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Energy situation, current status and resource potential of run of the river (RoR) large hydro power projects in Jammu and Kashmir: India

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ABSTRACT

Power is the critical infrastructure on which the socio-economic development of the country depends. The growth of the economy hinges on the availability of quality power at competitive rates. Therefore, it is imperative that electricity is made readily available for growth of infrastructure, economy and overall better quality of life of the people of the country. Hydro energy, when compared with other sources, including the renewable one, stands in the top position as it is one of the cheapest and convenient energy available. Being one of the oldest technologies adopted in the world for energy generation it comprises of large, medium and small hydro projects. In this research paper field survey is done in Jammu and Kashmir (J & K) state which has a huge potential for power generation from large hydro projects as when properly tapped will certainly boost growth considerably. A lot of research work has taken place throughout the world for the assessment of sustainability factors related to large hydro projects, but these are mostly for reservoir based projects. Less literature was available which highlight the factors related to the sustainability of without reservoir-based hydro projects especially in the western Himalayan regions of India. The main objective of this research article is to identify the factors which are responsible for the slow development of the large hydropower projects in Jammu and Kashmir. It is very important to utilize the state's water resources in an environment-friendly manner to provide a solution to the energy problems in remote and hilly areas of J & K.

1. Introduction

Energy is the lifeline of today's world [80]. India, which is the seventh largest energy consumer of the world, is facing great challenges in meeting its energy demand. There is a huge gap between the energy required and the energy availability which is further increasing and is a matter of great concern [1]. As per the estimation, up to the year 2011 about 400 million people of India were not having access to electricity and about 836 million were depending upon the traditional biomass for cooking. This shows that the majority is still devoid of modern and cleaner ways of living [2]. In order to maintain the desired growth rate for 25–30 years, the country has to improve its energy production at a reasonable price. For this supply has to be increased by 4–5 times and generation by 6–7 times than its 2012–2013 level. The policy therefore is required to be formulated in a manner so as to meet the future demand after taking into account the environmental concerns [81].

In India the viable hydro potential estimated to be about 84,000 MW at 60% load factor, which is equal to the capacity of 150,000 MW [3]. Jammu and Kashmir, Uttrakhand, Arunachal Pradesh and Himachal Pradesh consist more than 80% of the total hydro potential of the country. These 4 Himalayan states are also known as the water tower of India [5,6]. Fig. 1 shows the all India installed generation capacity till February 2014. The coal/lignite power houses have an installed generation capacity of 130,221 MW and where as the hydro energy powerhouses have installed capacity of 40,195 MW. This shows that hydro energy in India has installed generation capacity of about 17.7%, whereas the coal energy have installed generation capacity of 58%, followed by gas 9%, diesel 1%, Nuclear 2% and renewable energy 13%. So the hydro energy is having the second largest percentage share in the overall power generation and growth rate. The potential for renewable energy can also be explored by promoting innovation and research work in the field [82]. Global warming and climate changes are a waking call for the country to plan for augmentation of renewable energy's share [7,86]. The main thrust of the Indian government now a day is on developing its basic infrastructure as well as industrial sector so that the ever increasing unemployment problem of the country can be solved. To achieve this goal the country has to improve its energy sector to meet its growing demand. The hydro power potential of the country therefore needs to be fully exploited to its optimum limit in a sustainable way [83,84].

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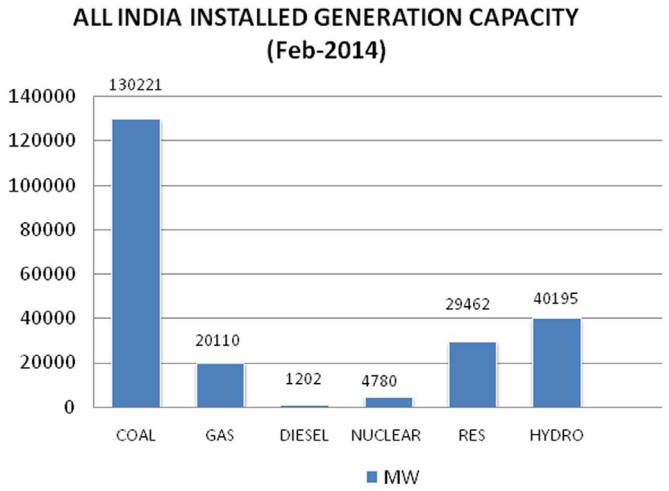

Fig. 1. Shows the all India installed generation capacity in India [4,67].

Among the hydro power projects, run of the river type is found to be more sustainable and economical when compared with the storage type projects because of the less submergence area involved and due to which less population gets dislocated. Therefore these types of projects are gaining more popularity now days in India, especially in the Himalayan regions because of its environmental benefits. In India the 75% of the available hydro power potential still remain untapped therefore central and state governments are interested to increase the power generation capacity of the country at the fastest rate in order to cater to the need of growing demand. To tap this available hydro power potential, the power developers are rushing to the government of concerned states for obtaining the allotment for the construction of hydro power projects. So, under the circumstances it has become very important that sustainability factors related to the hydro power projects do not get ignored in the process of speedy allocation of works. In the past these factors related to the sustainability of hydro power projects were not given much importance and due to which the recent floods in Uttrakhand and Jammu & Kashmir has become an eye opener for the researchers and planners. Construction of hydro projects in the fragile Himalayan zones without taking into consideration the environmental and ecological factors may cause catastrophe for the living beings of the area. For the rapid construction of hydro power projects in India it is becoming very important to have a detailed and comprehensive approach to study its impact on the environment and ecology for the long term sustainable progress [8]. Most of the countries have developed a system for assessing the impact of large hydro power projects on the local environment and this system helps in making their hydro power projects more sustainable and environment friendly. Sometimes power developers in connivance with the government authorities' manipulates by terming these processes as hurdles in the development of the hydro projects and get the environmental clearance. The hydro power projects whose rating is less than 25 MW are exempted from the environmental impact assessment process in India. Despite hydroelectric projects being recognized as the most economic and preferred source of electricity still the share of hydro power remained declining steadily since 1963 in India i.e. from 44% in 1970 to 17% in 2014.

The J & K is only state of India where all the hydro power projects which are already commissioned and under construction are based on the run of the river type, because of the Indus Water Treaty (IWT) between India and Pakistan. So, this is the main reason for selecting this region in western Himalayan for field survey in order to understand the major factors which are responsible for the slow development of large hydro power projects in the area. In this study the main focus is western Himalayan region. The most of the states in this region are gifted with very good hydro power potential and these states are attempting to develop large hydro power projects in their regions in order to improve their energy resources. So a case study of Jammu & Kashmir region has been discussed in this paper. Some authors in the past have highlighted environmental and social impacts of the large hydro power projects in this region but none of them highlighted the challenges which are faced by the power developers during the construction of large run of the river hydro power projects in this part of the country. Since the state is having power supply shortage therefore, it is highlighted in this article. The main objectives of the present study are: (a) to review the importance of Run of the River (RoR) large hydro power projects in terms of their ability to overcome the power crisis in the state (b) to undertake a case study of one large RoR hydro power project in the Chenab river basin of J & K from environmental, social and economic perspectives and (c) to know challenges faced by the power producers during the constructions of large RoR hydro power projects in the state.

2. Methodology

In this paper, we have adopted a subjective approach to perform a case study on one of the top most hydro rich state in the western Himalayan region of India i.e. Jammu and Kashmir (J & K). A study has been made in respect of policies related to large hydro power development in Jammu and Kashmir and assessment of various indicators related to the sustainability of without reservoir based hydro power projects in the state. It is seen that very less literature is available in respect of issues responsible for the slow development of these kinds of projects. The major problems faced by the power developers in J & K during the construction of these large hydro projects are identified and it is observed that inspite of huge hydro power potential, various factors like administrative, social, economical, geological, and environmental and security issues hampered the growth of these power projects. So the field study is conducted of some projects, technical persons which remained associated with these kinds of projects for the past 25 years were interviewed and gathered information for the secondary data like power generation annual report, economic survey report, research papers, international agreements, newspaper reports, detail project reports, environmental impact assessment reports, environmental management progress reports of large hydro power projects for the better understanding of the topic.

3. Validity of criticism against the reservoir based large hydro power projects in India

For some time now, environmentalists mostly from the developed countries as well as from the developing countries have been voicing concern about the adverse impacts of large storage type hydro power projects. These types of projects involve loss of property, economic, social, heritage and ecological resources, in the area where these are constructed. Therefore the question arises that whether storage type large hydro projects are sustainable at the generating end or not. So in order to answer this question, the various linkages and concerns of hydro resources development needs to be studied [9].

3.1. Submergence

The submergence of forest as well as agriculture land is often considered as the major concern in India and in developing countries where it is reducing rapidly. Moreover due to increase in the human population, natural resources have already been encroached to great extent [10]. Since most of the dams are located in the upper reaches of a river basin, the submergence of area is either on waste land or forest land. But it is seen that in India the large storage type dams are responsible for only 2% forest land losses during the period 1950–2000, whereas 98% forest area losses were due to other causes. Besides, above it is also seen that construction of storage type hydro power

projects means submergence of some area and in view of the limited cultivable area, the country should keep this aspect into consideration.

In India the prevailing impression in the mind of public is that all hydro power projects cause large submergence, therefore, it is necessary to make it clear in the mind of general masses that only storage type of schemes cause major submergence and the schemes without storage type or run of the river type causes nil or negligible submergence when compared with storage type hydro power projects [11].

3.2. Displacement/ re-location of population

This again is one of the major criticisms against large storage type dams like any developmental activity which involves some displacement. It is also seen that out of 3600 large dams in India 3300 have been built after independence and because of this construction about 30–40 million people got displaced (here displacement refers to the forced migration) [12]. It is also a fact that in the past adequate care was not taken of the displaced population in some cases as, in one of the case of Himachal Pradesh where the Pong Dam was developed extensive number of families has been constrained dislodged, but the State Government has given the Restoration and Resettlement area in Rajasthan's outskirt. The displaced families were confronted countless by the local administration for providing water, other supports, area title, and so forth, on the grounds that the Rajasthan Government was not bound to give them entire facility, with the result they returned back after 15 years to their original area for seeking their jobs. At present they are living in remote and far flung regions without much facility. It is also seen that when the population of particular hilly area having their own particular culture, values and close relationship with nature were resettled in the plain area, it become extremely troublesome for them to get adjusted to the new environment and recovery of such individuals turns out to be a complex issue [13]. It is therefore very important that where the large projects are involved, special monitoring system is required to be developed so that the implementation of re-location and resettlement plan related to the local people is carried out in a proper way [14].

3.3. Water logging

Changes in water table levels where a storage based dam is introduced may also cause water logging and salinity. The potential water tightness of storage has to be investigated by examining hydro geological conditions to ensure that there are no routes for flow to escape under the increased hydrostatic pressure of a full reservoir. A number of steps have been taken on various projects in India to reduce the adverse effects of water logging. These include measures such as conjunctive use of surface and groundwater. The lining of canal and field channels, leveling of irrigated lands and the adoption of a cropping pattern, takes into account the crop water soil relationship.

3.4. Earthquake

If the stress on account of weight of water at the bottom of a lake is worked out, it will be found that it is comparatively of a small order to cause an earthquake. The actual effect, however, will depend upon the material in the bed of a lake. If the material of the bed is sandy, conglomerate or a mixture of loose material, then it will continually be compacted as the dam is built and water is stored, and by the time the lake fills to its maximum capacity, the bed material will gets compacted adequately. It is possible that no tremor may result after a certain depth is reached due to further compaction and such tremors may be recorded by using sensitive instruments. In India only Koyan dam experienced an earthquake, but not at the time of reservoir filling. Impoundment was done in 1962 whereas earthquake was experienced in 1967 after completing four complete seasonal cycles. Seismological observations established at Bhakra, Pong and Ramganga dams in the Himalayan region that they have not registered any increase in seismicity due to reservoir formation.

3.5. Time and cost overrun

Time and cost overrun is not a characteristic of storage type hydro power projects alone. Projects of almost every sector are affected by this due to overall resource constraint and shifting priorities. Further, storage type hydro power projects are different from compact and location specific industrial units. They are spread out in large areas where unexpected technical, social and administrative problems crop up very often which lead to revision of designs, shifting of sites, land acquisition, expansion in scope during implementation, the decision to extend the distribution system, adoption of higher standards of rehabilitation and environmental protection [15–18].

4. Global perspective of large run of the river hydro power projects

Run of the river based hydro power projects are advantageous when compared with the storage type hydro projects therefore researchers throughout the world gave more importance to these projects. The adverse effects of storage type large hydro projects on the rivers have been commented by the various researchers as follows Premalatha et al. [19] commented on adverse effects of large hydro projects on river habitat, which is affected by the interruption of water flow, water loss from evaporation etc. Xingang et al. [20] commented that small hydro power projects improve living of farmers due to its low cost of electricity where as the large hydro projects causes environmental problems as observed in China. These projects also cause soil erosion, having seismic effects and changes of the ecology of the area. Reddy et al. [21] commented that due to construction of large hydro projects the environment gets effected and social problems also increases. This is the reason that attentions to the development of run of the river projects in the hilly region of northern India are promoted which causes little effect on the environment and natural resources. The critical linkage between run of the river projects, local people and environment benefits are studied in a village level research and Slariya [22] commented that the reservoir of large storage type power plants in tropical regions produces large amount of methane gas. He further highlighted other disadvantages like the rehabilitation of the affected population of the area and failure risks. Sperling [23] highlighted the main negative impacts of the large storage type hydro power project changes in water quality, people relocation, change in the structure of the aquatic community, loss of genetic patrimony (flora and fauna), slopes destabilization and climate alternations including those related to the emission of greenhouse gases. Williams et al. [24] compare the large, small and Pico hydro power generation, focusing on the adverse environmental and social effects of each and their economic performance. They also identified that all the negative environmental and ecological effects associated with large storage type dams such as greenhouse gas emission, obstruction to fish migration, reduced delivery of sediment to the sea, loss of diversification of ecosystem and population displacement and resettlement. Lata et al. [25] felt that run of the river type hydro projects has low environmental impacts, more sustainable and have reliable supply, low transportation cost, high operating efficiency and special government incentives. Eigre et al. [26] illustrated on the run of the river projects and state that because of the absence of any sizable reservoir helps considerably in both social and the environmental impacts as the river is not transformed into a lake. Also the flow pattern of the river remains unchanged, which reduces downstream impacts of the projects. Kumar and Katoch [27–30] also felt that run of the river scheme projects is more advantageous than the storage based projects and therefore have sustainable type of power generation system. This is mainly because of saving in the submergence area, resulting in small dislocation of local people. So, the

run of river scheme projects is becoming more beneficial than the storage based projects globally. Jain [31] expressed that the run of the river hydro power projects have the ability to generate energy by causing minimum damage to the local environment. So it is established that run of the river hydro power projects are more reliable, sustainable, environmental friendly when compared with the storage type of hydro power projects. In earlier days, when the proposal for installation of hydro power projects were made the economical factor was only considered, but as time progressed all the three factors economical, environmental, social factor related to the hydro power projects are taken into consideration. Table 11 show the comparison between reservoir based and run of the river based hydropower projects in the western Himalayan region. So it's very much clear from this table that total area required per MW for the run of the river project compare to the storage based large hydropower project along with the submergence and displacement of the local people is very less in the case of RoR project.

5. Study area: Jammu and Kashmir

The state of Jammu and Kashmir (J & K), situated in the transverse segment of the Himalayas, between 32° 15' & 37° 05' north latitude and 72^0 35' and 80^0 20' east longitude and is the northern most state of India. The State is bounded by China and Tibet in the north and east, respectively, and by Pakistan in the west. State of Himachal Pradesh and Punjab are contiguous with its southern boundary. The state has border disputes with neighboring countries and therefore the area close to borders have security concerns especially in Kashmir valley. The population of the state is 1, 25, 48,926 with 20, 15,088 households (i.e. 14, 97,920 rural and 5, 17,168 urban) as per 2011 census. The three main rivers i.e. Chenab, Jhelum and Indus passes through the state, Chenab passes through Jammu, Jhelum through Kashmir and Indus through Ladakh region [32–35,51]. The average rainfall in the state is 100 cm and mountainous ranges are covered with huge glaciers which makes the state a heaven for hydro power generation. The hydro power potential of Jammu and Kashmir State is assessed to be about 20,000 MW out of which locations for the generation of 16,480 MW have already been identified, but so far too less available potential has been exploited. The state of Jammu and Kashmir is the second in India, next to the state of Mysore in having tremendous hydro power potential, but because of Indus water treaty with neighboring Pakistan country its potential cannot be exploited to its fullest extent [36]. According to this treaty which bars India to interfere with the river flows of the Indus, Chenab and Jhelum the projects constructed on these rivers are designed on the basis of river run off [37]. The hydro power projects are designed on the basis of run of the river cannot generate constant power throughout a year, as the rivers flow varies from summer to winter. The topography of the region is complex which also compounds the energy deficit problem, especially in places which are inaccessible and snow bound and are situated quite far off from the main cities. Moreover, during winter season the various parts of Kashmir, and Ladakh remains cut off from other areas. So in such a complex topography transmission and distribution of power become a challenging task. Ladakh region of the state is not connected to the northern grid of India. Presently the diesel generators and solar power energy are used for electrifying, this area that too only for a fixed schedule per day [38,39]. National Hydro Electric Power Corporation (NHPC) has developed large hydro power projects in the state and power generated is sent to the northern grid of India from where this power is transmitted and distributed to other states as per their power demand requirement.

Tables 1 and 2 show various hydro power projects which are planned for execution and under construction stage in Jammu and Kashmir. The present state government has engaged a United Kingdom based consultancy agency to work out the losses Jammu and Kashmir State has to suffer owing to the impact of Indus water treaty and consequent failure to develop the hydro power sector. The state under the treaty can only store 0.40 million acre feet on the Indus in Ladakh, 1.50 million acre feet on the Jhelum in Kashmir and 1.70 million acre feet on the Chenab in Jammu whereas the average annual flow of the rivers of Indus basin are about168 million acre feet out of which the western rivers of the state are contributing a maximum of 135 million acre feet and eastern rivers are only contributing 33 million acre feet [40]. The state of Himachal Pradesh which is also extremely rich in its hydro power potential is having about 13.6% of the national hydro potential. As per the estimate 23,000 MW power can be generated by constructing more hydro projects on the five perennial river basins of the state. The state is already generating 8432 MW power out of which only 7.6% is under the control of Himachal Pradesh government while the rest is under control with the northern grid of the country [41,49]. Drawing comparisons between the two adjoining states having almost same hydro power potential, the Jammu and Kashmir state harnessed 2456.2 MW where as Himachal Pradesh harnessed 8432 MW. This shows the state of Jammu and Kashmir has to pay adequate attention for further development at a much faster rate. Table 3 shows state wise installed capacity of small hydro power projects as on 31.3.2011 and 30.3.2012 in Mega watt.

In J & K state the hydro power potential of 758.70 MW stood already harnessed by the state agencies and projects of 452 MW are under execution. Future projects of 2566.50 MW are under planning stage with the state agencies. The central agencies like National Hydro Electric Power Corporation and others are also generating 1680 MW power in the state whereas projects of 659 MW are under the process of execution with them. Moreover development of projects of about

Table 1
Comparison between reservoir based and run of the river based hydro power projects [27,87].

Project Name	Ranjit sagar dam	Nathpa Jhakari
Type	Storage	Run of the river
Capacity of the project	600 MW	1500 MW
Commissioning year	2001	2004
Dam height (meter)	160	62.5
Reservoir length (Km)	0.617	2.5
Reservoir area (sq. Km)	87	0.24
Total land required for the project (acers)	25,990.5	395
Number of people effected	3868	3000
Resettlement and rehabilitation	Completed	Completed

Table 2
Hydro power projects planned for execution in Jammu and Kashmir [68].

Sector	Projects	Capacity (MW)
State	1200 MW Sawalkote, 990 MW Kirthai-II, 240 MW Kirthai-I, 93 MW New Ganderbal, 37.5 MW Parnai, 3 MW Hanu and 3 MW Dah	2566.50
Centre	Bursar	1020
Private	50 MW Lower Kalnai	50
Joint venture	600 MW Kiru, 520 MW Kawar and 1000 MW Pakaldull	2120
	Total	5756.5

Table 3
Hydro power projects under execution in Jammu and Kashmir [68].

Sector	Projects	Capacity (MW)
State	450 MW Baglihar-II, 1.26 MW Sanjak, 1.5 MW Pahalgam	452.7
Centre	45 MW Nimo Bazgo,44 MW Chutak,240 MW Uri-II, 330 MW Kishanganga	659
	Total	1111.7

1020 MW is under planning stage with these agencies. In addition the projects of 2120 MW are proposed to be taken up under joint venture with central and state agencies. In state the graph of peak demand goes on higher scale during winter months and whereas generation dwindles substantially due to lean discharge in the rivers. So purchase of a considerable amount of power from the northern grid becomes a necessity. The harnessing of extra available hydro power potential therefore is a must to meet the growing power demand of the state.

6. Unbalanced growth and power shortages in Jammu and Kashmir

The state of Jammu and Kashmir is endowed with significant hydro power potential, which when exploited fully, will provide a strong impetus for the growth of its economy. The estimated hydro power potential of the state is 20,000 MW (MW), of which about 16,475 MW has been identified. This comprises 11,283 MW in Chenab basin, 3084 MW in Jhelum basin 500 MW in Ravi Basin & 1608 MW in Indus basin. For making the power sector efficient and more competitive, reforms in this sector have been and are underway. While there is some progress, power shortage continues to haunt the state and is a major constraint of the development of the industry and economy. The biggest weakness is on the distribution front because aggregate Technical and Commercial (AT & C) losses of J & K State are about 54% in 2014 as shown in Table 4. This has posed a major challenge to the fiscal health of the state [42,43]. Though the power availability has been augmented but at the same time demand has gone up considerably due to population and industrial growth. According to the survey conducted by the Rural Electrification Corporation Government of India the number of villages un-electrified in the Jammu and Kashmir state are quite large. So the construction of more hydroelectric projects has full justification to cope up with the demand. Fig. 2 shows the sector wise consumption of energy and from this data it becomes evident that the consumption of energy in the domestic sector is much more which is about 42%, industrial sector is 20% and consumption on account of public lighting and water works is 10%. The hydro power potential of Jammu and Kashmir state is sufficient not only to meet its own energy demand, but also for the whole northern states, however the energy generation of the state is lagging far behind to even meet its own demand. From Fig. 3 it is seen that the power deficit in 2004 was 20.87%, which further increased to 22.85% in the year 2014.

During the 11th five year plan of the country energy requirement of the state has increased at an annual rate varying from 5% to 6% whereas the rate of increase in demand during the year 2012–13 was 2% above the year 2011–12. So to meet the increased demand the department has enforced power cuts. These power cuts were even of the order of 8 h in summer and 10 h in winter. The restricted demand even after power curtailments were around 13,459 MW in 2014, this necessitated power banking during the summer with other state utilities and using the same in winter. For this the department entered into banking arrangements with other states like Chhattisgarh, Punjab, Haryana and also arranges power from the Power Trading Corporation, Vidyut Vyapar Nigam Limited, Northern Grid [44]. To meet the demand during peak period some over drawls were also made.

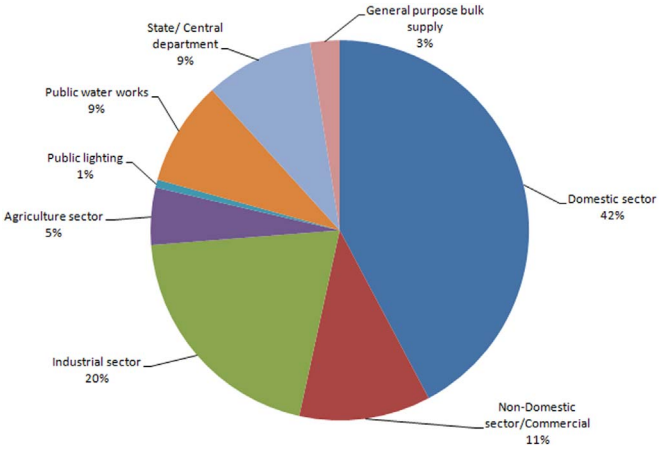

Fig. 2. Shows sector wise energy consumption in Jammu and Kashmir for 2013 [39].

During winter months the unrestricted power demand was of the order of 2550 MW and whereas the availability was only 1817 MW during the year 2012–13 which is shown in Table 5 and Table 6. The major component of purchase up to 70% was from the Northern grid. In the year 2012–13 only 35.94% energy output was realized which is the lowest in the country. The transmission and distribution losses are about 58.35% in 2013 as shown in Table 7. The major drawback confronting the state are the non optimal utilization of existing supply, inadequate inter regional transmission links, ageing of sub-transmission and distribution network, thereby leading to power cuts, local failures and faults, high Transmission and distribution losses, theft, slow pace of rural electrification in hilly and complex terrain, lack of grid discipline, irrational use of electricity. The Jammu and Kashmir government conducted audit of all the hydroelectric power projects, which made the following observations [45].

- No proper system of comparison of readings of main meter with the power house meter has been followed in most of the powerhouses.
- No standard operating procedure has been followed in case of meter failure or discrepancies.
- No system of periodical testing and re-calibration of meters have been followed. In certain cases the meters have not been tested since installation. System of periodical testing of meters is suggested to be introduced otherwise the meter readings may not be reliable and therefore leads to wrong conclusions.
- All interface meters, accounting and audit meters should be of static type and should conform to Bureau of Indian Standard (BIS) specifications. In case of non-availability of BIS standard for a particular equipment or material, the relevant British Standards, International Electro-Technical Commission standards or any other equivalent shall be followed which should further conform to the standards of installation and operation of meters as specified in the electricity grid code of the Central Electricity Authority (CEA).
- It is also seen that no manual, standards are in place due to which

Table 4
State-wise (sector-wise) break up of identified Hydro Electric Projects for benefits during 12th Plan (from 2012 to 2017) and installed capacity of Small Hydro power as on 31.3.2011 and 30.3.2012 in Mega watt [69,70].

State	Central Sector		State Sector		Private Sector		Installed capacity of Small Hydro Power	
	No	MW	No	MW	No	MW	March 2011	March 2012
Himachal Pradesh	2	816	7	892	6	749	393.47	527.66
Jammu & Kashmir	4	2450	4	1473	0	0	129.33	130.53
Uttarakhand	12	4374	7	1655	5	829	134.62	170.82
Arunachal Pradesh	3	1610	0	0	23	7969	78.84	79.23

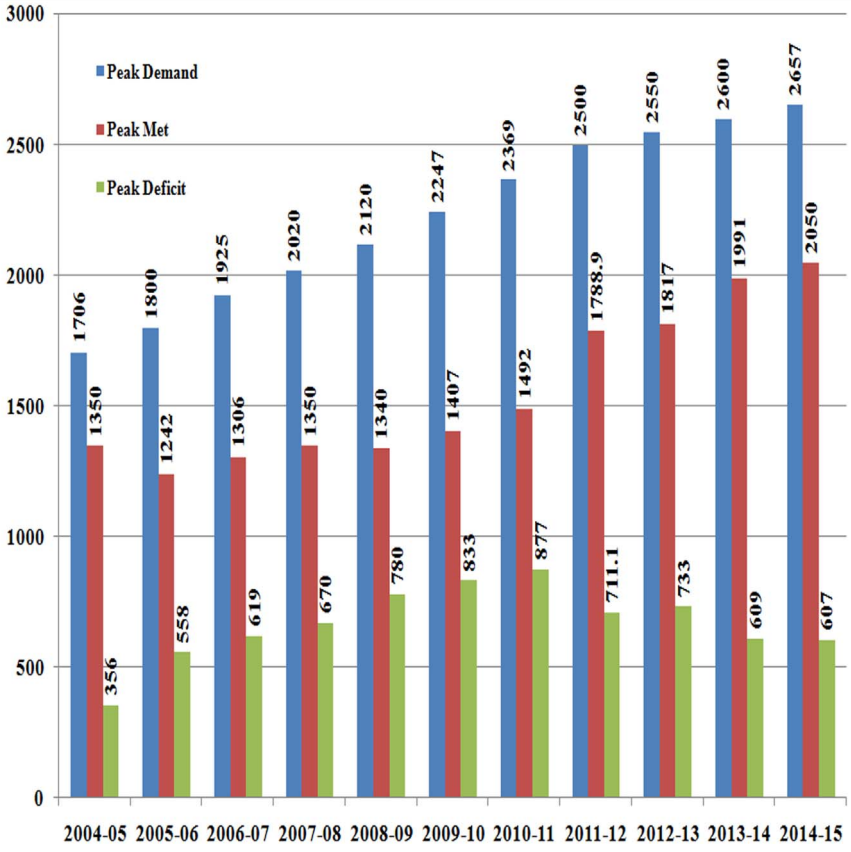

Fig. 3. Shows the power demand and availability (Peak) Scenario in Jammu and Kashmir (MW) [63].

Table 5
Calculation of gap between Average Cost of Supply (ACS) and Average Revenue Realized (ARR) along with Aggregate Technical and Commercial losses in J & K.
Source: [42].

S.no.	Item	Unit	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	Total Energy (self generated and imported)	Million Unit (MU)	7157.5	7306	7916.4	8236.5	8744	9425.6	10,371	10,667	11,115	12,120	12,666.5	13,459
2	Billed Energy	MU	3718.8	3856	4188.6	4030.8	3331.6	3478	3833	4041	4267	5163	5754	6372
3	Billing Efficiency (2/1×100)	percent	51.96	52.78	52.91	48.94	38.1	36.9	36.96	37.88	38.39	42.64	45.43	47.34
4	Energy Costs													
5	Power purchase from CPUs	Crore	1343.2	1339.6	1671.5	1415.5	1744.3	1459.5	1996.7	2157.6	3051	3489.7	3989.2	4320.3
6	Power Purchase from state	Crore	107.7	103.88	124.76	129.86	81.43	324.18	546.7	639.5	710.7	592.2	482.4	522.5
7	Total power purchase cost (5+7)	Crore	1450.9	1443.5	1796.3	1545.3	1825.8	1783.7	2543.4	2797.2	3761.8	4081.9	4471.6	4842.8
8	Operation and maintenance	Crore	26.27	32.43	28.28	28.78	41.27	43.34	55.35	48.72	58.96	55.32	46.36	53.47
9	Establishment	Crore	115.07	155.59	123.93	211.52	288.95	237.58	339.04	410.82	536.39	515.98	459.58	502.77
10	Depreciation	Crore	49.1	55.1	57.15	58.52	62.58	68.94	82.73	87.85	105.14	179.6	143.49	202.2
11	Interest	Crore	22	32.89	22.67	21.46	16.97	14.37	14.97	11.2	15.76	25.88	16.14	18.16
12	Total cost of supply (7+8+9+10+11)	Crore	1663.3	1719.5	2028.3	1865.6	2235.5	2147.9	3035.5	3355.8	4478	4858.7	5137.23	5619.37
13	Cost of supply (After losses i.e on billed energy) (12/2)	Paisa/Unit	474.05	447.27	445.93	484.25	462.83	671.01	606.97	791.94	830.41	941.07	892.8	881.9
14	Average Cost of Supply(Before losses i.e on input energy)ACS(12/1)*100	Paisa/Unit	250.85	232.39	235.34	256.22	226.5	255.67	235.06	292.7	314.56	400.89	405.57	417.52
15	Pure Revenue Billed or Assessed(Gross)	Crore	446.44	549	543.7	590.59	592.53	816.24	829.5	928	1180.7	1682.44	1757.17	1845.03
16	Average Revenue Relaised(ARR) (15/1)	Paisa/Unit	71	77	74	74	72	971	90.99	89.48	110.68	138.81	138.72	137.09
17	Gap between ACS and ARR (14–16)	Paisa/Unit	179.82	155.68	161.1	181.79	154.44	158.59	144.07	203.22	203.9	262.07	266.85	280.43
18	Revenue Realized	Crore	193.65	308.67	341.47	371.54	393.41	591.97	628	702.3	802.82	1419.29	1667.40	1777.41
19	Average Tariff	Rupee/Unit	1.34	1.41	1.41	1.41	1.47	2.45	2.38	2.42	2.53	3.86	3.56	3.34
20	Collection Efficiency (18/15 *100)	Percent	65.78	56.22	62.95	63.06	66.28	69.74	75.71	75.68	68	84.36	94.05	96.34
21	Energy Realized (2×20)/100	MU	2191.4	2189.2	2421.8	2635	2676.3	2416.2	2633.1	2902.1	3173.2	4355.47	5412.2	6138.47
22	Transmission & Distribution losses (T & D) (1–2)/1*100)	Percent	47.08	48.04	47.22	47.09	51.06	61.9	63.1	63.04	61.61	57.4	54.57	52.66
23	Aggregate Technical and Commercial losses (AT & C)	Percent	65.14	69.41	66.85	66.71	67.51	72.37	72.06	72.79	71.45	64.06	57.27	54.39

Table 6
Shows the restricted peak demand in Jammu And Kashmir State [63].

Peak Demand	2012-13		2013-14		2014-15 (E)	
	Summer	Winter	Summer	Winter	Summer	Winter
a. Unrestricted Demand	2400	2550	2500	2600	2500	2650
a. Restricted Demand	1712	1817	1819	1991	1950	2200

Note: Summer=8 h curtailment, Winter=10 h curtailment

required meters, data recording system is not available in certain cases. Moreover the meters were found not displaying the parameters required for proper monitoring of energy data.

7. Salient features of the state policy for development of non reservoir based large hydro power projects in Jammu and Kashmir

The power generation from the projects of 2 MW and above falls under the control of Jammu and Kashmir State Power Development Corporation Limited (JKSPDCL) which was carved out in 1989 and incorporated as a company in 1995 [46]. At identified locations of the remote areas where provision of grid network is a difficult task, the state government has devised a construction policy for the development of small hydro projects. The private parties taking part in the development of 2–10 MW capacity hydro projects will be free to sell power within or outside the state [47]. For the development of large hydro power projects bids are invited from the state investors and the work is allotted to the highest bidder for the cost payable per megawatt of energy [48]. JKSPDCL is responsible for preparation of pre-feasibility report, carrying out the bidding process and monitoring of the development of allotted projects/delivery as per timelines. In case the Detailed Project Report (DPR) is prepared by the JKSPDCL, the same shall be made available to the Independent Power Producers (IPPs) against actual cost incurred on its preparation. A period of six months is allowed for review/revalidation of the DPR and other milestones/timelines are adjusted accordingly.

7.1. Policy guidelines for the large run of the river hydro projects in Jammu and Kashmir State

- The hydro projects under the independent power developer mode shall initially be offered a concession period of 35 years from the date of operation. The commercial operation date is fixed according to the techno economic clearance of the project by the Jammu and Kashmir State Power Development Corporation after giving suitable allowance for the completion period from the date of award of the project.
- The successful bidders shall be required to pay a premium which shall not be less than 66,667 dollars per MW for 2–25 MW projects, not less than 10,000 dollars for projects above 25 MW and up to 50 MW and not less than 13,333 dollars per MW for projects above 50 MW and up to 100 MW.
- After the concession period is over, the project shall be handed over to Jammu and Kashmir State Power Development Corporation on payment of terminal value without any encumbrances. The concession period can further be extended beyond 35 years on mutually agreed terms and conditions.
- The power developers are to maintain the project assets to a condition that ensures its residual life at the rated capacity for at least 20 years, which includes the time of transfer of the project to the state by the independent power developers. The authorized agencies shall be inspecting the assets on a regular basis to ensure its maintenance level, for which the developer will facilitate the representatives of authorized agencies to enter the projects for inspection.
- If the inspections carried out by the authorized agencies reveal that capacity or residual life of the project is undermined due to an inadequate maintenance the authorized agencies shall order the developer to take immediate appropriate steps to fulfill the deficiencies noticed in maintenance work. In case the independent power developer fails to comply with the directions, the action can be initiated against them.
- The power developers shall be responsible for other related activities like rehabilitation, resettlement, environment impact assessment, preparation of the environment management plan and its implementation, as per the guidelines of the central and state governments.
- The power developers shall have no right over the water for power generation as the discharge of water in canals depends on the irrigation demand of the agriculture command area under the canal.
- The independent power developers shall be acquiring land through Jammu and Kashmir State Power Development Corporation on lease basis on payment of premium or rentals fixed by the government.
- The power developers shall bear all the cost involved in construction of a project infrastructure including approach road and other allied works.
- Project sites and its potential for generation shall be identified by the Jammu and Kashmir State Power Development Corporation on the basis of preliminary survey and pre-feasibility report, whereas power producers are only expected to verify project related parameters like habitations, head available, availability of discharge in the river during a particular period of the season.
- IPPs shall also ensure that the project components do not fall in wild life sanctuaries, national parks, eco protection zones, etc. and also do not interfere/overlap with the existing or ongoing Hydel Projects. The implementation of projects shall be governed by Indus Water Treaty 1960 between India and Pakistan and therefore clearance

Table 7
Shows the power generated by the central public sector undertaking and self generation [44,63].

Source	2012- 13		2013-14		2014-15 (E)	
	Summer	Winter	Summer	Winter	Summer	Winter
a. CPSUs	850–1350	750–1250	875–1030	1004–1455	900–1200	1100–1650
b. Self Generation	250–425	100–350	250–425	100–350	250–425	100–350
Total	1100–1775	850–1600	1125–1455	1104–1805	1150–1625	1200–2000

from Indus Water Treaty angle is required.

- On allotment of a project, the IPP shall approach the appropriate utility authorities for the grant of open access, who shall analyze the system availability and grant open access, duly identifying the interconnection point, infrastructure required upto the interconnection point, specifications and evacuation voltage. The IPP shall be responsible for developing the necessary infrastructure to facilitate the connectivity/synchronization with the main grid. Priority shall be accorded to the IPPs for dispatch into the grid ahead of merit order and any other source of supply, subject to any system constraints/grid disturbances or restrictions imposed by the state government in the interest of the state.
- For supply of committed power that is free power plus power procured by the State in grid connected or isolated mode, the available transmission/distribution networks of the state's transmission/distribution utilities shall be utilized and IPP shall not be required to pay any wheeling/transmission charges.
- For supply of balance power (other than committed power to J & K), the state transmission/distribution networks of transmission/distribution utility, can be utilized for which open access charges shall be borne by the IPP as per Jammu and Kashmir State Electricity Regulatory Commission (JKSERC) regulations.

Though almost all the Himalayan region in India have framed special hydro policies for the development of these ventures but still the implementation part is very poor, may be due to poor planning. The monitoring issue can be considered as the major reasons behind the slow and sluggish installation rate of these kinds of projects in Himalayan states [29].

8. Calculation of investment required and benefits drawn from the large run of the river power projects in Jammu and Kashmir

In the calculation it is assumed that the cost of one unit of electric energy to be Rupees 3.34 [50]. This is the cost at which the state government purchases power from Northern grid.

8.1. Calculations

- The energy consumed by one kilowatt load used for 60 min=1unit of energy.
- 1 MW load used for 60 min consumes energy=1000 units.
- 1Gigawatt load used for 60 min consumes energy=1000×1000=1,000,000 units=1Million unit.
- 20Gigawatt (hydro potential of J & K) load used for 13 h a day consumes=20×13=260 Million units.
- Similarly 20Gigawatt load used for 13 h for 365 days consumes energy=260×365=94900 Million units.
- So the cost of 94,900 Mega units at the rate of rupees 3.34 per unit comes to 94,900×1,000,000×3.34=316,966 million rupees.
- In Jammu and Kashmir State the cost for installation of the 1 MW hydro power project is estimated to about 65 million rupees.
- The total investment required to exploit 20,000 MW=20,000×65=1,300,000 million rupees (1 dollar=61 rupees).
- 70% of the project cost is spent, on civil works including compensation for land acquisition, employment and rehabilitation.
- 1Gigawatt load used for 60 min consumes=1000×1000=1,000,000 units=1 million unit.
- 1Gigawatt load used for 13 h a day can generate energy=13 Million units.
- 1Gigawatt load used for 13 h a day for 1 year can generate=13×365=4745 Million units.
- 4Gigawatt load used for 13 h a day for 1 year can generate=4745×4=18,980 Million units.

For meeting the domestic power demand of the state which is estimated to about 18,562 Million units in the year 2014 only 4 Giga watt will be required, the remaining 16 Giga watt of power can be exported to other states and which will earn revenue to the tune of 253,572 million rupees, if the full hydro potential of the state is exploited.

As per the national survey conducted in July 2011 to June 2012, based on Usual Principal Status (UPS), J & K has the highest Unemployment rate of 4.9% in comparison to its neighboring States like Punjab (2.8%), H.P (2.0%), Delhi (4.7%), Haryana (3.2%). However all India figures for unemployment rate stood at 2.7% only. Unemployment rate for Males in J & K was 3.2% only whereas that of females was 20.2% which is far too high when compared to the unemployment of females in neighboring States viz Punjab (5.6%), Haryana (4.8%), Delhi (4.3%), H.P (2.2%). As more of these hydro projects are going to be installed within the state, thereby results in creating more job opportunities for the youth of J & K and help in reducing this unemployment rate which is the highest in north India [33].

9. Projects under study: 48 MW Lower Kalnai large hydro project

The Lower Kalnai Hydel Project in Jammu and Kashmir State is a run of the river hydropower project. Project area is located in district Doda of Jammu and Kashmir State with head works at Dunadi having latitude 33° –8′ – 6″ north, longitude 75° –45′ –30″ east. The project site can be approached by National Highway I-A (Jammu to Batote) and National Highway I-B (Batote to Thathri) having a distance of 200 km. Further the head works can be approached through 7 km long link road from Thathri to Dunadi. The project envisages diversion of Upper Kalnai and Kaguneged Nallah, about 200 m downstream of their confluence at Dunadi by constructing a concrete dam of 49 m height (above the deepest foundation) across the Lower Kalnai River. Water is proposed to be diverted through a Water Conductor System (WCS) of 4.56 km (including 3.96 km long Head Race Tunnel) with its inlet portal upstream and exit portal about 200 m upstream of the confluence where a Surge shaft is proposed at the HRT. A power house is proposed on the left bank of Lower Kalnai River about 200 m upstream of its confluence with Chenab river. The investigation work on the tributaries of Chenab river was taken up by the Power Development Department of the state in 1973, when a separate circle of civil Investigation and design wing was set up for Jammu division. The investigation works on three tributaries of river Chenab River identified as Kaguneged-gad Nallah, Upper Kalnai Nallah and Kuligad Nallah in tehsil Thathri was taken up by civil investigation & Design Circle Jammu in 1973. Accordingly, four schemes were proposed on the said nallah, Kagunegad Hydel scheme, Upper Kalnai Hydel Scheme, Rangalla-Dunadi Hydel scheme and Lower Kalnai Hydel scheme. Most of the above mentioned schemes are not easily approachable for want of proper accessibility as such it was proposed to take up the Lower Kalnai Hydel Scheme in the first instance by constructing a diversion dam just down-stream of the confluence of Upper Kalnai and Kaguneged-gad Nallahas at Dunadi for which the Pre-feasibility Report was submitted to the Government in June 1982.

The Total Estimated Basic Cost of the Project Scheme is Rs.372 crores at July 2010 price level. The completed cost of the project is estimated as Rs. 492.38 crores including escalation during construction period and IDC. The project is also eligible to get the benefit of commercialization of equivalent amount of Certified Emission Reductions (CERs) units. Though it is not a mandatory requirement specified by Central Electricity Authority (CEA) for Technical Clearance of Hydro Power Projects, CEA, however, have issued guide lines for assessing carbon credit benefits under the Kyoto Protocol of United Nation Framework Convention on Climate Change (UNFCCC). The generation cost for the Lower Kalnai H.E. Project shall be Rs 3.90/kWh

with 12% discount rate per kWh for (90% dependable year) which is high. JKSPDCL purchased power at Rs.2.65 per kWh during 2010–2011 and has projected purchase rate of Rs. 2.72 per kWh for the year 2011–2012. Hence taking advantage of the tariff benefit of Carbon Credit which is considered essential to reduce the tariff for the project, the carbon credit benefit has been quantified at Rs 0.54 per kWh. The generation cost, taking benefit of carbon credit, works out to Rs 3.36 per kWh, which is still high. However, considering the shortage of power in the J & K State, particularly during winter, and the projected increase in power purchase price in future, it is recommended that JKSPDCL may take up this project for implementation with due action initiated to obtain Carbon Credit benefits from concerned agencies [52].

9.1. Identification and evaluation of impacts of lower Kalnai project

Due to construction activities there shall be temporary and nominal effect on the ambient temperature and humidity. The operation stage of a hydroelectric project through a surface power house is also not going to create any impact on the meteorology and climatology of the area. For the construction of project about 73.4 ha land will be acquired from private owners, revenue and forest department. Out of this 1.01 ha agriculture land and 15.01 ha revenue land shall have its land use class changed from agriculture and wasteland to water body. The land use class of 28.72 ha wasteland and 7.06 ha agriculture land required for project components and internal roads shall have land use class changed to built-up area. About 2.12 million cubic meters muck will be dumped in designated dumping areas, on slopes of the bank of river which will bring no change into landscape of the area. There is small requirement of water during the project construction which shall be met from the Kalnai and Kagunegad River and the local resources. Further the existing drainage system in the area will not be modified or affected during the construction phase. Since the water usage will be mainly from the local khad for construction purposes, no adverse impact on ground water availability is expected. Since, the water from the river is neither used by the villagers along the river, nor there is any significant aquatic flora/ fauna population; the reduced flow is not likely to have any adverse impact and therefore no negative impact due to water withdrawal shall be experienced [53].

9.2. Environmental degradation due to labour immigration and impact on air quality

During the construction phase congregation of 1200 workers approximately is likely to take place in the project area, which will increase pressure on land and water resources. Conflict between the migrants and the local population may occur for employment. Labour engaged in construction activity will also move away once the project is completed therefore no additional impact is expected. Temporary changes in air quality during construction phase are expected due to emission of hydrocarbons from vehicles and gases from blasting operations. Temporary increase in noise levels will also be present during construction phase only. The ambient air quality and noise level during the operation phase are not expected to deteriorate as the power house will be underground.

9.3. Impact on local hydrological cycle and water environment

During the construction phase, the water environment of the Chenab due to this project shall be impaired due to increase in silt rate from the discharge coming out from open air works, batching and crushing plants and from the foundation works of power house. Due to this minor impact on the water quality and aquatic fauna of temporary nature shall be experienced in the river water. The sewage generated at the labour camps and other residential areas may also bring considerable pollutants to river sections, if disposed off in the river section without treatment. In the operation phase of the project the water environment in general will not deteriorate owing to its being a run of the river scheme whereby the water will be continuously used for power generation and released simultaneously. The quality of river water used for non-consumptive purpose for power generation will again return to the system without any consumption, thus there will not be any change in the hydrological cycle in context to the project.

9.4. Impact on flora and fauna

It is also seen that from the submergence influence zone of the proposed project none of the tree species, shrub, herb or any climber or grass species are either vulnerable or endangered except two herb species that is Bunium pericum and Quercus baloot. Interestingly the vegetation composition of the submergence zone is also widely distributed in the influence zone in abundance and there will be no significant loss to the habitat. However, any loss of riverine vegetation during the project activity period will be restored in the reservoir periphery in due course of time. The floral abundance of the project area in post construction phase will increase by many folds as the plantation under catchment area treatment, green belt, restoration and landscaping will be completed. As the project activity is not going to submerge all the major habitats, there is little concern for these niche birds. There will be no alteration to the existing habitat of endangered and threatened species. There is also no wildlife sanctuary, national park and biosphere reserves near the project area. The project is having its submergence mostly along the gorge, therefore will not create any type of threat to the recorded butterfly species. Increase in temporary stress levels of wildlife during construction phase due to noise, human interference and reduction in present habitat, may increase. Due to this project, there will be improvement in the habitat for mainly water birds, reptiles, mammals, amphibians and improvement in food chain of some reptiles, birds and carnivorous mammals due to creation of reservoir and increase in humidity level. The butterfly diversity in the area would be enhanced as scrub habitat around the submergence will receive substantial amount of moisture which will help in natural regeneration of forest canopy. Table 8 shows the concerns highlighted or observed during the survey of the large RoR by the local community in J & K.

9.5. Impacts on the social-economics

- Total 5 villages will be partially affected due to acquisition of 11.99 ha of agriculture land for the project and submergence purpose.
- 40 families shall be displaced due to acquisition of land, home,

Table 8
Analyzing the transmission and distribution losses for 2013-14 in Jammu and Kashmir [63].

Energy	Million Units
• Energy purchased from central public sector undertaking (A)	10,329.33
• Self generation of the state (B)	2337.237
• Total energy input(C=A+B)	12,666.59
• Inter state transmission losses i.e. pool losses (D= 3.34% of A)	371.86
• Net energy input to the state (E=C-D)	12,294.73
• Intra state transmission losses i.e. losses at 200/132 kV level (F)	568.2
• Total transmission losses (G=D+F)	940.06
• Transmission. loss %	7.42%
• Energy available for distribution at 33 kV level (H"C-G)	11,726.53
• Energy billed(I)	5754.35
• Distribution losses (J= H-I)	5972.18
• Distribution losses % (Energy with respect to Energy available to distribution=J/CX100)	50.93%
• Distribution losses % (Energy with respect to input Energy=(C-I)/C*100)	47.15%

shops and 19 families will be partially affected due to acquisition of land only.

- Additional infrastructural facilities such as schools, hospital, drinking water, and bank will have an access to the project affected people and local population.
- Subsidized gas connections for all project affected families may be provided to decrease the dependency of locals on forest for firewood.
- The project affected people may be provided training and financial help for entrepreneurship development.
- Preferential employment in semi-skilled and skilled categories will enhance the socio-economic status of project affected families.
- Pressure on the existing provincial/state road will increase.
- Due to project the quality of water in the downstream is not going to be affected as the water received by the project will be discharged in the downstream after power generation round the clock.
- The residential colonies proposed will have proper sanitation, solid waste and sewage disposal facilities. The project colonies and roads will have well laid green belts.
- During construction phase, migratory population though in limited numbers, is expected from other parts of the country having different cultural habits. However, no cultural conflicts are foreseen due to the migratory population, as they will be largely settled in separate conglomerates having all inbuilt facilities. Since major work force will be drawn from the local people and the people of J & K state, which by interaction with outside labour during course of construction, shall develop affinity and friendship with the outside workers, thus minimizing the chances of conflict [54].

10. Challenges faced by power producers during the construction of large hydropower projects especially in Jammu and Kashmir State

In Jammu and Kashmir all the hydro projects are run of the river schemes because of the Indus valley water treaty between the two countries (India and Pakistan). There are three main sources with the help we can identify the sustainability factors related to the without reservoir based hydro power projects, i.e. research articles, survey of various project sites and expert opinion. In Table 9 the most of the indicators which are highlighted by the other researchers are related to storage based hydro power projects. Very small amount of work has been reported in the literature to list out the sustainability factors related to Run of the River type hydro power projects in north western Himalayan regions. The conditions which were not studied in the past are (a) the amount of the muck generated during construction process. (b) Effect on religious places like temples, mosques and cremation grounds etc. (c) Impact of government policies on the development of hydro power projects in an area and (d) the security concerns of a region like J & K state of India. Impact on the temples, mosques, cremation grounds and Islamic cemetery can be considered as one of the main social factor related to the sustainability of RoR hydro projects in north western Himalayan regions. Possible loss of archaeological remains is feared at times. Hydro power projects being remotely located, their sites rarely encompass such historical or religious monuments. However conscious effort is required to save properties/monuments of culture/religion/archaeological importance while planning the hydro power projects. In case of Uri run of the river hydro power project in Jammu and Kashmir one old pandava temple of archaeological importance was being submerged as per the original detailed report of the project. A high level committee considered the issue and after detailed technical deliberations, it was decided to shift the axis of the dam upstream so as to save the temple above. The effect on local tourism, impact of other hydro power projects in the near vicinity and international water treaty with the neighboring country are also some factors which have influence on these kinds of projects. Environmental factors like total length by which a main stream is diverted and minimum flow to be maintained in the stream are some other factors which are crucial for the run of the river type hydro projects. There are some factors which are common and are applicable to both kind of hydro projects (i.e. storage and RoR type) like effect of large transmission lines, noise pollution, air pollution during the construction phase of these projects and effect on the water quality. Considering the literature gap and the missing factors from Table 9 as mentioned in the above paragraph, Table 10 has been established. More factors are included after having the site visits, meeting with the expert persons, power developers, local people and studying the detailed project reports of the large RoR projects in the region of J & K state (Table 11).

The state is having a hydro power potential of 20000 MW and ranks 4th in the list of top most hydro power potential states in India as shown in the Fig. 4. The social, economical and environmental factors changes from region to region; culture to culture; project to project for example small hydro power projects have different sustainability factors while large hydro projects have different ones. The establishment of large hydel projects in Jammu and Kashmir (J & K) state is a complicated and costly affair when such type of project construction is compared with other areas of the country like Karnataka, Maharashtra

Table 9
Concerns highlighted or observed during the survey of the large RoR by the local community in J & K.

Issues highlighted or observed	Duration of the impact of the issues highlighted	Lower Kalnai
Impact on agriculture	Long term	No
Impact on the water mills	Long term	No
Noise pollution	Short term	Yes
Air pollution	Short term	Yes
Water pollution	Short term	Yes
Public acceptance of the project	Long term	Yes
False promise made by the developer	Long term	No
Flouting of the rules & regulation by the developer	Long term	No
Security threats	Long term	Yes
Increase in the local area crime rate (like theft)	Medium/Long term	Yes
Employment generation	Long term	Yes
Improvement in the transportation facility	Long term	Yes
Communication facility	Long term	Yes
Improvement in the power supply (decrease in the power cuts)	Long term	Yes
Conflicts between the local people and the developers	Short term/ Medium term	No
Improvement in the education level among the youth	Medium term/ long term	Yes
Fear in the local people related to large components installed in the project	Long term	Yes
Improvement in the local tourism	Medium term	Yes
Improvement in the local business (like private shops)	Long term	Yes
Increase in the local population near the project area	Long term	Yes

Table 10
Shows the sustainability factors highlighted by other researchers related to large hydro projects.

Reference	Social factors	Environmental factors	Economical factors
Rojanamon et al. [71]	Socio condition, use of forest, quality life values, change, condition of house hold and community	Location of national park, wildlife sanctuary, land use type, annual sediment yield	Preparation work, environmental mitigation, civil works, hydraulic, electrical, mechanical equipment installation
Sharma and Rana [16]	Blasting activity results in dust cloud, houses developing cracks	Effects on horticulture/Agriculture	Loss of livelihoods for the forest dependent people
Willams and Porter [24]	Population displacement and resettlement	Green house gas emission, obstruction to fish migration	Cheaper Electricity
Yuksel [72]	Creating Employment	Maintain local air quality, Limit and reduce the contribution to regional and global environmental issues	Export opportunities in the energy industry, emphasize the use of renewable energy sources
Bakken et al. [73]	More attention from the General public, NGO and Government authorities	Reduction in water flow, fish fauna affected by the project, cultural heritage sites affected changes water quality, water temperature	–
Bose et al. [74]	Health problems, water borne Diseases such as malaria and Schistosmiasis, Social, cultural and economic base of the families which were built over generations are dismantled	Sudden drop in food, crop production and loss of harvest takes place	Loss of access to common property
Erlewein [75]	Public participation, follow up	Destroying of the habitats of animal and plant species, obstacles for fish migration, drying of natural strings due to blasting for tunnel construction	Single use of transmission line to be connected to different hydro projects in same region
Wang et al. [76]	Shifting of people, effect on natural heritage	Water temperature, aquatic living, hydrological regime, water quality environmental geology, terrestrial living	–
Sperling [23]	Employment generation during the construction phase	Carbon dioxide emission, emission of green house gases, change in water quality, Climate alternations, siltation	Energy production, Tourist attraction
Almeida et al. [77]	Creation of new activities associated to sport, tourism promoting the diversification of the economy and an increase of the employment in the nearby area	Flood control, significant impact in the water supply systems, river eco systems that effect the fauna and the flora in the river region	–
Lata et al. [78]	Education status in the region	Lower level of dissolved oxygen, Increase in slitting, change in water Temperature, destruction of the natural vegetation	–
Kaunda et al. [79]	Displace settlements, destroy Infrastructure loss of livelihood And cultural identity	Destroy of ecosystem, inundation of land, air and water pollution loss of biodiversity, change of landscape	–

Table 11
Suggested sustainability factors for run of river hydro projects in Jammu and Kashmir.

Social Factors	Environmental factors	Economic factors
• Direct employment generation	Emission of green house gases	Payback period
• Indirect employment generation	Air pollution	Unit generation cost
• Participation of public in decision making	Noise pollution	Construction, Installation cost
• Effect on agriculture production	Effect on water quality	Distance from the load centre
• Change in standard of living	Effect of large transmission lines	Number of transmission line
• Effect on transport facilities	Effects on animals and birds	Effect on tourism
• Effect on communication facilities	Effect on forest land	Effect on the commercial activities
• Cracks in houses due to blasting activities	Soil erosion	Effect on the local industry
• Health problem because of air and water Pollution	Quantity of muck generated and its disposal	Resettlement and rehabilitation cost of the people who are affected
• Shifting of people to other places due to project construction	Impact on aquatic life	Impact of the hydro policies of state and centre governments
• International water treaty with neighboring countries	Total area required for the project	
• Terrorist threats and safety issues	Total length by which the main stream is diverted	
• Cultural, religious and archaeological aspects	Impact of the other projects installed in the near by area	

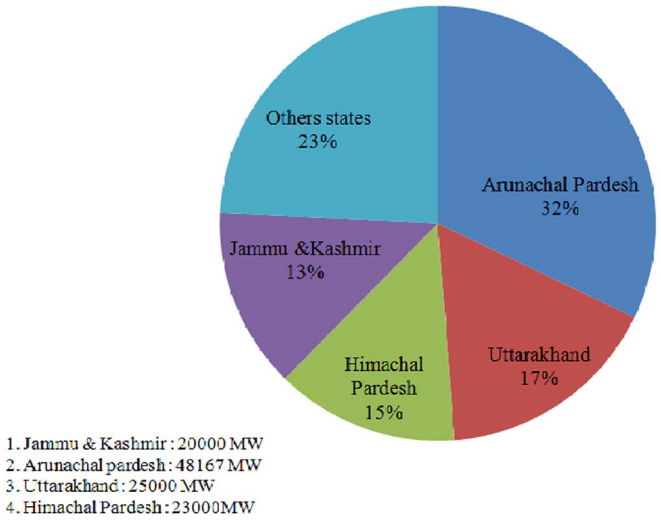

Fig. 4. State wise breakup of hydropower potential in hydro rich states of India (out of 150000 MW) [46,64–66].

Fig. 5. Shows proceeding of discussion with the expert regarding the factors effecting the development of large hydro power projects in J & K. Source: Author's own contribution.

and other states in the southern region of India. This is in view of the inaccessible and remote areas where these projects are identified, which also lacks in communication facilities thereby increasing its construction cost. The climatic conditions of the Himalayan region of the state is also harsh and unpredictable and construction period of the region is also limited (i.e. varying between six to seven months only during a year) as the construction work have to be stopped during winter months due to sub zero temperature and snow fall. This factor further increases the project cost and its time of completion. There are numerous other difficulties which are confronted by the private executing agencies during the construction of these projects. These difficulties should therefore, be studied in details by going through the project reports, paying visit to the site of construction, gathering relevant inputs from the local people and the administration representatives connected with these works before taking up the work in hand. Fig. 5 shows proceeding of discussion with the expert person (like Chief Engineer and other senior officers) regarding the factors effecting the development of large hydro power projects in J & K.

10.1. Policies and regulation challenges

The systems embraced by the state government in giving no objection certificate from different quarters are extremely long and tedious which results in delay to begin the project. The Project Implementing Authorities have to obtain clearance from different departments like Forest, Revenue for transfer of government land on lease basis, environment and also consent from local village level organizations before the start of work. If the process for according such clearances is made smooth and time bound for all the administrative units involved, then such delays can be minimized. The online method can also be adopted for applying and according clearances from different quarters which will facilitate the power developers in a big way and the time consumed will also be less. In addition to this the process of transfer of Government land for the project and purchase of land from private parties shall also needs to be simplified after the site for the project location is finalized. So, to complete this process of land transfer and acquisition in a time bound manner a state nodal agency can be established to exclusively look after such issues and try to complete them in a given time frame. In the event of any complicacy which may arise during the land acquisition/transfer process, the same shall be solved in a minimum possible required time.

Special permission is also required to be taken from Pakistan by the power developers before the construction of large hydro projects which

are going to be installed in the state because of the Indus Valley Water Treaty agreement. The treaty was signed in Karachi on September 19, 1960 between the Prime minister of India and the President of Pakistan. This governs the rights and obligations of each party in relation of the use of the waters of the western rivers, i.e. Indus, Jhelum, and Chenab. The Indus system of rivers comprises three Western rivers - the Indus, the Jhelum and Chenab and three Eastern rivers Sutlej, Beas, Ravi and with minor exceptions, the treaty gives India exclusive right to use all waters of the eastern rivers and their tributaries before the point where the rivers enter Pakistan. Similarly Pakistan has exclusive right to use of Western rivers.

Some of the main features related to this Indus Valley Water Treaty are given below [55–58].

- The design of any new Run-of-River Plant (here in after in this Part referred to as a Plant) shall conform to the following criteria especially in case of Jammu and Kashmir state in India: -

1) The works themselves shall not be capable of raising artificially the water level in the Operating Pool above the Full Poundage level specified in the design.
2) The design of the works shall take due account of the requirements of Surcharge Storage and of Secondary Power.
3) The maximum pond of water in the Operating Pool shall not exceed twice the pond size required for Firm Power.
4) There shall be no outlets below the Dead Storage Level, unless necessary for sediment control or any other technical purpose; any such outlet shall be of the minimum size, and located at the highest level, consistent with sound and economical design and with satisfactory operation of the works.
5) If the conditions at the site of a Plant make a gated spillway necessary, the bottom level of the gates in normal closed position shall be located at the highest level consistent with sound and economical design and satisfactory construction and operation of the works.
6) If any Plant is constructed on the Chenab Main at a site below Kotru (Longitude 74° – 59' East and Latitude 33° – 09' North), a Regulating Basin shall be incorporated.

- To enable Pakistan to satisfy itself that the design of a Plant conforms to the criteria mentioned in this treaty, India shall, and at least six months in advance of the beginning of construction of river works connected with the Plant communicate to Pakistan, in writing. If any such information is not available or is not pertinent to the design of the Plant or to the conditions at the site, it will be so stated.
- Within three months of the receipt by Pakistan of the information specified in Paragraph 9, Pakistan shall communicate to India, in writing, any objection that it may have with regard to the proposed design on the ground that it does not conform to the criteria mentioned in above Para-graph. If the no- objection intimation is not received by India from Pakistan within the specified period of three months, then it shall be deemed to have no objection.
- If any alteration proposed in the design of a Plant after it comes into operation would result in a material change in the information furnished to Pakistan under the provisions of above paragraph, India shall, at least four months in advance of making the alteration, communicate particulars of the change to Pakistan in writing, but the period of three months specified in above paragraph shall be reduced to two months.

To make the implementation of projects more realistic, the state has to incorporate a provision for extension at various levels, so that if the project work gets affected due to extraordinary delays then the same can be regularized and brought back to the track.

10.2. Social challenges

The significant social difficulties confronted by the major hydro power ventures in Jammu and Kashmir are the population living close to these hydro projects which demands besides employments also higher compensation rates for their property coming under the project. The main problem faced by the developers in providing employment to the local unemployed population is lack of their experience and technical know-how in the execution of such major works. However if the demands are not agreed, the people then resort to protests and hold demonstrations against these developers and do not allow the developers to start the work. Sometimes these peoples also raise the issues related to the blasting carried out for the cutting of rocky strata adjacent to their inhabited areas. These sorts of social issues can be sorted out if the power producers before beginning the work on the project meet the neighborhood population, listen to their demands/requests, conduct open gatherings and resolve the issues by mutual agreement. These agreements shall be executed in the presence of a legally authorized designated authority. For carrying out the blasting activity during the execution of a work it is imperative for the project developers to inform the adjacent population 1–2 days in advance about the timing of blasting and the safety precautions taken. The power developers should also employ the local people in their project as unskilled workers and should also provide opportunity to the technically qualified persons of the area as per their qualification. They should also fix the training capability criteria for the works where talented persons are required. Those persons who satisfy this criterion should be sent for imparting training to them to some other projects so that these local persons can get the working background and after that should be provided employments in the project.

It is likewise important for the hydro power developers to keep some percentage of project cost for the development of area adjoining the project. They should provide i) free education facilities to the poor students of the area, ii) medical centers in these remote ranges, iii) power to the area at a low cost and iv) good communication and local transportation facilities, so that the general population of the region gets benefited. This will create conducive atmosphere for the developers and the people will welcome development of such projects in their areas. In cases where the individuals land and property is coming under the project such persons can be either appropriately compensated by providing them alternative land having similar properties and the property with more better facilities or by paying mutually agreed compensation and providing them permanent job in the project so that they happily surrender their permanent assets in the shape of land and property to the developers. This kind of technique will be beneficial to the people and will accept such arrangements. Use of this kind of framework will require liberal change in the present legitimate structure existing in the nation and can give new impulse to the advancement of large hydro ventures if such a component is accomplished. The hydro power projects can be made more beneficial to the area if the private developers give employment to the local people in the field of skilled/unskilled labour and other non-executives as may be required for execution, operation and maintenance of the project. If it is not possible to consider 100% staff from the J & K for justified reasons, only then the private developers shall maintain atleast not less than 50% of total staff from the state. The state has to introduce provisions for the local area development fund at the rate of 1.5% of the project cost to be spent on the development of area where these projects are constructed. This type of approach can considerably contribute in the local area development and majority of the local population will show a satisfactory response towards construction of these projects.

10.3. Economical challenges

The large hydro projects in J & K State are situated mostly in the remote and inaccessible zones where their requirement of labour

(skilled, semi-skilled and unskilled) and construction material is hardly available. Moreover the developers also find it difficult to transport heavy machinery and equipments required for the work to these areas. For the construction of large hydro projects there is requirement of different type of electrical equipments like alternators, step up transformers, insulators, circuit breakers, control relay panels, low tension electrical switches etc which are also to be brought to project sites from outside the state as the same are not available within the state thereby adding further to the project cost. The specialized labour for such works also have to be brought from other states of the country and these labors demand higher wages for working in these areas as compared with other parts of the country. The lengthy transmission line which passes through the precipitous hilly terrain of the region required to be installed for supply of power generated from these projects to the main grids of the state thereby increasing the project cost further.

To overcome such problems it is essential for the state government to provide proper road connectivity to the area before the start of project which will help the power developers in a big way and simultaneously reduces the project cost. Every effort should be made by the project Engineers to utilize locally available construction material to the maximum extent in order to reduce the cost. The water usage charges in the state are also stated to be on the higher side by the developers when they compare it with other states like Himachal Pradesh and Uttrakhand. The state government can therefore also look into this aspect and change the water usage charges if possible keeping in view the interests of the government. The loan facility to private developers on lower interest rates and subsidy can also be worked out by the state government after taking into consideration the expeditious development of the power sector and its energy needs vis-à-vis the overall benefit drawn by the state by resorting to this method by calculating the cost / benefit ratio. Similarly by adopting the new construction methods in common works the cost of such works can be reduced and also by minimizing the measurements of the power houses with the construction of efficient civil works already constructed on the river, controlling equipments, measuring devices and protections, the overall area of power house can be reduced. The construction cost can also be further minimized by using sandy soil and stone work procedures [59]. The state government for achieving optimization of the total hydro potential has to engage some reputed consultancy firm for digitization of basin wise plans, and identification of new projects. From the point of view of optimization of the existing projects, the government has to formulate a policy for enhancement of the existing capacities by imposing additional benefits as applicable on the increased capacity.

10.4. Topographical and geological challenges

The area of Jammu and Kashmir State lies mostly in hilly terrain of fragile young Himalayan ranges and the sites identified for construction of large projects falls in these precipitous hilly inaccessible terrains. The hydro power potential in the Districts of Leh, Kargil, Anantnag, Ramban, Doda, Kishtwar, Reasi and Kathua areas of the State is very high. In the regions of State like Leh, Kargil, Marwah, and Zanskar, where these huge hydro power undertakings can be built, the power developers have to face lot of hardships during the winter months when the territory gets cut off from rest of the country for nearly six months because of snowfall on hill tops and also faces harsh climatic conditions due to steep fall in temperature which ranges between −15 °C and −35 °C. So the working period for the power developers remain for six months only in these areas. There is no rail connectivity to the area at present and the road transport availability to these zones is only for six months during summer period. The power developers therefore have to air lift the material required for their establishments during winter months which further add to the project cost. In addition to this the power developers also have to face difficulties caused due to landslides during rainy season. Moreover the state is situated in the western Himalayan areas of India and the districts falls under seismic zone V of the country and therefore the designers have to take into consideration the additional stresses caused due to this magnitude of seismic forces in the various structure components of the project which increases the project cost.

The Government of India realizing the difficulties being faced by the population of Ladakh region of the state during winter months due to disruption in road communication to the area, recently has approved the construction of road tunnel under Jozila pass which will provide all weather road connectivity to this zone of the state throughout the year on its completion. Similarly for the Marwah region of Kishtwar district, the road network from Kishtwar side is under construction which will connect the area throughout the year. The state government may also consider some incentive for the power developers for taking up projects in these inhospitable zones. As these large hydro projects are situated in zones where there is no grid connectivity, so the developers can be assisted financially by providing them bank loans on lower interest rates for the construction of proper grid connectivity for the project so that energy produced by them can be effectively utilized. Keeping in view the adverse effect of dam break on human population, loss of property and environment in and around the areas of impact of the dam break, it is imperative to assess the possibility of such failures and formulate a proper disaster management plan for large hydro projects in J & K [60]. Number of hydropower projects is planned on the various rivers and their major tributaries in the state of J & K. Although each project is planned to be environmentally compliant free and sustainable, but still their cumulative or aggregate impact is generally not known and seldom studied. Following an understanding that each hydroelectric project is generally has its environment norm complaint yet their aggregate or cumulative impact may not be as favorable. Hence, assessment of cumulative impact has to be computed by the state and accordingly go ahead in a phased manner with cumulative environmental impact assessment study for all the river basins in the state.

10.5. Security issues and environmental challenges

In the state of Jammu and Kashmir in some pockets of the area the developers are also faced with the safety and security concerns. The events of militancy in some pockets of the state create psychological impact in the minds of outside private developers who hesitate to take the work in such areas. In fact, even the local staff and engineers try to avoid working in these disturbed zones due to safety reasons. So these issues can be resolved if the state government provides fool proof security for the safety of all the concerned persons connected with these ventures in order to make them feel secured in the area in which they are working. Hydro power is considered as the most reliable and cost effective source of energy [61]. Young Himalayan ranges in Jammu and Kashmir State are gifted by the nature with scenic and human friendly atmosphere and therefore any kind of development/construction in the region shall have no impact on the ecology of the area which needs to be preserved. The power projects in this areas ought to be got approved from the ecological specialists with a specific aim to minimize the ecological harm in the area. All the hydro projects developed in the state are run of the river type in view of the Indus water treaty and these projects have little impact on the natural ecology of the area when contrasted with reservoir based hydro projects. The project developers are also required to allow minimum flow on the downstream of the project dam site in order to preserve the aquatic life, natural water sources and the irrigation needs of the agriculture fields in the area upto the location where the river flow gets again restored by disposal of river water from the tail race channel of the project. The project producers should also install some auto type electronically monitoring devices to keep check on the minimum flow of water in the main stream as per environmental and irrigation needs and provide safe passage for

Fig. 6. Baglihar hydro power project (run of the river type) constructed on the Chenab River in Jammu. Source: Author's own contribution.

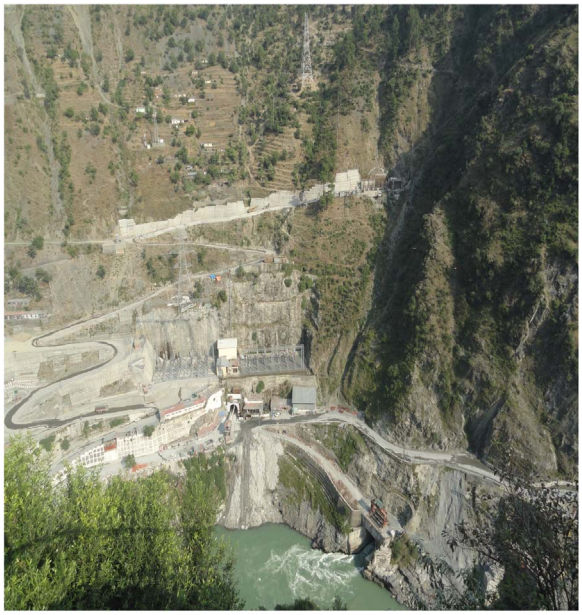

Fig. 7. Power house of Baglihar hydro power project constructed on the Chenab river in J & K. Source: Author's own contribution.

the aquatic life in accordance to the environmental laws. It is also important for the developers to dispose of the excavated material from the construction sites to the dumping location fixed by the environment experts with the consent of local population. Fig. 6 and Fig. 7 shows the dam and power house of Baglihar large hydro power project constructed on the Chenab River in Jammu region. For precise designing of the project, the developers are required to collect hydraulic data of the river flow for minimum 15–20 years period for the sustainability of the projects for longer terms. From the environmental point of view it is also imperative for the constructors to effectively utilize all the useable stones obtained from the cutting of rocky strata in the walling and other protection works required for the project. The project developers should also required to follow government directions, in areas where it is made mandatory for them to utilize the excavated muck for the purpose of developing energy parks instead of making dumping grounds. In western Himalayan areas there are different hydro ventures which are introduced on the same river with a specific end goal to tap optimum hydro potential of the river. There are no particular rules/laws available which clarify that upto what extent a distance between two hydro ventures is kept so that the negative impact on the nearby environment can be minimized. It is therefore, important to investigate and have proper environmental study of all the river basins so that these project areas can be predefined with a specific end goal to keep away from any unsafe ecological impact of those activities which are situated in the same basin [62,85]. The state has to develop, adopt and implement a web based real time monitoring of milestones in the implementation of hydroelectric projects in various sectors. The programming of online monitoring mechanism through the official website has to be put in place associated with National Informatics Centre. The monitoring of progress of implementation of plans, release of environmental flows and social parameters can also be made possible by providing web linked access to the web sites of the concerned departments/organization.

11. Discussion

One of the major factor which is discovered during the study while making this research paper is the lack of private players in this sector, which is one of the major reason that hydro energy in J & K state is not being exploited to its full potential as compared with other states of India. The state government therefore needs to take necessary steps to attract/motivate the private parties to come and invest in this sector. As these type of projects have the ability to uplift the economy of the region and create job opportunities for the unemployed youths, which is one of the major concern of the state government besides creating improvement in the local environment by implementing compensatory afforestation, green belt development and reduction in the green gas emissions. In western Himalayan regions there is huge scope of run of the river type projects because of large hydro potential of the region which remain still untapped, however installation of these projects now days are becoming more difficult because of the social-economic and environmental factors. Most of important factors which are responsible for the sluggish growth of these projects in J & K are security concerns besides other challenges like social, administrative and geological. In some cases it is also seen that clearance from the government department takes more time than that of the actual installation period. For avoiding such delays in the upcoming large hydro projects in this region it is very important to have more fast track, easy, transparent and less time consuming mechanism. Just having separate hydro policies for large hydro projects will not be sufficient as the effective implementation of these norms and proper monitoring will also be equally important. It is also observed that the distribution losses in the state are very high, to the extent of 51% of the energy while the transmission losses are 7.42% only. Therefore, the huge difference is noticed in the transmission and distribution losses which are a cause of concern related to an inefficient distribution system of the state. State government and the state power agencies like Jammu and Kashmir Power Development Department dealing with the electric distribution system has to take the necessary remedial measures to reduce these losses. If these losses which are of the order of 51% are allowed to continue then the energy deficit will keep on increasing and no alternate source of energy (conventional and non-conventional sources) will be able to full fill this gap. In order to meet the growing demand for energy especially in Jammu and Kashmir, it is important to install larger and small run of the river scheme type hydel power projects within the state, but in a more sustainable manner. In recent times these types of projects are gaining its recognition not only in J & K but also throughout the country as such projects are more sustainable when compared with the storage type of large hydro power projects. The outcome of group discussion with the local people living close to these projects helps in identifying some sustainability indicators which were never been reported before by other researchers in the

international community. These are like fear in the minds of local people with regard to large components of the machinery installed in the project and their failure apprehensions, security threat perceptions, and impact on the local environment because of deployment of large labors at the work sites and total length of diverted reach of main stream which is responsible for generating major quantity of muck. These factors which are highlighted in this paper are very important and play a very important role in the overall sustainability of these large RoR hydro power projects in any part of the world having similar conditions. It is also important to study the long term impact of these RoR types of large hydro power projects on the social life of the native people. Separate study of Social Impact Assessment (SIA) should be done for a hydro power project before taking up its construction on the line of EIA study in order to assess the impact on social life and should be made mandatory for the projects above 25 MW capacity. Also every attempt should be made to minimize displacement, but even after that, there will be cases where some displacement will take place. If a private company or the state is building a dam by putting in capital resources, people whose land is required should be treated as partners, who will invest by putting in their natural resources. If the project shares its substantial benefits with the people who for example have to surrender their land, they will agree to such an arrangement. Land used for the project becomes their share of investment in the project which entitles them to share its benefits, rather than just costs. Implementation of this will require substantial modification in the present legal framework and the concept of eminent domain. The affected people should be given first preference for the employment in the projects. The agricultural families due to the submergence of the land lost the income yielding produce. The landlessness the joblessness should be taken care of and other income yielding resources should be encouraged to compensate their loss. The seats should be reserved for the affected people in other jobs also. The prime requirements of the affected people should be provided to them. Their prime requirements of getting employment, making them accessible to irrigation water and investing in local infrastructures of the region are some of the expectations of the public from the hydropower project authorities.

Regular monitoring of water quality and ambient air quality in the area, twice a year, should be undertaken and the agencies associated with construction of various projects should ensure that no debris is dumped near the aquatic resources. Proper disposal of the generated muck is also a major concern in the area where these projects are constructed. The quantity of muck is also quite large in case of RoR type hydro projects when compared with storage based hydropower projects, so proper disposal of generated muck is very important from the environmental sustainability point of view. Proper sewage and drainage system needs to be provided while constructing residential colonies and office complexes. Healthy hygienic conditions for the residential population living near to these projects and project laborers should be made available by providing facilities like dispensaries, hospitals, medical doctors and sanitary inspectors. Moreover open dumping sites for the solid waste disposal should not be allowed at any cost. More financial provision is to be kept for the local area development to improve the quality of life of the people living close to these projects for the construction of schools, colleges, hospitals etc. and provide special subsidy for the electricity used by them including free cooking gas connections for the poor families. Some of the vacancies in large hydro power projects should be reserved for the females belonging to the local area, as the unemployment rate of female in J & K are highest in north India. From the above case study it is noticed that these projects have some negative effects also like loss of agriculture land, change of river status from riverine to lacustrine regime, loss of forest due to submergence in reservoir and construction of dam and appurtenant works. Some of the disadvantages which are identified during the visit of run of the river large hydro power projects in western Himalayan region are mentioned below:

- During the construction of these projects civil activates like blasting, drilling, excavation work and transportation of raw material to the site results in the air & noise pollution. But these disturbances are related to the civil work and are for short period till the completion of construction work.
- Effect on the agriculture and forest land, as these projects are located in the remote areas their construction activity have negative effect on the agriculture and forest land and also on local infrastructure of the region where these projects are installed. But it is observed that the lands required for construction of these projects are small when compared with the large storage based hydro power projects.
- The artificial reservoir or construction of small dams in case of these projects may results in the negative effect on the local aquatic life of the main stream on which these projects are installed. This is because reservoir formation transforms a flowing river system to a quiescent lacustrine environment which leads to a number of physical and chemical changes. In case of RoR type projects the reservoirs are very small but produce the same effect though at a limited scale. As a result of change of riverine conditions to lacustrine habitats the micro-benthic life is perhaps the worst affected. The micro-benthic flora, which normally grows over bottom stones as thin film of green color, serve as the food for the fishes. Due to reduction in flow and increase in turbidity in the distance stretch, several groups of micro benthic organisms, would be adversely affected in the downside stretches of the main stream.
- The RoR type projects in which separate canals (Power canal and tale race canal) are to be constructed to divert the water from the main stream and again re-dispose it in the stream after generation of power which results in large quantity of muck generation during the construction of these canals. The quantity of muck depends upon the length of diverted reach of the main stream. So the impact due to muck disposal activities may have adverse environmental problems. Unprotected borrow pits and muck disposal sites may lead to increased soil erosion and sedimentation problems on the downstream side of the river.
- These type of projects may have negative impact on the water quality because of increased use of agro chemical and fertilizers in the agriculture fields which will be developed after the construction of project with irrigation facilities, may be one of the sources of water pollution. However, the magnitude due to this phenomenon may not be significantly much.

The sustainability factors related to these types of large hydro projects especially in J & K state which are highlighted in above section need to be addressed properly by the power developers for the long term sustainability of these projects. The factors which are recommended in this study will be helpful for the policy makers, as well as for the power developers, while drafting the policies for these projects.

12. Conclusion

In this research article an attempt is made to show a case of detail field study of large RoR hydro power projects in the western Himalayan region. The first objective of the study was to review the potential of the RoR large projects and how they are going to help in overcoming the energy crisis in J & K, so it is made clear from the calculation that if 4000 MW of hydro potential is harnessed it will end the power shortage within the state. The second objective was to study a case of one large hydro power project in the Chenab basin along with group discussion with the local people in order to know their perception about these large hydro power projects. In this study sustainability indictors related to RoR hydro power projects are identified and some of them are also validated in the field. It is also noted that intensity or extent of issues varies from one RoR large hydro power project to another. Under the third objective of the study, attempt is made to highlight the challenges

faced by the power producers during construction of these projects in the state. Hence this paper targets both the sections which are connected with these kinds of projects that is the local people living close to these RoR hydro projects and the power developers which are installing these projects in the western Himalayan region. In this paper, an attempt has been made to conduct interviews with the local people as well as the power developers to highlight the major issues along with disadvantages related to these projects. During the field survey it is found that awareness is lacking among the local people of the project affected areas about these large projects. Therefore, it is important for the authorities concerned to educate these people to make them understand on importance of such projects for the development of area and their social life. Such hydro power policies will help in creating an investor friendly atmosphere and will be acceptable to people of the area. The researchers and planners taking cognizance of the growing pollution in the atmosphere in under developed and developed countries due to increase in population and developmental activities, lays more emphasis on environment and ecology safety. So under the circumstances it has become more important to construct all the new hydro power projects in a more sustainable manner taking all the related factors into consideration. As large numbers of hydro power projects are yet to be constructed in the state of J & K and other parts of India, therefore it is important to give more preference to the hydro power projects which are more sustainable and eco-friendly. It is observed during the study of hydro power potential of western Himalayan regions that if more private power developers are invited for installation of projects in the region, the hydro potential can be fully exploited in a time bound manner. The suggested indicators highlighted in this study related to the RoR hydro projects can also help the power developers and policy makers to design these kind of projects while considering all the factors related to their sustainability. The analytical tool such as analytical hericary process can be used to check the factors causing more impact on sustainability of these projects in a particular region. Time and cost overrun is also a significant concern with these kinds of large without reservoir-based hydropower projects, especially in Jammu & Kashmir state. The construction activities of these projects got hampered due to unfamiliar snowfall during winter season and flash floods during monsoon season which increases the overall cost of projects. It is also observed that during monsoon period chances of landslides increases tremendously which results in stoppage of road communication to these projects from other parts of the country. The clearances from various government departments for the project construction are also a time-consuming process which causes delays and enhance cost overrun. So, it is imperative for the state government to introduce a single window clearance approach in which common No Objection Certificate (NOC) is to be issued on behalf of all the departments from where the approval is needed. The availability of reliable contractors, technical staff and consultants is also very important for the construction of such projects especially in the western Himalayan regions of India, because it is seen that construction of some large projects initially started by the contractors but because of one or the other reasons left the project without completion. The close monitoring of under development projects by the governmental agencies is very important in order to see that whether the power developers are following the norms and specifications properly or not. This kind of approach is suggested to be adopted for all hydro power projects throughout the world in order to meet the fast growing energy demand and by this dependence on fossil fuel will be minimized especially in developing countries.

So, it is evident from the above discussion that social, economical and environmental factors play a critical role in the development of RoR hydropower projects, not in India but also throughout the world. However, sub-factors of these main factors, mentioned in Table 10 vary from country to country and project to project. In case of the western Himalayan region of India, the significant three sub-factors identified after field survey and visit to various RoR hydropower projects in this region are the safety issues, participation of public in decision making, and employment generation in case of social factors payback period, capital cost and hydro policies of the state & central government are among also the significant sub-factors in the list of social factors. As regards environmental factors the quantity of muck generated, length by which a mainstream is diverted, and impact on aquatic life are the important sub-factors. The indicators identified in this study may also be helpful to the power developers and policy makers in the world over where such geological conditions like western Himalayan regions persist. To achieve the goals of sustainable development and for the development itself to sustain, it must come from the bottom. A functional grass root democracy and people's participation in decision making that benefits and harmonizes all interests, is probably the best possible way to complete the projects on time and keep the costs from escalating and minimizing the miseries of affected. A good deal of authority in this regard ought to be vested with the local bodies meaning that their decisions and recommendations be regarded of utmost importance, bearing effectively on the very viability of proposed projects. At the end it is to suggest that run of the river type hydro power projects being more environmental friendly therefore needs to be preferred over the reservoir based large hydro power projects throughout the world.

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Appendix-A. Sample of questionnaire prepared for the focus on group discussion in the project influenced area of J & K:

1. What is the villager's desire in respect of identified large hydro venture which is introduced in their general vicinity?
2. What were the initial promises made by the power developer at the time when the construction work of this project is started and whether they have fulfilled these promises or not?
3. Were some differences between the local people and the power developer arise during the time of construction of these large hydro projects?
4. Are the local people is aware of the LADA (Local Area Development Fund) and what are the initiatives taken by the power developer for the improvement of the living standards of the local people by using these funds?
5. Do the local area people feel that the employment will be generated after the installation of this project?
6. What are the initiatives people feel to be taken by the power producer and the J & K government for the development and improvement of the living standard of local population and creation of more job opportunities for the unemployed youths of the remote areas?
7. Is the people feel that these large hydro power projects will attract local tourism in the area which will give rise to construction of more business establishments and other related infrastructure?
8. Is there any private land which came under the construction of this large hydro power project? If yes, then are the project affected people satisfied with the benefits/compensation amount which is disbursed among the families?
9. Is there is any improvement in the transport and communication facilities after the construction of project is started?
10. Is there are any negative effects on the local environment while the construction work is under progress? If yes, then please give details.
11. Do the local people in the nearby area find any security threats/ social disturbances in the area during the construction work of the project?

12. Do people who are living close to these large hydro projects recommend for construction of more large projects in other areas of J & K in order to improve the socio-economic conditions of the local people?
13. During providing of benefits/compensation in the area where these projects are constructed, did the people have feeling that there was some favoritism or discrimination done by the power developer among the project affected people (like financial, employment, land distribution)?
14. Are the suggestions and advice made by the local people related to without reservoir based large projects has been taken into consideration by the power producer?

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