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The Hydropower Paradox: Nepal's Vast Water Resources Amidst Energy Scarcity

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ABSTRACT: Water resources and its hydropower potential is probably the most important natural asset of Nepal. However, Nepal has not been able to effectively harness this significant resource for various reasons. Despite being the second Asian country to build its first hydropower plant, and having one of the largest per capita hydro power potentials in the world, Nepal is one of the least developed countries in terms of per capita electric power consumption. Nepal is also behind most of its neighbors in its power generation capacity, as well as in the use of hydropower in industry, agriculture, transportation and domestic applications.

KEYWORDS: Hydropower Potential, Hydropower Plant, Industry, Agriculture, Transportation

I. INTRODUCTION

Nepal is a Himalayan republic bordering China's autonomous region, Tibet, on the north and India's Sikkim, West Bengal, Bihar, Uttar Pradesh and Uttarakhand states on the east, south, and the west. Nepal is separated from its another close neighbor, Bangladesh, by the narrow Siliguri corridor of West Bengal. Also known as the "chicken's Neck" the corridor is 60 kilometer long and 22 kilometer wide, which is a potential route for Nepal to export hydropower to Bangladesh.

The Himalayan Mountain region that covers about 15% of the country's land mass, ranges in altitude from about 4800 meters to 8850 meters, and is popular for several high mountain ranges including Sagarmatha, the highest peak of the world.Terai region in the south, the food basket of the country, covers about 17% of the land. The Hilly region in the middle covers about 68%, and presents the highest hydropower potential in the country.

Electricity not only works as the lifeblood of modern living as well as that of all sectors of an economy (industry, agriculture, transportation, information technology, etc.), but also its innovation has shaped major world events, including industrial revolution, world wars, space exploration and computer revolution. Yet, it is very different from various other products traded in the market. It is an essential product (or service) but cannot be seen or touched; It is a perishable product as it cannot be stored economically; It requires networks of wires and transformers to transport to consumers, although it travels at the speed of light, and it takes the path of least resistance.

Just as other developing countries, Nepal's energy needs have skyrocketed in recent years. With the political transformation of the country in the 1990, peoples' development expectations have also been growing rapidly. To achieve peoples' development aspirations and become a middle-income country, Nepal needs its economy to grow rapidly, which requires rapid capacity expansion in the energy sector. Nepal is a mountainous country with thousands of streams, rivers and lakes, which make Nepal one of the richest countries in hydropower potential. As such, hydropower is one of the most important resources of the country. For Nepal, hydropower is especially important because this not only works as the engine of growth but also has the potential to become the major earner of foreign currency. The fact that hydropower is a green energy and plays a significant role in providing grid stability, unlike solar and wind energies, Nepal's hydropower potential can be utilized for the benefit of the whole South Asian region. However, this sector is marred by a number of operational and strategic problems, and the focus of this study has been finding the solutions to them.

Various estimates have been made regarding the total hydropower generation potential of Nepal. The previous generation of Nepal's water resource experts used to suggest that Nepal's hydropower potential is the second largest in the world after that of Brazil. More recent surveys, however, have shown that this is not true in absolute terms, but probably true in terms of per capita, and as a percentage of its gross domestic product. Asian Development Bank's (ADB) Country Director in Nepal asserted recently that having over "6000 rivers with a total length of about 45,000 KM, discharging about 220 billion cubic meters of water annually, Nepal has one of the largest hydropower potentials in the region, both

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per capita and units of its GDP" (Cauchois, 2022). In addition, Nepal's topography that ranges from 119 feet, or 58 meters (Nepalish, 2023) to over 8000 feet from sea level within a span of 120 miles make Nepal one of the most potential countries for hydropower generation (World Atlas, 2024).

As per recent surveys, the maximum and minimum potentials are believed to be 100 thousand MW, and 40 thousand MW respectively. However, most experts agree that Nepal's maximum technical potential is 83 thousand MW and economically viable potential is about 43 thousand MW (Thakuri, 2011). It should be noted that these are mere estimates based on certain assumptions. For example, if electricity is generated by utilizing only the regular flow of water in its rivers (ROR system), Nepal can generate about 43 thousand megawatts. Whereas if dams, large and small, are built to store water, including rainwater, and use it to produce electricity (PROR, Reservoir systems) Nepal can produce over 83 thousand megawatts. If Nepal chooses a mix of these systems while building power stations, it can produce an amount between 43 thousand and 83 thousand megawatts. Simply put, more ROR less megawatts and more dams and reservoirs more megawatts.

Another similar strategy that determines how much electricity we can generate from a particular location is conceptualized as a "Q" percentage, such as Q25, Q40, or Q60, which is chosen while designing the project. For example, Q40 means the project will run in full capacity only 40% days of the year (or, 146 days). Since the volume of water in Nepal's rivers changes in different seasons, the generation potential differs at different times of the year; more in the rainy season and less in the dry season. Now the question is whether to determine the capacity of a powerhouse based on the water flow in the rainy season or dry season or somewhere between them, and here comes the Q percentage. For example, Arun Third was designed to produce about 400 megawatts (Mahat, 2019) when it was being explored by the World Bank. But when India's Satlaj took over the project, they chose a strategy that made it possible to produce 900 megawatts. The implication is that if we want to produce more hydro power, we will have to build high-capacity powerhouses and large dams and bear the risks and consequences coming with it. But if we choose a risk-free approach we will have to settle with a smaller amount of hydropower.

Problem Statement of the Study

Despite significant potential and political commitment, the progress made by Nepal so far in the hydropower sector is significantly poor. Nepal produced 500 kilowatts of electricity in 1911 and after 114 years, its total production is less than 3,500 megawatts. It shows that Nepal has been lagging behind significantly in production and distribution of hydropower. In addition, although Nepal was one of the first developers of hydropower projects in Asia, its current per capita consumption is the lowest among the SAARC countries.

Just as the production capacity, the growth in distribution capacity, particularly the building of transmission lines and substations, has also been slow. The latest achievement in access to electricity is limited to 97% households. While all 7 provinces have not been able to achieve universal access, Karnali and Far west provinces are far behind others (Adhikary M., 2022). Even in those households that have access, the supply is far from being reliable and regular. The distribution infrastructure is fragile and gets disturbed frequently.

Expressing concern on Nepal's poor performance in this sector ADB notes, "Despite some recent successful efforts to use these vast water resources for its development, Nepal has not been able to use this enormous resource fully for its economic development. It is strange that the country has an underperforming power sector with supply shortages, reliability issues, and poor access to electricity, while sitting on an enormous potential to produce hydropower." (Gunatilake et. al., 2020)

II. LITERATURE REVIEW

This study conducted the literature review with two basic purposes: One, to make sure that the proposed research topic has not been researched in the past, and conducting this research will fill a void and help solve problems and add to the knowledge base. Two, to provide a comprehensive background of the study so it helps the readers to correctly understand and interpret the findings of this research. The background of the hydropower sector that is covered in this chapter will provide a conceptual structure to the research. Apparently, there has been a lot of research on the geographical, technical and strategic problems of Nepal's hydropower sector. However, no study has so far been carried out on cognitive problems of the hydropower sector of Nepal. As such, this study will fill a void, and help tackle some of the most stubborn problems of Nepal's hydropower sector and accelerate its growth. In order to achieve the above mentioned objectives of the literature review, this study has made a comprehensive review covering various topics as called for by the scope and objectives of the research, which include: Brief history of hydropower development in Nepal; The energy

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sector and the role of hydropower; Current status of the sector including current level of production, capacity of transmission infrastructure; local demand and export; Critical problems faced by the sector, including various technical, operational as well as policy and strategic problems, and cognitive problems as identified in the literature.

Rana Era (1846-1951): When Nepal established its first hydropower plant in 1911 the Rana dynasty was effectively ruling the country, although kings were believed to be the head of the state and government. Abolished in 1951, these rulers were considered cruel, ruthless, and self-serving, and used the nation's income and fiscal system as their personal property. They used to minimize expenses and maximize taxes to enrich their personal coffers. As such, not much development could be expected from them. Despite this, several significant milestones in the development of hydropower have been achieved during their reign. For example, the Pharping hydropower plant (0.5 MW), Chandra Prakash Bijuli Adda (institution to develop hydropower), Sarada Barrage, Sundarijal hydropower project (0.9 MW), and Morang Hydro project (2.0 MW) were established during Rana regime. In addition, some diesel plants were also established for domestic and industrial usage.

Transition Era (1951-1960): With the fall of the Rana regime, the country entered into a decade-long political instability, which delayed the growth of the hydropower sector. Some progress that was made during this era included the Kosi project (1954, 10 MW) and the Gandak project (December 1959, 15 MW), signed with India during the prime ministership of Matrika Prasad Koirala (6/1953-4/1955) and BP Koirala (5/1959- 12/1960) respectively (Araro, 2025**)**. Construction of the Koshi Project started in 1958 and completed in 1962 (Bista, 2008). The construction of the Gandak Project started in 1963 and was completed in 1968. Although agreements were signed during the transition era, the construction mostly took place during the following Panchayat era. In addition, a few diesel plants were established and institutional improvements were made during the transition era.

III. RESEARCH METHODOLOGY

Research Design

A comprehensive and rigorous methodology had been designed to carry out this research, which addressed all aspects of the study systematically and in a controlled fashion so it could generate the results that are well founded, verifiable empirically and able to withstand critical scrutiny of the research process as well as the findings and conclusions. Since the research aimed to explore the so far unnoticed cognitive problems, an explorative research approach was applied. Primarily, qualitative research approaches were used such as in-depth interviews. Quantitative research techniques were also used to measure which side of the cognitive argument was more popular among the key stakeholders and the general public. This information was expected to be useful while designing policies and programs that need to address unfounded perceptions regarding the development of the hydropower sector. Literature review, as discussed above, was also a major source of information needed to achieve several of the objectives of this study. The various elements of the research design that were used during this research are elaborated below.

Organization and Analysis of Data:

Data collected from in-depth interviews and questionnaires was cleaned, coded, organized and analyzed. The data was cleaned for any ambiguity or for any incomplete responses. SPSS software was used to analyze the data, and hence questionnaires were coded before feeding the data into SPSS software. Queries were set up as per predetermined data tables as well as statistical results sought such as averages, deviation and percentages. Results have been presented in tables with totals, averages and percentages. These statistical results were analyzed and interpreted in the contexts of the objectives of the study. The statistical results were also discussed from various points of views and implications were drawn.

IV. DATA PRESENTATION, ANALYSIS AND FINDINGS

The key focus of the study was to identify dominant cognitive problems and measure what proportion (%) of the stakeholders, including the general public, believe on either side of the cognitive debate. However, immediate problems of the sector such as operational and technical problems as well as policy and strategic concerns have also been identified and discussed below. This is done to demonstrate how strategic and policy issues as well as technical and operational problems stem from cognitive problems. Clear understanding of these inter-relationships between the problems will help to identify and implement effective measures that address not only the cognitive problems but also the policy and strategic concerns, and technical and operational problems. Nepal's Hydropower sector will progress rapidly as it has in neighboring countries such as India, China and Bhutan only when the cognitive obstacles as the main sources of other problems are clearly understood and addressed. However, before presenting and analyzing data pertinent to various study

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objectives, this chapter describes below the key characteristics of the actual sample population; discusses how data quality was ensured; and explains the conceptual framework of the study.

V. CONCLUSIONS

However, the growth in the power generation capacity started to multiply as the country transformed from an autocracy to multiparty and republican democracy. During the 19 years of multiparty democracy the generation capacity multiplied two times and during 18 years of federal republic the power generation capacity multiplied 12 times compared to the capacity achieved during the 29 years of Panchayat regime**.** This rapid growth became possible due to a change in the vision of the democratic governments, which was to become a welfare state and uplift the living standards of every citizen, including the poorest and marginalized. This vision led to strategies such as (a) growing the generation capacity by 10,000 MW in ten years, 15,000 MWs in 15 years, (b) encouraging the private sector to invest in power generation, (c) emphasizing on medium and large projects, not only micro and small projects, (d) meeting domestic demand but also exporting power to earn foreign currency, and (e) attempting to use hydropower export to balance trade and substitute imports. Some may argue that the engine of growth under democratic governments has been the widespread corruption, and there is some truth in this assertion (discussed in details below). The study shows, however, that the real engine of growth has been the country's commitment to become a welfare state and the government's efforts to take the benefits of development to all people, including the poor and marginalized. The government should continue this vision and related strategies.

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