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Assessment of Hydroelectric Power Potential in North East India and its Implications

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Abstract—*Since the dawn of industrial revolution, Electricity has been the consistent backbone of the modern civilized human society. In the current age of growing global energy crisis as well as rapid proliferation of environmental calamities, New and eco-friendly methods of electricity generation are the needs of hour. Among all the renewable power sources hydroelectric power seems to be a pretty viable option from the view point of both economic as well as social aspects. Hydroelectric power plants with accumulation reservoirs offer incomparable operational flexibility, since they can immediately respond to fluctuations in the demand for electricity. The flexibility and storage capacity of hydroelectric power plants make them more efficient and economical in supporting the use of intermittent sources of renewable energy, such as solar energy or Aeolian energy. Having been blessed with enormous water reservoirs as well as quick running waterways, North Eastern India has been touted as being in vanguard position of future hydroelectric power generation system in India. This paper is a logical way to deal with the Hydro possibility of North-Eastern part of India and key components of methodology, both quantitative and qualitative, that ought to be taken after for ideal acknowledgment of this potential. It will likewise give a diagram of the hydroelectric power improvement alternatives in the North East India with respect to the water assets in various waterway bowls, including thought of surge control and watering system. Overall development and installation of hydropower in North east India can reap multilateral as well as pluralistic benefits for the currently industrially backward region as well as its society.*

1. INTRODUCTION

Around 26% of energy is contributed by hydro energy to India [1] (World Bank, n.d.). For India, the aggregate limit is more than 2 Lakh MW thus hold the fifth position for power era on the planet. As indicated by the 2010 evaluation of India arranging commission, almost 28.8% of Indian are beneath neediness line. India's per capita utilization is among the most reduced on the planet. In numerous villages family unit have no access to electricity. India's electricity deficiency of 10 percent (ascending to 13.5 percent at peak) likewise attempts to keep the poor settled in neediness. The Northeastern region of India holds a great deal of potential for harnessing hydroelectric power. Hydro capability of this region is 63257M.W , just 1911 megawatts has been outfit so far which is just 3.02% of its hydro potential.[2] (J). The fact that such a potential is still unexplored is due to the regions remote location and inhospitable physical conditions. This paper explores the Hydro potentiality of North-Eastern part of India. Both quantitative and qualitative data are taken in consideration.

2. GEOGRAPHY OF NORTH EAST INDIA

2.1 Location

Geographically, the North- Eastern region of India lies between 275°7’ N and 28°23’ N latitude, 89 °46’ E and 97°25’ E longitude and situated to the south of Himalaya. The total area of the Northeastern Region is 26.22 million hectares where total area of India is 329 million hectares [3] (NEDFI Databank, n.d.). Politically it comprises of eight states in North-East Assam, Meghalaya, Arunachal Pradesh, Nagaland, Tripura, Manipur, Mizoram and Sikkim. The region shares borders with China in the north and northeast; with Bhutan, located between the states of Sikkim and Arunachal Pradesh.

Fig. 1: North East India

It also shares boundary with Bangladesh and Myanmar on the south and south- east. Assam and Tripura occupy the plains while the rest of the states are mostly mountainous with much

rugged and inaccessible terrain. The western part of the region is connected to the eastern part of the country through a narrow land (in between Nepal and Bangladesh), the Siliguri corridor, is popularly known as the Chicken's Neck [3].

2.2 Geological features

Geologically, the Northeast and the adjoining region constitute a complex geological province With convergence of two Tertiary mobile belts, the east-west Eastern Himalaya and the north south Patkai, Naga, Manipur, Chin, Arakan, and Yoma hill ranges (of Indo-Burmese origin), are developed as a consequence of the collision and Subsequent subduction between the land masses of India and Eurasia. These two belts are truncated to the northeast by the northwest trending diorite-granodiorite complex of the Mishmi massif. In the core of these mutually orthogonally disposed mobile belts lies the Archaean-Proterozoic cratonic elements of the Meghalaya plateau and the Mikir Hills, with Cretaceous to recent shelf-platform sedimentary cover on the southern margin of the Meghalaya plateau [4] (Nandy, 1991) .The Shillong (Meghalaya) massif is the oldest and the only landmass that existed in the region before the break up of Gondwanaland during the Jurassic period. The plateau consists of high-grade gneissic complex, overlain by mildly deformed Proterozoic intracratonic sediments of the Shillong group with metavolcanic Khasi greenstones, both indented by Upper Proterozoic and late Precambrian granite plutons [4].

2.3 Climatic conditions

The North Eastern region has distinct climate variations .It has a subtropical climate that is influenced by its relief and influences from the southwest and northeast monsoons .The rapid changes in topography result in climate changes within short distance. Generally the daily temperature in the plains of Brahmaputra and the Barak Valley as well as in Tripura and in the western portion of Mizo Hills is about 15° C in January, whereas in other parts of the region, the temperature is between 10°C to 15°C [3]. From April it rises and in July except the south-eastern portion of Mizo hills and Shillong, the mean temperature ranges from 25°C to 27.5°C. During October, daily mean temperature in the hilly areas ranges between 20°C and 25°C, whereas in Brahmaputra and Barak Valley, Tripura and the western portion of the Mizo hills it is above 25°C [3]. Further the lowest temperature is experienced below freezing point in the upper Himalayas in Arunachal Pradesh. Cherrapunji (Meghalaya) is one of the wettest places in the world, the average annual rainfall at Cherrapunjee from 1973-2012 (40 years) was 11,859.4 mm (38.90 feet/466.90 inches) [5] (htt).

2.4 River systems of North East India

The North Eastern region is endowed with immense water resources and quick running rivers. Primarily it is drained by two large river systems of the world – the Brahmaputra and the Barka(Meghna) . Both are trans-national rivers cutting across various national borders. Among them Brahmaputra originates from Angsi or Chema-Yung-Dung glacier in the Kailas range of the Tibetan plateau [6] (Lina, n.d.). It travels near about 1800 km through the Tibetan plateau, Arunachal Pradesh and Assam of India and Bangladesh. In Bangladesh it is known as Yamuna. After joining with the Padma (distributaries of the Ganges) the name of the joint channel is Meghana and then it merges with Bay of Bengal. The Barak has its origin at the Manipur-Nagaland border, passes through the southern part of Assam as a tributary of Brahmaputra it enters to Bangladesh [7] (htt1). Third river system of North – East, Irrawaddy has its origins in Myanmar, passes entirely through Myanmar and empties in to Bay of Bengal. Thus all rivers of this region and many of their tributaries are international in character with courses lying in more than one country and their basin shared by many countries.

Individually the basin of Brahmaputra, the Barak and the Irrawaddy occupy 68.42 % (174528 sq km), 16.36% (41723sq km) and 7.27% (18539 sq km) of the region. These three rivers basins together occupy 92.04% (234790 sq km) of the total area of North East India. The joint catchment area of Brahmaputra- Barak claim 84.78% (216251 sq km) of North-East and it is the dominant river system [8] (J.). The surface water resource of the region is near to 652.3 billion cubic meters that shares 34% of country's total water wealth. Whereas this entire region occupy only 8% of land mass of India. Per capita and per hectare availability of water in this region is highest in the country.

2.5 Ground water resources

The region has a total groundwater potential of 855 million cubic meters (excluding Sikkim) [9].The Central Groundwater Board has assessed the replenish able groundwater potential as 265.5 million cubic meters [9] (Das). All the hilly regions have low groundwater potential, the lowest being in Sikkim. Most of the surface water in this zone is in a highly dynamic state due to its high gradient and only a very small quantity of freshwater percolates to the ground. There is considerable scope for exploiting groundwater in the Barak valley, the Manipur valley, and other isolated pockets of the plains. By and large, the groundwater of the Northeastern Region is of a quality suitable for irrigation.

3. HISTORY, CURRENT STATE POTENTIAL AND CURRENT STATUS OF DEVELOPMENT

The historical backdrop of Indian hydro-power began with establishment of a smaller than usual hydro-power plant almost a tea bequest at Sidrapong for the Darjeeling Municipality in 1897 close to this area [9]. Before autonomy there was no such exceptional hydro-power plant in North-Eastern India. After the freedom Government of India understood the hydro possibility of the locale. The hydro capability of the Northeast was studied amid 1953–1959 by the Central Water and Power Commission's Power Wing [10]

(Hydro Development Plan for 12TH 5 Year Plan, 2008). It was assessed that monetarily exploitable hydro capability of the Brahmaputra bowl could be 13,417 megawatts at 60 percent load component, which constituted around 31.86 % of the nation's hydropower capability of 42,100 megawatts at 60percent burden variable. Another study was done by the Central Electricity Authority amid 1978–1987[10]. This study recommended that hypothetical hydropower capability of the nation would be 148701 M.W and 84,044 megawatts at 60 percent load component from a sum of 845 activities, which would yield vitality of 442 billion kilowatt-hours every year [10]. Around 75 percent of the hydro capability of India will originate from the Himalayan waterway frameworks i.e. the Indus - Ganga-Brahmaputra waterway framework and rest 25% from other stream frameworks.

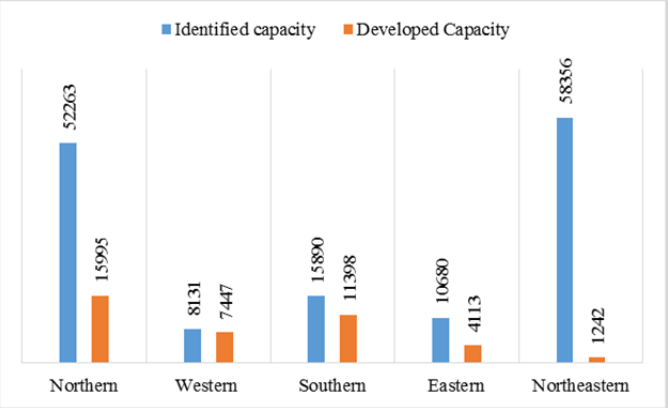
Table 1: Basin wise hydropower potential in India

Basin/River	Probable Installed Capacity (MW)
Indus	33,028
Ganga	20,252
Central Indian Rivers	3,868
West Flowing Rivers	8,997
East Flowing Rivers	13,775
Brahmaputra	65,400
TOTAL	145,320

The total hydropower potential available in Western, Southern, and part of Eastern (excluding

Sikkim) power regions is relatively limited, constituting about 25 percent of the potential in the country. The potential exploited in these regions is also relatively high, at 64, 62, and 41 percent respectively [10]. Further, the hydro potential of these regions is from peninsular rivers, which have more than 80 percent of their flows during the monsoon, requiring construction of storage reservoirs for economic hydropower generation. The development of the potential of these riversystems is constrained by submergence, environmental, and interstate issues (as with projects in Karnataka and Tamil Nadu, Indravati basin, Western Ghats). There is also concern about the impact of an adverse hydro-thermal mix on the power system in the country, particularly in the Western and Eastern power regions, and also to some extent in the Southern region, where hydro development has slowed down.

It is a recognized fact that the operational flexibility and economics of generation of hydro stations make them best suited to peaking power. The hydro Development scenario in the Western, Southern, and Eastern power region systems indicates that the future peaking needs of these regions would have to be substantially met from sources outside the region. Lack of complementary peaking capacity in these systems could lead to suboptimal utilization of large base load thermal capacities in these regions. In this context, development of the large unexploited hydro potential in the Northeastern power region assumes importance and urgency.



Source: Jindal Power Limited *capacity depicted in MW

Fig. 2: Potential and Installed Capacity In various regions of India

Table 2: Hydro Power Status of North-Eastern States

State	Capacity under operation (MW)	Capacity under construction (MW)	Capacity yet to be developed (MW)
Meghalaya	282	40	2072
Tripura	0	0	15
Manipur	105	0	1679
Assam	375	0	305
Nagaland	75	0	1499
Arunachal Pradesh	405	2710	47213
Mizoram	0	60	2136
Sikkim	669	2322	1295
TOTAL	1911	5132	56214

Source:
http://www.cea.nic.in/reports/hydro/he_potentialstatus_region.pdf

The Northeastern region (counting Sikkim) has accomplished just 3.02% of its 'hydro possibility up to October 2013, whereas national normal is 23.53%. Indeed, even after conclusion of various hydro plans under development, the possibility will be accomplished up to 4.84 % as it were.

Among the eight states of the North East, Arunachal Pradesh has the highest Hydro probability with 50328

M.W that is 79.56% of this area and 33.84 % of the nation. Arunachal Pradesh itself could be the 'Force House' of India. Till October 2010, there were 132 memoranda of understanding (MOU) marked between the Government of Arunachal Pradesh and developers of hydropower tasks with an aggregate limit of 40,140.5 MW. 120 of those memoranda are with privately owned businesses. [15]According to one estimate, in a ten-year period, Arunachal Pradesh proposes to include hydro-power limit which is just somewhat less than the aggregate hydropower limit included the entire nation in 60 years of autonomy. Sikkim stands second with 6.77% and

Meghalaya stands third with 3.78% hydro potential among all states of the district.

4. RECENT DEVELOPMENTS AND FUTURE PROSPECTS

Amid 2001, to give further stimulus to the endeavors for the advancement of hydropower potential, the Central Electricity Authority attempted a preparatory positioning investigation of the yet to be created destinations. The study investigated 399 out of the 845 distinguished locales (barring plans under operation or development or cleared, and little hydro plots under 25 megawatts) to decide the need for improvement of plans distinguished in the reassessment concentrates on. This was trailed by the 50,000 megawatt hydroelectric activity, dispatched by the head administrator of India in May 2003 as a component of the Mission 2012: Power for All arrangement. Under this activity, preparatory practicality reports for 162 hydroelectric plans (spread crosswise over 16 states) chose on the premise of a preparatory positioning study, were readied. The preparatory possibility reports secured applied designs and arranging of the task works, hydrological thinks about, force potential appraisal, determination of introduced limit, cost gauges, ecological perspectives (counting restoration and resettlement perspectives), power clearing framework, and tax calculation.

5. BENEFITS OF HYDROPOWER DEVELOPMENT

Hydropower development in North Eastern India will bring in various multilateral benefits for the region. Some of them are pointed below---

- First of all, hydroelectric power is a renewable source of energy and thus is a sustainable source of energy and also has zero carbon emulation rate.
- The attendant development and improvement of infrastructure owing to hydropower development and the increased availability of electricity could trigger economic progress in the region.
- In contrast to other conventional energy resources hydropower is not affected by fluctuations in market commodities, as the raw material, which is water is available for free.
- In flood prone states like Assam, hydropower station can provide additional benefits such as flood control, irrigation etc.
- As the hydropower potential of the region, when fully harnessed will create surplus energy and the governments of the states can earn revenue by selling power to neighboring states as well as countries.

6. ISSUES IN DEVELOPMENT OF HYDROPOWER

Even with these benefits, development of Hydropower in North-East India is not satisfactory at all in spite of its' huge potentiality due to several issues.

6.1 Seismic and tectonic factors

The seismicity of the Northeastern Region is a basic issue that should be sufficiently tended to in any water asset improvement venture. The region lies at the intersection of the Himalayan bend toward the north and the Burmese circular segment toward the east and is one of the six most seismically dynamic locales of the world. In the most recent 100 years upwards of 18 extensive seismic tremors have been recorded from this seismotectonic area, two of which – in 1897 and 1950 – were among the most intense recorded all inclusive. Multipurpose water asset ventures and hydroelectric undertakings worked in the Northeast have for the most part considered seismic components in their configuration. The contention that high dams ought not be inherent the high seismic zones in the Himalayas, a very dynamic tectonic locale, has been countered by driving researchers, designers, and columnists referring to illustrations of dams inherent a few nations in comparative seismotectonic conditions. Dams can be intended to withstand the crest stresses brought about by seismic tremors by altered dam balance outline, by fortifying the dam structures, and by the utilization of site change procedures, for example, dynamic compaction dewatering, vibroflotation, and the utilization of geosynthetics

6.2 Economic factors

To accomplish the hydro probability of North-East, the Central Government needs to hold up under a gigantic measure of cash. As we probably am aware the underlying expense of any hydro venture is high. This expense incorporates the site advancement cost, resettlement and restoration measures and so on.

6.3 Transmission Problems

The Power Grid Corporation of India Ltd has studied that to transmit the immense power generated in the NE region, it has to develop long distance high-capacity transmission lines at considerable cost. Apart from the cost, the transmission lines out of the Northeastern Region have to pass through the Siliguri corridor, a narrow land corridor about 22 kilometers wide and 18 kilometers in length with dense population. [11]. (Das). The power from the neighboring countries (Bhutan and Myanmar) has also to pass through this narrow corridor. It would not be possible to construct so many transmission lines in Siliguri corridor. The Power Grid Corporation of India studied that only to transmit the hydro power of Kameng (600 megawatt) project it has to expense Rs. 11,000 million, near about 50% of the cost of the whole project. Similarly, in the case of the lower Subansiri (2,000 megawatts), the transmission cost would be near about Rs. 100 billion. [11]

6.4 Environmental and ecological factors

Construction of dams on across the river will have impact on river ecosystems and the livelihoods and cultural heritage of the populations of river basins. Dams block rivers and reduce downstream river levels, thus reducing the amount of water in

the downstream ecosystem .Fish habitat is further affected by alterations to the water temperature, oxygen and silt levels, and speed of river flows. As a result fish resources of Assam have been reduced dangerously. After competition of all the proposed dams more than 20% of forest of the region will be affected and can loss biodiversity. It is also can be said that these hydro projects on the Brahmaputra river system could be ruined the floodplain ecology of wetlands (*beels*) and grasslands in its valley [12] (Neeraj). So, the ecology of renounced Kaziranga National Park in Assam could be in danger.

6.5 International issues

6.5.1 China

The Brahmaputra River originates in Tibet as the Tsangpo, flows into India as the Siang (or Dihang), and empties into the Bay of Bengal after traversing Bangladesh. Some of the tributaries of the Brahmaputra also have catchment areas in Tibet. There are no proposals for the basin involving submergence beyond Indian Territory. Diversion and consumptive use of the waters in Tibet would have an impact, particularly on post-monsoon flows in the basin. There is no specific information on any such proposals except for occasional media speculation .There are possibilities for utilizing the U-bend (called the "Big Bend") in the Tsango River (Brahmaputra) between Tibet (China) and Arunachal Pradesh in India for large-scale hydropower development. A drop of about 3,000 meters is available where the Tsangpo flows at an altitude of 3,600 meters and descends to Gelling in Arunachal Pradesh, which could be utilized for generation of a very large amount of power [13] (CHELLANEY). This possibility has been identified in studies but has not been mooted so far between the two countries for initiating any feasibility study. The issues between the two countries in the development of the Brahmaputra and other trans-boundary rivers are yet to be conceptualized and would have to be discussed between the governments for resolution in a spirit of cooperation for mutual benefit and satisfactory utilization of the waters of the river system.

6.5.2 Bhutan

The river systems (the Pagladiya, Manas, Sankosh, Rydak, and Torsa) of Bhutan join the Brahmaputra from the north in Indian Territory.Two hydro projects in Bhutan – the Chukha project (336 megawatts) and the Kurichu project (45 megawatts) – have been implemented with Indian assistance. Surplus power from these projects is exported to India. There will be a large increase in this revenue when the Tala hydro project (1,020 megawatts) becomes operational in 2006–2007 [14] (Ulmasova). Bhutan has also identified a number of potential hydropower projects, out of its total identified potential of 30,000 megawatts that require a fairly solid measure of regional investment. Surveys and investigations, with Indian assistance, are also in progress for the Punatsangchu project (870 megawatts), which is identified for more export of power to India. These projects when implemented could provide flood control and irrigation benefits in addition to a large amount of hydropower, though the environmental and submergence issues of the two projects need further detailed study. These and other projects in Bhutan could be developed for the mutual economic benefit of the two countries.

6.5.3 Bangladesh

Bangladesh is a riverine nation. As a lower stream state, the roots of water streams of the nation is outside of its domain. Bangladesh is essentially on edge about the Testa flood and Tipaimukh venture over the Barak River in Manipur. Individuals of Bangladesh believe that these two activities will upset the occasional cadence of the waterway framework and will adversely affect down stream's horticulture and fisheries. The legislature of Bangladesh has chosen to send a specialist group to the dam region to analyze the elements and likely effect on the earth of lower bowls. The Barak River has entered Bangladesh as the Surma and Kushiara, which assume a vital part in keeping the natural parity in the more prominent Sylhet district dabbed with several water-bodies. A huge number of anglers and agriculturists are subject to the waterway. Tista is significant wellspring of water in Northern Bangladesh. Development of dams without thought the nervousness of Bangladeshi individuals might be influenced the reciprocal relationship.

6.5.4 Myanmar

The Kolodyne River of Mizoram and Manipur flows into Myanmar. Under a memorandum of understanding signed between India and Myanmar, NHPC has completed investigations on the 800-megawatt Tamanthi hydro project in Myanmar. The power from the project would be mainly for export to India. The cooperation on this project augurs well for the development of the potential of the border and transboundary Rivers between the two countries.

7. CONCLUSIONS AND RECOMMENDATIONS

The immense untapped hydropower potential of the Northeastern Region is an economic source of electricity that can contribute significantly to the future power demands of the country. More over this region has the potentiality to partially fulfill the energy demand of the neighboring countries especially Bangladesh. However some issues need to be addressed for fully harnessing the benefits of hydropower generations in the region---

1. First of all, before proceeding to the establishment of hydroelectric power plants on the seismic prone areas, the government must do a complete and comprehensive study on the effects of building the projects on such areas. Technically it is possible to build such projects on hilly areas of Arunachal Pradesh.

2. As many of the rivers of North-Eastern states are trans-boundary Rivers, it is highly likely that any move by one nation will cause water dispute with other nation-states. India should build river commission like organizations to tackle such issues. Already India has formed such organizations with Bangladesh. The similar moves with China and other countries will help to reduce the existing friction on the river issues.
3. Also by exporting the surplus energy generated to low stream countries like Bangladesh, the Indian Government can assuage the Bangladeshi objection to Indian power projects. It will also help to reduce energy crisis in Bangladesh to some extent. Also Both Bangladesh and India can benefit economically from this buyer-seller agreement.
4. Transmission loss due to load factor is a serious problem of power grids. When the distance between demand area and supply area is minimized, only then transmission loss can be less. The power consumption rate of the North-Eastern States is lower than the national average; the annual per capita consumption in the region is 119 kilowatt/hours where national average is 390 kilowatt/hours. So, if the rate of village electrification and industrialization processes will be increased, the proper utilization of hydro-power of this region would be possible.
5. Instead of developing large capacity hydroelectric Power Stations, which in turn requires a huge amount of investments and also involves mass displacement of the local people; the government should try to develop stations with low capacity (<100MW). Such hydel plants, when developed will also mitigate the ecological damage that the large stations usually do. Also it will result in low land and economic requirements.
6. To remove friction with the local community, the government should make them aware of the various benefits that the locals can get from the project. Also for all people who are going to be displaced because of land procurement for the projects, the government should provide them quick rehabilitation. That way mass support for the project can be ensured.

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