufacturing

Hydropower projects have complex designs [82]. Each new project typically has a unique and site-specific design as no standard designs are available it requires long term for planning purpose [82]. This engenders more design effort, more environmental review effort, and increased manufacturing effort, each of which increases schedule and cost [13, 83]. Lack of advances in design is also one of the major drawback in this regard.

Dearth of Good Contractors

Experienced personnel must be adopted on to develop and initiate safe and reliable operational and maintenance protocols and procedures [70, 82, 84]. Non-availability of technically skilled manpower to operate advanced machinery/control panels [53, 59]. A matter of concern in the execution of large projects is the dearth of competent and resourceful contractors, as it often results in time and cost overruns of hydro projects [42].

Tariff

Tariffs from hydropower projects are higher in the initial years as compared to other sources due to lack of incentives like tax concessions, financing cost and construction of projects in remote areas with inadequate infrastructure [75]. Due to present tariff formulation norms for Hydropower projects (based on a cost plus approach) with no premium for peaking services and the provision for 12% free power to distressed states from the initial years are also proving to be Obstacles [85, 49, 11].

Inter-State Aspects

Under Indian Constitution, water is a State subject [19, 66, 62, 67, 70]. No objection certificate is required from each down-stream state for getting sanction even for Run-of-River projects and this is very time consuming [19]. Many of these Hydropower projects have common river systems between the states and this end up with several inter-state issues [42]. Some of these

projects have received techno-economic clearance (TEC) of CEA but the investment sanction could not be accorded due to inter-state aspects ^[40, 42, 67]. A number of projects have also not been accorded CEA clearance on account of inter-state issues ^[42].

Valuation of Forest land

NPV is paid for the land if forest land is diverted for non forest use or for constructing Hydro power projects ^[86]. But the state governments also demand for the rights and privileges. In some cases where tribal people live both NPV as well as Rights and Privileges are applicable ^[86]. In some cases the state governments also demand additional charges for carrying out forestry/wildlife activities and for bio-diversity management to be done at the project sites ^[86]. This leads to increase in project cost and also takes much time in evaluating the land.

Power Purchase Agreements

In the present scenario, there is focus on renewable capacity addition (mainly Solar, Wind and Biomass) and it is becoming difficult to sell hydropower as tariff is the major barrier ^[75]. There is hesitation with respect to distribution utilities or DISCOM's to go into long term Power Purchase Agreements (PPAs) ^[75].

Market Trends

Hydro power may encounter typical seasonal market challenges, deficient supply amid the dry season and oversupply amid the wet season ^[64]. During dry months, a relatively low percentage of generated power is sold at premium prices when demand is high ^[64]. During the wet season, prices are low and there is likely an oversupply of generated power, unless it can be exported ^[64].

Small hydro segment

Development of small hydro often suffered due to inaccessibility of the sites, lack of power evacuation infrastructure, investigation and construction difficulties, land acquisition and financing difficulties, inadequacies in institutional support and in some cases law and order problems ^[42].

Security Concerns

Tremendous hydro potential of the nation is accessible in the zones influenced by revolt and militant issues ^[20]. The peace issue in such ranges prompt deferral in execution of the projects and also cost over runs ^[20]. Also in several instances Maoists targeted hydro power projects and damaged the machines and vital structures in the power house. This also hinders in developing new hydro projects ^[87].

Conclusion

Worldwide Policy makers are promoting sustainable development to counter the challenges of climate change and energy security. Hydropower is a clean source of energy and is a desirable constituent of power generation mix of a country resulting in energy security and sustainable development. Hydro power plant also helps in flood control, irrigation and water supply. Despite of several advantages of hydropower

generation, hydropower development is facing several barriers and risks. Longer gestation period, environmental and rehabilitation issues, land acquisition problems, geological surprises, location disadvantages, financial constraints, and lack of public awareness etc., are the major barriers to the development of hydropower. This paper should be basis for future studies in creating framework for reducing bottlenecks in industry and to promote hydroelectricity.

References

1. Aiyar S. Twenty-Five Years of Indian Economic Reform, Policy Anal. CATO Inst., 2016; 803:1-24.
2. PwC. Future of India - The Winning Leap, Win. Leap, 2004; 1-148.
3. Trading Economics. India GDP Growth Rate, 2011, 1-9.
4. AD. Bank, Meeting the Low-Carbon Growth Challenge OUTLOOK 2016 UPDATE OUTLOOK 2016. 2016.
5. Bergasse E. The Relationship between Energy and Socio-Economic Development in the Southern and Eastern Mediterranean. 2013.
6. Sen S, Ganguly S. Opportunities, barriers and issues with renewable energy development - A discussion, Renew. Sustain. Energy Rev., 2017; 69:1170-1181.
7. Conference A. Presidential address delivered by the author at the Gujarat Economic Association's 31 Annual Conference held at Idar no. August, 2001.
8. Central Electricity Authority. All India Installed Capacity of Power Stations, Minist. Power, Gov. India, 2016; 1(5):1-7.
9. Ali J, Semwal A. Renewable energy in India: Historical developments and prospects, Int. J. Appl. Eng. Res., 2014; 9(10):1169-1183.
10. Block DS. Renewable Energy and Green Growth in India For more information, 2468.
11. Planning Commission. Report of The Working Group on Power for Twelfth Plan, Plan. Comm. India Website, 2012; 12:466.
12. International Hydropower Association. Hydropower and the World's Energy Future Technologies and Programmes, Notes, 2000; 4:2000.
13. Kaunda CS, Kimambo CZ, Nielsen TK. Hydropower in the Context of Sustainable Energy Supply: A Review of Technologies and Challenges, ISRN Renew. Energy, 2012, 1-15.
14. Perlman H. Advantages of Hydroelectric Power Production and Usage, US Dep. Inter. US. Geol. Surv, 2016; 1-3.
15. Sovacool BK, Dhakal S, Gippner O, Bambawale MJ. Halting hydro: A review of the socio-technical barriers to hydroelectric power plants in Nepal, Energy, 2011; 36(5):3468-3476.
16. Bhoi R, Ali DSM. Potential of Hydro Power Plant in India and its Impact on Environment, Int. J Eng. Trends Technol., 2014; 10(3):114-119.
17. Tshering S, Tamang B. Hydropower - key to sustainable, socio-economic development of Bhutan, United Nations Symp. Hydropower Sustain. Dev., 2004, 27-29.
18. Locher H, Scanlon A. Sustainable Hydropower-Issues and Approaches, 2012, 1-23.

19. Madan MM. The hydropower development in India-challenges and way forward, *Mind an Eng.*, 2015; 441-442.
20. Madan MM. The Hydro Power Development in India-Challenges and Way Forward, no. 2015, 1-49.
21. Shrestha Y, Arun B, Kumar Rajesh, Shen. An Overview of Glaciers, Glacier Retreat, and Subsequent Impacts in Nepal, India and China, 2005, 70.
22. Sivakumar N, Das D, Padhy NP, Senthil Kumar AR, Bisoyi N. Status of pumped hydro-storage schemes and its future in India, *Renew. Sustain. Energy Rev.*, 2013; 19:208-213.
23. Naidu BSK. Small hydro in India : environment friendly alternative energy source, 1996; 1:81-93.
24. Jaber JO. Prospects and challenges of small hydropower development in Jordan, *Jordan J. Mech. Ind. Eng.*, 2012; 6(2):110-118.
25. Brown C. World Energy Resources: Hydropower, 2016, 810.
26. IRENA, ETSAP. Hydropower Technology Brief, 2015, 1-18.
27. Purohit P. Small hydro power projects under clean development mechanism in India: A preliminary assessment, *Energy Policy*, 2008; 36(6)2000–2015.
28. Back G *et al.* Hydropower Potential in India, 2016, 5-7.
29. Report G. Preliminary Ranking Study of Hydro Electric Schemes Page 1 Preliminary Ranking Study of Hydro Electric Schemes, 2002, 1-7.
30. Sharma NK, Tiwari PK, Sood YR. A comprehensive analysis of strategies, policies and development of hydropower in India: Special emphasis on small hydro power, *Renew. Sustain. Energy Rev.*, 2013; 18:460-470.
31. Baidya G. Development of Small Hydro, Himal. Small Hydropower Summit, 2006, 34-43.
32. De Araujo JL, Rosa LP, da Silva NF. Hydroelectricity, *Gener. Electr. a Carbon-Constrained World*, 2010, 323-344.
33. Oprea D. the Hydropower 1. Hydroelectric Power, 2000.
34. Roy D. Hydropower in Uttarakhand: Is 'development' the real objective? *Econ. Polit. Wkly.*, 2008; 43(11):19-22.
35. Sharma A. Hydro Power Vs Thermal Power : A Comparative Cost-Benefit Analysis Need and Importance of Hydroelectric Power, *Int. J Arts Sci.*, 2010; 3(9):125-143.
36. Chairman FO, CEE Lectricity. H Ydropower in the N Orth E Ast : P Otential and H Arnessing S Strategy, 2006, 6.
37. Rahi OP, Chandel AK. Refurbishment and uprating of hydro power plants - A literature review, *Renew. Sustain. Energy Rev.*, 2015; 48:726-737.
38. Basins B. Hydropower Development, Assess. Cumul. Impact Hydropower Proj. Alaknanda Bhagirathi basin, 2011.
39. Gonzalez D, Kilinc A, Weidmann N. Renewable Energy Development Hydropower in Norway, *Cent. Appl. Int. Financ*, 2011.
40. Khurana S, Kumar A. Small Hydro Power- A review, *Int. J Therm. Technol.*, 2011; 1(1):107-110.
41. Saxena P, Kumar A. Hydropower Development in India, *Ighem*, 2010, 1-6.
42. K, Ramanathan AP. Hydropower Development in India, 2007.
43. Here C, Index FOR, Layout PIN, Npn OF, FOR Electronics. Click Here for Index Page, Search, 2010, 4-5.
44. Wikipedia F. percent of global hydropower in 2010. China, 2014, 1-15.
45. Rehman S, Al-Hadhrami LM, Alam MM. Pumped hydro energy storage system: A technological review, *Renew. Sustain. Energy Rev.*, 2015; 44:586-598.
46. Khan R. Small Hydro Power in India: Is it a sustainable business? *Appl. Energy*, 2015; 152:207-216.
47. Hydroelectric Power and Dams. A look at the Environmental, Social and Economic, 2011.
48. kumar R, Singal SK. Operation and Maintenance Problems in Hydro Turbine Material in Small Hydro Power Plant, *Mater. Today Proc.*, 2015; 2(4-5):2323-2331.
49. Handique K, Dutta A. Power and North East: The Hydro Power Scenario of North East, *Int. J Sci. Res.*, 2014; 3:12.
50. Eisenhower PDD. Eport of, 2000.
51. Sharma AK, Thakur NS. Resource potential and development of small hydro power projects in Jammu and Kashmir in the western Himalayan region: India, *Renew. Sustain. Energy Rev.*, 2015; 52:1354-1368.
52. Chandel SS, Shrivastva R, Sharma V, Ramasamy P. Overview of the initiatives in renewable energy sector under the national action plan on climate change in India, *Renew. Sustain. Energy Rev.*, 2016; 54:866-873.
53. Kumar D, Katoch SS. Small hydropower development in western Himalayas: Strategy for faster implementation, *Renew. Energy*, 2015; 77:571-578.
54. Joshi MC. Hydro Power Potential in Uttarakhand, *Int. Conf. Small Hydropower - Hydro Sri Lanka*, 2007, 22-24.
55. Pranab Kr. Das. North-East. The Power House of India': Prospects and Problemsn, *IOSR J. Humanit. Soc. Sci.*, 2013; 18(3):36-48.
56. MNRE. Statewise Aggregate Capacity of Shp Projects, 2014, 1.
57. Place M, Products A. Power Scenario of Uttarakhand, 2017, 1-2.
58. Cea. Load Generation Load Generation Balance Balance Report 2015-16, *Cent. Electr. Auth.*, 2015, 1-4.
59. Yaqoot M, Diwan P, Kandpal TC. Review of barriers to the dissemination of decentralized renewable energy systems, *Renew. Sustain. Energy Rev.*, 2016; 58(477-490).
60. Painuly JP. Barriers to renewable energy penetration: A framework for analysis, *Renew. Energy*, 2001; 24(1):73-89.
61. Luthra S, Kumar S, Garg D, Haleem A. Barriers to renewable/sustainable energy technologies adoption: Indian perspective, *Renew. Sustain. Energy Rev.*, 2015; 41:762-776.
62. Mishra MK, Khare N, Agrawal AB. Small hydro power in India: Current status and future perspectives, *Renew. Sustain. Energy Rev.*, 2015; 51:101-115.
63. International Hydropower Association. Hydropower Status Report 2016, 1-41.
64. Balmer M, Spreng D. Hydroelectric Power, *Fuel*, 2012, 193-209.

65. Singh S. Green Growth and Transport in India, 2015, 37.
66. Nautiyal H, Singal SK, Varun A, Sharma. Small hydropower for sustainable energy development in India, *Renew. Sustain. Energy Rev.*, 2011; 15(4):2021-2027.
67. Subrahmanyam DS. Status of Electric power generation in India with special emphasis on Hydropower expansion, *Int J Renew Energ Env. Eng*, 2013; 1(1):31-33.
68. GOI. Faster, Sustainable and More Inclusive Growth - An Approach to Twelfth Five Year Plan, *Plan. Comm. Gov. India*, 2011, 146.
69. HYDRO POWER POTENTIAL DEVELOPMENT IN INDIA, 1-27.
70. House IE. Hydropower Policy, 2008; 41(0).
71. Government of India. Draft National Electricity Plan, 2016; 1(1).
72. Singh PSV. Distribution generation scenario in Indian context: An review, 2015; 2(7):29-33.
73. US department of the Interior Bureau of Reclamation Power Resources office, Reclamation: managing water for the west, *Hydroelectr. Power*, 2005, 2.
74. Palit D. Renewable energy in Northeast India: issues and prospects, *Energy Technol. Sustain. Dev.*, 2003.
75. Madan MM. Hydropower Project Development in India: Issues and Way Forward, 2017, 1-4.
76. Sharma AK, Thakur NS. Analyze the Factors Effecting the Development of Hydro Power Projects in Hydro Rich Regions of India, *Perspect. Sci.*, 2016; 8:4-6.
77. GEI. Global Electricity Initiative Glob. Electr. Initiat. Rep., 2014, 54.
78. Alley KD, Hile R, Mitra C. Visualizing hydropower across the himalayas: Mapping in a time of regulatory decline, *Himalaya*, 2014; 34(2):52-66.
79. NITI Aayog G. Draft National Energy Policy-India, NITI Aayog, Gov. India, 2017, 1-106.
80. Development H, Sector P, State THE, Uttaranchal OF. Policy on Hydropower Development by Private Sector in the State of Uttaranchal, 1-8.
81. Tortajada C. Policy dimensions of development and financing of water infrastructure: The cases of China and India, *Environ. Sci. Policy*, 2016; 64:177-187.
82. Bishop NJ *et al.* New Pathways for Hydropower : Getting Hydropower Built - What Does It Take ?, 2015.
83. Hodgkinson A, Wilson A. Effective Allocation of Excavation Risk in Hydropower Projects.
84. Kristinsdottir A. Risks and decision making in development of new power plant projects, 2012, 245.
85. Höffken JI. A closer look at small hydropower projects in India: Social acceptability of two storage-based projects in Karnataka, *Renew. Sustain. Energy Rev.*, 2014; 34:155-166.
86. Verma M, Negandhi D, Wahal AK, Kumar R. Revision of rates of NPV applicable for different class/category of forests, 2013, 143.
87. 11/18/2017 Untitled Page, 2017.