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Impact of Hydropower Construction Delay in Energy Banking Opportunities between Nepal and India

by

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled "**Impact of Hydropower Construction Delay in Energy Banking Opportunities between Nepal and India**" submitted by Mr. Sunil Subedi in partial fulfillment of the requirements for the degree of Master of Science in Energy Systems Planning and Management.

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ABSTRACT

Nepal has been a power surplus country since 2021 during wet season and energy deficiency in the dry season is increasing year by year as most of the hydropower are of RoR type and they generate full capacity in wet season and produce almost one third of energy in the dry months compared to wet months as the water flow in the river decreases. The surplus energy in the wet season can be exported to India and it could be imported back to Nepal in dry months when we are energy deficient using the concept of energy banking.

In this work, the energy demand scenario of Nepal in the present and future, energy generation scenario of Nepal in the present and future, energy demand scenario of India in the present are studied and Energy Banking mechanism are discussed between India and Nepal from Nepal's perspective. The required data are collected from NEA, WECS, CEA and DOED publications and various reports. The impacts of construction delay of projects on opportunities of Energy Banking between Nepal and India are discussed.

Though yearly energy requirement can be met from the internal production if the present under construction projects are completed on time but major problem is that during wet season Nepal's energy gets spilled and during dry season Nepal could not produce electricity as required. In order to solve this problem, Nepal could make arrangement of reliable energy banking mechanism with India so that excess energy in the wet months is exported to India and deficient energy in the dry months are imported back to Nepal. Under Reference Scenario of demand, net electrical energy surplus decreases by 69 %, 72 %, 56 %, 47%, 44 % and 24 % for year 2022 to 2027 for one year delay in construction of project and for two-year delay in construction net energy surplus decreases by 69 %, 78 %, 62%, 86 %, 80% and 67 % respectively. Nepal should focus primarily on construction of hydroelectric projects and cross border transmission line after assuring market for excess produced electricity in India.

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List of Abbreviations

BAU	Business As Usual
CBR	Conduct of Business Rule
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
DAM	Day Ahead Market
DSM	Demand Side Management
DOED	Department of Electricity Development
DA	Designated Authority
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GoN	Government of Nepal
GWh	Giga Watt Hour
IEX	Indian Energy Exchange
IPP	Independent Power Producer
JWG	Joint Working Group
JSC	Joint Steering Committee
KWh	Kilowatt Hour
MAED	Model for Analysis of Energy Demand
MoEWRI	Ministry of Energy, Water Resources and Irrigation
MW	Mega Watt
MU	Million Unit
NEA	Nepal Electricity Authority
NTPC	National Thermal Power Corporation
NVVN	NTPC Vidhyut Vyapar Nigam
PGCIL	Power Grid Corporation of India
PPA	Power Purchase Agreement

PXIL	Power Exchange India Limited
PTA	Power Trade Agreement
ROR	Run of River
RE	Renewable Energy
SAARC	South Asian Association for Regional Corporation
TAM	Term Ahead Market
WECS	Water and Energy Commission Secretariat

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CHAPTER 1 INTRODUCTION

1.1 Background

Total hydropower installed capacity in the world reached to 1360 GW in 2021 which is an increase by 26 GW from previous year (IHA, 2022). In South Asia region, Bangladesh India and Pakistan fossil fuels are important energy sources on the other hand Nepal and Bhutan relay on hydropower (R Vaidhya et al, 2020). The huge potential of hydropower in Nepal and Bhutan can be used to meet growing electricity need of South Asia (Srivastava L, Misra N, 2007). Water resources is one of the most important natural resources of Nepal and it is one of the richest countries in terms of water resources availability in the world. In the form of snow covers, rivers, springs and lakes, water resources are abundant throughout the country (WEPA). The share of Renewable energy in electrical sector in the world is about 26 % only in 2020 (Renewables, 2021). Though there is huge potential of renewable energy worldwide only 27 % of world population obtains electricity from renewable energy (Poudyal R, Loskot P et al, 2019).

Nepal's estimated water resources is 225 billion m^3/km^2/year. It is four times higher than world's average (World Bank, 2016). There are altogether 6,000 rivers in Nepal with cumulative length of 45,000 km. There are about 24 rivers that are more than 100 km long and 1000 rivers longer than 10 km in length. The major river system of Nepal i.e Koshi, Gandaki, Karnali and Mahakali and their tributaries are snow fed and their flow regimes are governed by melting of snow and glaciers (WEPA). As a result, river flow is perennial and even in the dry season they have sustained flow.

Nepal has huge potential of hydropower, but about two percent of the 83,000 MW (technically possible) of hydropower is currently harnessed. 42,000MW is feasible with no environmental hazards (ICH, 2019). The available potential could not be achieved due to political instability, inability to attract FDIs and delay in project execution in the last decades. Nepal's huge potential in hydropower can be utilized to enhance its economic growth not only increasing internal consumption also fulfilling increasing energy demand in South Asia. The Per MW construction cost of hydropower project in Nepal is $2 million USD (Poudyal R, Loskot P et al, 2016).

The power system in Nepal is dominated by Run-Of-River (ROR) hydropower plants. There is a shortage of storage type hydropower plants (Yang M, 2005). The surplus energy available will increase from month of April to November and thereafter starts to decrease in each fiscal year (Puri B and Mishra A. K., 2019). Nepal became a power surplus country for the wet season after the 456 MW Upper Tamakoshi Hydropower Project, largest power plant, came into operation in July 2021. Nepal has surplus energy generation especially in the wet season as other RoR plants are also being add up in the system. In the wet season during 2021 Nepal's spill energy reached up to 500 MW. On the other hand, Nepal had to import about 2,826 GWh of Energy in the dry season of 2020. This clearly shows that Nepal has imbalance nature of demand and supply. To be specific electrical demand seems to increase slightly in the dry season on contrary generation seems to be reduced almost by greater than one third of installed generation capacity. Nepal's seasonal surplus, daily surplus and peak shortage of power/energy are expected to be balanced by utilizing energy exchange with India.

1.2 Cross Border Power Trading

A Power Trade Agreement (PTA) on Electric Power Trade, Cross Border Transmission Interconnection and Grid Connectivity was signed between Nepal and India on October 21, 2014 emphasizing on the free, unrestricted and non-discriminatory power trading between Nepal and India. After this PTA signing, a major development towards its implementation is that India has issued the "Guidelines on Import/Export (Cross Border) of Electricity – 2018" replacing the earlier one issued in 2016, by addressing some of the concerns of the neighboring countries.

In fiscal year 2019/20, 1,729 GWh of electricity was imported through various transmission links by Nepal which increased to 2,826 GWh in FY 2020/21. Nepal has also been able to export 107 GWh of electricity to India, an increase of 18.6% from the previous year through power exchange mechanism (NEA, 2021).

As Nepal has unbalanced type of Demand Supply matching of electricity in both wet and dry season, marketing arrangements need to be indispensably explored for balancing the generation and consumption. Both domestic and cross-border power markets need to be explored in possible dimensions to cope with the emerging situation of high domestic generation. All tools and mechanisms for cross-border markets need to be deployed both at policy level and implementation level in the near future.

1.3 Problem Statement

The main concern of this study is to study impact of hydropower construction delay in energy banking opportunities between Nepal and India in Nepalese prospective. The major study of this research are:

- What is the energy demand scenario of Nepal in the present and future?
- What is the energy generation scenario of Nepal in the future?
- What is the impact of construction delay of hydropower projects on energy production?

1.4 Research Objective

The main objective of this work is

- to study impact of hydropower construction delay in energy banking opportunities between Nepal and India.

The specific objective of this study are

- To analyze energy demand scenario of Nepal in the present, past and future
- To forecast energy generation scenario of Nepal in the future
- To evaluate required capacity of cross boarder transmission line in future

1.5 Data Collection

The main sources of data for this work are obtained from different publication of Nepal Electricity Authority (NEA), Water and Energy Commissions Secretariat (WECS), Department of Electricity Development (DOED) and Central Electricity Authority (CEA), India. Future year demand forecast of Nepal are obtained from demand forecast of NEA publication and Water and Energy Commissions Secretariat (WECS) publication. The contribution of different sources to meet electrical demand of country is extracted from NEA publications for different previous years. Similarly monthly energy demand is extracted from NEA published reports. The previous year’s month wise generation of major hydropower are extracted from yearly publication of NEA. The future electricity generation data of Nepal from different utilities (NEA and IPP) are derived from NEA publications and DOED website. Similarly, energy demand and supply pattern of India is obtained from the website of Ministry of Power and Central Electricity Authority (CEA), India.

1.6 Limitation of Study

In this work, data required are collected using secondary source. Nepal's energy generation and consumption are collected from NEA publications. The future year demand forecast of Nepal are obtained from WECS publications and NEA forecast. Similarly, energy demand and supply pattern of India is obtained from the website of Ministry of Power and Central Electricity Authority (CEA), India. The energy forecast of Independent Power Producer (IPP) of only above 10 MW capacity projects are considered for the study. The demand forecast and energy forecast of generation are considered only upto 2027. The project completion period of NEA and its subsidiary company project are taken from NEA publications. The month wise energy generation and consumption for future year are obtained based on the past year percentage generation and consumption of energy respectively. The plant factor of previous year generation of hydropower project is used to obtain energy in the future year from the completed projects. The technical and non-technical losses of energy are not considered in this study. Energy banking between Nepal and India is studied from Nepalese perspective only.

CHAPTER 2 LITERATURE REVIEW

Cross border power trading urgently needs action-oriented policies in South Asia region and sub-region. Nepal's abundant hydropower resources may prove a bold measure towards de-carbonizing this region as an initiative in line with the Paris climate accord of 2015 AD. South Asia is an energy-shortage region and that's why regional power trading needs to be accomplished through sub-continental power grid interconnection.

2.1 Energy Banking between India and Nepal

Nepal's power generation is predominantly hydro-based Run-Off-River (ROR) type. ROR hydropower generally generate energy in full capacity in wet/monsoon season which normally lies from May to October, whereas the load is not comparatively higher in Nepal in these months and it will lead to the seasonal power surplus situation in Nepal if the current scenario as per the load forecast continues without policy intervention.

However, the electricity demand in various States of India like Uttar Pradesh, Hariyana and Punjab is quite high during the same period due to highly increasing agricultural and cooling loads in these States. Nepal can supply power to India during wet season to meet India's increased load. It also helps in generation mix of hydro, solar and thermal power to some extent.

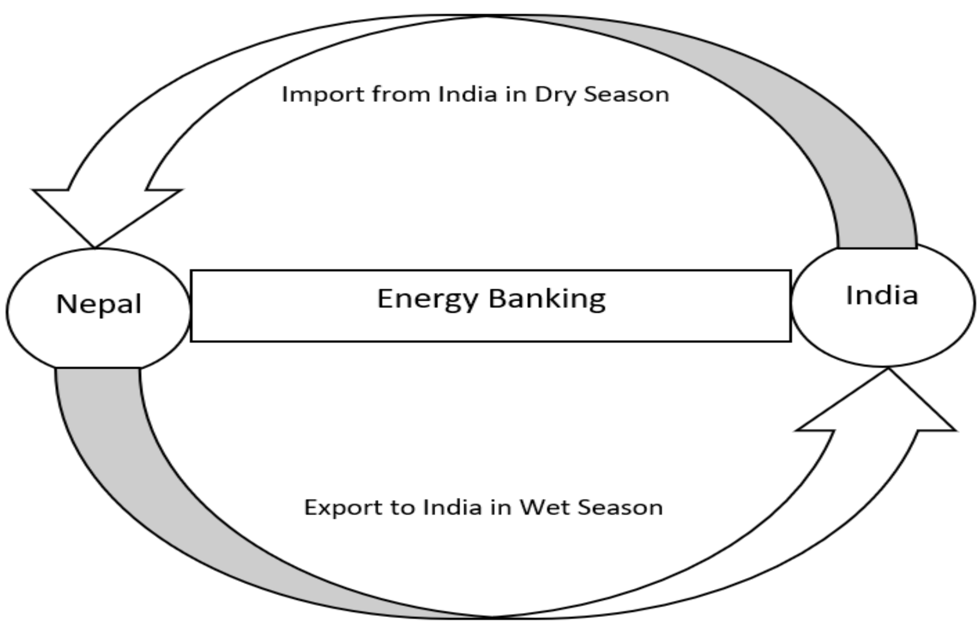

Figure 2-1: Conceptual framework of Energy Banking

The seasonal imbalances of demand and supply of electricity that exist between Nepal and India make energy banking a highly suitable model for power transaction at seasonal basis to benefit both countries.

Power can flow in reverse direction from India to Nepal in dry season period during which Nepal's own generation cannot meet demand as hydropower generation is drastically diminished to almost one third of the installed capacity of a ROR hydropower plant due to low discharge in rivers. It makes power import from India an inevitable option for Nepal for balancing demand and supply of electricity as Nepal does not have enough reservoir hydropower capacity right now.

Deficient power in dry month in Nepal can be balanced by importing power from India as exchange of power that was transferred from Nepal to India during wet season. This concept of transferring energy to and fro is called energy banking.

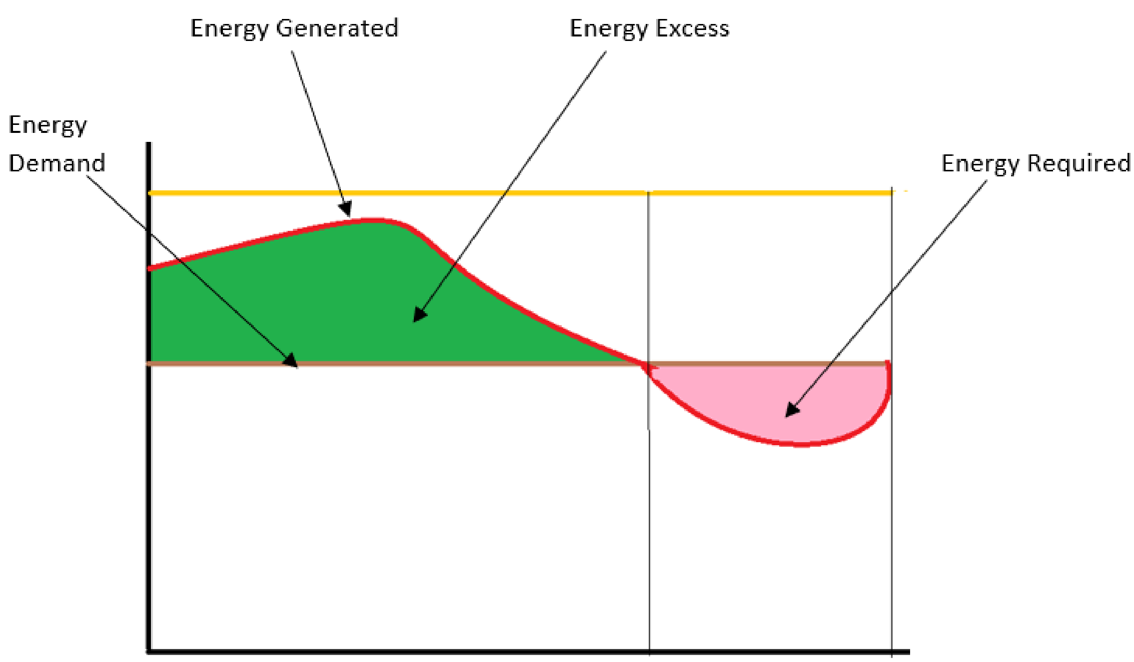

Figure 2-2: Typical Energy Demand and Energy Production Pattern of Nepal

Furthermore, there exists a prospect for sharing of energy resources by having interconnections of grid among these countries. Since, transmission connectivity is vital and minimum requirement for sharing the resources, there should be connectivity beyond the border countries for the effective and optimal utilization of resources. This provides the high possibility of trading in the region. With various benefits of power trading, power system integration in South Asia can bring potentially large technical, operational, economic benefits in the region. Therefore, power trading between the countries in the South Asia will fascinate to bridge the seasonal demand and supply gap (wet season/ Dry season) in the hydropower rich countries like Nepal and Bhutan.

Moreover, seasonal difference in generation and consumption pattern in different countries will lead to optimize the use of resources. Hence, in spite of long-term capital investment, the countries can have cheap power available from their neighboring countries.

Both the countries can benefit from this transaction through energy banking by virtue of seasonal complementarities of demand and supply of electricity and it will allow the optimal utilization of electricity resources in terms of both transmission and generation capacity of existing facilities.

2.2 Recent Development in Cross Border Electricity

Cross Border Trade of Electricity Regulation, 2019 has been made by Central Electricity Regulatory Commission (CERC) of India. Central Electricity Authority (CEA) has been appointed as the Designated Authority (DA) of India for cross border power trade. CEA has worked out the Conduct of Business Rules (CBR or Procedures) for cross boarder energy exchange.

Ministry of Energy, Water Resources and Irrigation, of Nepal on 28th February 2020, has appointed Nepal Electricity Authority (NEA) as the Nodal Agency of Nepal to coordinate and facilitate on the matters like Planning, Grid Operations and Electricity Transactions with CEA. Government of Nepal has decided to give prior approval to NEA for all types of cross border power trading including Day Ahead Market (DAM), Term Ahead Market (TAM) and long term, medium term and short-term power trading with Indian Electricity Board (NEA, 2020).

A Committee has been set up at Ministry of Energy, Water Resources and Irrigation, Nepal for working out cross border guidelines by harmonizing it with the Indian one. In addition to power exchanges, NEA has also commenced the commercial preparations by signing a composite agreement with NTPC Vidyut Vyapar Nigam (NVVN) for transactions involving both purchase and sale of electrical energy. Nepal should try to export power to Bangladesh using SAARC Framework agreement for energy Cooperation (2014) by making tripartite consent of India Bangladesh and Nepal (Pun SB, 2018).

The first 400 kV Cross Border transmission line between Nepal and India, from Dhalkebar to Muzaffarpur, was charged at 220 kV voltage level in August, 2018 and it was charged at 400 kV in November, 2020. Through this transmission line now power exchange up to 1000 MW could be done between India and Nepal (RPGCL, 2018). The seventh Joint Working Committee (JWG)/Joint Steering Committee (JSC) meeting held in Bangalore, India on 14-15 October, 2019 at the Joint Secretary/Secretary level has agreed on the implementation and funding modality of the second 400 kV transmission line, New Butwal – Gorakhpur, with its estimated cost of INR 693.5 Cr (231.5 Cr. Nepal side and 462 Cr. India side) and expected commissioning in about three and a half years.

The agreement for the formation of JV Company between Nepal Electricity Authority (NEA) and Power Grid Corporation of India Limited (PGCIL) was signed on 8th September 2021 for the implementation of New Butwal – Gorakhpur line. Both the parties have committed 50 % investment on the project. Detailed Project Report (DPR) for Inaruwa - Purnia New and Dododhara - Bareilli 400 kV transmission lines are also finalized by India and Nepal. These are the lines out of the total eleven high voltage cross border lines proposed in Nepal- India cross border transmission master plan. Two countries agreed to conduct detail study of New Duhabi - Purnia and Lamki - Bareilli 400kV transmission line (NEA, 2020).

Connecting Nepal with India through these high voltage transmission lines in various timeframes will be highly beneficial not only to Nepal and India, but also to the BBIN (Bhutan, Bangladesh, India and Nepal) sub-region and the entire South Asia region. A Power Purchase Agreement (PPA) has been signed between NTPC Vidyut Nigam Limited (NVVN) and Nepal Electricity Authority (NEA) for supply of power up to 350 MW through Dhalkebar-Mujaffarpur (D-M) Transmission Line effective from 16th July 2020. The agreed documents for power exchange between India and Nepal and SAARC Framework agreement for energy Cooperation (2014) should be brought into implementation for Cross-border power transmission (Pun SB, 2018).

2.3 Benefits of Cross Border Electricity

The demand of clean power in India and other South Asian (SA) countries has been increasing. This can be met by utilizing hydropower resources of countries like Bhutan and Nepal. It shall also help in improving their financial situation. Nepal faces seasonal generation shortage especially in dry season which can be offset from other South Asian countries. Small countries like Nepal, which is primarily focused in hydropower at present can obtain diversity in energy mix which is at present global trend by promoting cross boarder export/import of electricity.

SAARC countries particularly Nepal, Bhutan, Bangladesh and India have diverse energy resources. Nepal and Bhutan have hydro resources far in excess of their internal demand while India and Bangladesh will have robust demand growth in long term. Similarly, with increased RE power addition in India, there exists complementary with the hydro abundant countries like Bhutan and Nepal with storage-based projects to meet balancing power, seasonal load, peak load requirements and grid stability.

2.4 Agreement for Power Trading through Exchange Markets (APTEM):

NEA and NVVN entered into an Agreement for Power Trading through Exchange Markets (APTEM) on 22nd April, 2019. The power shall be purchased and supplied by/or from NEA at the delivery point which is the boundary of regional transmission system or as specified by guidelines of Power Exchange from time to time. NEA shall become a "Member Client" of NVVN for purchase and sale of power on Indian Energy Exchange Limited (IEX) as per this Agreement. NEA will use Power Exchange India Limited (PXIL) platforms through NVVN and therefore NVVN shall submit purchase and sale bids on behalf of NEA.

India has granted permission to Nepal Electricity Authority (NEA), state owned utility of Nepal to enter into Indian Energy Exchange (IEX) in November 2021. India opened its door to purchase Nepal's energy. Nepal had exported 39 MW (Devighat and Trishuli Hydropower) of electricity to India under the Indian Energy Exchange (IEX) becoming India's first neighbor to participate in the IEX in 2021. India has granted permission to export additional 325 MW power from Nepal for the year 2022 from Kaligandaki 'A' (144 MW), Mid-Marsyangdi (70 MW), Marsyangdi (69 MW) and Likhu-IV (51 MW).

2.5 Future Prospects of Electricity

Hydropower is regarded as the most suitable option for Nepal's future economic development (K.C. Surendra, S.K. Khanal et al, 2011). Nepal Electricity Authority has signed PPAs with Independent Power Producers for the capacity of about 4300 MW and more than 6000 MW hydropower projects are in process for PPA, most of them being RoR type. So, Nepal shall have higher generation than required in the wet season. On the other hand, it could face electricity deficiency in the dry season. This problem can be resolved by energy banking with India. In wet season excess energy can be banked and banked energy can be returned in dry season. If energy banking could work effectively in future, dry season tariff of the hydropower generator could be reduced which is higher than wet seasonal tariff at present. (Adhikari P, 2018).

Under a business-as-usual scenario, the demand forecast of Bangladesh has shown its electricity demand shall reach to 50,000 MW by 2040 (Bhattrai D, 2021). The major source of electricity is Natural gas contributing for around 61% of power generated. The massive dependence on natural gas for electricity generation is one of the biggest challenges for Bangladesh. Bangladesh definitely needs to work on electricity source diversification for power generation. This could be done by increasing the share of renewable energy (Bhandari D, 2019). Government of Nepal and Bangladesh are working together for exporting hydro electricity from Nepal. Since there is no land linkage between two countries, India should also be involved in this task as in order to export power transmission line of India is needed.

India's peak electricity demand was 200 GW (in July) in 2021 and it is expected to reach 299 GW by 2027. India has set a target of producing 175 GW by 2022 from renewables. This would make the energy mix of 50% from renewable energy of different types. The rest 50% of energy demand shall be obtained from conventional sources (Bhandari D, 2019). The energy transaction between Nepal and India may be characterized by both energy banking and export for some years up to 2025/26 as the dry season deficit is less than the wet season surplus in these years (Adhikari P, 2018). Demand and supply of electricity should be balanced in such way that demand does not surpass the supply. The national utility must invest in Demand Side Management to make a balance between demand and supply (Shrestha S, Nakarmi A, 2015).

India's energy forecast is overestimated which has led to 2.6 % energy peak and 1.1 % energy surplus respectively. During last decade India has increased its generation by 240 % (Bhandari D, 2019). On the other hand, Nepal and Bangladesh energy forecasts are underestimated. So, it can be inferred that India may not be interested in power purchase from other countries rather it can be interested in Energy Banking scheme as it prevents money flow outside the country for India.

Through energy banking in practice, the utilization of cross border transmission lines can be enhanced and there will be no need to restrict Precedence of Exceedance (PoE) to Q40 as per NEA’s current policy for ROR and PROR hydropower projects in Power Purchase Agreement (PPA). As higher generation in wet season will be transferred to dry season through the mode of energy banking. In this way, energy banking may be considered analogous to the function of a reservoir project storing water during monsoon period and using it to generate power in low-discharge period of the Nepalese rivers in winter season. It can be looked as a process to turn ROR and PROR projects into storage projects without additional infrastructures for storing water (Adhikari P, 2018).

In comparison with Nepal and Bangladesh, the cost of power generation in India is much lower. So, it can be said that from Indian perspective, it seems uneconomical to buy electricity from Nepal as its production cost is higher. For Bangladesh, though investing in Nepal’s hydropower doesn’t look price competitive at present, it supports the long-term strategy of increasing the clean energy mix as major portion of electricity demand is met by coal and gas in Bangladesh (Bhandari D, 2019). Nepal alone cannot directly sell electricity to Bangladesh at present context because two countries are not land connected. In order to use transmission networks of India, Nepal and Bangladesh need to sign agreement with India. However, Nepal and Bangladesh have already signed a memorandum of understanding (MoU) for cooperating in the field of power exchange.

India is the world's third largest producer as well as consumer of electricity in the world. With installed capacity of 373.43 GW of electricity, share of hydroelectric plants constitutes 36.17 % of installed capacity. The major source of electricity in India is fossil fuel. India has committed to achieve net zero emission by 2070 in the climate change summit held in Glasgow. India needs to invest huge money during 2020-30 in power sector (Vishwanathan S.S., Garg A, 2020). The boarder states of India, Bihar and Uttar Pradesh have increasing electricity demand and major source of electricity is coal of near states of India. As hydropower cost is cheaper and availability is higher, Nepal can be benefited from energy export. Nepal’s hydropower can provide flexibility for integrating large scale renewables as well as helps in decarbonizing the Indian power grid (Gyanwali K et al, 2020).

2.6 Research Gap

The information obtained from different articles, research and publications regarding energy banking and related field are tabulated below. The table shows title of article/publication/report and findings obtained and author/publisher.

Table 2-1: List of Different Articles, Publications and Research Works

S.N.	Title of Research/ Article/ Publication	Finding	Author
1	The Role of hydropower in south Asia's energy future	In South Asia region, Bangladesh India and Pakistan fossil fuels are important energy sources on the other hand Nepal and Bhutan relay on hydropower	Vaidya R et al, 2021
2	Promoting regional energy co-operation in South Asia	The huge potential of hydropower in Nepal and Bhutan can be used to meet growing electricity need of South Asia	Srivastava L, Misra N, 2007
3	Energy Situation in Nepal	Nepal has huge potential of hydropower, but about two percent of the 83,000 MW (technically possible) of hydropower is currently harnessed. 42,000MW is feasible with no environmental hazards	ICH, 2019
4	Demand side management in Nepal	The power system in Nepal is dominated by run-of-river (ROR) hydropower plants. There is a shortage of storage type hydropower plants	Yang M, 2005
5	A Year in Review (NEA Annual Publication)	Nepal became a power surplus country for the wet season after the 456 MW Upper Tamakoshi Hydropower Project, largest power plant, came into operation in July 2021. Nepal has surplus energy generation	NEA, 2021

		especially in the wet season as other RoR plants are also being add up in the system.	
6	A Year in Review (NEA Annual Publication)	In fiscal year 2019/20, 1,729 GWh of electricity was imported through various transmission links by Nepal which increased to 2,826 GWh in FY 2020/21.	NEA, 2021
7	A Year in Review (NEA Annual Publication)	Indian Government has given access in Day Ahead Market, Term Ahead Market and long term, medium term and short-term power trading in Indian for Nepal	NEA, 2020
8	Reflections on SAARC Framework Agreement for Energy Cooperation	The agreed documents for power exchange between India and Nepal and SAARC Framework agreement for energy Cooperation (2014) should be brought into implementation for Cross-border power transmission	Pun SB, 2018
9	Fostering Joint Initiative in Energy Cooperation between Nepal and India through Energy Banking	The energy transaction between Nepal and India may be characterized by both energy banking and export for some years up to 2025/26 as the dry season deficit is less than the wet season surplus in these years	Adhikari P., 2018
10	Who will buy Nepal's hydropower?	Though the cost of energy generation from hydropower is 9 cent per unit in India, the cost of energy generation from solar and coal is much lower and equal to 4.6 cents per unit. So economically it may be hard to sell the electrical energy from Nepal to India because India finds more economical to produce its energy from coal rather than import from Nepal.	Parsai S., 2018

11	Obtained from website of Statistica	The monthly power requirements of India for 2021 shows that power requirements from June to October is higher compared to other months in India, on the other hand Nepal will have spill energy during these months	Statistica, 2022
12	Fostering Joint Initiative in Energy Cooperation between Nepal and India through Energy Banking	Energy Banking can be looked as a process to turn ROR and PROR projects into storage projects without additional infrastructures for storing water	Adhikari P, 2018

From these articles/publications it can be concluded that Nepal is rich in hydropower resources. It can be observed that Energy Banking could solve the problem of both Nepal and India. Nepal has spill energy generation in the wet season and suffers from energy deficiency in the dry months. On the other hand, India has increased demand in the wet season. Nepal can supply its excess energy to India to help India to meet its increased load in wet season and Nepal can meet its energy deficiency in the dry month importing from India. Feasibility of energy banking between Nepal and India from Nepalese perspective is studied in this work.

2.7 Challenges on Energy Banking

Though Nepal has huge potentiality of hydropower, Nepal could not produce sufficient electricity to meet its demand. On the other hand, different policies speak that electricity could be exported to India and beyond. Nepal should focus on increasing per capita electricity consumption and internal consumption which is much lower compared to other neighboring countries. Energy cooperation and grid connectivity at regional level are being discussed in SAARC forum. However, there is no any significant progress has been achieved in regional grid connectivity (UN-ESCAP, 2018). In order to achieve successful execution of energy trade at regional level following challenges should be addressed at national and regional level.

2.7.1 Lack of Determined Plans and Institutions

After the formulation of Water Resource Strategy (WRS) in 2002 to the announcement of Electricity Development Decade of 2016, there are different targets of hydropower development announced by government like 5000 MW in five-year, 10,000 MW in ten year. There is lack of coordination between these plans.

RPGCL has prepared cross-border transmission line plan in 2018. On the other hand, NEA has too prepared this plan previously. These two plans should be interlinked and coordinated to formulate single national plan. Moreover, there should be one entity handling the issues related to cross boarder transmission.

2.7.2 Lack of Regional Cooperation

The cross-border trade with India seems not easy as perceived or depicted by national plans and policies. The India's Guidelines on Cross-Border Trade of Electricity published in 2016 had some contradictory clauses with the essence of SAARC Framework Agreement, 2014 and Indo-Nepal Power Trade Agreement, 2014 (Pun S.B., 2018). Ganges Strategic Basin Assessment Report (2014) published by The World Bank has stated that power trade among basin countries is simple to negotiate. There are four major barriers to regional power market namely technical barriers, institutional barriers, commercial barriers and policy barrier (Khadka and Adhikari, 2005). Malla (2005) has identified legal mistrust as major concern for energy cooperation in south Asian region. Regional co-operation is really not an easy task.

2.7.3 Lack of free Electricity Trade in the Region

Electricity (hydro) consumption should be increased within the country by establishing numbers of industries and shifting petroleum and gas consumers to electricity consumers rather than exporting as raw material. However surplus electricity can be traded with other country and national policy should be built for cross border electricity trade. However, there are not enough infrastructures as well as flexible policies needed for free electrdity trade in the South Asian region. There are examples in the world which shows that exporting electricity alone could not lead a country to prosperity. Paraguay, one of the main electricity exporters in South America is still the second poorest country in the region (Pun, 2008; Thanju and Canese, 2011). Bhutan exports major share of its hydropower produced electricity to India in nominal rate in the wet season. On the other hand, in dry season Bhutan imports back electricity from India in higher rates (SARI/EI, 2016). Electricity trade may not lead to prosperity.

2.7.4 Development of Storage Projects

Ganges Strategic Basin Assessment Report (2014) published by The World Bank's has stated that construction of storage projects in Nepal would contribute hydropower as the greatest benefits compared to flood control and water regulation. On the other hand, Pun (2013) strongly commented this report as Indo-centric and suggested Nepal not to rush for construction of storage projects just for energy trade as a multiple benefit could be obtained in irrigation, tourism, flood control and others by implementing these storage projects. Budhi Gandaki Storage Project (1200 MW) is under discussion of construction since long and consideration of downstream benefit has not been discussed fruitfully. Nepal can develop Budhi Gandaki Project considering multipurpose perspectives (Upadhyay and Gaudel, 2014). Storage projects are more stable sources of energy compared to ROR type's hydropower projects. If number of storage projects are increased Nepal's dependency with India for energy during dry months can be reduced to great extent.

2.7.5 Increasing Socio-Environmental Concerns

Hydropower projects are facing social and Environmental issues. The water diversions projects used for hydropower generation will make downstream completely dry. This affects both aquatic and terrestrial ecosystem. People who are directly dependent on river for their livelihood also get affected. Construction of hydropower requires large land areas which may be difficult to obtain in most cases.

2.8 Energy Banking Practice in India

In order to promote wind and solar energy industry, the concept of energy banking has been used by state of Tamilnadu since 1986 as power utilities and regulators recognized that in order to enable a wind project's commercial viability, banking is needed as it is intermittent in nature. The quantum of wind energy generated varies notably during the days as well as season to season and does not match the load profile of the customer.

Banking charges are levied upon the renewable energy (RE) generator for the energy banked and are paid to the distribution company and determined by state electricity regulatory commissions.

Tata Power Delhi has entered into the power banking arrangements with different states including Jammu and Kasmir, Madhya Pradesh, Meghalaya and Odisa among others. Under the arrangement utility exports power to these states during the off-peak winter month and the same is imported back by it during the summer.

2.9 Status of Cross Boarder Transmission Line between Nepal and India

There are five major cross boarder transmission line above 132 kV between India and Nepal in different locations. The maximum power transfer capacity at present through existing transmission line under consideration is 1455 MW. The list of operational cross boarder transmission line and their capacity and voltage level are presented in the table below.

Table 2-2: List of Existing Cross Boarder Transmission Line between Nepal and India

S.N.	Cross Boarder Transmission Line	Capacity (MW)	Remarks
1	Dhalkebar - Mujaffarpur (400 kV)	1200	Operational
2	Kusaha - Kataiya Transmission Line (132 kV)	150	Operational
3	Parwanipur - Raxaul Transmission Line (132 kV)	50	Operational
4	Gandak - Ramnagar Transmission Line (132 kV)	25	Operational
5	Mahendranagar - Tanakakpur Transmission Line (132 kV)	30	Operational
Total capacity of Power Flow		1455	

CHAPTER 3 RESEARCH METHODOLOGY

3.1 Research Flow Chart

After completing adequate literature review regarding energy scenario and present status of energy exchange between Nepal and India flow chart of conducting research study is made. The flow chart is presented in the below figure:

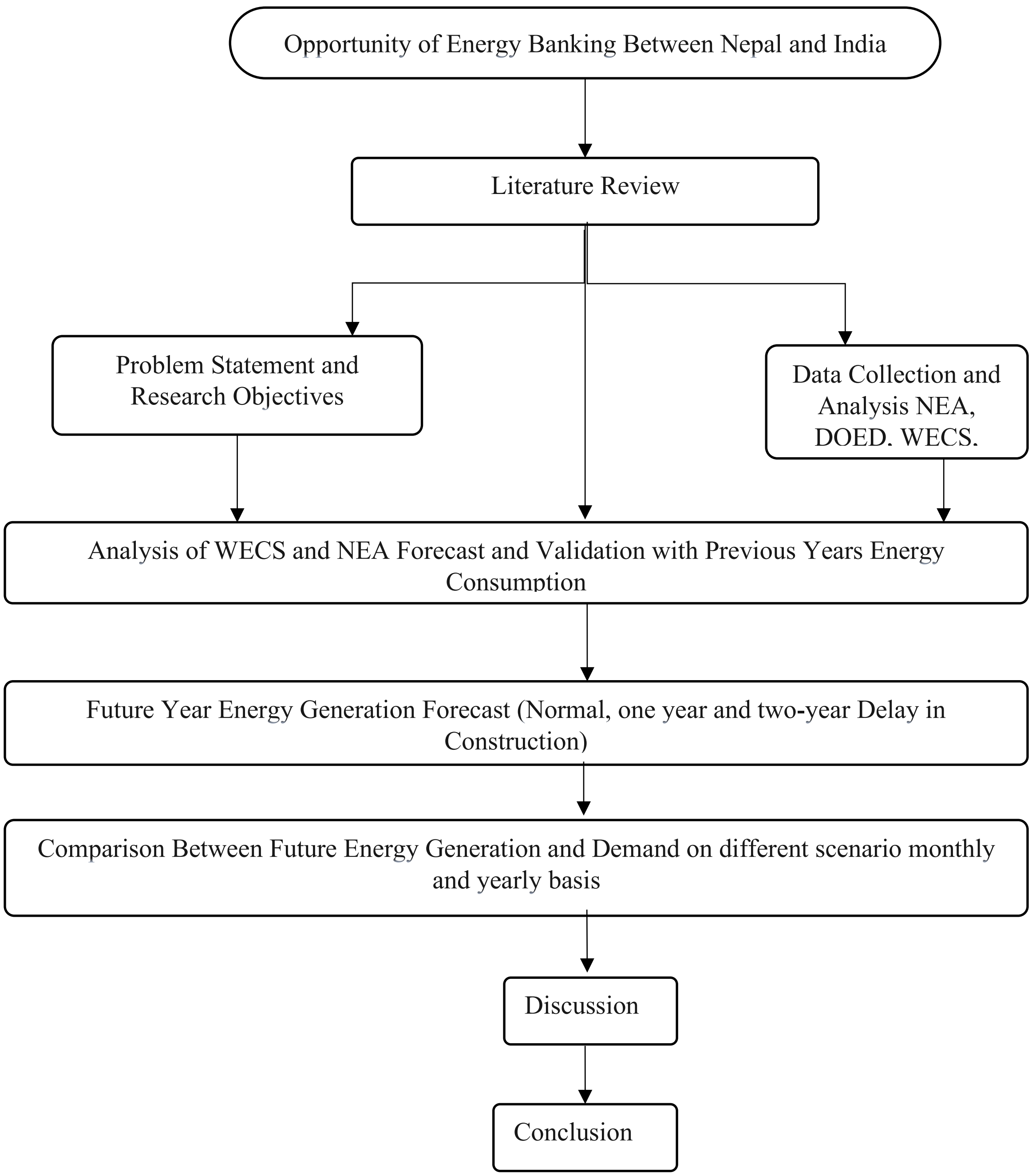

Figure 3-1: Flow chart of Research Study

At first relevant data of energy consumption of different past year of Nepal from different sources are collected from NEA publications. Data of different sources like NEA generation, IPP generation and import from India are also collected and their contribution to meet country's demand is evaluated. Data regarding import/export of energy with India in the recent year are also collected and studied.

The forecast of future energy requirement obtained from WECS, NEA publications are tabulated and analyzed. WECS forecast have three different scenarios i.e. Business As Usual (4.5 % GDP growth), Reference Scenario (7.2 % GDP growth) and High Scenario (9.2 % GDP Growth).

In order to obtain Nepal's future energy generation, forecast; generation is divided into two different sources, IPP and NEA. There are three different scenarios considered, project completion within stipulated time, one year delay in generation and two-year delay in generation. After obtaining energy demand and generation forecast, they are matched for different year and whether balance between generation and demand could be obtained or not is studied. The energy generation from the installed capacity is obtained by multiplying with plant factor which is obtained from the past year energy generation of different hydropower.

The monthly energy generation pattern of hydro powers of past three years are collected to obtain the average percentage generation for different month. This percentage generation factor is used to obtain the monthly forecasted generation for different future year. This helps to find out monthly forecasted generation.

The monthly consumption pattern of last three year are extracted from NEA report and the percentage of monthly consumption for each year are calculated. The average monthly consumption factor obtained is used to get the monthly energy consumption for different future year under consideration.

After obtaining monthly generation and consumption energy for future year they are matched whether balance between generation and demand could be obtained or not and how energy banking shall help Nepal to obtain balance between generation and supply of electricity are analyzed.

3.2 Data Collection

3.2.1 Energy Demand/Supply Pattern of Nepal

Energy consumption pattern of Nepal as obtained from different fiscal year report of Nepal Electricity Authority for different year are presented in the table. Growth of energy for different fiscal year seems different as observed in the table. The major increase in load in fiscal year 2015/16 is due to increase in power import from India after the Dhalkebar - Mujaffarpur 400 kV Transmission line came into operation. The slow growth of 3 % in fiscal year 2019/20 is due to the outbreak of Covid Pandemic in the country.

Table 3-1: Energy Consumption of Nepal for Different Years

S.N.	Fiscal Year	Energy Consumption (GWh)	Growth %
1	2014/15	3492	
2	2015/16	3743	7 %
3	2016/17	5100	36 %
4	2017/18	5614	10 %
5	2018/19	6303	12 %
6	2019/20	6529	3 %
7	2020/21	7319	12 %

Total energy consumption in FY 2020/21 was 7,319 GWh, a slight increase over the corresponding figure of 6,529 GWh in the FY 2019/20, with an increase of 12 % growth in energy consumption. The percentage growth of energy in fiscal year 2017/18, 2018/19, 2019/20 are respectively 10%, 12%, and 3% respectively. There is normal growth pattern of energy of about 10 % per year. The lower energy consumption growth in 2019/20 is mainly due to effect of COVID Pandemic. Energy supply from different sources as obtained from different fiscal year report of Nepal Electricity Authority to meet the demand of whole country are shown in below table.

For the fiscal year 2020/21 it can be observed from the table that about 32 % of energy is obtained from NEA sources, about 36 % from IPPs and rest 32 % is obtained from import from India. The share of NEA, IPP and import was respectively 39 %, 39% and 22 % in the fiscal year 2019/20. The total power purchased from Independent Power Producers (IPPs) in 2019/20 was 2,991 GWh, an increase by 36.57 % from the figure of 2,190 GWh in the FY 2018/19.

Table 3-2: Energy Supply from Different Sources

S.N.	Fiscal Year	Energy Availability (GWh)			Total Energy Availability (GWh)	Peak Demand (MW)
		NEA	IPP	India (Import)		
1	2011/12	2125	1038	694	3858	946
2	2012/13	2358	1073	746	4178	1026
3	2013/14	2291	1175	790	4258	1094
4	2014/15	2297	1070	1318	4687	1200
5	2015/16	2366	1268	1369	5005	1291
6	2016/17	2305	1778	2175	6258	1444
7	2017/18	2308	2168	2582	7058	1508
8	2018/19	2548	2190	2813	7551	1320
9	2019/20	3021	2991	1729	7741	1408
10	2020/21	2808	3241	2826	8875	1482

IPPs contributed a total of 3,241 GWh of energy to the country in FY 2020/21. The total energy imported from India was 1,729 GWh as compared to 2,813.07 GWh in FY 2018/19, a decrease by 38.55 percentage. Nepal imported 2,826 GWh of electricity from India in FY 2020/21.

Large numbers of hydropower in Nepal are run-of-river type, hence during dry months when river discharge is low hydropower production also reduces significantly (Poudyal R, Loskot P et al, 2019). Monthly energy demand and import/export from/to India for fiscal year 2018/19, 2019/20 and 2020/21 are shown in the table below. It can be depicted from the table that import in the dry months are always higher than in the wet month in all three years. In the wet season import of energy from India seems in the decreasing ratio on the other hand the gap of import of energy in the dry season is in increasing trend as shown in the below table. This is because though installed capacity of country is increasing year by year but almost all hydropower is Run of River type. So, they run in rated capacity in the wet season but in the dry season ratio of increase in demand is higher than that of generation.

Table 3-3: Energy Import/Export for Different Months for Three Fiscal Years

Month/ Year	2018/19		2019/20		2020/21	
	Import (GWh)	Export (GWh)	Import (GWh)	Export (GWh)	Import (GWh)	Export (GWh)
July	176.49	2	179.5	28.05	91.1	31.19
August	183.86	3.5	205.67	12.07	71.15	4.71
September	164.29	5.56	80.16	29.57	52.25	1.06
October	87.05	7.47	42.43	20.19	36.38	0.71
November	187.9		105.66	3.59	125.45	
December	326.58		255.22		313.06	
January	311.75		290.66		396.77	
February	323.97		290.17		402.79	
March	275.55		158.81		468.61	
April	260.82	2.2	28		422.99	
May	270.38	2.54	28.33		207.6	
June	244.44	15.64	55.99	4.74	217.64	32.48
Total	2,813.08	38.91	1,720.60	98.21	2,805.79	70.15

3.2.2 Forecast of Demand of Electricity

Energy and power demand forecast of Nepal are extracted from three different sources i.e., forecast developed by Nepal Electricity Authority and energy forecast developed by Water and Energy Commission Secretariat (WECS) and Government's strategic planning on energy published in 2018.

3.2.2.1 WECS Energy and Power Forecast

"The Electricity Demand Forecast Report (2015-2040)" was published in January 2017 by Water and Energy Commission Secretariat. MAED model was used in load forecasting (MOEWRI, 2017). Three scenarios of economic development have been taken into consideration. They are listed below.

(i) Business as usual (4.5% GDP growth rate),

(ii) Reference (7.2% GDP growth rate), and

(iii) High growth (9.2% GDP growth rate).

The following table shows the WECS Energy Forecast data. Policy intervention scenario considers 100 % of cooking in urban area is done by electricity. It also considers penetration of electric vehicles in transportation sector.

Table 3-4: WECS Demand Forecast Data from 2015 to 2040

Year	Final Electricity Demand (GWh)			
	BAU 4.5%	**Reference Scenario 7.2%**	**High Scenario 9.2%**	**Policy Intervention @ 7.2%**
2015	3866.36	3866.36	3866.36	3866.36
2020	7600.76	8110.66	8522.97	14570.9
2025	12998.3	14863.7	16545.8	22431.7
2030	20073.8	24956.8	29864.1	35334.7
2035	29744.7	40709.8	52983.2	51771.8
2040	43016.7	66096.6	94851.1	81959

The installed capacity requirement from 2015 to 2040 at different time steps published by WECS with different scenario is presented in the table below. Table shows that in BAU scenario the installed capacity requirement was 3,384 MW in the year 2020, but we hardly had 1,400 MW of installed capacity, which made us to import electricity from India. Likewise, the forecasted electricity demand requirement was 7600 GWh and we had 7741 GWh total electricity available in the grid in the year of 2020.

Table 3-5: WECS installed capacity Requirement (MW) Forecast

Year	Total Installed Capacity Requirement (MW)		
	BAU 4.5%	**Reference Scenario 7.2%**	**High Scenario 9.2%**
2015	1721	1721	1721
2020	3384	3611	3794
2025	5787	6617	7366
2030	8937	11111	13296
2035	13242	18124	23588
2040	19151	29427	42228

Even if we follow the past trend of GDP growth, i.e., 4.5%, there will be a need of 5,787 MW of installed capacity by 2025, whereas in case of high scenario the requirement will be 7366 MW. By 2030, the installed capacity requirement is 11,111 MW in reference scenario, whereas by 2040, the installed capacity requirement will increase to 29,427 MW. If the policy interventions are made while achieving 7.2% GDP growth rate, the installed capacity requirement will reach up to 18,000 MW in 2030 and more than 50,000 MW by 2040. The yearly values demand forecast for interval year for different scenario as required are obtained by interpolation of the available data.

3.2.2.2 NEA Demand Forecast

System Planning Department of NEA carried out load forecast up to 2033/34 and published the Load Forecast Report on 2015 (System Planning Department NEA, 2015). Load forecast carried out by NEA is based on assumptions on macro-economic indicators, and level of electrification in the country. As per the Load forecast data published by NEA total generation (GWH) requirement by 2025, 2030 and 2040 is about 18,579.5 GWh, 31,196.38 GWh and 82,620.73 GWh whereas system peak of these years is about 4078.75 MW, 6,848.52 MW and 18,137.67 MW. The following table shows the System Energy Requirement (GWh) and System Peak Load (MW) forecasted by NEA for fiscal year 2019-20 to 2039-40. If we compare WECS forecast and NEA forecast it can be observed that NEA forecast seems in higher range.

Table 3-6: System Energy Requirement (GWh) and System Peak Load (MW) forecasted by NEA for fiscal year 2019-20 to 2039-40

Fiscal Year	System Energy Requirement (GWh)	System Peak Load (MW)
2017/18	7,489.62	1,644.19
2018/19	8,391.28	1,842.13
2019/20	10,138.28	2,225.65
2020/2 1	12,017.96	2,638.29
2021/2 2	13,952.00	3,062.87
2022/2 3	15,332.65	3,365.97
2023/24	16,869.13	3,703.27
2024/25	18579.53	4,078.75
2025/26	20,585.22	4,519.06
2026/27	22,826.63	5,011.11

2027/28	25,332.50	5,561.23
2028/29	28,111.30	6,171.26
2029/30	31,196.38	6,848.52
2030/31	34,355.49	7,542.04
2031/32	37861.08	8,311.62
2032/33	41,754.21	9,166.27
2033/34	46,079.83	10,115.87
2034/35	50,887.42	11,171.28
2035/36	56,007.87	12,295.37
2036/37	61,677.62	13,540.05
2037/38	67,957.59	14,918.68
2038/39	74,913.54	16,445.72
2039/40	82,620.73	18,137.67

3.2.2.3 Government Strategic Policy

The GoN has taken a strategic direction to reach electricity generation to 5,000 MW by 2023 and 15,000 MW by 2028 including 5,000 MW for export through a White paper published by Ministry of Energy, Water Resources and Irrigation (MoEWRI) on May 2018. Likewise, GoN has taken to expand access to electricity and clean cooking to 100 percent of population by 2023 and increase per capita consumption of electricity to 1,500 kWh by 2028 through this White Paper. This policy shows targeted generation capacity (MW) and Total Energy Generation (GWh) from FY 2074/75 to FY 2084/85 from NEA, NEA subsidiary and other companies, Independent Power Producers (IPP), Export Oriented project and Solar & Other Renewable Energy Sources (RES).

All the above-mentioned energy forecast are plotted in the same graph and shown in the figure below. The white paper energy forecast shows sharp upshot as it is based on the assumption of generation of 5000 MW in 5 years and 15,000 MW in 10 years.

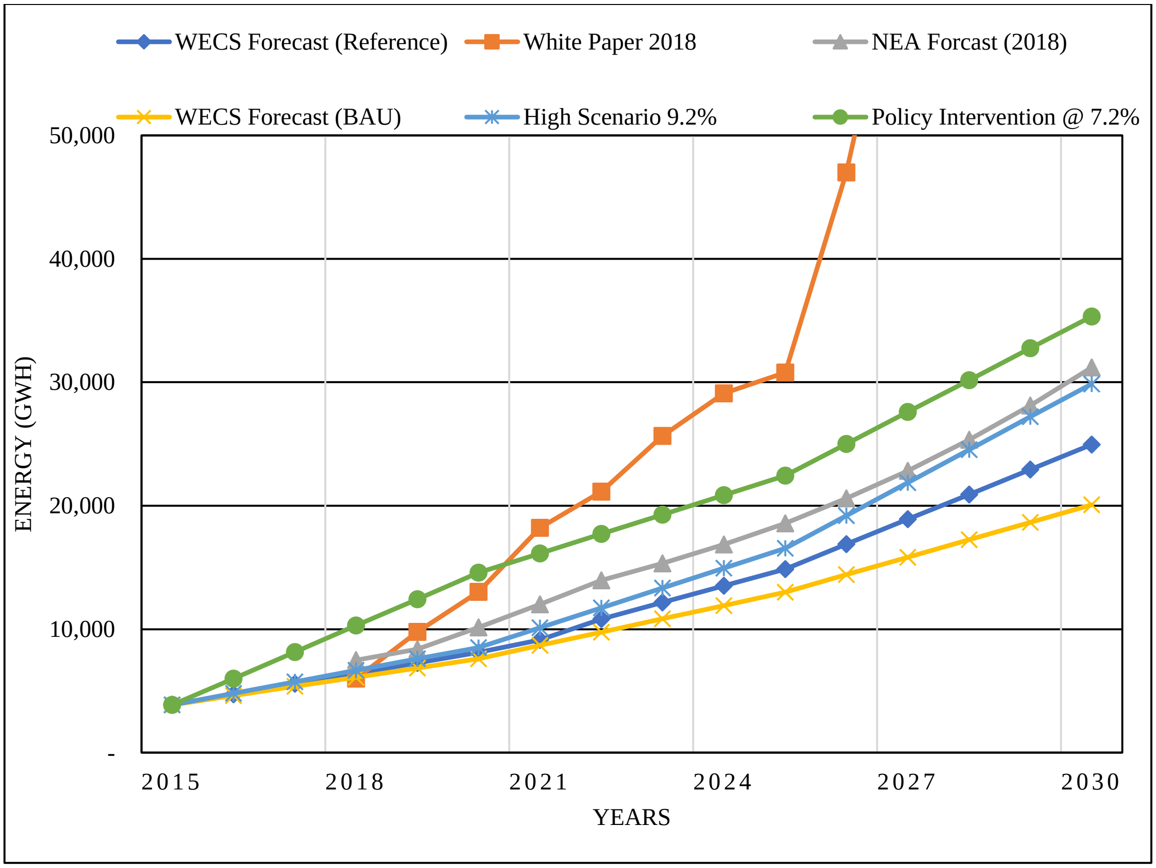

Figure 3-2: Different Energy Demand/Generation in GWh forecast published by WECS, NEA and GoN

The WECS different forecasts BAU (4.5 %), Reference (7.2 %), High (9.2%) and Policy Intervention (7.2 %) from year 2015 to 2030 are plotted in the graph. NEA energy consumption forecast from 2018 to 2030 are also plotted in the same graph.

3.2.3 Future Energy Generation Forecast

In order to obtain future energy generation scenario only projects under construction are considered. The projects under construction are divided into two categories, IPP Projects and NEA and its Subsidiary Projects. Large hydropower projects in Nepal suffer from time overruns which leads to increased costs of the projects. The probable reasons for time extension of project are weak management capacity of NEA, lengthy procurement process and degraded capacity of contractors (Poudyal R, Loskot P et al, 2016).

In order to find out the completion period of the IPP project (above 10 MW) which are under construction, PPA date and completion date of the operating hydropower (above 10 MW) are listed and time period taken to complete project from PPA date of individual operational project are obtained. The average years for completion of project is obtained to be 8 years from these operational projects under consideration. The list of completed project and their PPA date, Commercial Operation Date (COD) and time taken for completion are kept in annex. The probable completion date of under construction IPP projects are obtained by adding the average completion time to PPA date of under construction projects. The completion date of NEA and its subsidiary company projects are retrieved from NEA publications. For every year additional MW of power are obtained by adding the IPP and NEA projects that are scheduled to be completed in the particular year. The addition of electrical power from 2022 to 2027 from IPP and NEA are shown in the table below.

Table 3-7: Addition of Capacity (MW) from 2022 to 2027 from IPP and NEA and its Subsidiaries

Year	Additional Capacity MW (IPP)	Additional Capacity MW (NEA)	Total Additional MW	Total Additional Energy (GWh)
2022	228.8	513.3	742.1	4,225.52
2023	359.03	111	470.03	2,676.35
2024	373.86	142	515.86	2,937.31
2025	427.22	177	604.22	3,440.43
2026	647.94	94.8	742.74	4,229.18
2027	319	61.8	380.8	2,168.28

The average plant factor of Nepalese hydropower's is calculated from the past two years (2020 and 2021) hydropower generation data and is obtained to be 0.66. Same plant factor is used to find out the additional energy produced in different coming years. Two additional cases are considered assuming there shall be delay in completion of project by one year and by two years. These cases data are kept in annex.

3.2.3.1 Monthly Energy Generation and Consumption Forecast

The energy generation pattern of different hydropower for year 2019, 2020 and 2021 are extracted from NEA publications A Year in Review book of different years in monthly basis.

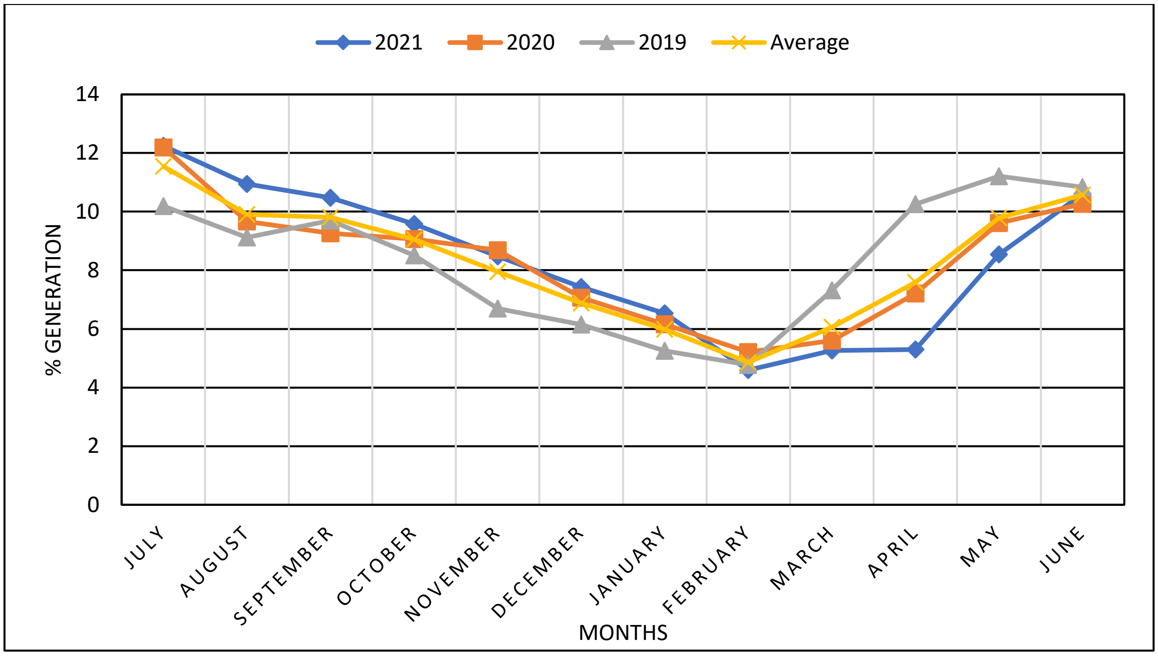

Figure 3-3: Average Generation Percent of Total Generation of Three Year for Different Month

The energy consumption pattern of different months for year 2019, 2020 and 2021 are extracted from NEA publication A Year in Review book for different years are shown in figure below. The average monthly energy consumption percentage of total consumption of three year for each month are calculated. The average factors are used to obtain monthly consumption in future year from yearly energy consumption.

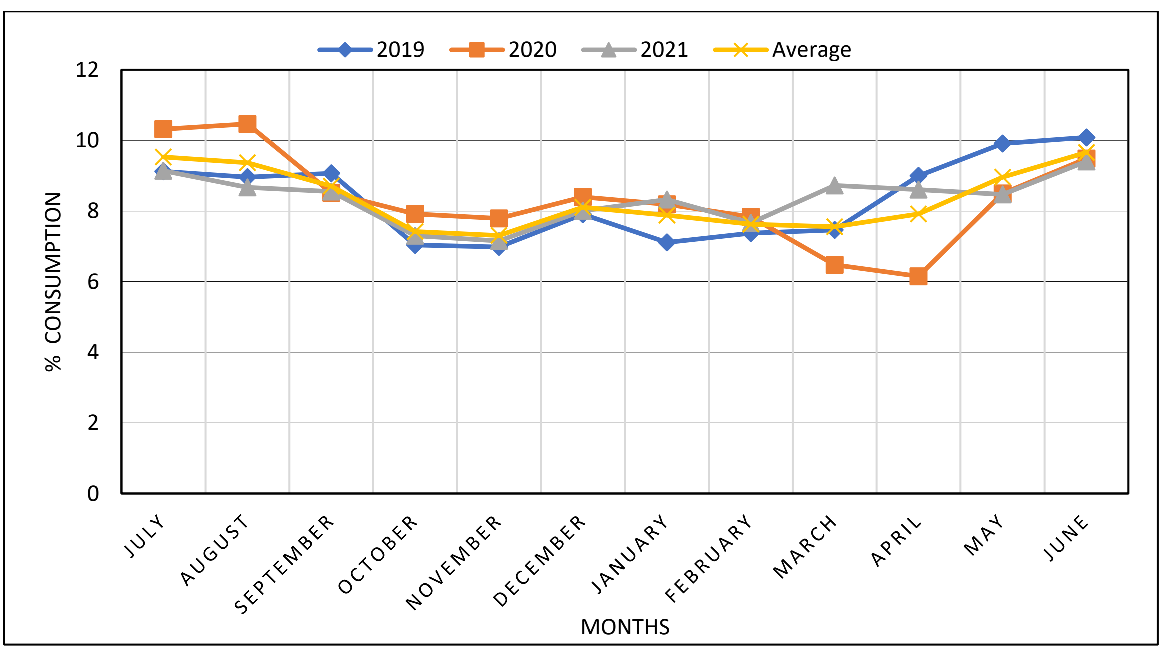

Figure 3-4: Average Consumption Percent of Total Consumption of Three Year for Different Month

3.2.4 Comparison between Forecasted Energy Production and Consumption

The average yearly GDP Growth rate from 2015 to 2021 are shown in the following figure (Economic Survey, 2020/21). The GDP growth rate have higher fluctuations from highest value of 8.20% in year 2017 to lowest value of -2.09 in 2019. The lower value of GDP in the year 2016 is due to the effect of devastating earthquake.

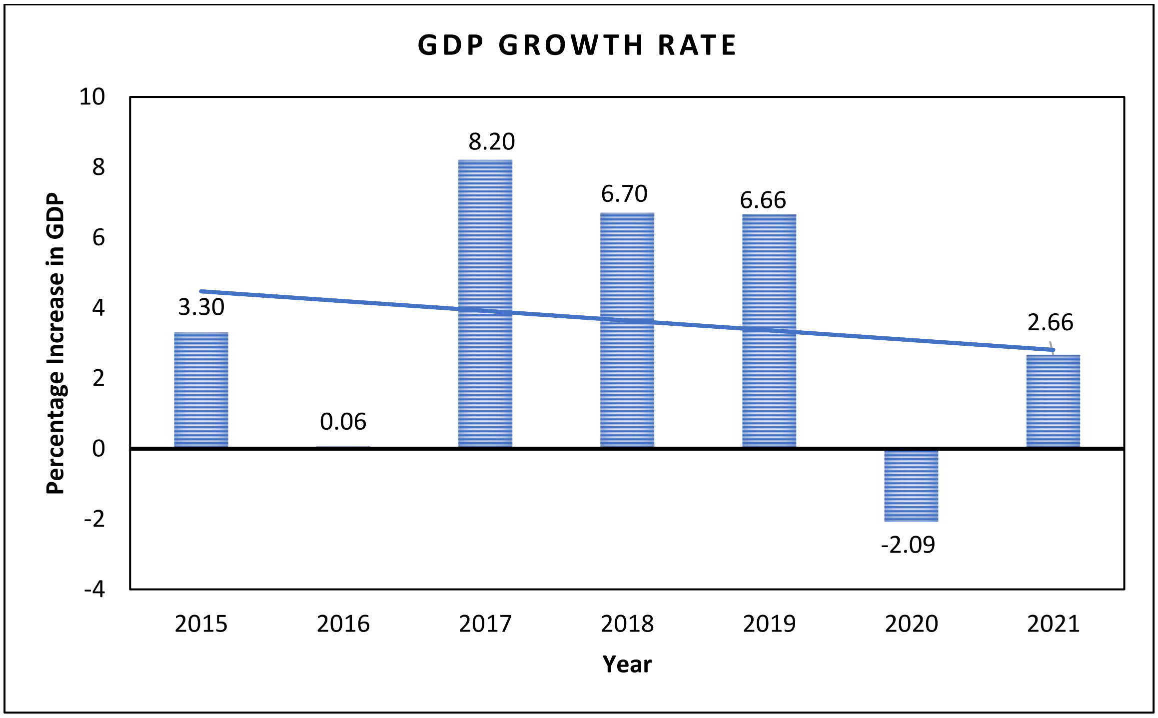

Figure 3-5: GDP Growth Rate from 2015 to 2021

The lower value of GDP growth rate in 2019 to 2021 is due to effect of Corona Pandemic in Nepal. The average value of growth in GDP is obtained to be about 4% in this period from 2015 to 2021. The actual energy consumption of Nepal and WECS Energy forecast for Business-as-Usual Scenario (GDP Growth rate 4.5 % per annum) are plotted in the following figure. It can be concluded that energy consumption pattern from year 2015 to 2021 follows Business-as-Usual Scenario (GDP Growth rate 4% per annum) of energy forecast in this period.

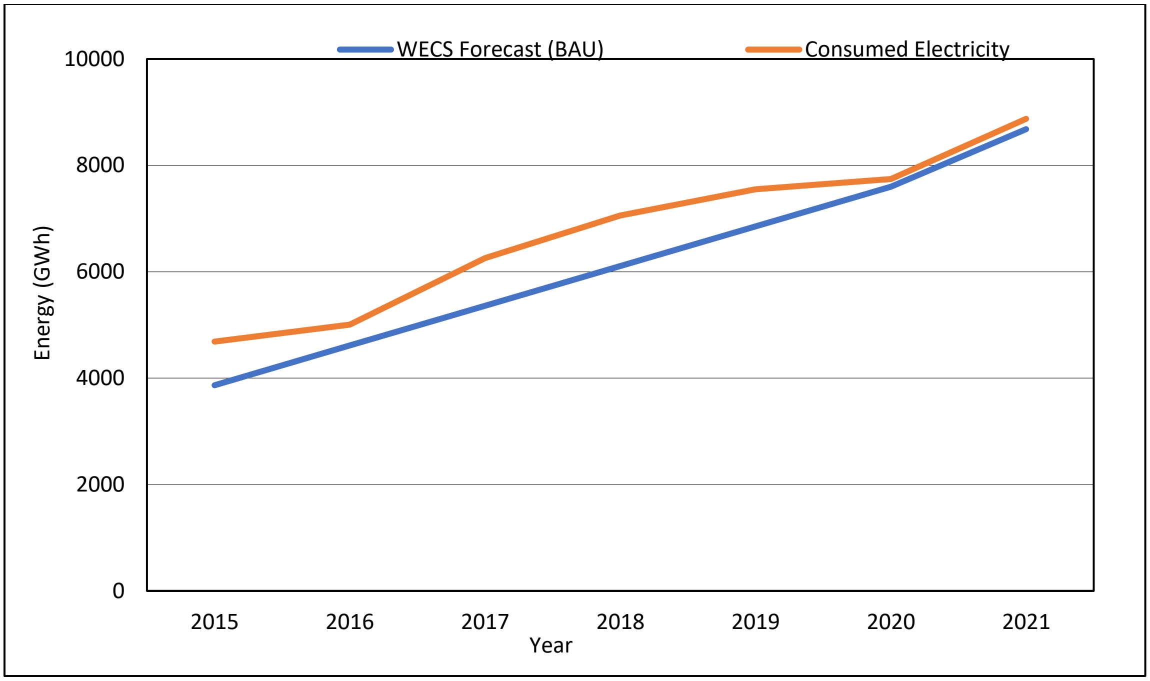

Figure 3-6: Actual Energy Consumption and WECS Energy Forecast Business-as-Usual Scenario

The average growth rate in this period is about 4 % and under BAU scenario of WECS forecast, the considered growth rate is 4.5 %. Energy consumption during year 2017 and 2018 are higher than forecast and in this period growth rate is also higher. It can be concluded that during this period, actual energy consumption and energy forecast of WECS for BAU scenario are comparable to each other.

3.2.5 India Power Demand and Supply

The energy consumption pattern of India is obtained from website of Central Electricity Authority (CEA) for past years and presented in the table below (CEA, 2022). It is observed that energy deficiency of India has been in decreasing trend. In the fiscal year 2019/20 there was energy deficiency of 6,566 Million Units (MU) which decreased to 4,871 MU in the fiscal year 2020/21.

Table 3-8: Energy Requirement and Availability of India for past years

	Energy (MU)			
Year	**Requirement**	**Availability**	**Deficit (-)**	**(%)**
2009-10	830,594.00	746,644.00	(83,950.00)	-10.11
2010-11	861,591.00	788,355.00	(73,236.00)	-8.50

2011-12	937,199.00	857,886.00	(79,313.00)	-8.46
2012-13	995,557.00	908,652.00	(86,905.00)	-8.73
2013-14	1,002,257.00	959,829.00	(42,428.00)	-4.23
2014-15	1,068,923.00	1,030,785.00	(38,138.00)	-3.57
2015-16	1,114,408.00	1,090,850.00	(23,558.00)	-2.11
2016-17	1,142,929.00	1,135,334.00	(7,595.00)	-0.66
2017-18	1,213,326.00	1,204,697.00	(8,629.00)	-0.71
2018-19	1,274,595.00	1,267,526.00	(7,069.00)	-0.55
2019-20	1,291,010.00	1,284,444.00	(6,566.00)	-0.51
2020-21	1,275,534.00	1,270,663.00	(4,871.00)	-0.38

The peak demand of India for different years are presented in the table below (CEA, 2022). It is observed that India is not being able to meet its peak demand in the past years. Energy deficiency of India has been in decreasing trend. In the fiscal year 2019/20 there was deficiency of peak demand by 1,271 MW which decreased to 802 MW in the fiscal year 2020/21.

Table 3-9: Peak Demand of India for Different Years

Year	**Peak Demand (MW)**	**Peak Met (MW)**	**Deficit (-)**	**(%)**
2009-10	119,166	104,009	-15,157	-12.7
2010-11	122,287	110,256	-12,031	-9.8
2011-12	130,006	116,191	-13,815	-10.6
2012-13	135,453	123,294	-12,159	-9
2013-14	135,918	129,815	-6,103	-4.5
2014-15	148,166	141,160	-7,006	-4.7
2015-16	153,366	148,463	-4,903	-3.2
2016-17	159,542	156,934	-2,608	-1.6
2017-18	164,066	160,752	-3,314	-2
2018-19	177,022	175,528	-1,494	-0.8
2019-20	183,804	182,533	-1,271	-0.7
2020-21	190,198	189,395	-802	-0.4

The contribution of different sources of energy to meet the demand of India are presented in the table below (MOP, 2022). The contribution of Fossil Fuel is about 60 % and rest 40 % are met from combinations of renewable energy.

Table 3-10: Different Energy Sources of India

Category	**Installed Generation Capacity (MW)**	**% of Share in Total**
Fossil Fuel		
Coal	2,03,900	51.60%
Lignite	6,620	1.7%
Gas	24,900	6.30%
Diesel	510	0.10%
Total Fossil Fuel	**2,35,929**	**59.70%**
Non-Fossil Fuel		
Renewable Energy Sources (Incl. Hydro)	**1,52,366**	38.50%
Hydro	**46,512**	**11.80%**
Wind, Solar & Other RE	1,05,854	26.80%
Wind	40,101	10.20%
Solar	50,304	12.70%
BM Power/Cogen	10,176	2.60%
Waste to Energy	434	0.10%
Small Hydro Power	4,840	1.20%
Nuclear		
Nuclear	6,780	1.70%
Total Non-Fossil Fuel	**1,59,146**	40.30%
Total Installed Capacity	**3,95,075**	**100%**

The monthly power requirements of India are shown in the figure below (Statistica, 2022*)*. It can be observed that power requirements from June to October is higher compared to other months in India, on the other hand Nepal will have spill energy during these months and amount of this spill energy goes on increasing as additional hydropower come into operation. The best practice could be energy banking to India during monsoon when Nepal's generation is higher than requirement and get back banked energy during dry month when Nepal suffers power shortage.

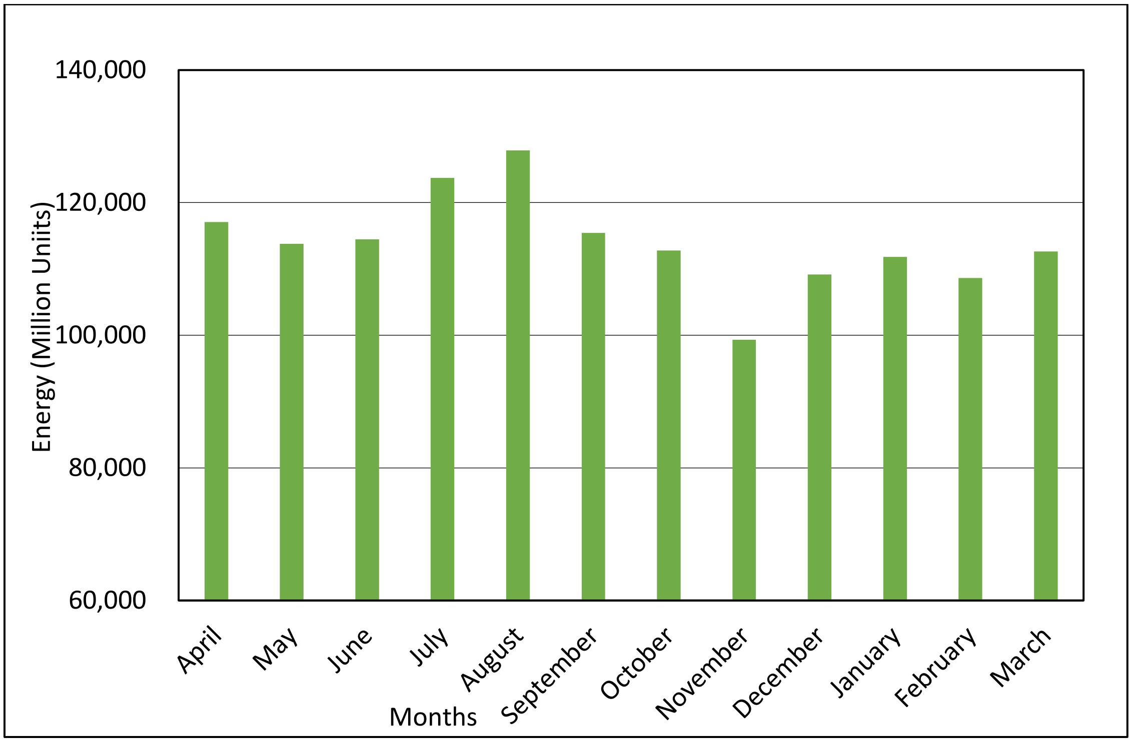

Figure 3-7: Monthly Energy Demand of India for the year 2021

CHAPTER 4 RESULT AND DISCUSSION

4.1 Analysis of Previous Year Data

Contribution of major three sectors i.e., NEA, IPP and Import from India are obtained from NEA publications and their percentage contribution in electricity is calculated and presented in the below table from year 2012 to 2021.

Table 4-1: Percentage share of NEA, IPP and Import of total energy demand for different year

Year	NEA	IPP	Import (India)
2012	55.08	26.91	17.99
2013	56.44	25.68	17.86
2014	53.80	27.60	18.55
2015	49.01	22.83	28.12
2016	47.27	25.33	27.35
2017	36.83	28.41	34.76
2018	32.70	30.72	36.58
2019	33.74	29.00	37.25
2020	39.03	38.64	22.34
2021	31.64	36.52	31.84

The percentage share of NEA seems to be in decreasing trend and that of IPP and Import is in increasing trend as shown in the figure below.

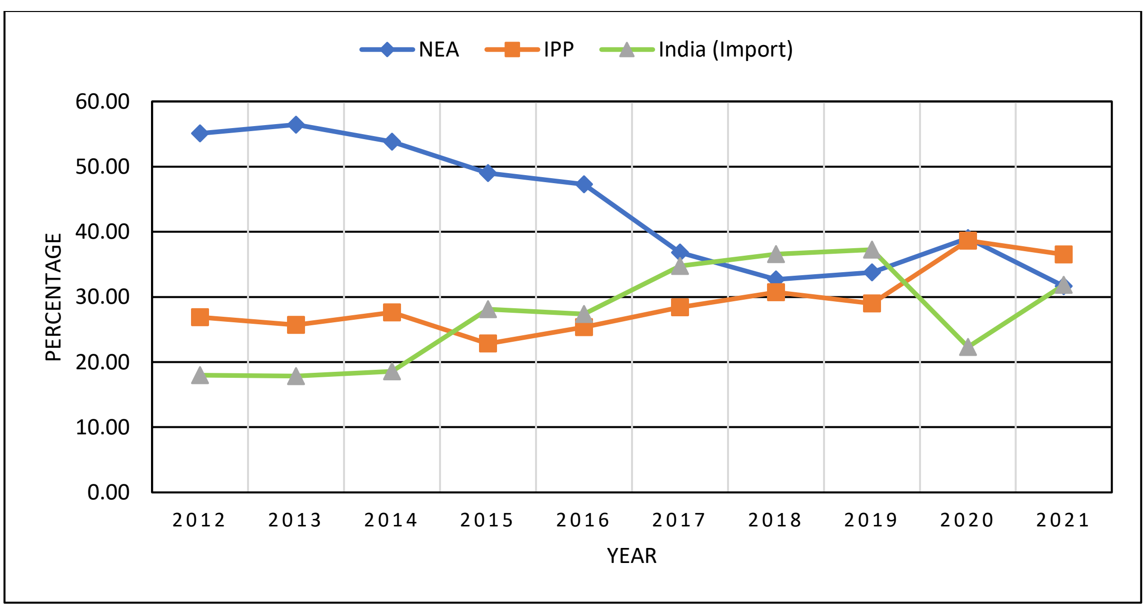

Figure 4-1: Percentage Contribution of Different Sectors in Electricity from 2012 to 2021

Slight deviation in the import from India in the year 2020 is due to decrease in electricity demand due to lock down announced by government because of COVID 19 pandemic in the country. The scenario of energy demand, import and country's generations are presented in the table below for the recent three years i.e., 2019, 2020 and 2021. These data are extracted from the A Year in Review books of different years published by NEA.

Table 4-2: Total Electricity Demand, Import from India and Nepal's Generation for fiscal year 2019, 2020 and 2021

Month/ Year	2019 (in GWh)		2020 (in GWh)		2021 (in GWh)	
	Import	Generation	Import	Generation	Import	Generation
July	176.49	514.98	179.5	634.63	91.1	727.91
August	183.86	495.07	205.67	620.47	71.15	705.51
September	164.29	523.1	80.16	591.56	52.25	713.67
October	87.05	446.09	42.43	582.19	36.38	618.03
November	187.9	341.24	105.66	508.83	125.45	515.34
December	326.58	273.01	255.22	407.2	313.06	404.29
January	311.75	227.5	290.66	355.94	396.77	349.12
February	323.97	234.67	290.17	328.36	402.79	283.54
March	275.55	290.46	158.81	352.06	468.61	312.5
April	260.82	421.16	28	457.53	422.99	348.12
May	270.38	480.81	28.33	642.03	207.6	551.52
June	244.44	520.06	55.99	692.9	217.64	624.98
Total	2813.08	4768.15	1,720.60	6,173.70	2,805.79	6,154.53

The percentage share of country's generation with respect to total energy demand for different months for year 2019, 2020 and 2021 are calculated and results are plotted in the figure is shown below. It can be observed that for dry months (October to April) country's generation can be able to meet just about 40 % of total demand. During the months of wet season (April to October) the country's generation is being able to meet the demand as shown in the figure. For three consecutive years trend line is almost similar in nature.

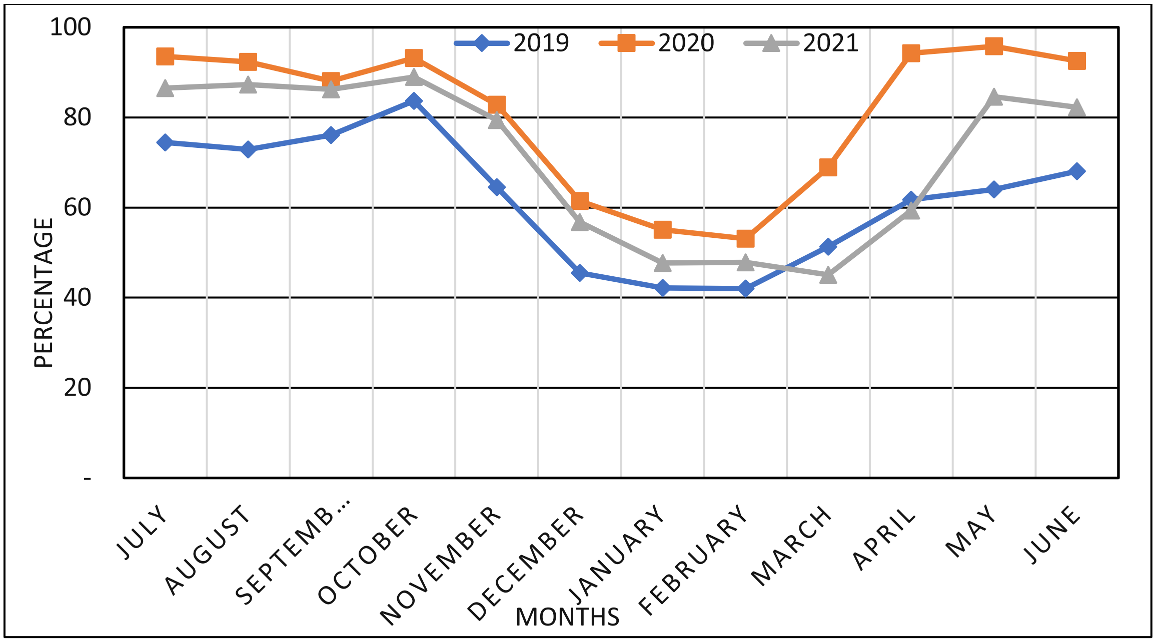

Figure 4-2: Percentage Share of Country's Generation with Respect to Total Energy Demand for Different Months for Year 2019, 2020 and 2021

The percentage share of import from India with respect to total energy demand for different months for year 2019, 2020 and 2021 are calculated and results are plotted in the figure shown below. It can be observed that for dry months (October to April) country has been importing almost about 40 % of total demand.

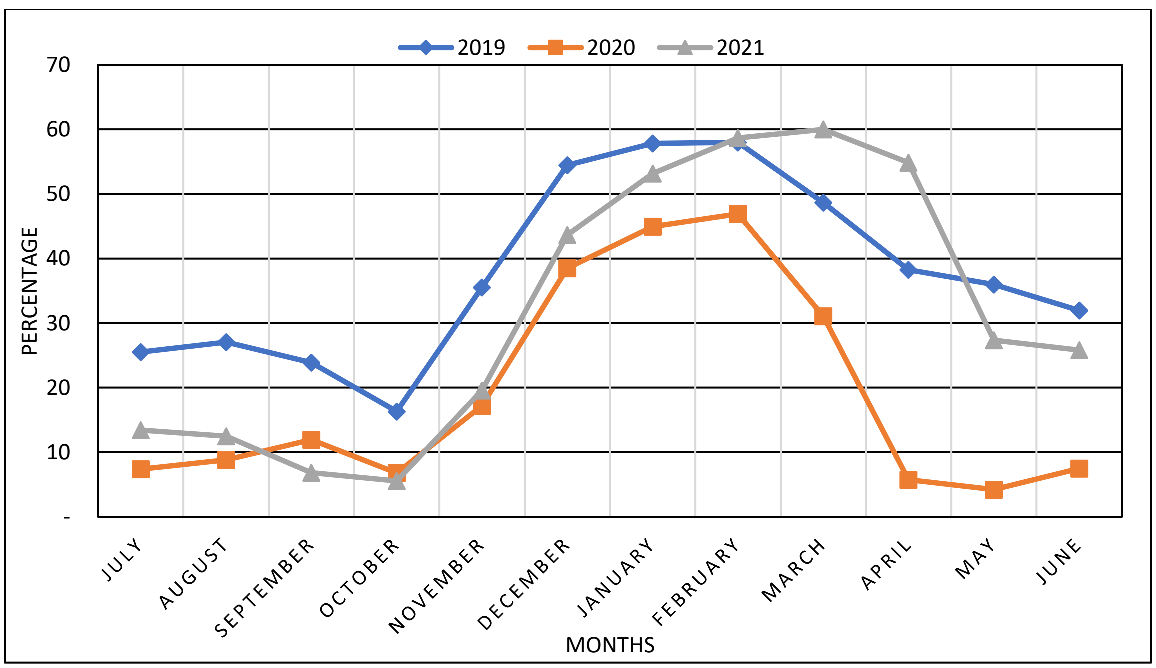

Figure 4-3: Percentage Share of Import from India with Respect to Total Energy Demand for Different Months for Year 2019, 2020 and 2021

During the months of wet season (April to October) the import is being reduced as shown in the figure. For three consecutive years trend line is almost similar in nature.

4.2 Different Scenario of Generation and Demand

We have three different scenarios in future generation of energy namely normal generation, one year delay in generation and two-year delay in generation. The forecasted MW and energy are presented in the table below.

Table 4-3: Forecasted Power and Energy Production in different Scenarios

Year	Forecast Power Capacity (MW)			Forecast Energy Production Capacity (GWh)		
	Normal Condition	One Year Delay	Two Year Delay	Normal Condition	One Year Delay	Two Year Delay
2022	2,183.10	1,897.00	1,897.00	13,185.84	11,556.78	11,556.78
2023	2,653.13	2,183.10	1,897.00	15,862.19	3,185.84	11,556.78
2024	3,168.99	2,653.13	2,183.10	18,799.50	15,862.19	13,185.84
2025	3,773.21	3,168.99	2,653.13	22,239.92	18,799.50	15,862.19
2026	4,515.95	3,773.21	3,168.99	26,469.11	22,239.92	18,799.50
2027	4,896.75	4,515.95	3,773.21	28,637.38	26,469.11	2,239.92

The different scenario of energy requirements for different GDP growth percentage as forecasted by WECS for the period under study are presented in the table. There are three different scenarios and two policy intervention scenarios as listed in table.

Table 4-4: Forecast Energy requirement (WECS different scenario)

Year	WECS Forecast Energy Requirement (GWh)				
	BAU 4.5 %	Reference Scenario 7.2%	High Scenario 9.2%	Policy Intervention @ 7.2%	Policy Intervention @ 9.2%
2022	9,759.76	10,811.86	11,732.12	17,715.22	18,888.59
2023	10,839.25	12,162.47	13,336.69	19,287.38	20,680.75
2024	11,918.75	13,513.07	14,941.27	20,859.53	22,472.90
2025	12,998.25	14,863.67	16,545.84	22,431.68	24,265.05
2026	14,413.37	16,882.29	19,209.49	25,012.28	27,665.00
2027	15,828.48	18,900.92	21,873.14	27,592.87	31,064.96

4.3 Results on Different Scenario

4.3.1 Business As Usual Scenario of Demand Forecast

In this scenario, energy requirement is considered as WECS forecasted energy requirement under BAU scenario. In this condition GDP growth rate is considered as 4.5 %. Normal generation condition is the condition in which hydropower completion takes place as planned without delay in construction, one year delay in generation refers to the condition in which hydropower completion is pushed one year later than as planned. Two-year delay in generation condition is the condition in which hydropower completion is pushed two year later than as planned with delay in construction. The below figure shows the year wise forecasted demand under BAU and generation forecast under different scenario.

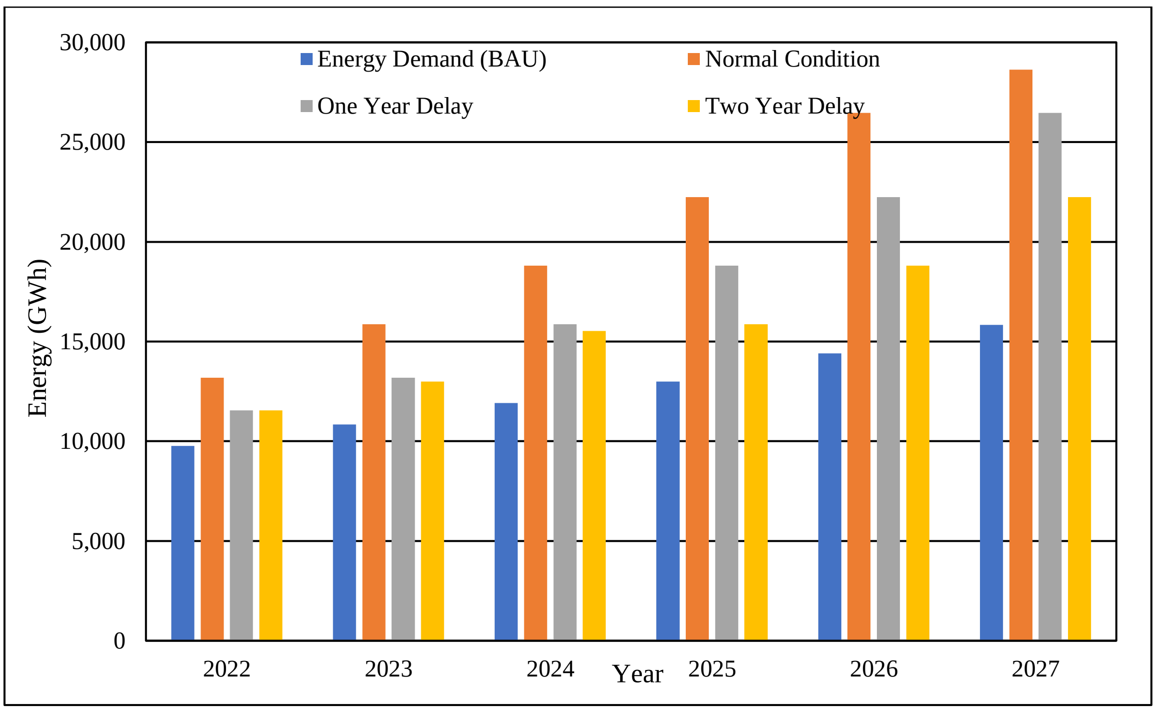

Figure 4-4: Forecasted Yearly Energy Requirement (BAU Scenario; Different Generation Condition)

In this condition all year energy demand is met by all three types of generation forecast and there is excess of energy in all year. The gap of excess energy seems increasing year by year. For the year 2024, 2025, 2026 and 2027 there is energy excess of 6,880 GWh, 9,241 GWh, 12,055 GWh and 12,808 GWh respectively if normal generation is considered. Similarly, if two-year delay in construction is considered, there is energy excess of 3819 GWh, 3250 GWh, 4630 GWh and 6527 GWh respectively.

The comparison of monthly energy demand and supply is shown in the below figure under this condition for the year 2023 for two-year delay in generation. There is energy deficiency of 29 GWh, 189 GWh, 112 GWh and 46 GWh respectively for the month from January to April. We can observe that there is excess generation during other months. There is excess generation of 2,525 GWh in this scenario in the year 2023.

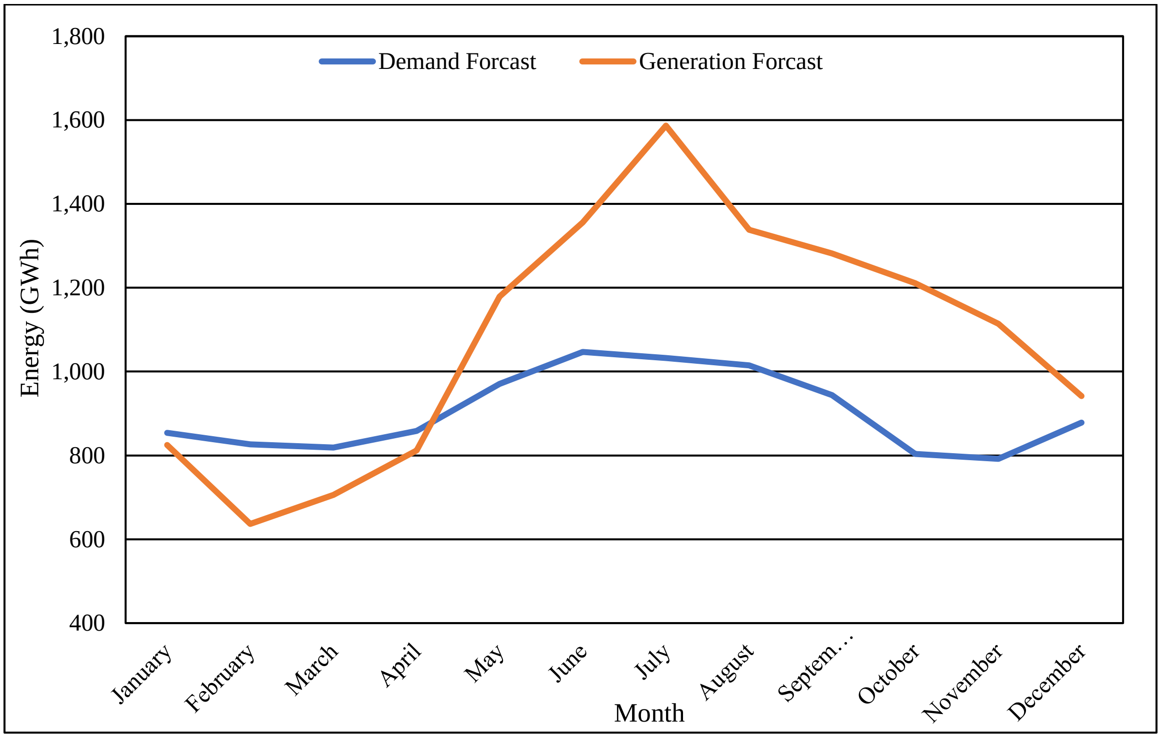

Figure 4-5: Forecasted Monthly Energy Requirement (BAU Scenario; Two-year Delay Generation) for 2023

4.3.2 Reference Scenario of Demand Forecast

In this scenario, energy requirement is considered as WECS forecasted energy requirement under Reference scenario. In this condition GDP growth rate is considered as 7.2 %. The below figure shows the year wise generation for different condition and demand of energy under this scenario for year 2022 to 2027.

In this condition all year energy demand is met by generation and there is excess of energy in all year. There is excess energy of 744 GWh, 1023 GWh and 7,711 GWh energy for year 2022, 2023 and 2027 respectively if there is one year delay in generation. In the recent year there is smaller gap between forecasted demand and generation as compared to later year.

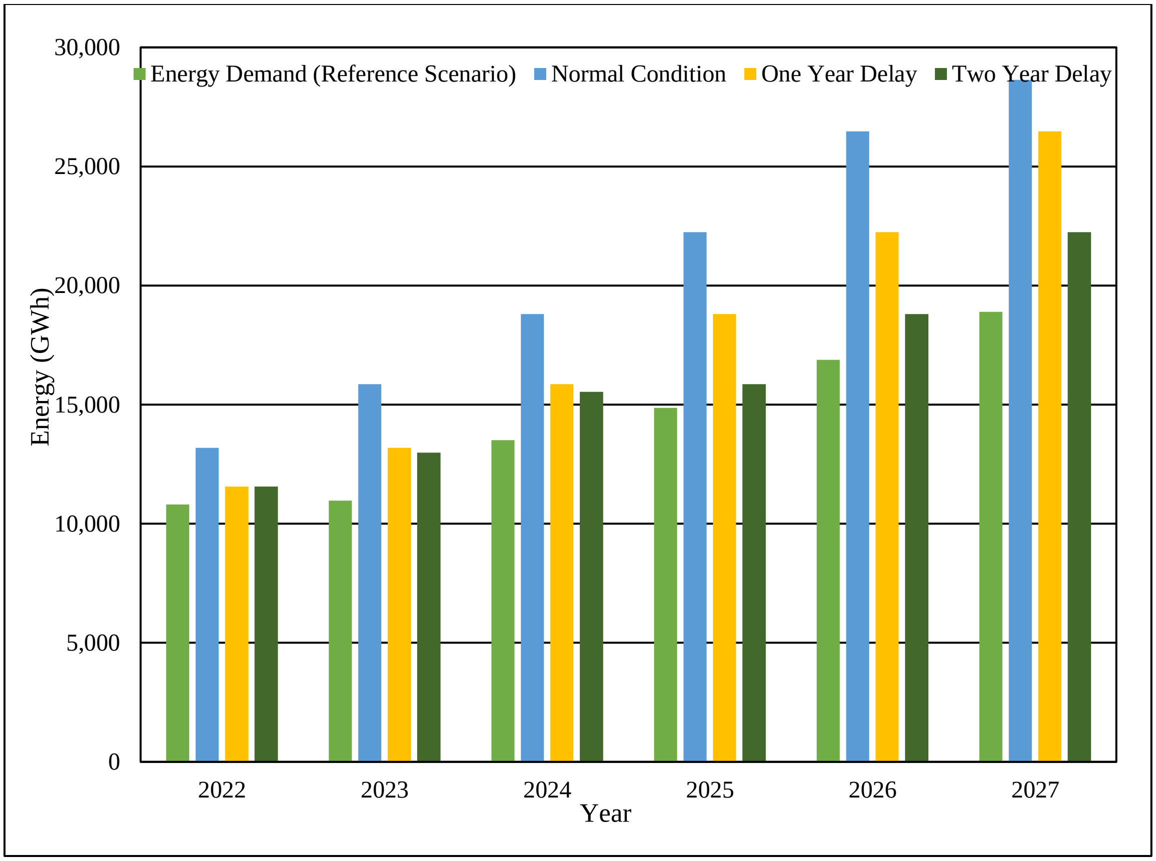

Figure 4-6: Forecasted Yearly Energy Requirement (Reference Scenario; Different Generation Condition)

The amount of excess energy is 744 GWh, 2021 GWh, 2022 GWh, 998 GWh and 1917 GWh and 3339 GWh for the years 2022 to 2027 respectively if there is two-year delay in construction of project.

The comparison of monthly energy demand and supply is shown in the below figure under one year delay in generation for the year 2024. We can observe that there is excess generation during wet season which amounts to 2895 GWh from May to December. During dry season (January to April), there is energy deficiency of 546.32 GWh. Hence it can be observed that total amount of energy excess is greater than energy deficiency in dry months. So, by doing proper energy banking with India, Nepal's energy demand can be met throughout year and Nepal can even earn revenue if it could sell its excess energy.

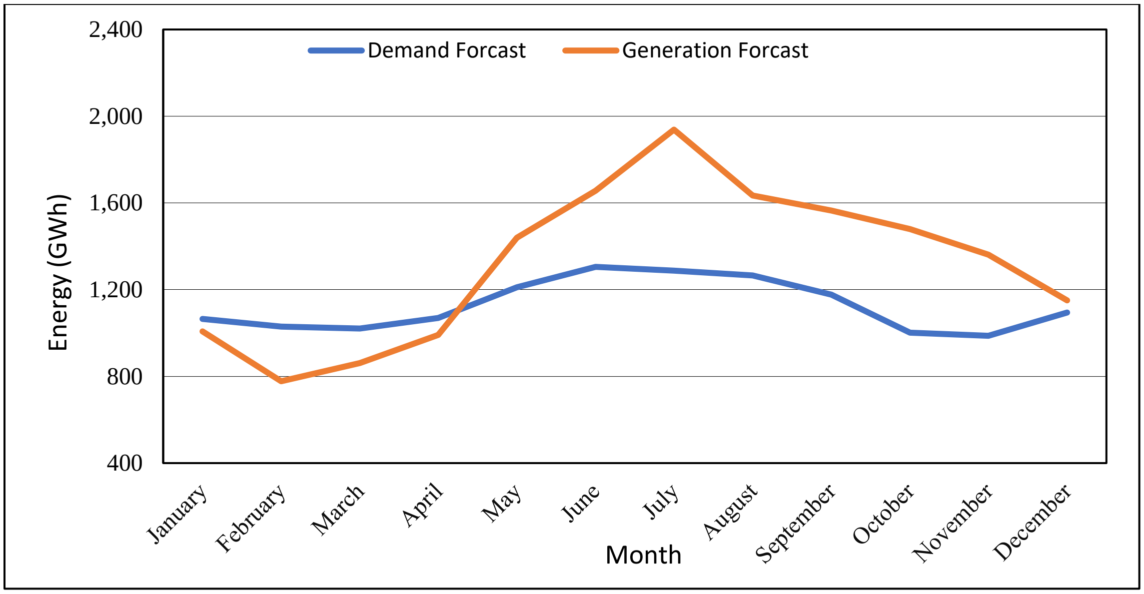

Figure 4-7: Forecasted Yearly Energy Requirement (Reference Scenario; One Year Delay Generation) for Different Months

The comparison of monthly energy demand and supply is shown in the figure below under this condition for the year 2022. We can observe that there is excess generation from May to November by 1480 GWh and during dry season (December to May), there is energy deficiency of total 735 GWh. If energy banking concept is utilized with India, Nepal can still meet its energy requirements of dry months in this scenario.

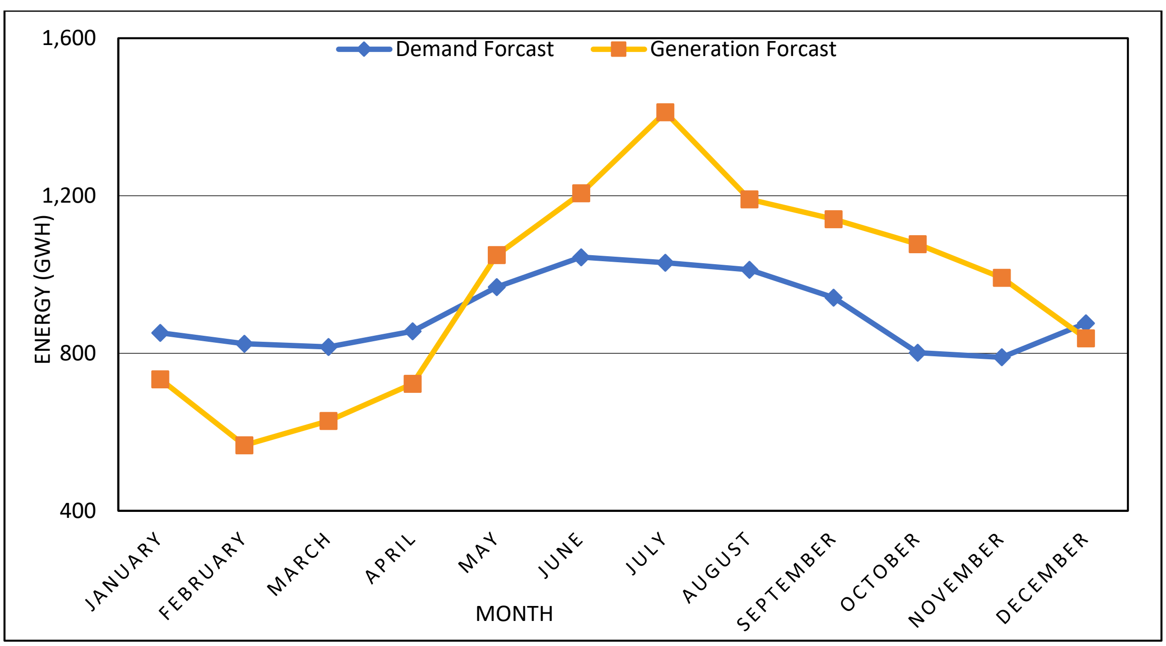

Figure 4-8: Forecasted Monthly Energy Requirement (Reference Scenario; Two Year Delay Generation) for 2022

4.3.3 High Scenario of Demand Forecast

In this scenario, energy requirement is considered as WECS forecasted energy requirement under High scenario. In this condition GDP growth rate is considered as 9.2 %. There is energy excess through all year under consideration if there is no delay in hydropower construction. There is energy deficiency of 175 GWh and 150 GWh in the year 2022 and 2023 and there is excess generation of 920 GWh, 2253 GWh, 3030 GWh and 4595 GWh respectively from year 2024 to 2027 under one year delay in generation condition. When there is two-year delay in construction, there is energy deficiency up to 2026.

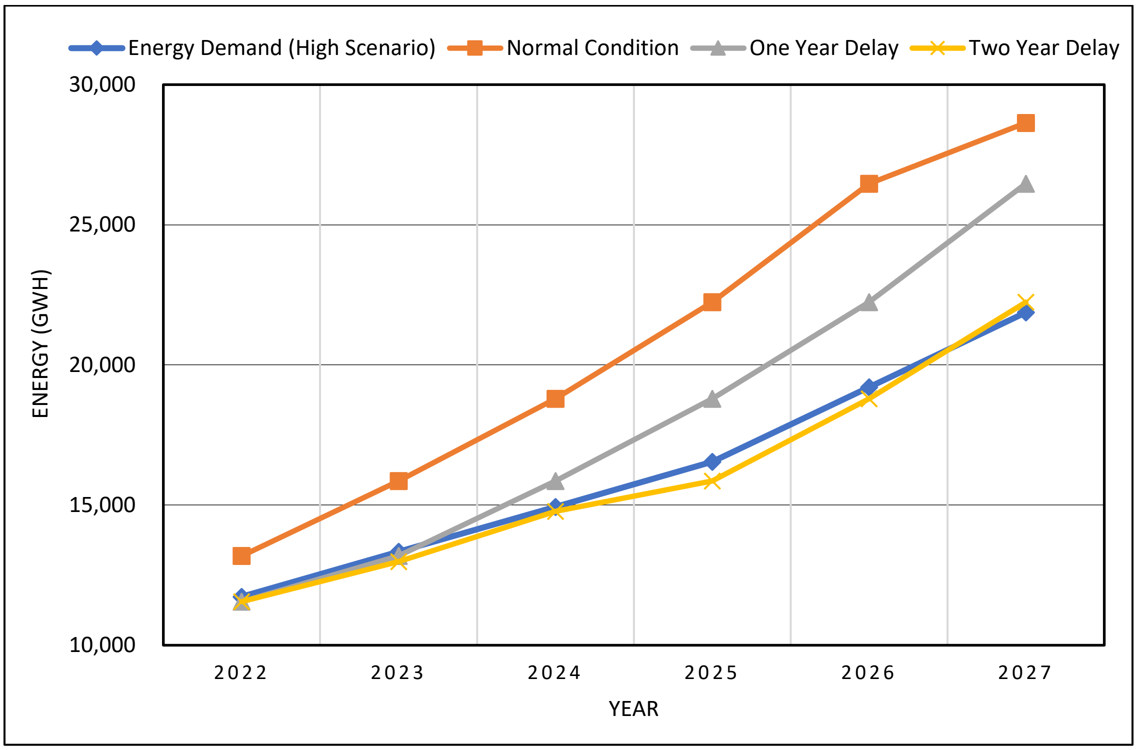

Figure 4-9: Forecasted Energy Requirement (High Scenario; Different Generation Condition)

The comparison of monthly energy demand and supply is shown in the below figure for one year delay in generation under this condition for the year 2023. We can observe that there is excess generation during wet season and during dry season (December to May), there is energy deficiency. During dry months from December to May there is energy deficiency of 1230 GWh and during rest of the months there is energy excess of about 1080 GWh. If energy banking concept is utilized with India, Nepal can meet its 87 % of energy deficiency. Nepal needs to import only 150 GWh of energy to fulfil its demand throughout the year.

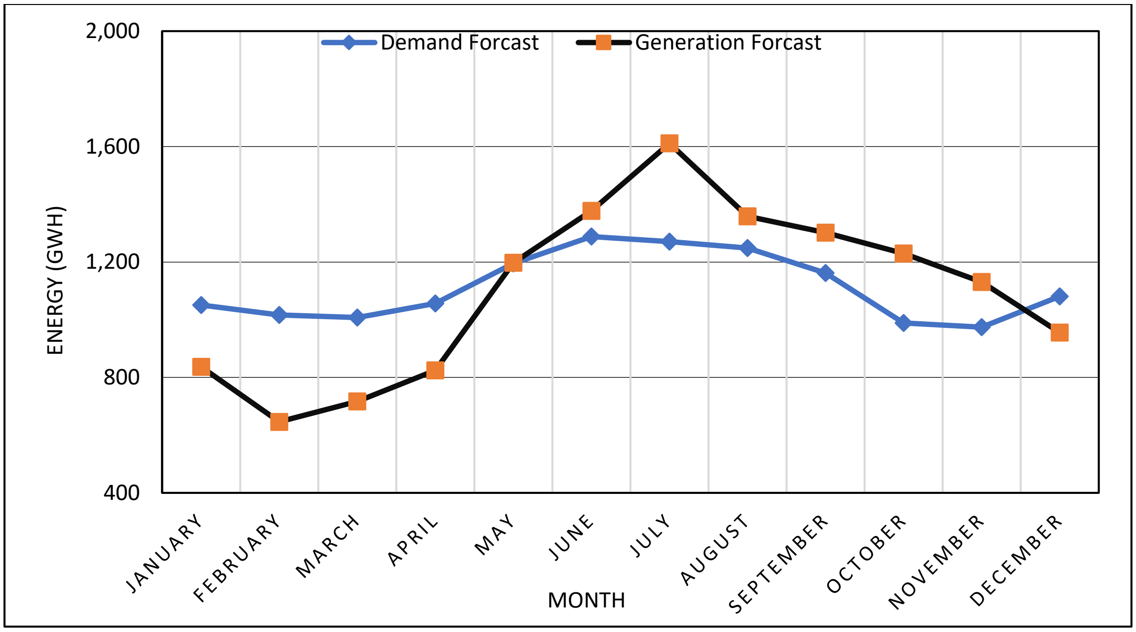

Figure 4-10: Forecasted Monthly Energy Requirement (High Scenario; One Year Delay Generation) for 2023

4.3.4 Policy Intervention at Reference Scenario Demand Forecast

In this scenario, energy requirement is considered as WECS forecasted energy requirement under Reference Scenario with policy intervention. Policy intervention scenario considers 100 % of cooking in urban area is done by electricity. It also considers penetration of electric vehicles in transportation sector.

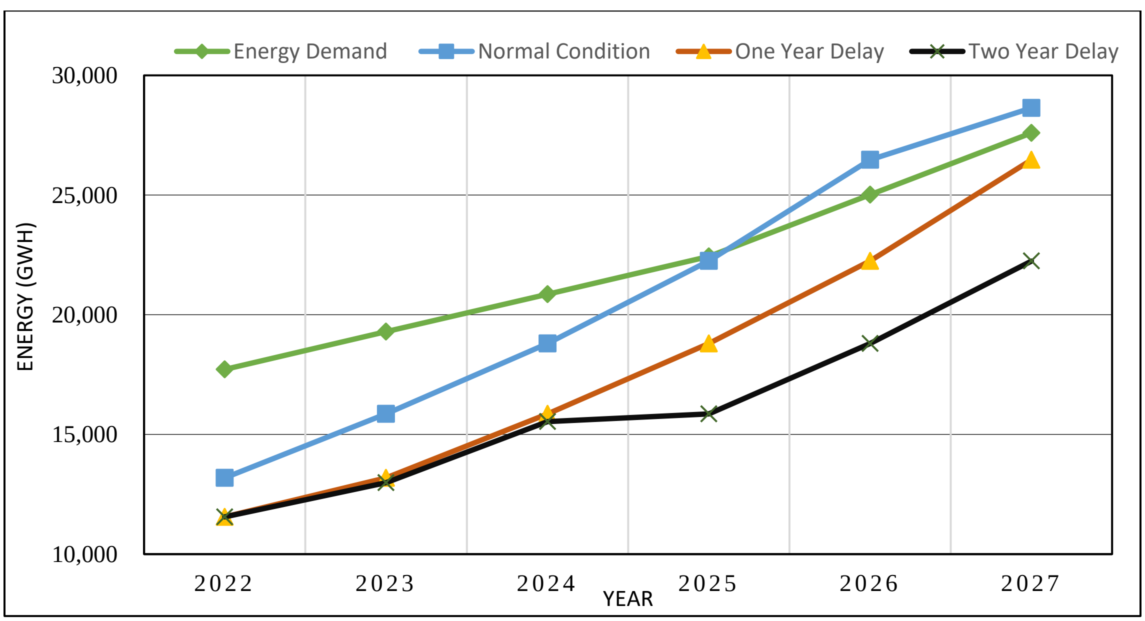

Figure 4-11: Energy Requirement (Policy Intervention 7.2 %) and Different Generation Forecast

It can be observed from above figure that under normal generation forecast, Nepal faces energy deficiency by 4529 GWh, 3425 GWh, 2060 GWh and 191 GWh respectively from 2022 to 2025. The energy deficiency gap goes on decreasing trend from 2022 to 2025. From 2025 onward yearly energy required is met by country's generation. There is excess of generation by 1456 GWh and 1044 GWh respectively for year 2026 and 2027. For delay in generation condition Nepal could not meet its demand for all the year under consideration.

The monthly energy requirement and generation for the year 2025 under normal generation scenario is shown in the figure below. It can be observed that Nepal can have excess production of 1858 GWh for the month from May to November. For the rest of the months Nepal could not meet its energy demand and total deficient energy for the rest of the month is 2050 GWh. Maximum energy deficiency of 619 GWh occurs in the month of February for this year.

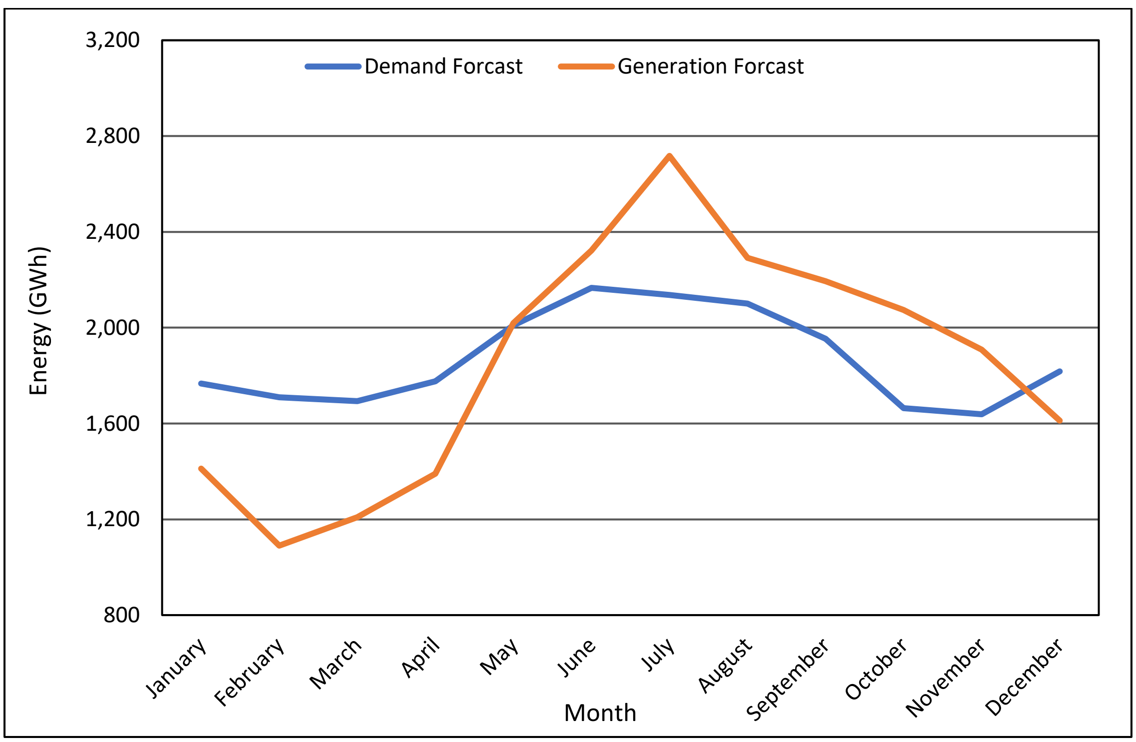

Figure 4-12: Energy Requirement (Policy Intervention 7.2 %) and Normal Generation Forecast for 2025

4.4 Comparison of Demand and Generation of Energy for Year 2023 to 2026

The result of sum of wet energy surplus and dry energy deficiency for the year 2023 under different scenario considered are tabulated below. It can be observed from the table that there is energy surplus of 5022.93 GWh under BAU demand scenario and normal generation condition. There is surplus energy generation of 1023.37 GWh under reference scenario in demand and one year delay in Generation. Similarly, there is energy surplus of 824.33 GWh under references scenario of demand and two-year delay in generation.

Table 4-5: Sum of Monthly Excess Energy and Deficient Energy for Different Scenarios for Year 2023

Scenario	Generation Condition	Wet Excess Energy Outflow	Dry Deficient Energy Inflow	Net Energy (Wet-Dry) in GWh
BAU (4.5 % GDP)	Normal Condition	5,071.49	48.56	5,022.93
	One Year Delay	2,678.78	332.19	2,346.58
	Two Year Delay	2,525.38	377.85	2,147.54
Reference Scenario (7.2 % GDP)	Normal Condition	3,905.66	205.94	3,699.72
	One Year Delay	1,794.93	771.56	1,023.37
	Two Year Delay	1,655.97	831.64	824.33
High Scenario (9.2 % GDP)	Normal Condition	3,017.20	491.70	2,525.50
	One Year Delay	1,079.45	1,230.31	(150.85)
	Two Year Delay	955.98	1,305.88	(349.90)
Policy Intervention at 7.2 % GDP	Normal Condition	149.67	3,574.86	(3,425.19)
	One Year Delay	-	6,101.54	(6,101.54)
	Two Year Delay	-	6,300.58	(6,300.58)

There is energy deficiency by 150.85 GWh and 3425.19 GWh respectively under high scenario of demand and one year delay generation scenario and under policy intervention (at 7.2 % GDP) and normal generation condition.

Though under high scenario of demand and one year delay generation scenario, there is energy deficiency of 1230.31 GWh, the excess energy 1079.45 GWh in the wet months can be banked to India and used in the dry months. However, under policy intervention (at 7.2 % GDP) and normal generation condition, the deficient amount of energy amounts to

3425.19 GWh and there is excess generation of only 149.67 GWh. Under this scenario country need to import almost all the deficient energy to balance demand and supply.

The result of sum of wet energy surplus and dry energy deficiency for the year 2024 under different scenario considered are tabulated below. For Business As Usual scenario and normal generation condition there is net surplus of 6880.74 GWh. Under Reference Scenario (7.2 % GDP) of demand and two-year delay in generation condition there is generation surplus of 2022.11 GWh throughout the year. Under high scenario of demand and one year delay generation scenario, there is energy surplus of 920.92 GWh, the excess energy 1970.26 GWh in the wet months can be banked to India and used in the dry months to balance the deficient energy of 1049.34 GWh. However, under policy intervention (at 7.2 % GDP) and normal generation condition, the deficient amount of energy amounts to 2703.92 GWh in dry season and there is excess generation of only 643.89 GWh in wet season. Under this scenario country need to import 2060.33 GWh energy to balance demand and supply.

Table 4-6: Sum of Monthly Excess Energy and Deficient Energy for Different Scenarios for Year 2024

Scenario	Generation Condition	Wet Excess Energy Outflow	Dry Deficient Energy Inflow	Net Energy (Wet-Dry) in GWh
BAU (4.5 % GDP)	Normal Condition	6,880.74	-	6,880.74
	One Year Delay	4,112.40	168.96	3,943.44
	Two Year Delay	3,819.19	202.76	3,616.43
Reference Scenario (7.2 % GDP)	Normal Condition	5,394.78	108.35	5,286.43
	One Year Delay	2,895.44	546.32	2,349.12
	Two Year Delay	2,643.43	621.32	2,022.11
High Scenario (9.2 % GDP)	Normal Condition	3,858.23	331.65	3,526.58
	One Year Delay	1,970.26	1,049.34	920.92
	Two Year Delay	1,741.96	1,148.05	593.91

Policy Intervention at 7.2 % GDP	Normal Condition	643.89	2,703.92	(2,060.03)
	One Year Delay	-	4,997.34	(4,997.34)
	Two Year Delay	-	5,324.35	(5,324.35)

The result of sum of energy surplus and energy deficiency for the year 2025 under different scenario considered are presented in the table below. It can be observed from the table that there is energy surplus in all scenario under consideration except policy intervention (at 7.2 % GDP). There is energy surplus of 9241.67 GWh under BAU demand scenario and normal generation condition and 3935.83 GWh under reference scenario of demand; one year delay in generation. There is energy surplus of 998.52 GWh under reference scenario; two-year delay in generation and 2253.66 GWh under high scenario; one year delay in generation respectively.

Under reference scenario of demand and one year delay in generation, there is energy deficiency of 313.73 GWh in dry season, which can be met from energy banking with India. The excess amount of 3935.83 GWh can be sold to India. Similarly, under reference scenario of demand and two-year delay in generation, the dry season deficiency of 1019.03 GWh can be fulfilled by proper energy banking with India. Similarly, under policy intervention at 7.2 % and normal generation condition, energy deficiency in dry month is 2050.61 GWh. However, 1858.86 GWh energy can be fulfilled by proper energy banking with India.

Table 4-7: Sum of Monthly Excess Energy and Deficient Energy for Different Scenarios for Year 2025

Scenario	Generation Condition	Wet Excess Energy Outflow	Dry Deficient Energy Inflow	Net Energy (Wet-Dry) in GWh
BAU (4.5 % GDP)	Normal Condition	9,241.67	-	9,241.67
	One Year Delay	5,870.36	69.12	5,801.24
	Two Year Delay	3,250.84	386.90	2,863.94

Reference Scenario (7.2 % GDP)	Normal Condition	7,418.90	42.65	7,376.25
	One Year Delay	4,249.56	313.73	3,935.83
	Two Year Delay	2,017.54	1,019.03	998.52
High Scenario (9.2 % GDP)	Normal Condition	5,905.93	211.85	5,694.08
	One Year Delay	3,065.41	811.75	2,253.66
	Two Year Delay	1,034.44	1,718.09	(683.65)
Policy Intervention at 7.2 % GDP	Normal Condition	1,858.86	2,050.61	(191.76)
	One Year Delay	-	3,881.96	(3,881.96)
	Two Year Delay	-	6,569.49	(6,569.49)

The result of sum of wet energy surplus and dry energy deficiency for the year 2026 under different scenario considered are tabulated below. For Business As Usual scenario and normal generation condition there is net surplus of 12,055.74 GWh. Under Reference Scenario (7.2 % GDP) of demand and two-year delay in generation condition there is net generation surplus of 1917.20 GWh throughout the year.

Under high scenario of demand and one year delay generation scenario the excess energy 3877.92 GWh in the wet months can be banked to India and used in the dry months to balance the deficient energy of 847.48 GWh and there is net energy surplus of 3030.43 GWh. However, under policy intervention (at 7.2 % GDP) and two-year delay in generation condition, the deficient amount of energy amounts to 6212.78 GWh in the year 2026. Under this condition there is no excess energy even in the wet months so country needs to import throughout the year to balance demand and supply.

Table 4-8: Sum of Monthly Excess Energy and Deficient Energy for Different Scenarios for Year 2026

Scenario	Generation Condition	Wet Excess Energy Outflow	Dry Deficient Energy Inflow	Net Energy (Wet-Dry) in GWh
BAU (4.5 % GDP)	Normal Condition	12,055.74	-	12,055.74
	One Year Delay	7,834.88	-	7,834.88
	Two Year Delay	4,630.01	243.88	4,386.13
Reference Scenario (7.2 % GDP)	Normal Condition	9,586.81	-	9,586.81
	One Year Delay	5,620.53	262.90	5,357.63
	Two Year Delay	2,838.25	921.05	1,917.20
High Scenario (9.2 % GDP)	Normal Condition	7,438.51	178.89	7,259.62
	One Year Delay	3,877.92	847.48	3,030.43
	Two Year Delay	1,434.03	1,844.02	(409.99)
Policy Intervention at 7.2 % GDP	Normal Condition	3,239.08	1,782.24	1,456.83
	One Year Delay	745.95	3,373.57	(2,627.61)
	Two Year Delay	-	6,212.78	(6,212.78)

4.5 Comparison of Excess and Deficient Energy for Year 2024 and 2027

The month wise energy excess for different month for the year 2024 and 2027 under reference scenario of demand and two-year delay in generation are shown in the graph below. For year 2024 there is energy deficiency from January to April and for the rest of the months energy generated is higher than that of consumption. There is energy excess of 2022 GWh in this year under the said scenario. There is energy excess of 3339 GWh for year 2027 for the same scenario.

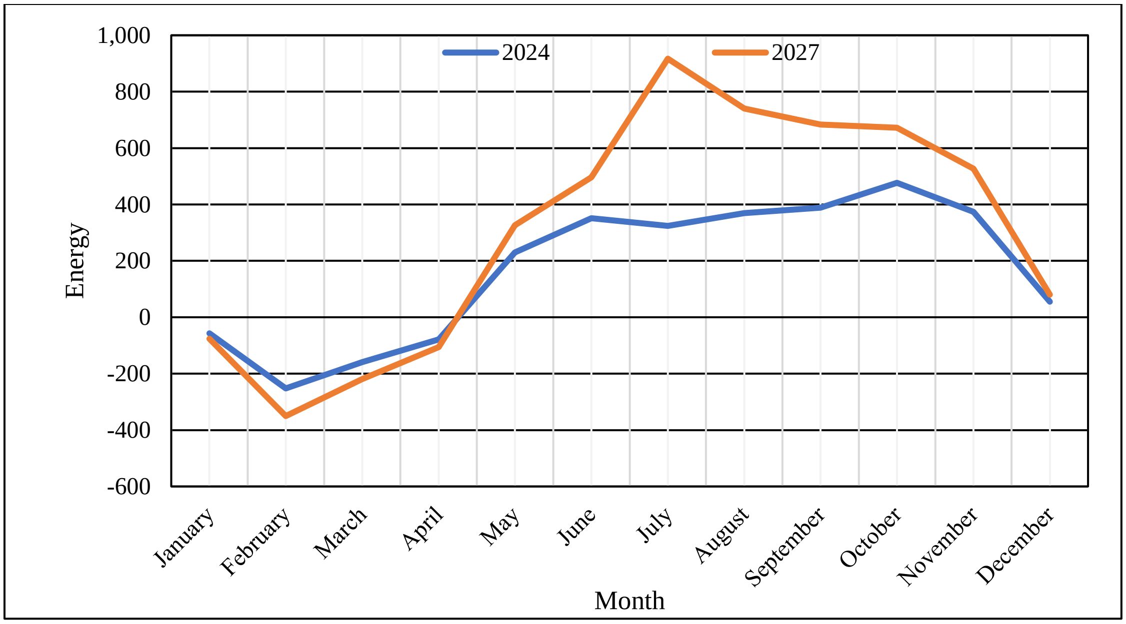

Figure 4-13: Excess Energy (Reference Scenario; Two Year Delay Generation) in GWh for year 2024 and 2027

The month wise energy excess/deficiency for different month for the year 2024 and 2027 under high scenario of demand and one-year delay in generation are shown in the graph below. For year 2024 there is energy deficiency from December to April and for the rest of the months energy generated is higher than that of consumption.

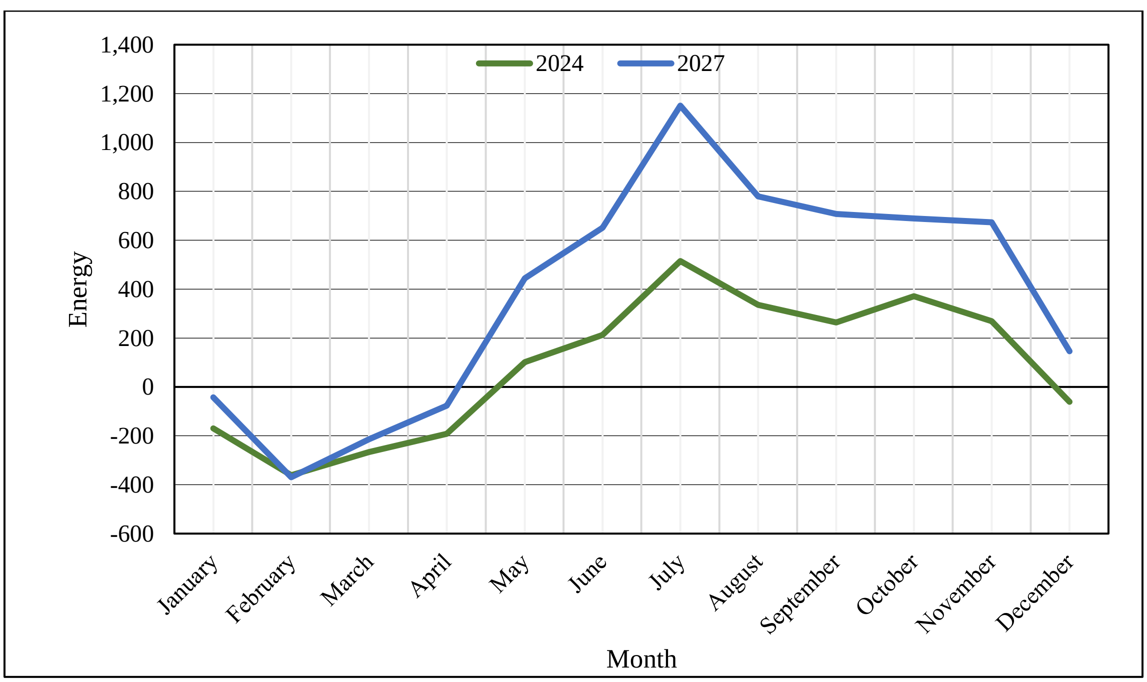

Figure 4-14: Excess Energy (High Scenario; One Year Delay Generation) in GWh for year 2024 and 2027

There is energy excess of 3044 GWh in this year under the said scenario. For year 2027 there is energy deficiency from January to April and for the rest of the months energy generated is higher than that of consumption There is energy excess of 6722 GWh for year 2027 for the same scenario.

The month wise energy excess/deficiency for different month for the year 2024 and 2027 under policy intervention (at 7.2 % of GDP) demand and normal generation of projects are presented in the graph below. For year 2024 there is energy deficiency from December to June and amount of deficient energy is 2688 GWh for these months. The amount of excess energy from July to November is 1074 GWh. Hence there is energy deficiency of 1614 GWh for the year if proper energy banking is done. For year 2027 there is energy deficiency from December to April and amount of deficient energy is 2135 GWh for these months. For the rest of the months, energy generated is higher than that of consumption. The amount of excess energy from May to November is 3380 GWh. Hence there is energy excess of 1245 GWh for the year if proper energy banking is done.

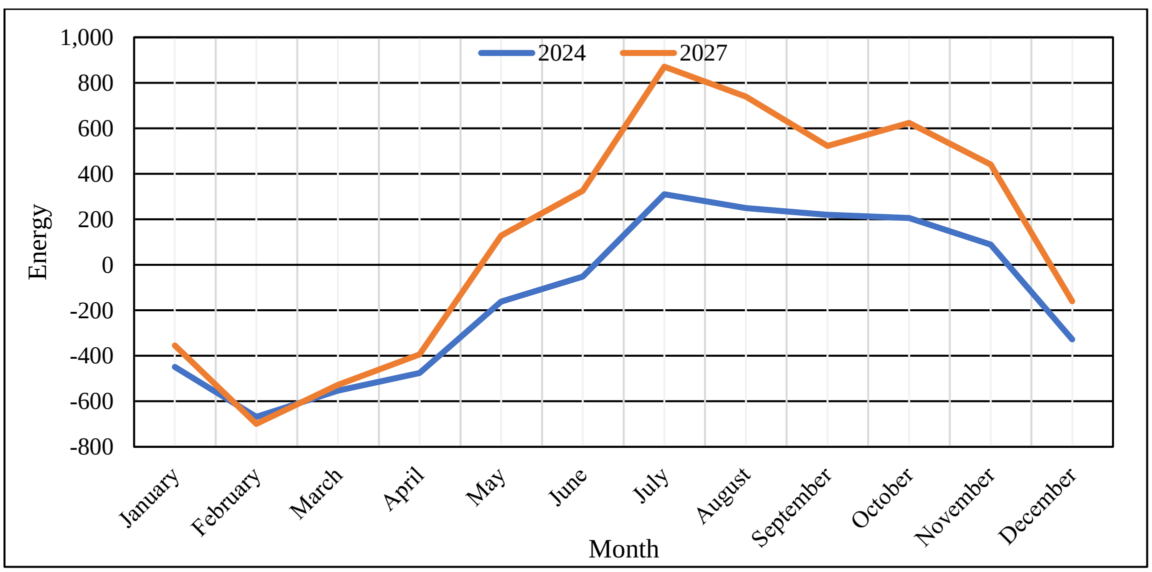

Figure 4-15: Excess Energy (policy intervention at 7.2 % and normal generation) in GWh for year 2024 and 2027

4.6 Capacity Requirement of Cross Boarder Transmission Line

The monthly forecasted optimum power flow for different scenario for the year 2024 are listed in the table. It is observed that the maximum power out flow occur for the BAU scenario of demand and normal generation condition for the month of July. The capacity requirement of transmission line is 1935 MW. The present capacity of transmission line considering only above 132 kV voltage level is 1455 MW only. So, under this condition transmission line capacity is not enough. Hence transmission line capacity should be increased. Moreover, there may be several constraints to flow this power like substation capacity, load center distance etc. Similarly maximum capacity of power flow for reference scenario and normal generation is 1681.67 MW and for high scenario one year delay in generation is 858.33 MW.

Table 4-9: Capacity Requirement of Transmission Line for Year 2024 under Different Scenarios

S.N.	Scenario	Maximum Monthly Energy Flow (GWh)	Month	Capacity of Transmission Line Required (MW)
1	BAU Scenario; Normal Generation	1161	July	1935.00
2	Reference Scenario; Normal Generation	1009	July	1681.67
3	High Scenario; One Year Delay Generation	515	July	858.33
4	Policy Intervention 7.2 % and Two-Year Delay Generation	828	February	1380.00

The monthly forecasted optimum power flow for different scenario for the year 2027 are listed in the table. It is observed that the maximum power out flow occur for the BAU scenario of demand and normal generation condition for the month of July. The capacity requirement of transmission line is 3318.33 MW. Similarly maximum capacity of power flow for reference scenario and normal generation is 2830 MW and for high scenario one year delay in generation is 1566.67 MW.

Hence transmission line capacity should be increased. Moreover, 900 MW Arun III project is under construction and scheduled to be completed by 2024. The energy generated from this hydropower is exported to India. So, the existing transmission structure needs to be enhanced.

Table 4-10: Capacity Requirement of Transmission Line for Year 2027 under Different Scenarios

S.N.	Scenario	Maximum Monthly Energy Flow (GWh)	Month	Capacity of Transmission Line Required (MW)
1	BAU Scenario; Normal Generation	1991	July	3318.33
2	Reference Scenario; Normal Generation	1698	July	2830.00
3	High Scenario; One Year Delay Generation	940	July	1566.67
4	Policy Intervention 7.2 % and Two-Year Delay Generation	1016	February	1693.33

Hence in order to make reliable power flow more transmission lines needed to be constructed. The agreement for construction of New Butwal – Gorakhpur Transmission Line (400 kV) which shall have power flow capacity of 3500 MW has been done. The transmission lines Inaruwa - Purnia Transmission Line (400 kV), Dododhara - Bareilli Transmission Line (400 kV) and Lamki - Bareilli Transmission Line (400 kV) which are at the stage of DPR preparation should be soon started for construction.

CHAPTER 5 CONCLUSION AND RECOMENDATION

5.1 Conclusion

After the successful commissioning of Upper Tamakoshi Hydroelectric Project, currently Nepal has surplus generation in wet season and the volume of this surplus amount will increase as almost all of the hydropower under construction are either ROR or PROR types. However, in the dry season Nepal need to import electricity from India to fulfill its demand as the generation goes down because of reduced water availability in the river. Hence Nepal has mismatch in the demand supply balance both in wet and dry season. During dry season its demand is higher than generation and during wet season its generation is higher than required.

5.1.1 Future Demand and Generation Forecast

As almost all of the construction license issued from DOED are of ROR types projects at present; the energy demand supply matching is going to be very difficult task in Nepalese power system during dry season in coming year. Generation forecast for three conditions i.e. generation under normal condition, one year delay in construction and two year delay in construction are considered. Demand forecast of WECS for different scenario are considered for year under study.

- For the year 2022 to 2027, under BAU scenario of demand and two-year delay in generation condition yearly generation energy exceeds demand energy by 1739 GWh, 2147 GWh, 3616 GWh, 2863 GWh, 4386 GWh and 6411 GWh respectively. For the year 2022 to 2027, under reference scenario of demand and two-year delay in generation condition yearly generation energy exceeds demand energy by 744 GWh, 824 GWh, 2022 GWh, 998 GWh, 1917 GWh and 3339 GWh respectively. Under high scenario of demand and two-year delay in generation, yearly demand energy exceeds generation energy by 175 GWh, 349 GWh, 539 GWh, 683 GWh, 409 GWh for year 2022 to 2026. In the year 2027 yearly generation exceeds demand by 366 GWh. Hence if proper energy banking concept is utilized with India, Nepal can meet its energy requirements except for the case of high scenario of demand during the period under study.

- In Business As Usual, Reference and High Scenario of demand, there is net surplus energy for all year under consideration if proper energy banking mechanism is employed between Nepal and India. However, under Policy Intervention scenario, Nepal faces net energy deficiency after employing energy banking mechanism too. The excess energy can be sold to India making necessary arrangement and Nepal can get benefitted.
- The maximum capacity of cross boarder transmission line required for available power flow to India is 2835 MW for the year 2024 and 4218 MW respectively. The maximum possible power flow occurs for BAU Scenario of demand and Normal Generation condition of project.

5.1.2 Impact of Construction Delay of Hydropower Projects

The impact of construction delay of projects on energy generation are studied. There are three conditions assumed for the construction and completion of project namely, completion of project under normal condition, one year delay and two-year delay. There is significant effect of construction delay on the net surplus energy of country.

- Under Business As Usual Scenario of demand, net electrical energy surplus decreases by 48 %, 53 %, 43 %, 37 %, 35 % and 19 % for year 2022 to 2027 for one year delay in construction of project and net energy surplus decreases by 48 %, 57 %, 47 %, 69 %, 64 % and 50 %respectively for year 2022 to 2027 if there is two year delay in construction of projects.
- Under Reference Scenario of demand, net electrical energy surplus decreases by 69 %, 72 %, 56 %, 47%, 44 % and 24 % for year 2022 to 2027 for one year delay in construction of project and net energy surplus decreases by 69 %, 78 %, 62%, 86 %, 80% and 67 % respectively for year 2022 to 2027.
- Under High Scenario, there is electrical energy deficiency for both delays in generation for all year under consideration.

5.2 Recommendation

In the future, Nepal shall have more generation surplus due to addition of completed project in the wet season on the other hand energy deficiency in the dry season becomes more problematic as the dry seasons increasing load demands cannot be met from internal energy production because most projects under construction are ROR types and their generation gets reduced in dry season. Based on the study following recommendations are made.

- Though yearly energy requirement can be met from the internal production if the present under construction projects are completed on time but major problem is that during wet season Nepal's energy spills out and during dry season Nepal could not produce electricity as required. In order to solve this problem, Nepal could make arrangement of reliable energy banking concept with India so that excess energy in the wet months is exported to India and deficient energy in the dry months are imported back to Nepal. This could solve both the problems of generation spill and generation deficiency for our country.
- Nepal has higher electrical energy surplus in wet season as compared to dry season deficient. The mechanism of obtaining net import and export of electricity for a year should be developed and payment provisions for excess supply of energy should be made in the energy banking mechanism as it is observed that in future years Nepal's wet season generation excess is higher than dry season deficient energy. Nepal should focus on electricity trade to generate foreign money from excess energy.
- To solve the problem of energy deficiency in dry months Nepal should focus on large storage projects so that they could be used to meet the demand during dry season.
- The existing cross border transmission line are not enough for future year energy evacuation hence under construction and under study cross broader transmission lines should be commissioned.

Hence if Nepal could make arrangements of clean hydroelectric electricity in larger quantity in reliable manner India seems to be a larger market for Nepalese hydropower sectors. In order to get benefited from India, Nepal should focus primarily on construction of hydroelectric projects and cross border transmission line after assuring market for produced electricity in India.

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Annex

IPPs' Hydro Power Projects (Operation) above 10 MW

S.N.	Developer	Projects	Location	Capacity (kW)	PPA Date	Commercial Operation Date	Average Construction period
1	Himal Power Ltd.	Khimti Khola	Dolakha	60000	2052	2057	5
2	Bhotekoshi Power Company	Bhotekoshi Khola	Sindhupalchowk	45000	2053	2058	5
3	Chilime Hydro Power Company Ltd.	Chilime	Rasuwa	22100	2054	2062	8
4	United Modi Hydropwer Pvt. Ltd.	Lower Modi 1	Parbat	10000	2065	2071	6
5	Sanima Mai Hydropower Limited	Mai Khola	Ilam	22000	2067	2073	6
6	Sinohydro-Sagarmatha Power Company (P) Ltd.	Upper Marsyangdi "A"	Lamjung	50000	2067	2073	6
7	Madi Power Pvt. Ltd.	Upper Madi	Kaski	25000	2066	2073	7
8	Panchthar Power Company Pvt. Ltd.	Hewa Khola A	Panchthar	14900	2068	2073	5
9	Mount Kailash Energy Pvt. Ltd.	Thapa Khola	Myagdi	13600	2068	2074	6

10	Sikles Hydropower Pvt. Ltd.	Madkyu Khola	Kaski	13000	2066	2074	8
11	Mandu Hydropower Ltd.	Bagmati Khola Small	Makawanpur/Lalitpur	22000	2069	2075	6
12	Mountain Hydro Nepal Pvt. Ltd.	Tallo Hewa Khola	Panchthar	22100	2071	2077	6
13	Arun Kabeli Power Ltd.	Kabeli B-1	Taplejung, Panchthar	25000	2069	2076	7
14	Upper Solu Hydroelectric Company Pvt. Ltd	Solu Khola	Solukhumbu	23500	2070	2076	6
15	Himalayan Hydropower Pvt.	Namarjun Madi	Kaski	11880	2066	2077	11
16	Shiva Shree Hydropower (P.)	Upper Chaku A	Sindhupalchowk	22200	2067	2078	11
17	Robust Energy Ltd.	Mistri Khola	Myagdi	42000	2067	2078	11
18	Singati Hydro Energy Pvt. Ltd.	Singati Khola	Dolakha	25000	2070	2078	8
19	Upper Tamakoshi Hydropower Ltd.	Upper Tamakoshi	Dolkha	456000	2067	2078	11
20	Manang Trade Link Pvt. Ltd.	Lower Modi	Parbat	20000	2068	2078	10
21	Green Ventures Pvt. Ltd.	Likhu-IV	Ramechhap	52400	2067	2078	11
22	Universal Power Company	Lower Khare	Dolakha	11000	2069	2078	9
23	Numbur Himalaya Hydropower Pvt. Ltd.	Likhu Khola A	Solukhumbu/Ramechap	24200	2071	2078	7
			TOTAL	**1,441,585**		Average	8

Source: NEPAL ELECTRICITY AUTHORITY

IPPs' Hydro Power Projects (Under Construction) above 10 MW

S.N.	Developers	Projects	Location	Installed Capacity (kW)	PPA Date	Expected Completion Date	Expected Completion Date	Expected Completion Date (English)
1	Greenlife Energy Pvt. Ltd.	Khani khola-1	Dolakha	40000	2074	2082	2082	2025
2	Suryakunda Hydroelectric Pvt. Ltd.	Upper Tadi	Nuwakot	11000	2068	2076	2079	2022
3	Himalayan Power Partner Pvt. Ltd.	Dordi Khola	Lamjung	27000	2069	2077	2079	2022
4	Sasha Engingeering Hydropower (P). Ltd	Khani Khola(Dolakha)	Dolakha	30000	2069	2077	2080	2023
5	Liberty Hydropower Pvt. Ltd.	Upper Dordi A	Lamjung	25000	2069	2077	2080	2023
6	Moonlight Hydropower Pvt. Ltd.	Balephi A	Sindhupalchowk	22140	2069	2077	2080	2023
7	Middle Modi Hydropower Ltd.	Middle Modi	Parbat	15100	2069	2077	2081	2024
8	Beni Hydropower Project Pvt. Ltd.	Upper Solu	Solukhumbu	18000	2073	2081	2081	2024
9	Betrawoti Hydropower Company (P).Ltd	Phalankhu Khola	Rasuwa	13700	2069	2077	2077	2020
10	Essel-Clean Solu Hydropower Pvt. Ltd.	Lower Solu	Solukhumbu	82000	2070	2078	2078	2021

11	Consortium Power Developers Pvt. Ltd.	Khare Khola	Dolakha	24100	2070	2078	2078	2021
12	Maya Khola Hydropower Co. Pvt. Ltd.	Maya Khola	Sankhuwasabha	14900	2070	2078	2078	2021
13	Dordi Khola Jal Bidyut Company Ltd.	Dordi-1 Khola	Lamjung	12000	2075	2083	2083	2026
14	Peoples' Hydropower Company Pvt. Ltd.	Super Dordi 'Kha'	Lamjung	54000	2076	2084	2084	2027
15	Hydro Venture Private Limited	Solu Khola (Dudhkoshi)	Solukhumbu	86000	2071	2079	2079	2022
16	Global Hydropower Associate Pvt. Ltd.	Likhu-2	Solukhumbu/ Ramechap	33400	2071	2079	2079	2022
17	Paan Himalaya Energy Private Limited	Likhu-1	Solukhumbu/ Ramechap	51400	2071	2079	2079	2022
18	Hydro Empire Pvt. Ltd.	Upper Myagdi	Myagdi	20000	2071	2079	2079	2022
19	Nyadi Hydropower Limited	Nyadi	Lamjung	30000	2072	2080	2080	2023
20	Bungal Hydro Pvt. Ltd. (Previously Sanigad Hydro Pvt. Ltd.)	Upper Sanigad	Bajhang	10700	2072	2080	2080	2023
21	Kalanga Hydro Pvt. Ltd.	Kalangagad	Bajhang	15330	2072	2080	2080	2023
22	Sanigad Hydro Pvt. Ltd.	Upper Kalangagad	Bajhang	38460	2072	2080	2080	2023
23	Dhaulagiri Kalika Hydro Pvt. Ltd.	Darbang-Myagdi	Myagdi	25000	2072	2080	2080	2023
24	Kabeli Energy Limited	Kabeli-A	Panchthar and Taplejung	37600	2072	2080	2080	2023

25	Peoples Energy Ltd. (Previously Peoples Hydro Co-operative Ltd.)	Khimti-2	Dolakha and Ramechhap	48800	2072	2080	2080	2023
26	Huaning Development Pvt. Ltd.	Upper Balephi A	Sindhupalchowk	36000	2072	2080	2080	2023
27	Multi Energy Development Pvt. Ltd.	Langtang Khola	Rasuwa	20000	2072	2080	2080	2023
28	Ankhu Hydropower (P.) Ltd.	Ankhu Khola	Dhading	34000	2073	2081	2081	2024
29	Myagdi Hydropower Pvt. Ltd.	Ghar Khola	Myagdi	14000	2073	2081	2081	2024
30	Siddhi Hydropower Company Pvt. Ltd.	Siddhi Khola	Illam	10000	2074	2082	2082	2025
31	Nilgiri Khola Hydropower Co. Ltd.	Nilgiri Khola	Myagdi	38000	2073	2081	2081	2024
32	Siuri Nyadi Power Pvt. Ltd.	Super Nyadi	Lamjung	40270	2074	2082	2082	2025
33	Swet-Ganga Hydropower and Construction Ltd.	Lower Likhu	Ramechhap	28100	2073	2081	2081	2024
34	Nilgiri Khola Hydropower Co. Ltd.	Nilgiri Khola-2	Myagdi	62000	2074	2082	2082	2025
35	Diamond Hydropower Pvt. Ltd.	Upper Daraudi-1	Gorkha	10000	2072	2080	2080	2023
36	Makari Gad Hydropower Pvt. Ltd.	Makarigad	Darchula	10000	2072	2080	2080	2023

37	Super Madi Hydropower Ltd.	Super Madi	Kaski	44000	2073	2081	2081	2024
38	Mount Nilgiri Hydropower Company Pvt. Ltd.	Rurubanchu-1	Kalikot	13500	2074	2082	2082	2025
39	Sindhujwala Hydropower Ltd.	Upper Nyasem	Sindhupalchowk	41400	2073	2081	2081	2024
40	Energy Venture Pvt. Ltd.	Upper Lapche	Dolakha	52000	2073	2081	2081	2024
41	Orbit Energy Pvt. Ltd.	Sabha Khola B	Sankhuwasabha	15100	2074	2082	2082	2025
42	Him River Power Pvt. Ltd.	Liping Khola	Sindhupalchowk	16260	2073	2081	2081	2024
43	Nepal Water and Energy Development Company Pvt. Ltd.	Upper Trishuli -1	Rasuwa	216000	2076	2084	2084	2027
44	Mewa Developers Pvt. Ltd.	Middle Mewa	Taplejung	49000	2076	2084	2084	2027
45	Jhyamolongma Hydropower Development Ltd.	Karuwa Seti	Kaski	32000	2074	2082	2082	2025
46	Nasa Hydropower Pvt. Ltd.	Lapche Khola	Dolakha	99400	2074	2082	2082	2025
47	Sanima Middle Tamor Hydropower Ltd.	Middle Tamor	Taplejung	73000	2073	2081	2081	2024
48	Vision Energy and Power Pvt. Ltd.	Nupche Likhu	Ramechhap	57500	2074	2082	2082	2025

49	Dolakha Nirman Company Pvt. Ltd.	Isuwa Khola	Sankhuwasabha	97200	2075	2083	2083	2026
50	Tundi Power Pvt.Ltd	Rahughat Mangale	Myagdi	35500	2075	2083	2083	2026
51	Gaurishankar Power Development Pvt. Ltd.	Middle Hyongu Khola B	Solukhumbu	22900	2074	2082	2082	2025
52	Omega Energy Developer Pvt. Ltd.	Sunigad	Bajhang	11050	2074	2082	2082	2025
53	Gorakshya Hydropower Pvt. Ltd.	Super Ankhu Khola	Dhading	23500	2074	2082	2082	2025
54	Api Power Company Ltd.	Upper Chameliya	Darchula	40000	2075	2083	2083	2026
55	Vision Lumbini Ltd.	Seti Nadi	Kaski	25000	2075	2083	2083	2026
56	Kasuwa Khola Hydropower Ltd.	Kasuwa Khola	Sankhuwasabha	45000	2075	2083	2083	2026
57	Lower Irkhuwa Hydropower Co. Pvt. Ltd.	Lower Irkhuwa	Bhojpur	13040	2075	2083	2083	2026
58	Apex Makalu Hydro Power Pvt. Ltd.	Middle Hongu Khola A	Solukhumbu	22000	2075	2083	2083	2026
59	Tundi Power Pvt.Ltd	Upper Rahughat	Myagdi	48500	2075	2083	2083	2026
60	Blue Energy Pvt. Ltd.	Super Trishuli	Gorkha and Chitwan	70000	2075	2083	2083	2026
61	Samyukta Urja Pvt. Ltd.	Thulo Khola	Myagdi	21300	2075	2083	2083	2026
62	Mount Rasuwa Hydropower Pvt. Ltd.	Midim 1 Khola	Lamjung	13424	2075	2083	2083	2026

63	Hilton Hydro Energy Pvt. Ltd.	Super Kabeli	Taplejung	12000	2075	2083	2083	2026
64	Snow Rivers Pvt. Ltd.	Super Kabeli A	Taplejung	13500	2075	2083	2083	2026
65	Dhading Ankhu Khola Hydro Pvt. Ltd.	Upper Ankhu	Dhading	38000	2075	2083	2083	2026
66	Isuwa Energy Pvt. Ltd.	Lower Isuwa Cascade	Sankhuwasab ha	37700	2077	2085	2085	2028
67	Sailung Power Company Pvt. Ltd.	Bhotekoshi-1	Sindhupalcho wk	40000	2075	2083	2083	2026
68	River Side Hydro Energy Pvt. Ltd.	Tamor Khola-5	Taplejung	37520	2075	2083	2083	2026
69	Palun Khola Hydropower Pvt. Ltd.	Palun Khola	Taplejung	21000	2075	2083	2083	2026
70	Perfect Energy Development Pvt. Ltd	Middle Trishuli Ganga	Nuwakot	19410	2075	2083	2083	2026
71	Silk Power Pvt. Ltd.	Luja Khola	Solukhumbu	23550	2075	2083	2083	2026
			Total	**3,164,388**				

Source: NEPAL ELECTRICITY AUTHORITY

Capacity of IPP Hydropower Projects Completion in Different Year

Year	Capacity (KW)	Capacity (MW)
2022	228,800.00	228.80
2023	359,030.00	359.03
2024	373,860.00	373.86
2025	427,220.00	427.22
2026	647,944.00	647.94
2027	319,000.00	319.00
Total	2,355,854.00	2,355.85

List of under construction (NEA and Subsidiary Company) Hydropower and Completion Date

Name of Project	Capacity (MW)	Completion date
Upper Tamaksohi HEP	456.00	2022
Upper Sanjen HEP	14.80	2022
Sanjen HEP	42.50	2022
Rasuwagadhi HEP	111.00	2023
Rahughat HEP	40.00	2024
Madhya Bhotekoshi HEP	102.00	2024
Upper Trishuli 3B HEP	37.00	2025
Tanahu HEP HEP	140.00	2025
Tamakoshi V HEP	94.80	2026
Upper Modi A HEP	42.00	2027
Upper Modi HEP	19.80	2027
Total	1,099.90	

Source: NEPAL ELECTRICITY AUTHORITY

Case I Year wise Addition in MW for normal completion of projects

	IPP	NEA and Subsidary		
Year	Capacity (MW)	Capacity (MW)	Total MW	Total Energy Generation (GWh)
2022	228.80	513.3	742.10	4,225.52
2023	359.03	111	470.03	2,676.35

2024	373.86	142	515.86	2,937.31
2025	427.22	177	604.22	3,440.43
2026	647.94	94.8	742.74	4,229.18
2027	319.00	61.8	380.80	2,168.28

Case II Year wise Addition in MW for one year delay in completion of project

Year	Total MW	Total Energy Generation (GWh)
2022	456	2,596.46
2023	286.10	1,629.05
2024	470.03	2,676.35
2025	515.86	2,937.31
2026	604.22	3,440.43
2027	742.74	4,229.18
2028	380.80	2,168.28

Case III Year wise Addition in MW for two year delay in completion of project

Year	Total MW	Total Energy Generation (GWh)
2022	456	2,596.46
2023		
2024	286.10	1,629.05
2025	470.03	2,676.35
2026	515.86	2,937.31
2027	604.22	3,440.43
2028	742.74	4,229.18
2029	380.80	2,168.28

Forecast Power Capacity (MW) and Forecast Energy Production Capacity (GWh) in different scenario

Year	Forecast Power Capacity (MW)			Forecast Energy Production Capacity (GWh)		
	Normal Condition	One Year Delay	Two year delay	Normal Condition	One Year Delay	Two year delay
2022	2,183.10	1,897.00	1,897.00	13,185.84	11,556.78	11,556.78
2023	2,653.13	2,183.10	1,897.00	15,862.19	13,185.84	11,556.78
2024	3,168.99	2,653.13	2,183.10	18,799.50	15,862.19	13,185.84
2025	3,773.21	3,168.99	2,653.13	22,239.92	18,799.50	15,862.19
2026	4,515.95	3,773.21	3,168.99	26,469.11	22,239.92	18,799.50
2027	4,896.75	4,515.95	3,773.21	28,637.38	26,469.11	22,239.92