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Cross Border Electricity Trade Opportunities for Nepal: Development of Strategy for Deregulated Electricity Markets

By

Suman Aryal

A THESIS

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DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled **"Cross Border Electricity Trade Opportunities for Nepal: Development of Strategy for Deregulated Electricity Markets"** submitted by Suman Aryal in partial fulfilment of the requirements for the degree of Master of Science in Renewable Energy Engineering.

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DECLARATION

I declare that the work hereby submitted for Master of Science in Renewable Energy Engineering (MSREE) at IOE, Pulchowk Campus entitled "**Cross Border Electricity Trade Opportunities for Nepal: Development of Strategy for Deregulated Electricity Markets**" is my own work and has not been previously submitted by me at any university for any academic award.

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ABSTRACT

With an increase in energy generation energy but a lower growth rate in energy consumption, Nepal has a tremendous opportunity for cross-border electricity trading. This trading helps energy management between the two countries, addressing energy scarcity in both.

The future generations of energy and consumptions of energy are forecasted and compared. The results obtained from the analysis of generations and consumption of energy, surplus energy and deficit energy are observed. There is mix of surplus and deficit energy will occur with reference to the different scenario. In this study, the cross border trading opportunities for Nepal is analyzed by evaluating the future energy generations and future energy demand. And also reviewed the electricity market model adopted in different regions. During this study, the required data is taken from the reports published by the Nepal Electricity Authority, Water and Energy Commission Secretariat, Department of Electricity Development and other energy related institutions.

In the present situations, consumptions growth of energy is slightly increased but there are many under construction hydropower are in the pipeline for commissioning. This study covers the surplus deficit energy for the years 2023 to 2031. It has been observed that the surplus energy is predominant with compare to the deficit energy. The policy intervention scenarios introduce deficits in some years while still maintaining surpluses in others. In BAU 4.5%, reference scenario 7.2%, high scenario 9.2% and weighted average method forecast surplus energy is obtained with no deficit energy. However, in policy interventions there are mix of surplus and deficit energy in the studied years. Furthermore, the cross border transmission line is essential to export the surplus energy. Due to insufficient cross-border transmission line power transfer capacity, it is crucial to timely commission the planned and under-construction transmission lines.

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LIST OF ABBREVIATIONS

APCF	Average Yearly Plant Capacity Factor
BAU	Business as Usual
CEA	Central Electricity Authority
CBET	Cross Border Electricity Trade
DAM	Day Ahead Market
DOED	Department of Electricity Development
GDP	Gross Domestic Product
GoN	Government of Nepal
GWh	Giga Watt Hour
IEX	Indian Energy Exchange
IPP	Independent Power Producer
ISO	Independent system operator
KWh	Kilowatt Hour
MCA	Millennium Challenge Account
MoEWRI	Ministry of Energy, Water Resources and Irrigation
MW	Mega Watt
MU	Million Unit
NEA	Nepal Electricity Authority
NVVN	NTPC Vidhyut Vyapar Nigam
PPA	Power Purchase Agreement
ROR	Run of River
RE	Renewable Energy
REC	Renewable Energy Certificate
SARI/EI	South Asia Regional Initiative for Energy Integration
SAARC	South Asian Association for Regional Corporation
TSDP	Transmission System Development Plan
WAGR	Weighted Average Growth Rate
WECS	Water and Energy Commission Secretariat

CHAPTER 1 : INTRODUCTION

1.1 Background

The restructuring of power markets has created many opportunities for customers to reduce their electricity expenses. In a liberal power market, the buying and selling of energy is now becoming similar to that of other commodities. The introduction of private players and various companies in the energy market has created more competition, assuring the reliability and quality of energy supplied to consumers and ending the monopolistic behavior of vertically integrated utilities. In such a liberal market, consumers have various options, and their bargaining power has increased. There is a continuous flow and exchange of information between energy buyers, suppliers, and the market. The various participants in the market can make independent decisions. Energy consumers receive timely information from the market and develop strategies to maximize their benefits. Consumer groups can adjust their loads based on price signals in the market (J. Zhao, 2016).

Rich in hydropower potential and situated in a geopolitically important place, Nepal has the great opportunity for cross-border electricity trade. This thesis attempts to explore the major opportunities and challenges of cross-border trade of electricity for Nepal. Presenting the current status of bilateral and multilateral agreements and institutional arrangements, this thesis reinforces the fact that cross-border electricity trade is not an easy task. For fulfilling internal demands, it is high time for Nepal to address the existing challenges and grab the opportunities offered by cross-border electricity trade. In South Asia, India and Nepal have established transmission links through different regions where electricity is being traded. The opportunities for Cross Border Electricity Trade (CBET) in the south Asian regions has amplified particularly that energy security has become a political priority for all the South Asian governments. Rich in hydro resources, Nepal has the development potential of 83,000 megawatts (MW) and commercially feasible hydropower generating potential of about 42,000 MW. In Nepal, there are huge resource for development of hydropower projects, some projects are in construction phase after signing the PPA documents with legal parties and some are in pipeline for PPA (Adhikari, 2018). These all projects after completing, electricity will be spill and government bodies will face the financial problems due to the lack of electricity markets in Nepal. Therefore, Nepal should be planned for future electricity markets in Nepal and neighboring countries.

1.2 Problem Statement

After the end of load shedding and the gradual resolution of its scars, the possibility of achieving independence in electricity is increasing and consumer aspirations for improved quality and reliability of power supply in the country. However, independence of electricity can be achieved if all the projects will have completed in few years which are in construction phase and planning phase. The hydropower projects above 5600 MW being under construction from the private sector after signing power purchase agreements with Nepal Electricity Authority. The PPAs with regard to hydropower projects in different river basins have already crossed 5600 MW and many developers are awaiting PPAs to be signed (Adhikari, 2018).

In present situation, Nepal has been imported 1,833 GWh from India and exported 1,346 GWh to India in fiscal year 2022/23. We have agreed lots of hydropower doing power purchase agreement. After completing these all hydropower plants, there will be chanced of surplus energy. Due to the legal frameworks and practices, Nepal Electricity Authority will face the huge financial loss regarding power purchase agreements rate. To overcome this financial loss, all concerning government bodies should develop the strategies to consume more electricity and cross border transmissions throughout the Asian countries.

1.3 Objectives

Main objective of this thesis is to analyze the cross border electricity trade opportunities for Nepal after commissioning of upcoming hydropower projects.

Specific objective of this thesis are

- To determine the expected generations and expected consumption scenario of Nepalese electricity trends.
- To determine the challenges for cross border electricity trade in a deregulated electricity market.

1.4 Scope

In this study, most of the hydropower projects are of the runoff river type, while the remaining few projects are peaking runoff river projects. The future energy generation is calculated, excluding the planned storage projects. The energy generation from the storage power projects, peaking runoff river projects, and runoff river projects is not separated; therefore, future energy generation could be different if we were to study them separately. There are numerous storage hydropower projects in different phases of construction, and the government of Nepal has announced several projects for the development of electricity, incorporating them into the periodic plans. After the completion of all these hydropower projects, future energy generation could be different.

This research will also help to build the energy exchange mechanisms between the Nepal and neighboring countries. In the present situation, Nepal faces the seasonal power shortage during the dry months because of most of the operated hydropower project is run off river type due to the decrease of water flow in the river. However, during the wet seasons, all run-of-the-river hydropower plants can run at full capacity. In these situations, Nepal can export all surplus energy to India by balancing the seasonal power generation fluctuations.

CHAPTER 2 : LITEERATURE REVIEW

The South Asia region is gifted with limited fossil fuels but sufficient hydro resources. However, the distribution of these resources varies across the south Asian region. The Electricity generation mainly depends on available domestic resources. Nepal and Bhutan are widely dependent on hydro resources. Bangladesh, Maldives, and Sri Lanka are mainly dependent on fossil fuels. Afghanistan is struggling to rebuild its hydro-electric capacity, but investments for new capacity are yet to catch up with its requirements (SARI/EI, 2023). India and Pakistan depend on a mix of hydro based and fossil fuel based generation, though they are more depends on fossil fuels as compare to the hydro based generations. Bhutan and Nepal are almost completely dependent upon hydroelectricity to meet their energy requirements. It is observed that excessive dependence on one energy resource raises concerns related to energy security. Electricity sector integration in South Asia is in an initial stage and waiting for the regional power market for better energy security (SARI/EI, 2023). There are no any official market-based multilateral trading arrangements supported with a regulator and legal framework in south Asian countries. However successful cross border trading arrangements is done with India by Bangladesh, Bhutan and Nepall (Sharan, 2016). The existing and the proposed cross border transmission line in the South Asian region are the beneficial for the bilateral electricity trading among the Asian countries. With gradual harmonization of electricity codes and balancing mechanisms, and the strengthening of institutional cooperation, short-term transactions through bilateral and energy exchanges would become increasingly feasible.

2.1 Institution Related to the Electricity Sector of Nepal

2.1.1 Ministry of Energy, Water Resources and Irrigation

The Ministry of Energy, Water Resources and Irrigation (MoEWRI) is a government institution that manages and develops the overall energy, water resources and irrigation sectors throughout the country. It also formulates policies and plans related to these sectors in Nepal. The MoEWRI plays important roles in promoting and facilitating the participation of Private parties to develop overall economy of the nation.

2.1.2 Water and Energy Commission Secretariat (WECS)

The main objective of the Water and Energy Commission Secretariat which was established by the Government of Nepal, assisting different ministries in formulating policies and developing projects related to water resources in Nepal.

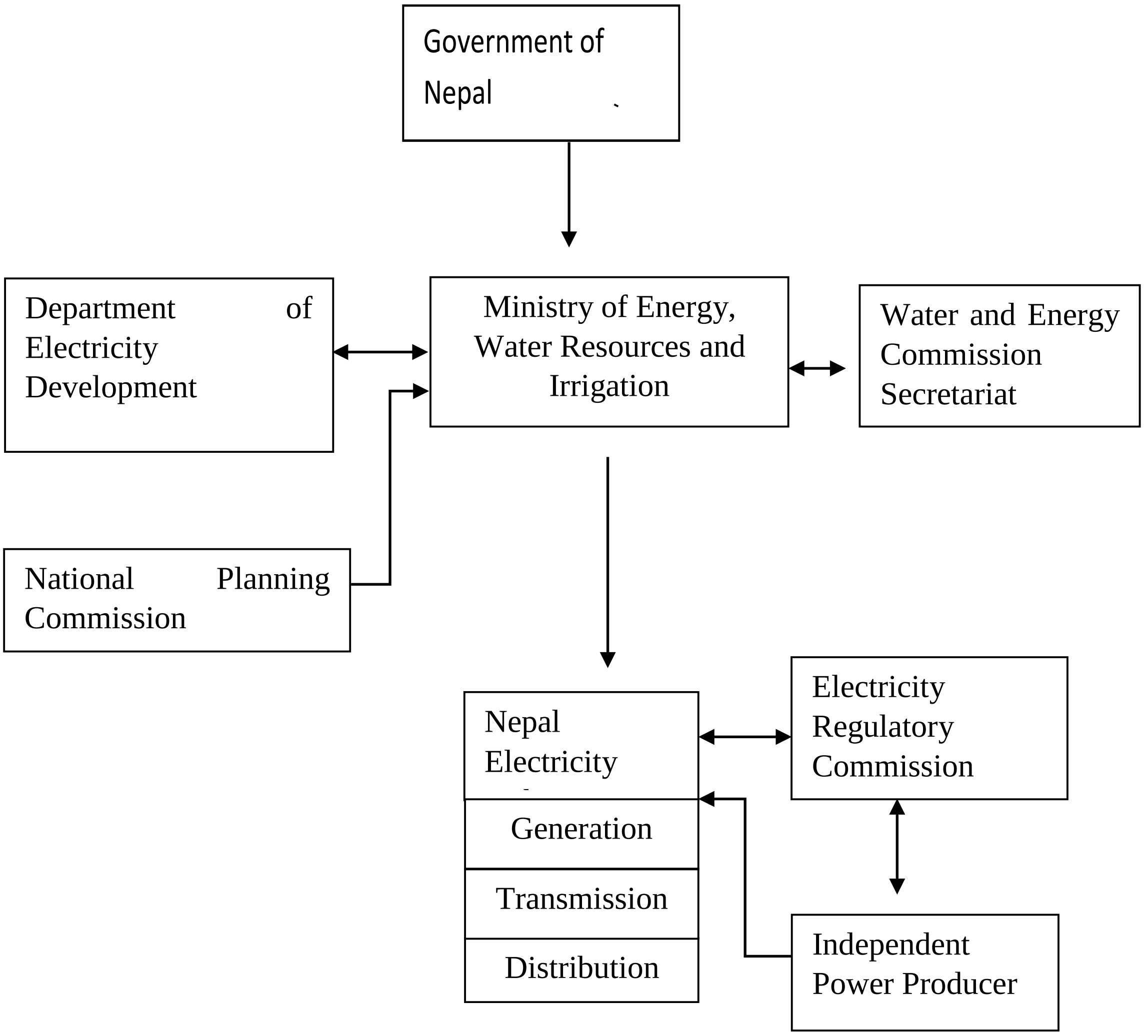


Figure 2.1 : Block Diagram of Institutions Related to the Electricity Sector of Nepal

2.1.3 Department of Electricity Development

The Department of Electricity Development was established by the Government of Nepal and is responsible for implementing policies related to the energy sector. Its main functions are ensuring transparency in the regulatory framework, promoting and facilitating private sector involvement in the power sector, and provide licenses to power producers.

2.1.4 National Planning Commission

The National Planning Commission was formed by the Government of Nepal. The main functions of this institution are to prepare periodic development plans, formulate development policies, and recommend to the Government of Nepal, different ministries, and departments for accelerating the pace of development.

2.1.5 Electricity Regulatory Commission

The Electricity Regulatory Commission was established by the Government of Nepal. It is the regulatory body responsible for regulating the generation, transmission, distribution, and business of electricity. It also maintains the balance of demand and supply of electricity generation, regulates the tariff, and protects the rights and interests of consumers by ensuring reliable, secure, and high-quality service.

2.2 Structure of Power System

The structure of the electricity market in the world has undergone changes in recent times. The activities of power generation, transmission, and distribution are owned and operated differently in various countries, according to their functions. In earlier days, all these activities, such as generation, transmission, and distribution, were carried out by a single institution known as a vertically integrated market. However, the market structure has now evolved, and competition is involved in generation, transmission, and distribution, resulting in a deregulated electricity market.

2.3 Regulated Electricity Market

In a regulated electricity market model, all activities such as generation, transmission, and distribution may be owned by government authorities or private utilities. In this market model, the rules are set by the government, and the operations of utilities are limited by certain rules and regulations. The regulatory framework aims to ensure fair competition, reliable supply, and affordable prices for consumers.

Figure 2.2 : Structure of regulated market

Symbols:

Energy Flow   Information flow   Money flow

The above-mentioned figure illustrates the structure of a regulated electricity market, indicating the direction of energy flow, information flow, and money flow using arrowheads corresponding to their functions. The figure clarifies that the information flow is bidirectional between generation and transmission, whereas the money flow is unidirectional from the distribution side to the generation side. The remaining energy flow is unidirectional, starting from generation, passing through transmission, and reaching distribution.

Features of regulated electricity market

- Vertically integrated

In a regulated electricity market, all aspects of power generation, transmission, and distribution are handled by a single entity that is fully owned and operated by itself.

- No competitions

Having full control over all aspects of generation, transmission, and distribution can lead to a monopoly in electricity markets. As a result, the lack of competition may lead to higher electricity prices and limited choices for consumers.

2.4 Deregulated Electricity market model

A deregulated electricity market refers to a system in which the government removes or reduces its control and regulations over the generation, transmission, and distribution of electricity, allowing for competition and market forces to determine prices and supply. In this model, multiple electricity suppliers can enter the market and offer their services to consumers. Deregulation of the electricity market occurs after the unbundling of the electricity market and is also known as reform, restructuring, or reregulation of the electricity market. In this market model, the functions of generation, transmission, and distribution are carried out by different companies, transforming the industry from the regulated electricity market model. There is open access in the generation, transmission, and distribution businesses, and competition is introduced among private companies, leading to competition in the electricity market. The transmission of energy incurs a wheeling charge set by an independent system operator. Customers in a deregulated market have different choices as they can purchase energy directly from generating companies or through distribution companies at competitive prices through negotiations with the authorities. Due to the variation in electricity prices over time, consumers can strategically plan their purchases to obtain competitive electricity prices.

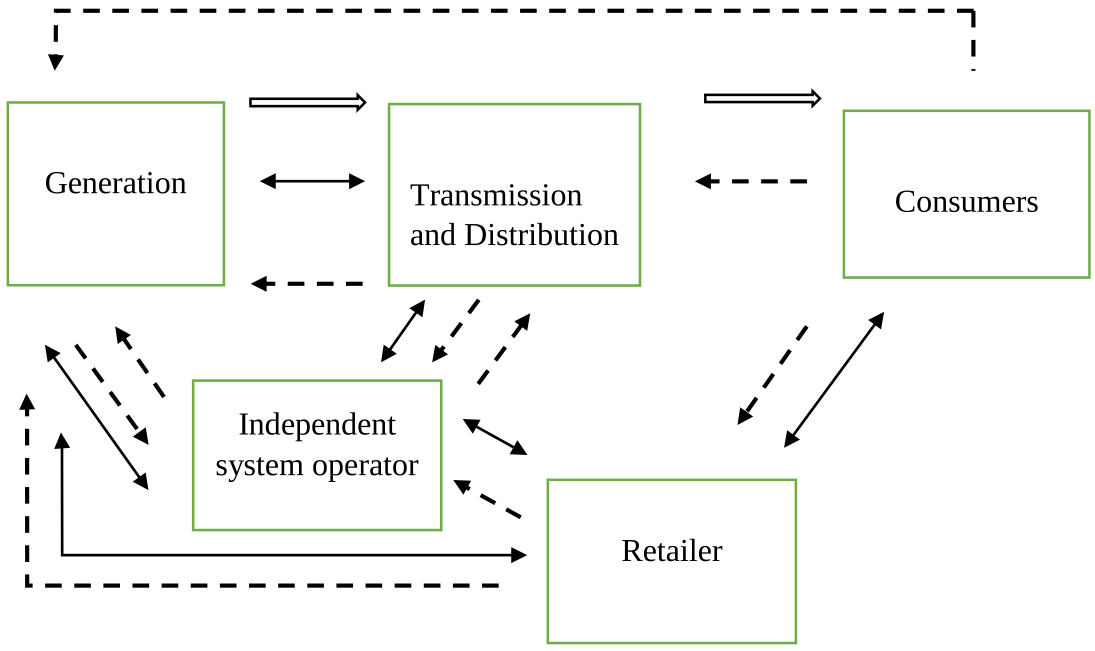
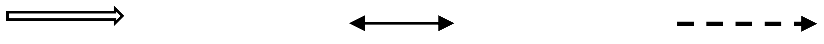


Figure 2.3 : Structure of regulated market

Symbols:

Energy Flow Information flow Money flow



The figure above illustrates the structure of a regulated electricity market, showing the direction of energy flow, information flow, and money flow through arrowheads corresponding to their respective functions. Various market models exist where consumers are aware of the instantaneous price of electricity and strategically plan their purchases to obtain an economical price while ensuring a reliable supply that meets their needs.

Components of Deregulated Electricity Market

Genco (Generation companies)

These are the companies which are responsible for generating the electrical energy using different energy resources. The primary function of a Genco is to generate electricity and supply it to the electricity grid or other entities within the electricity market. The generated electricity is then transmitted and distributed to end consumers by transmission and distribution companies. These company might be either government utility or private entities (called as independent power producers). These private or government companies (Genco) can sell the energy directly to the consumers or Distribution company or Retailed company through transmission lines.

Transco (Transmission Company)

These are the companies which are responsible for transmitting the electrical energy from generating companies to the distribution companies. These companies have large infrastructures to transmit the large amount of electrical energy to the distribution location. The wheeling charge of the transmission company is regulated and fixed by regulating company which is independent entities related to the electrical sectors.

Disco (Distribution Company)

These companies are responsible for the distribution of electricity from the transmission grid to end consumers. Their basic function is to deliver electricity to homes, businesses, and other entities within their designated distribution area. These companies own, maintain and operate the distribution infrastructure, including power lines, transformers, meters, and other equipment, to ensure the efficient and reliable distribution of electricity.

ISO (Independent system operator)

It is an independent regulatory authority that takes the responsibility to ensure the reliability, quality, and security of power quantities. It establishes various rules and regulations regarding power system operation and also advises the government to issue acts for proper monitoring of power markets. Additionally, it sets the electricity tariff rate, wheeling charge for electricity, and has the right to collect service charges from electricity market participants.

Customers

In a deregulated electricity market, customers have different choices to buy electricity at a competitive price, just like in other commodity markets. The sellers in the electricity market change their behavior and offer different rates and varying energy charges from time to time, giving customers options to purchase electricity at an economical price. Customers can buy electricity directly from generating companies, distribution companies, or locally available retail energy companies or wholesale companies wherever possible.

2.5 Market Model

The market model of electricity markets is mainly characterized by two approaches: the electricity market before deregulation and the electricity market after deregulation. The main objectives of the electricity market model are to enhance the electricity market by creating opportunities for generating companies and customers, similar to other commodity markets. The classification of market models provides insights and helps formulate strategies for deregulating the electricity market.

2.5.1 Monopoly market Model

The monopoly market model is a type of model in which the generation, transmission, and distribution of electricity are owned and operated by a single authority. The monopoly market model is shown in following block diagram.

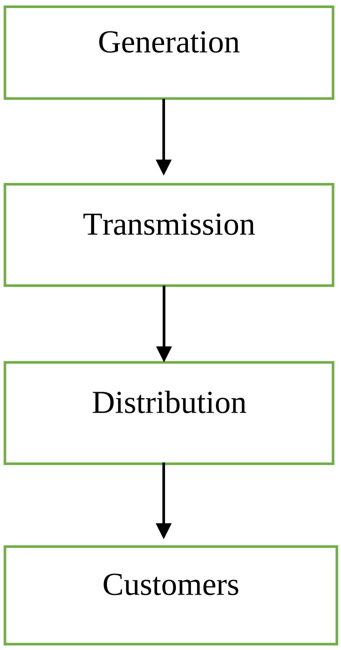


Figure 2.4 : Monopoly Model

In the context of Nepal, there is only one electricity authority company named Nepal Electricity Authority, which is fully owned by the government of Nepal and operates in the electricity market. However, a few private companies are involved only in the generation side.

2.5.2 Single Buyer Model

In this market model, competition is involved only in the generation side, while competition in distribution is not present. It mainly focuses on the involvement of the private sector in investing in generation, which ultimately leads to competition on the generation side. In this market model, consumers have no choices regarding electricity providers, but independent power producers (IPPs) can participate in generation. The main objectives of this market model are to introduce competition in generation and attract investment in electricity generation to meet the growing demand for electricity. The block diagram of single buyer model is shown in following diagram.

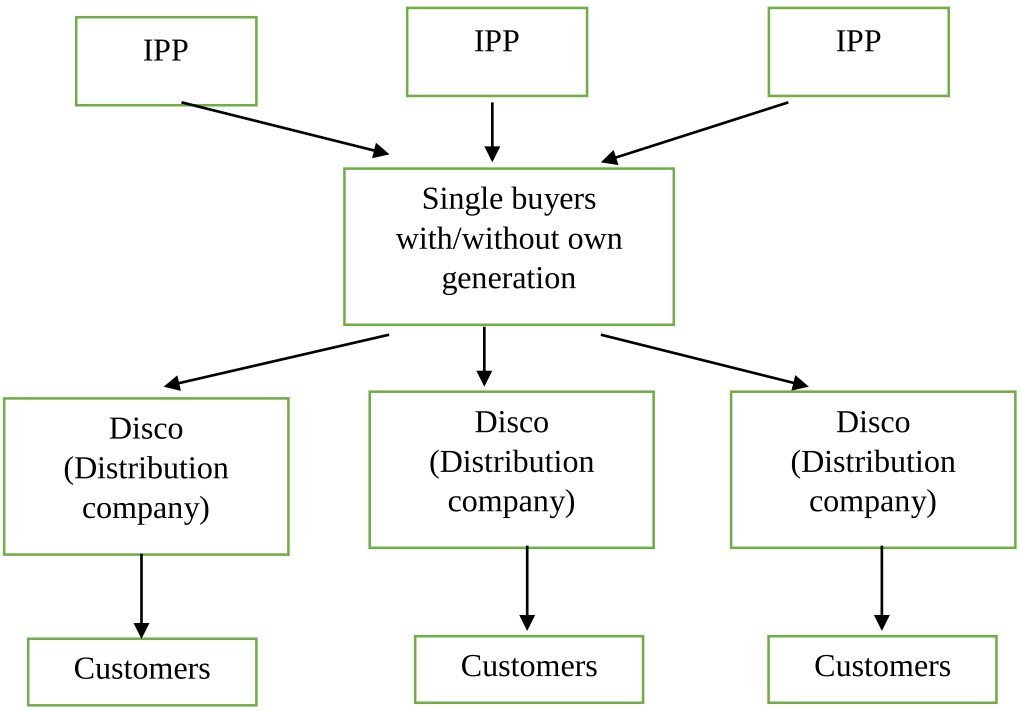


Figure 2.5 : Single buyer model

2.5.3 Wholesale Competition Model

In the wholesale competition market model, multiple participants are involved in generation and distribution.

The following block diagram illustrates the wholesale competition model of the electricity market.

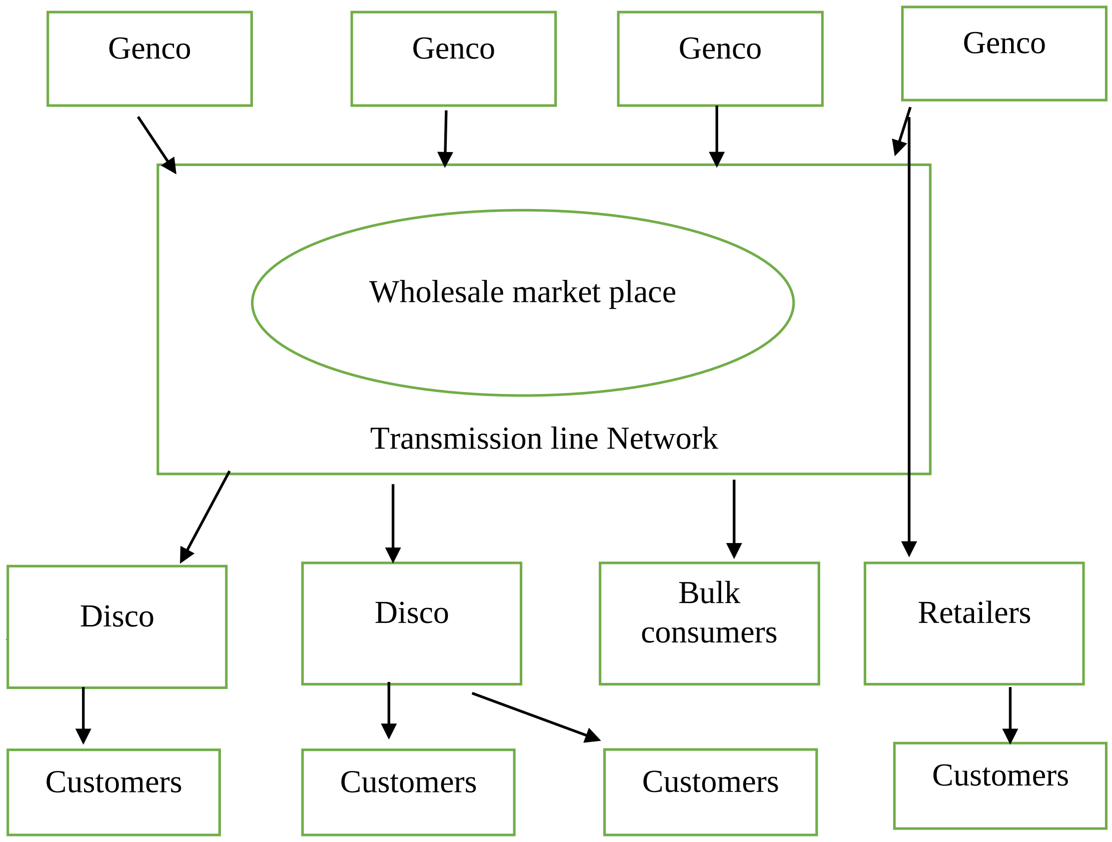


Figure 2.6 : Block Diagram of wholesale electricity market model

Generation companies sell their energy in the wholesale electricity marketplace, and distribution companies can buy electricity from the wholesale marketplace, creating a competitive choice for them. Retailers can also purchase electricity from the wholesale electricity market and sell it to consumers. However, it is important to note that small consumers in a specific area will not have choices to buy electricity at competitive prices.

2.5.4 Retail Competition Market Model

In this market model, we could say full of deregulation in electricity market. Competition is involved in generation as well as distribution side. The consumers have choices through retailed market. There is an open access in transmission line as well as distribution lines so that the consumers can buy energy directly from wholesale market place or from generation companies through retailed market or without retailed market. In this model the consumers can buy energy at competitive market at economy price.

The block diagram of retailed electricity market model is shown in following figure.

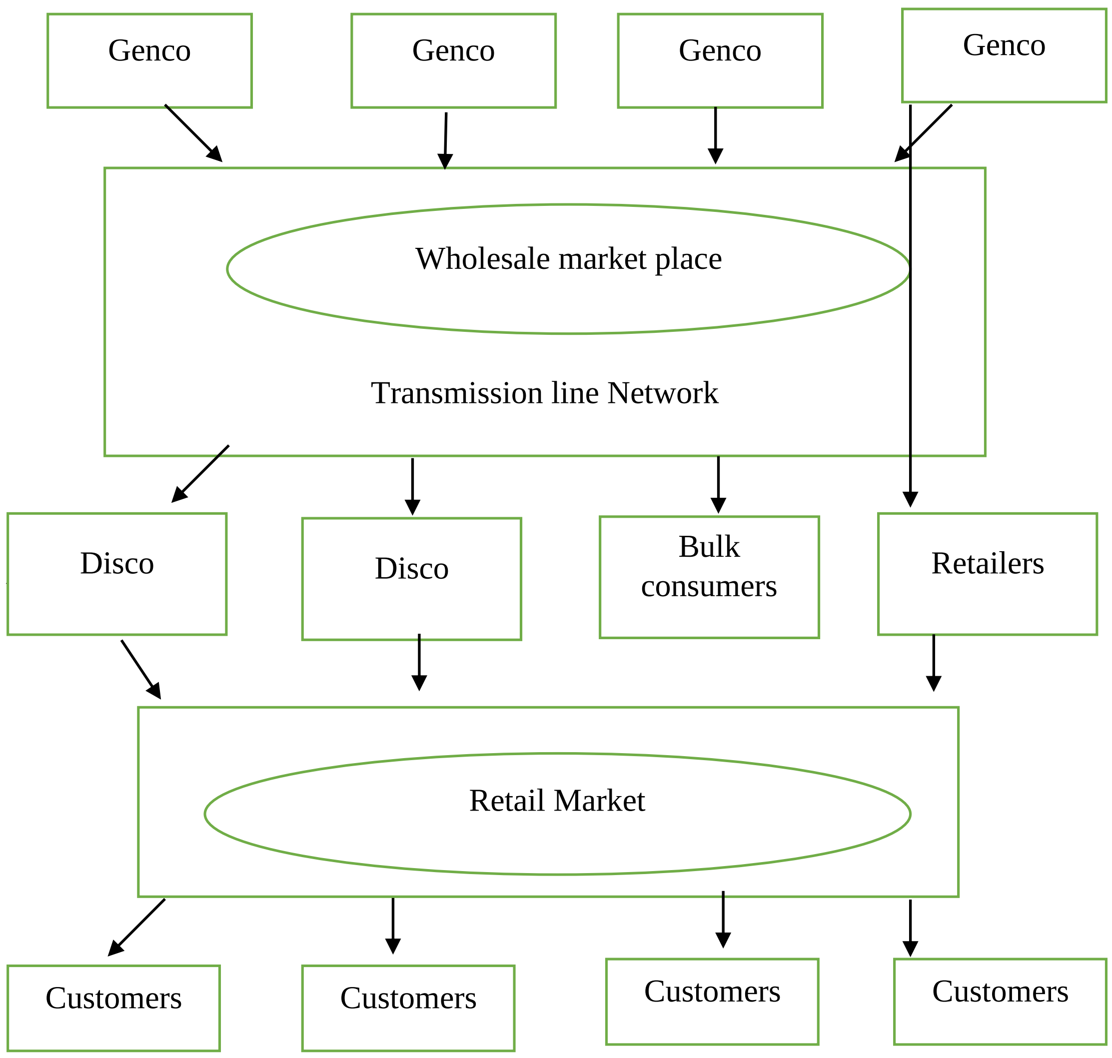


Figure 2.7 : Block Diagram of Retail Electricity Market Model

The advantages of this type of electricity market models are as follows.

- Fully deregulation
- Reliable and quality of electricity supply is available.
- Consumers choices is broad.

The disadvantages of this type of electricity market models are as follows

- Complex
- Huge infrastructures requirement.

2.6 Examples of Deregulated Electricity market

2.6.1 USA Electricity market model

In the United States, the electricity market is primarily classified into two models: the wholesale electricity market and the retail electricity market.

Wholesale electricity market model: The electricity markets in the United States consist of distinct wholesale and retail components. Wholesale markets facilitate the trade of electricity among electric utilities and traders, forming an intermediary step before it reaches consumers. On the other hand, retail markets directly provide to consumers by offering electricity for sale. It's worth noting that both wholesale and retail markets can function under either traditional regulatory frameworks or in competitive market settings.

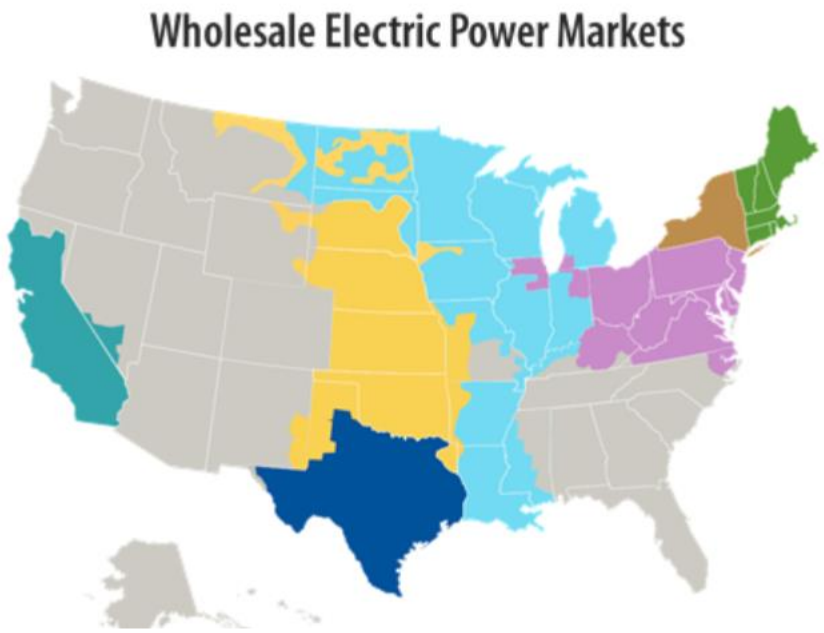


Figure 2.8 : Wholesale electricity market

Source: https://www.epa.gov/green-power-markets/us-electricity-grid-markets

The figure above illustrates certain segments of the U.S. wholesale electricity market, which are traditionally regulated (shown gray areas). In this context, vertically integrated utilities bear the responsibility for the generation, transmission, and distribution systems to supply electricity consumers. The wholesale market in Northeast, Midwest, Texas, and California, operates under a restructured and competitive model. These markets are overseen by independent system operators (ISOs), which include both regional transmission organizations (RTOs) and ISOs. ISOs employ competitive market mechanisms that facilitate the trading of power among independent power producers and non-utility generators. In these restructured competitive markets, the role of "utilities" primarily revolves around providing retail electricity services to customers, while their ownership of generation and transmission resources is less common (EPA, 2023).

Retail Electricity Market: Retail electricity markets in the United States can be categorized as either traditionally regulated or competitive. In traditionally regulated retail electricity markets (shown gray), consumers do not have the freedom to choose their power generators and are compelled to purchase electricity from the utility operating in their area.

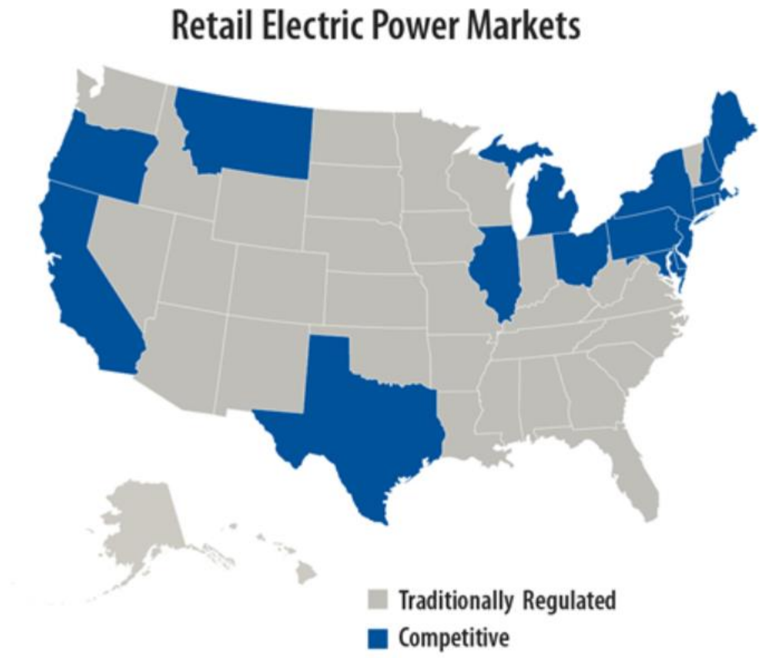


Figure 2.9 : Retail electricity market

Source: https://www.epa.gov/green-power-markets/us-electricity-grid-markets

This traditional regulatory model observes in most Southeastern, Northwestern, and a significant portion of Western states, excluding California. On the other hand, competitive retail electricity markets (represented as blue) provide electricity consumers with the ability to choose among various competitive retail suppliers. These markets have introduced competition in electricity generation in 24 states, including California, Texas, and the majority of Northeastern states. Additionally, eighteen states along with Washington, D.C., have implemented retail choice, granting residential and/or industrial consumers the freedom to select their electricity provider and opt for specific generation options, including renewable energy sources. This competitive market framework offers greater flexibility regarding the structure of retail supply contracts, project location, and the scale of renewable energy sources chosen (EPA, 2023).

2.6.2 Nord Pool Market

Nord Pool is the largest power market in Europe and operates as a power exchange for the Nordic and Baltic regions. It is an independent marketplace where electricity producers, consumers, and traders can buy and sell electricity contracts. Nord Pool facilitates both physical and financial trading of electricity, allowing participants to engage in spot trading, forward contracts, and derivatives. In physical power market, power market deals with the physical delivery of electricity. It involves the buying and selling of actual electricity, where market participants trade in kilowatt-hours (kWh) or megawatt-hours (MWh) of electricity. The physical power market focuses on the physical generation, transmission, and distribution of electricity from power plants to end consumers. However, in financial power market involves trading financial instruments based on electricity prices and market conditions. Instead of trading physical electricity, participants trade financial contracts or derivatives that are linked to the price of electricity. These derivatives include futures contracts, options, swaps, and other financial instruments. The financial power market allows participants to hedge against price fluctuations, speculate on future electricity prices, and manage their exposure to market risks. Nord Pool operates in several countries, including Norway, Sweden, Denmark, Finland, Estonia, Latvia, and Lithuania. It provides a transparent market for electricity, enabling market participants to trade electricity based on supply and demand. The exchange sets hourly electricity prices through an auction system, known as the day-ahead market. Participants submit their bids and offers, and the system determines the clearing price at which electricity is traded for each hour of the following day. Nord Pool also offers intraday trading, which allows market participants to adjust their positions closer to real-time delivery (Nord Pool, 2023). Nord Pool also plays a vital role in promoting competition, price transparency, and efficient electricity trading in the Nordic regions (N. Flatabo, 2003). It contributes to the integration of renewable energy sources, cross-border trading, and overall market efficiency in the European power sector.

2.6.3 India Electricity Market

India has a mix of power generation sources, including thermal (coal, gas, and oil), hydroelectric, nuclear, and renewable energy (solar, wind, biomass, and small hydropower). However, thermal power dominates the country's electricity generation, accounting for a major share of the total installed capacity. There are five regional grids are existing namely as Northern, Western, Southern, Eastern, and North-Eastern in India (CEA, 2023). The Power Grid Corporation of India Limited works on the field of development and maintenance of the transmission infrastructure. The grid infrastructure has been continuously expanding to accommodate the growing power generation capacity India has undertaken several market reforms to enhance competition, attract investments, and improve the overall efficiency of the electricity sector. These reforms include the introduction of open access, the establishment of power exchanges, and the implementation of a competitive bidding process for procurement of power from generators. Power trading has gained prominence in India with the establishment of power exchanges like Indian Energy Exchange (IEX) and Power Exchange India Limited (PXIL). These exchanges facilitate the trading of electricity among buyers and sellers, providing a platform for price discovery and optimizing power procurement (India Energy Exchange, 2023).

Features of India Energy Exchange market

Spot Market: The spot market on the IEX allows participants to buy and sell electricity for immediate delivery. Prices in the spot market are determined through a bidding process, where buyers and sellers submit their bids and offers. The matching process determines the clearing price and quantities for each trading interval.

Day-Ahead Market: The day-ahead market enables participants to trade electricity contracts for the next day's delivery. Market participants can submit their bids and offers based on their anticipated electricity requirements or generation capacities. The clearing price and quantities are determined through the auction process, ensuring efficient allocation of electricity resources.

Term-Ahead Market: The term-ahead market provides participants with the flexibility to trade electricity contracts for multiple days in advance. This allows market participants to manage their electricity procurement and supply requirements more effectively.

Renewable Energy Certificate (REC) Market: The IEX also facilitates the trading of Renewable Energy Certificates, which represent the environmental attributes of renewable energy generation. Market participants can buy and sell RECs to meet their renewable energy obligations or to demonstrate their support for clean energy.

2.7 TSDP (Transmission System Development Plan) forecast

The transmission system development plan presents an overview of the transmission network designed to accommodate the updated generation and load scenario projected for the year 2040. The computer model used for this plan incorporates data from existing, under construction, and planned/proposed hydroelectric projects and transmission lines, as well as load forecasts for the target year 2040 (TSDP, 2018). The proposed transmission network includes six cross-border connection points between Nepal and India in the Terai region, as well as two cross-border connection points between Nepal and China in the Himalayan region. Nepal's power grid is divided into five zones, spanning from West to East, with each zone having at least one interconnection point with India and China. To determine the trading capacity for the year 2040, the total load demand and total generation are derived from two reports; the Transmission System Development Plan (TSDP) of Nepal and the Electricity Demand Forecast Report (2015-2040). These reports provide forecasts for the zone-wise load profile and zone-wise power generation. The Table 3.1 below presents the zone-wise power generation and load demand.

Table 2.1 : Zone wise generation and load demand (TSDP, 2018)

zones	Zone -1	Zone-2	Zone-3	Zone-4	Zone-5
Districts	Kanchanpur, Kailali, Doti, Achham, Dadeldhur	Banke, Bardiya, Dang, Surkhet, Salyan,	Kapilvastu, Rupandehi, Nawalparasi, Chitwan, Arghakhanchi	Parsa, Bara, Rautahat, Makwanpur, Dhading, Kathmandu,	Jhapa, Illam, Panchthar, Tapejung, Morang, Dhankuta,

	a, Baitadi, Darchula, Bajhang, Bajura, Kalikot, Jumla, Mugu, Humla	Rolpa, Pyuthan, Dailekh, Jajarkot, Rukum and Dolpa	, Palpa, Tanahu, Syangja, Gulmi, Baglung, Parbat, Gorkha, Lamjung, Kaski, Myagdi, Mustang and Manag	Lalitpur, Bhaktapur, Kavrepalanchok, Nuwakot, Sindhupalchok, Rasuwa, Dhanusa, Mahottari, Sarlahi, Sindhuli, Ramechhap and Dolakha	Sankhuwasabha, Sunsari, Bhojpur Tehrathum Solukhumbu, Udayapur, Khotang, Okhaldhunga, Siraha, and Saptari
Total generation (GW)	9.92	4.47	7.4	8.03	7.78
Total load demand (MW)	2.360	2.300	4.095	6.480	2.8505

From the above table shows the total load demand and total generation for the year 2040 are 18.0855 GW and 37.6 GW, respectively (TSDP, 2018).

2.8 Proposed Cross-border Transmission line

In order to address the current power deficit and facilitate future power export, the establishment of cross-border transmission lines becomes essential. The transmission system development plan addressed six strategic locations for cross-border power lines with India, and two locations for cross-border transmission lines to facilitate power exchange with China. The selection of these cross-border locations has been carefully determined to ensure the proximity between load centers and generation hubs, optimizing the efficiency of power transmission (TSDP, 2018).

Table 2.2 : Proposed Cross Border Line with India (TSDP, 2018)

Transmission line	Nos. of circuit	Power flow(MW)	% loading	Connected zones for power evacuation
Attariya - Bareily	single line of double circuit 400kV	700	16.3	Mahakali, Karnali and Seti corridors in Zone-1
Dododhara - Bareily	Two numbers of double circuit 400kV	3000	34.6	Mahakali, Karnali and Seti corridors in Zone-1
Phulbari - Lucknow	Two numbers of double circuit 400kV	2600	29.9	Nalsyau Gad, Bheri Corridor in Zone-2
New Butwal - Gorakhpur	Two numbers of double circuit 400kV	2500	28.8	Marsyandi, Kaligandaki and Gandaki Corridor in Zone-3
Dhalkebar - Muzzafarpur	Two numbers of double circuit 400kV	3100	35.7	Khimti, Tamakoshi and Dudhkoshi Corridor in Zone-4
Inaurwa - Purnea	Two numbers of double circuit 400kV	1800	20.9	Arun and Koshi in Zone-5

Table 2.3 : Proposed Cross Border Line with China (TSDP, 2018)

Transmission line	Nos. of circuit	Power flow(MW)	% loading	Connected zones for power evacuation
Chilime - Keyrung	Two numbers of double circuit 400kV	1500	34.3	Trishuli river corridor in Zone-4
Kimanthanka -Latse	Two numbers of double circuit 400kV	700	15.9	Arun and Koshi Corriodor in Zone-5

2.8.1 Current status of Transmission Line

The Nepal Electricity Authority (NEA) mainly focuses on the planning, construction, expansion, and upgrading of cross-border lines for energy security and bulk electricity trade in the near future. Currently, the existing cross-border transmission line is insufficient to evacuate the power generated from hydropower projects. Furthermore, the Integrated Nepal Power System should operate in synchronous mode with the Indian grid for enhanced reliability and security. The first operational 400KV transmission line, the Dhalkebar-Muzaffarpur cross-border transmission line, is limited in its power supply capacity, allowing only 1000 MW to be transmitted through this line (Subedi, 2079). Additionally, a Joint Venture company consisting of Nepal and the Power Grid Corporation of India has been established to construct the Butwal-Gorakhpur 400 KV transmission line on the Indian side. The Millennium Challenge Corporation takes the responsibility of constructing the transmission line and substation on the Nepalese side. Furthermore, a Joint Steering Committee meeting has planned the construction of two more 400KV cross-border transmission lines: one connecting New Inaruwa to Purnia and another linking Dodhdhara to Bareli, with completion targeted for the fiscal years 2027/28 and 2028/29, respectively (NEA, 2023). Moreover, the feasibility study on the Nepalese side for the cross-border transmission line from Ratamate (Nepal) to Kerung (China) has been completed. After all these transmission lines are completed, the power transmission network will connect China with South Asian countries, facilitating regional energy connectivity.

Table 2.4 : Import/Export links with India (operation and Planned/Under construction)

S.N.	**Transmission Line**	**Expected Completion Date**	**Approximate Maximum Power flow(MW)**	**Status**
400KV Cross Border Transmission line				
1.	Dhalkebar - Muzzaffarpur	-	1000	Operation
2.	New Butwal - Gorakhpur	2025	2000	Under construction
3.	New Inaruwa - Purnia	2028	1800	Planned
4.	Dodhdhara to Bareli	2029	3000	Planned
5.	132 KV Cross Border Transmission Lines	-	500	Operation/ Under construction
		Total	8300	

2.9 MCA Nepal

The Government of Nepal and the Millennium Challenge Corporation signed the Nepal Compact Agreement in September 2017. The main objectives following this agreement are to accelerate economic growth and reduce poverty by enhancing the availability and quality of electricity. This agreement mainly focuses on electricity transmission lines and road maintenance. In this agreement, the electricity transmission project is designed to enhance the reliability of the national grid and promote economic growth by exporting surplus energy. The MCA-Nepal signed a Project Cooperation Agreement (PCA) for the Electricity Transmission Project (ETP) with Nepal Electricity Authority (NEA) in May 2023. The Government of Nepal has designated the ETP as a National Pride project, aimed at constructing essential infrastructure in Nepal to facilitate the planned India interconnection from New Butwal, Nepal to Gorakhpur, India (MCA Nepal, 2023). The project involves designing and constructing approximately 315 km of a double-circuit 400 kV transmission line, bridging gaps across various river basins. This agreement also holds the potential to support Nepal's domestic and cross-border transmission investment plans. Also in this agreement, three new 400 kV indoor gas-insulated substations (GIS) will be established Ratmate substation in Nuwakot District, the New Damauli substation in Tanahun District, and the New Butwal substation in Nawalparasi West District. Additionally, the transmission lines will be interconnected with the existing Nepal Electricity Authority substations at Lapsiphedi, Kathmandu District, and New Hetauda, Makawanpur District. By conducting power sector technical assistance activities, the project aims to support the Electricity Regulatory Commission (ERC) and NEA to enhance transparency, efficiency and competition within the Nepalese power sector.

2.10 NEA Demand forecast

The Nepal Electricity Authority (NEA) published the demand forecast in the 'A Year in Review Fiscal Year 2018/19' for the fiscal years 2019/20 to 2039/40, which is depicted in the following table. As per the load forecasted by Nepal electricity authority, the generation requirement in 2020, 2025, 2030, 2035 and 2040 is about 10,138.28 GWh, 18,579.53 GWh, 31,196.38 GWh, 50,887.42 GWh and 82,620.73 GWh respectively.

Table 2.5 : System Energy Requirement (GWh) forecasted by NEA for fiscal year 2019-20 to 2039/40

S.N.	Fiscal Year	Generation Requirement (GWh)
1.	2019/20	10,138.28
2.	2020/21	12,017.96
3.	2021/22	13,952.00
4.	2022/23	15,332.65
5.	2023/24	16,869.13
6.	2024/25	18,579.53
7.	2025/26	20,585.22
8.	2026/27	22,826.63
9.	2027/28	25,332.50
10.	2028/29	28,111.30
11.	2029/30	31,196.38
12.	2030/31	34,355.49
13.	2031/32	37,861.08
14.	2032/33	41,754.21
15.	2033/34	46,079.83
16.	2034/35	50,887.42
17.	2035/36	56,007.87
18.	2036/37	61,677.62
19.	2037/38	67,957.59
20.	2038/39	74,913.54
21.	2039/40	82,620.73

2.11 Power Trading Through IEX Market

Nepal has been fulfilling the power shortage by importing and spills energy by exporting from india electricity market. Nepal became the first south Asian country to join Indian Energy Exchange market started operation from May 1, 2021 after Nepal Electricity Authority (NEA) gained approval from Central Electricity Authority for trading from Day-Ahead Market of IEX. NEA is currently exporting up to 452 MW of power from 10 hydropower projects and it is anticipated that the quantum will increase in the near future following the approval of more hydropower projects from the Designated Authority of India (NEA, 2023). The Power Trading Unit in load dispatch center has been provided the responsibility to bid daily on IEX-DAM for selling and purchasing the power from India to balance the power generation. In the fiscal year 2022/23 1.3 Billion Units of energy has been sold to India from IEX, which helps to generate revenue of Nepal Electricity Authority (NEA, 2023). For power trade in the neighboring countries like india and Bangladesh, various arrangements were done in Fiscal year 2022/23. An agreement was signed between NEA and NTPC Vidhyut Vyapar Nigam (NVVN) On May 23, 2023 for supply of 200 MW of power to NVVN from five different hydropower projects. Also an agreement was signed between NEA and PTC India Ltd. on June 28, 2023 to import and export power up to 300 MW in the Indian market using Bihar’s transmission infrastructure. There is also discussions made between NEA, NVVN and Bangladesh Power Development Board (BPDB) for the export of power from NEA to Bangladesh via India (NEA, 2023).

CHAPTER 3 : METHODOLOGY

3.1 Research Flow Chart

This chapter presents fundamental information and applications of the proposed methods for analyzing opportunities in cross-border electricity trade within deregulated electricity markets. The analysis includes supply and demand assessments of the electricity markets in Nepal and neighboring countries. After conducting the literature review, the flowchart depicting the detailed study and analysis of the cross-border electricity trade opportunities in Nepal is presented Figure 3.1.

In the beginning, data on Nepal's energy consumption and generation from various sources in the recent previous year is collected through NEA annual publication reports and WECS. This data includes information on consumption, NEA generation, IPP generation, and energy imports and exports from India, all of which are assessed for their contributions to meeting the country's energy demand. Additionally, data on energy imports and exports with India in the recent year is gathered and studied.

The forecast for future energy requirements is obtained from various sources such as WECS, and NEA publications. WECS forecast presents three different scenarios based on GDP growth: Business as Usual (4.5% GDP growth), Reference Scenario (7.2% GDP growth), and High Scenario (9.2% GDP Growth). The energy generation from installed capacity is calculated by multiplying it with the plant factor, derived from the past year's energy generation data of various hydropower plants.

The expected energy consumption is calculated by using the weighted average method. By analyzing the expected energy generation and consumption data for future years, the balance between generation and demand is studied. Furthermore, the trading potential of energy through cross border is explored, investigating how it can be beneficial for Nepal to enhance the economy of Nepal.

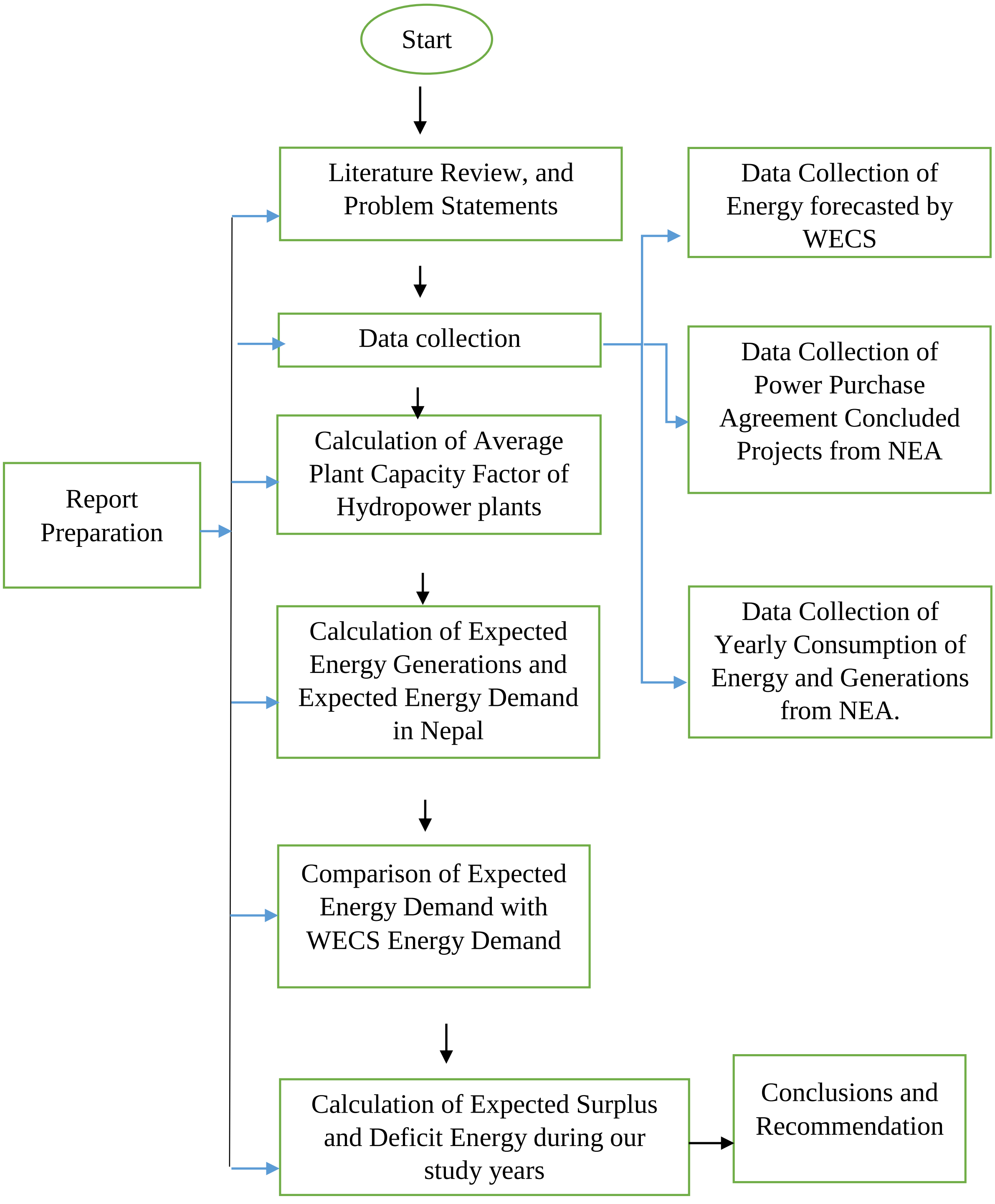


Figure 3.1 : Research Flow Chart

3.2 Data collection

Data collections regarding the cross border electricity transmission trade for extend of electricity markets from Nepal and neighboring concerned electricity utility.

3.2.1 WECS forecast

In January 2017, the Water and Energy Commission Secretariat published the Electricity Demand Forecast Report (2015-2040), projecting the twenty-five-year energy demand. The forecast considered three scenarios of economic development are Business as usual (4.5% GDP growth rate), Reference (7.2% GDP growth rate) and High growth (9.2% GDP growth rate).

Furthermore, an additional analysis was conducted, incorporating various policy interventions, such as achieving 100% cooking with electricity and 75% water heating with electricity in urban areas by 2020, and introducing metros in cities by 2025, at 7.2% and 9.2% GDP growth rates. The Model for Analysis of Energy Demand (MAED) was employed in this generation forecast report. The WECS electricity demand forecast between from 2015 to 2040 is depicted as shown in following table.

Table 3.1 : WECS Electricity Demand forecast

Year	Final Electricity Demand (GWh)				
	BAU	Reference Scenario	High Scenario	Policy Intervention @ 7.2%	Policy Intervention @ 9.2%
2015	3866.36	3866.36	3866.36	3866.36	3866.36
2020	7600.76	8110.66	8522.97	14870.92	15304.29
2025	12998.25	14863.67	16545.84	22431.68	24265.05
2030	20073.83	24956.79	29864.09	35334.66	41264.82
2035	29744.69	40709.77	52983.16	51771.84	65657.50
2040	43016.69	66096.60	94851.06	81958.97	115294.44

The WECS electricity capacity requirement from 2015 to 2040 is depicted in the below table.

Table 3.2 : WECS electricity capacity requirement

Year	Total Installed Capacity Requirement (MW)				
	BAU 4.5%	Reference Scenario 7.2%	High Scenario 9.2% growth	Policy intervention @ 7.2% growth	Policy intervention @ 9.2% growth
2015	1721	1721	1721	1721	1721
2020	3384	3611	3794	6621	6814
2025	5787	6617	7366	9987	10803
2030	8937	11111	13296	15731	18371
2035	13242	18124	23588	23049	29231
2040	19151	29427	42228	36489	51330

3.2.2 Plant Capacity Factor of Hydropower Plants

The capacity factor of a hydropower plant refers to the ratio of the actual energy output of the plant to its maximum possible output if it operated at its rated capacity continuously over a specific period. In other words, it represents the efficiency and utilization of the plant.

For hydropower plants, the capacity factor is typically quite high because they can produce electricity consistently as long as there is a reliable supply of water. The plant capacity factor of hydropower plant is calculated using following equation.

Plant capacity factor (PCF) = Actual Energy generation(AEG)/ (Install Capacity x Time Interval)

The plan capacity factor can vary based on the water availability, reservoir storage, seasonal variations, maintenance work etc.

The actual plant capacity factors of NEA-operated hydropower projects, and IPP-operated hydropower projects are determined based on past data of energy generation from Nepal Electricity Authority. The actual plant capacity factors for past years of NEA-operated ROR hydropower projects and IPP-operated ROR hydropower projects, based on yearly data collected from NEA, are presented in the annex. Hence, the average plant factors of projects are used to calculate the expected energy generation from hydropower projects in the coming years. The average plant capacity factor is calculated using data from the last three years and is determined using the following formula;

$$APCF = \frac{\text{YEARLY RECENT THREE YEAR PCF}}{3}$$

Where,

APCF= Average plant capacity factor

3.2.3 Generation Forecast

For the determination of future energy generation, only the projects under construction are considered. In Nepal, there are several hydropower projects based on natural flow river systems, including Run-of-River (ROR), Peaking Run-off- River (PROR), and Storage types. However, these projects face significant challenges, such as issues with environmental impact assessments, land acquisition problems, lack of inter-agency coordination, delays in construction work in forest areas, increased project costs due to delayed completions, and a lack of construction-friendly infrastructure for hydropower projects. Timely completion of hydropower projects is delayed by these major issues. The construction of hydropower is undertaken by two main bodies in Nepal: Independent Power Producers (IPP) and NEA (Nepal Electricity Authority) and its subsidiary companies.

To obtain the future generation scenario, the expected time of completion of hydropower projects is calculated by averaging the past completion periods of hydropower projects with the Power Purchase Agreement (PPA) date. The completion dates of NEA's subsidiary companies and IPP operated projects are obtained from NEA publications. The average time of completion for hydropower projects is estimated about eight years. Hence we can calculate the additional installed capacity and expected energy generation in coming years by considering the average completion date along with the Power Purchase Agreement (PPA) date of under construction projects.

3.2.4 Supply and Demand Pattern of Nepal

The supply and demand pattern of Nepal is obtained from different fiscal year reports published by Nepal Electricity Authority and is depicted in the table. The total energy imported from India increased from the year 2015, but in the year 2020, the total imported energy decreased to 1729 GWh due to the outbreak of the Covid pandemic. In the year 2022, the total energy imported from India to Nepal decreased, while the export to India increased due to the operation of Upper Tamakoshi Hydropower Limited and other Independent Power Producer (IPP) projects.

Table 3.3 : Supply and Demand of Nepal

Year	Import(GWh)	Total Internal Energy Consumption (GWh)	Peak Demand (MW)	Export (GWh)
2015	1370	3741	1291	3
2016	1,778	3,716	1,385	3
2017	2,175	4,774	1,444	3
2018	2,582	5,557	1,508	3
2019	2,813	6,303	1,320	35
2020	1,729	6,418	1,408	107
2021	2,806	7,275	1,482	38
2022	1,543	8,842	1,964	494

3.2.5 Energy Demand Forecast

For the determination of future electricity demand forecast past year's consumption data is taken. In this study, the expected energy demand or consumption is forecasted by weighted average method. In this method, the quantities which are needed to be averaged are assigned weight first as per their importance and then their average is determined. The weighted average is calculated using following formulae.

Weighted Average Growth Rate (%) = $\sum$ (Annual Growth Rate X Weight)/ $\sum$ Weights.

To determine the weighted average growth rate, we consider energy consumption spanning from the year 2015 to the year 2022. The calculated average growth rate is found to be 16.05%. After the weighted average growth rate calculation, we proceed to calculate the expected energy consumption using the following formula:

$EC_n = EC_{base} \times (1+WAGR/100)^n$

Where,

ECn = Expected Energy Consumption for n^{th} year from base year

EC_{base} = Energy Consumption of base year

WAGR = Weighted Average Growth Rate.

The expected energy consumption in each year are presented in the tabular form in appendix.

3.2.6 India Power Supply and Demand Scenario

The energy requirements and energy supplied in India from 2015-16 to 2021-2022 were taken from the Central Electricity Authority (CEA) and are depicted in the following figure. From this table, it can be observed that India's energy deficiency has been on a decreasing trend. In the fiscal year 2015-16, the energy deficiency was 23,558 million units, and in 2021-2022, the energy deficiency reduced to 5,787 million units.

Table 3.4 : India Power Supply and Demand Scenario for past years (CEA, 2023)

Year	Energy Requirement (MU)	Energy Supplied (MU)	Energy Deficit	
			(MU)	(%)
2015-16	1,114,408	1,090,850	23,558	2.1
2016-17	1,142,928	1,135,332	7,596	0.7
2017-18	1,213,326	1,204,697	8,629	0.7
2018-19	1,274,595	1,267,526	7,070	0.6
2019-20	1,291,010	1,284,444	6,566	0.5
2020-21	1,275,534	1,270,663	4,871	0.4
2021-22	1,379,812	1,374,024	5,787	0.4

The installed capacity of India from different energy sources to meet the power demand is shown in following table (Central Electricity Authority India, June 2023).

Table 3.5 : Energy Sources of India (CEA, 2023)

Types of Sources	**Installed Capacity(MW)**
Thermal	
Total Thermal	237928.91
Nuclear	
Nuclear	7480
Renewable Energy Sources including Large Hydro	
Total Renewable Energy sources including Hydro	176492.72
Total Installed Capacity	421901.63

The total Installed capacity of India as shown in the following pie char figure 3.2.

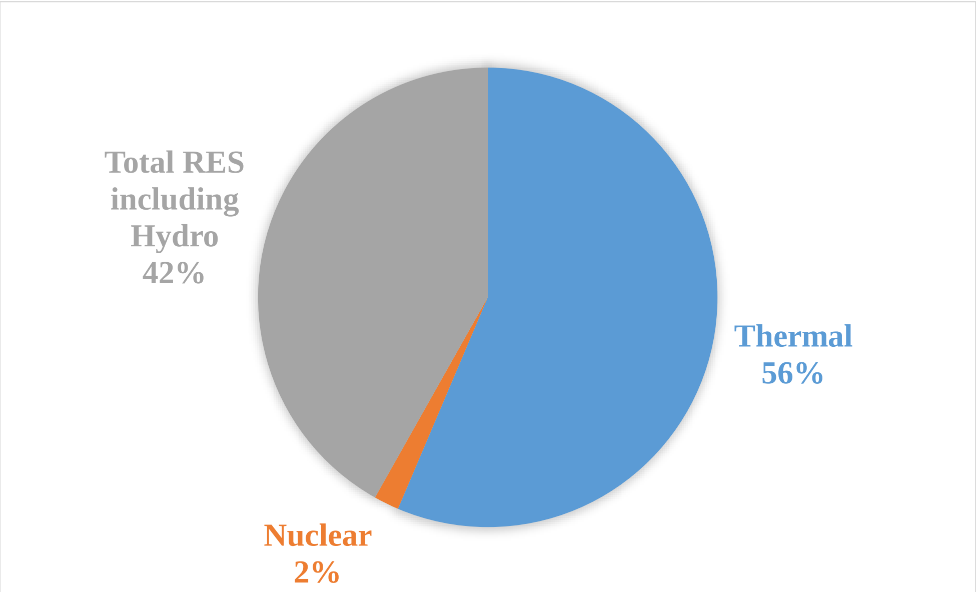


Figure 3.2 : Total Installed Capacity of India

The total contribution of thermal energy accounts for about 56% of the total installed capacity, while renewable energy sources, including hydro, constitute 42%. The remaining 2% is from nuclear energy.

CHAPTER 4 : RESULTS AND DISCUSSION

4.1 Average Yearly Plant Capacity Factor (APCF) for Groups of Projects

The average yearly plant capacity factor for three years is calculated by considering the average yearly plant capacity factor of eleven projects with a total capacity of 458.05 MW. The weighted average yearly plant capacity factor for NEA-operated projects is found to be highest for the fiscal year 2078/79, with a value of 0.66. Similarly, the lowest value is found for the fiscal year 2077/78, with a value of 0.56. The estimated average yearly plant capacity factor (APCF) for the three-year period of projects operated by NEA, presented in the appendix, is found to be 0.61. The graphical representation of the obtained weighted average yearly plant capacity factor is depicted in Figure 4.1 following.

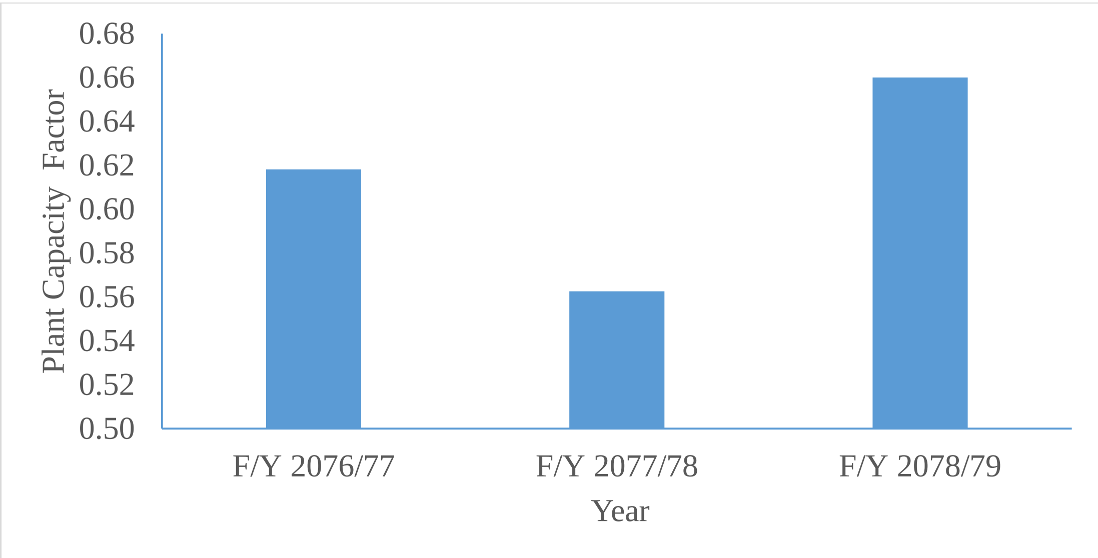


Figure 4.1 : Average Yearly Plant Capacity Factor of Three Different year for NEA operated Projects

4.2 Percentage Consumption Growth Scenario with Import and Export

The percentage growth of consumption, imported energy, and exported energy from India is analyzed. It has been observed that the percentage growth of consumption has increased slightly. However, in the year 2020, total consumption was 6418 GWh due to the outbreak of the Covid-19 pandemic. As a result, the percentage growth of consumption was only 1.82% compared to the previous year.

Imports from India have decreased, but exports to India have significantly increased since the fiscal year 2019. In the year 2022, imported energy was 1543 GWh, representing a decrease compared to the previous year. On the other hand, exported energy was 494 GWh, indicating a rapid increase compared to the previous year.

Table 4.1 : Percentage Growth Rate of Consumption, Import, and Export energy

Year	**Growth Rate**		
	Import Rate (%)	**Consumption (%)**	**Export (%)**
2015	-	-	-
2016	29.78	-0.67	0.00
2017	22.33	28.47	0.00
2018	18.71	16.40	0.00
2019	8.95	13.42	1066.67
2020	-38.54	1.82	205.71
2021	62.29	13.35	-64.49
2022	-45.01	21.54	1200.00

4.3 Total Energy Generation Forecast

The generation forecast scenario provides the total additional installed capacity, total installed capacity, total additional energy, and the future generation of energy for the different years between 2023 and 2031. To determine all these, the upcoming hydropower projects that have already secured power purchase agreements between Nepal Electricity Authority and Independent Power Producers are considered.

The forecasted additional installed capacity (MW), forecasted total installed capacity (MW), forecasted total additional energy (MW), and future energy (GWh) are obtained and depicted in the following Table 4.2

Table 4.2 : Forecasted Power Generation and Future Energy Generation(GWh)

Year	Total Additional Installed Capacity (MW)	Total Installed Capacity (MW)	Total Additional Energy (GWh)	Total Energy Generation (GWh)
2022	-	2384.891	-	12743.90
2023	1173.43	3558.33	6270.36	19014.27
2024	416.96	3975.29	2228.07	21242.33
2025	917.42	4892.71	4902.34	26144.67
2026	1761.71	6654.42	9413.87	35558.55
2027	47.98	6702.39	256.36	35814.91
2028	157.14	6859.53	839.69	36654.60
2029	142.50	7002.04	761.48	37416.08
2030	726.24	7728.28	3880.73	41296.81
2031	546.815	8275.09	2921.96	44218.77

From the table above, we observe that the least energy, 256.36 GWh, is achieved in 2027 due to the low rate of power purchase agreement between the Nepal Electricity Authority (NEA) and Independent Power Producers (IPP) in 2019. Similarly, in the years 2028 and 2029, the forecasted generation is 839.69 GWh and 761.48 GWh, respectively. However, the highest energy, about 9413.87 GWh, is achieved in 2026 because of the high rate of Power Purchase Agreement (PPA) between the Nepal Electricity Authority and Independent Power Producers (IPP) in 2018. According to the PPA in different year, the total energy generation is forecasted up to the year 2031 is about 44,218.77 GWh on the national grid of Nepal.

4.4 Comparison of Future Electricity Demand forecasted by Weighted Average Method (EC_n) and WECS.

The comparison of future electricity demand forecasted by WECS and weighted average method are presented in following Figure 4.2.

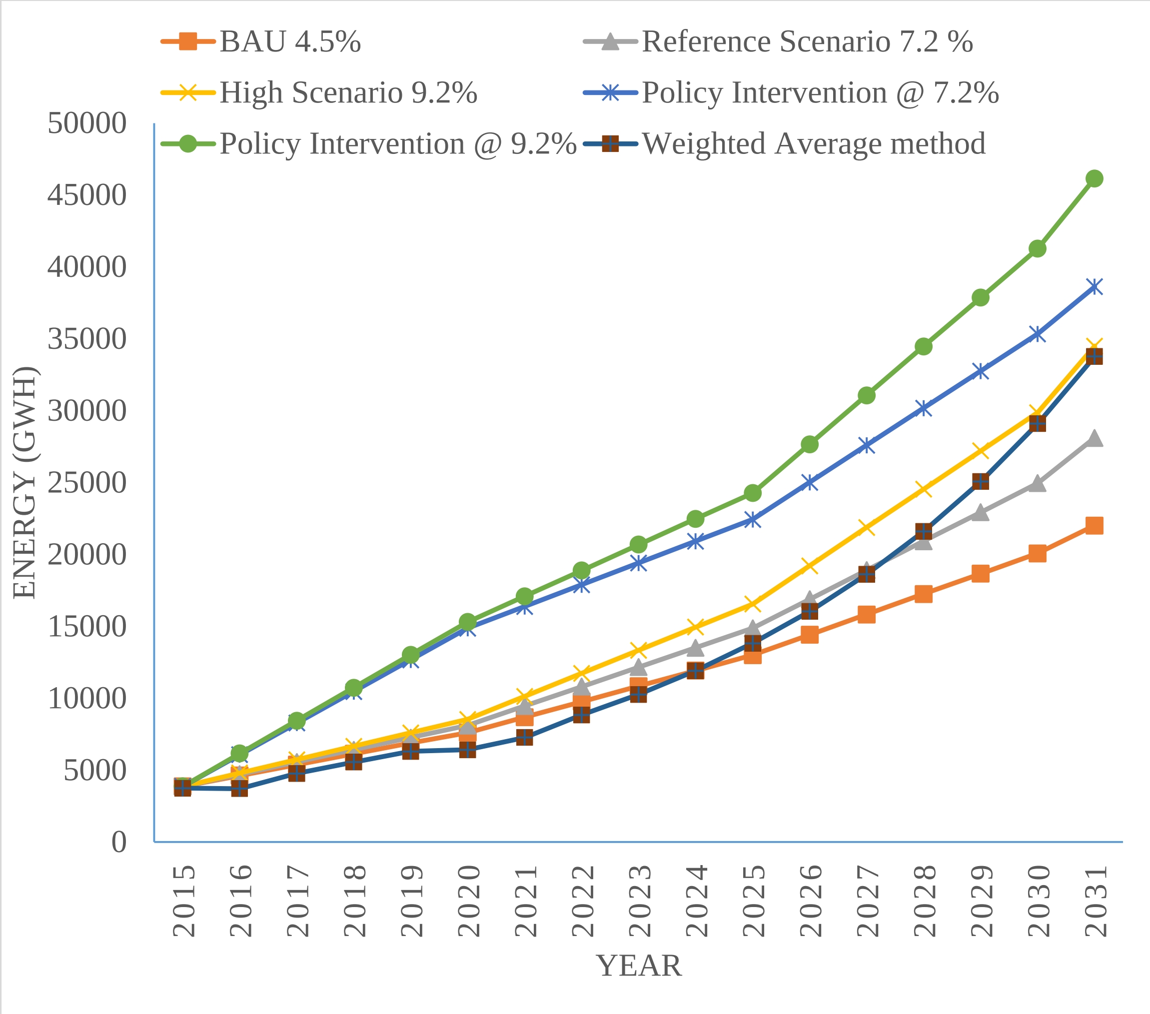


Figure 4.2 : Comparison of Electricity Demand Forecast by Weighted Average Method and WECS.

The future energy generation forecast by Weighted Average Method and Forecasted by the WECS is analyzed. It seems future demand forecasted by Weighted Average method is almost similar to the WECS forecast BAU 4.5% during the year 2015 to 2024. Then for the year 2024 to 2027, the electricity demand forecast by weighted average method follows WECS forecast Reference scenario 7.2%. After that in the year between 2027 to 2031 the electricity demand forecast by weighted average method follows WECS forecast High Scenario 9.2%.

4.5 Analysis of forecasted energy generation and demand forecast scenario

The forecasted energy generation and WECS demand forecast scenario are analyzed. In the WECS demand forecast, energy requirements under different scenarios are considered with varying GDP growth rates. The completion time of additional hydropower projects is taken as the average completion year mentioned in the PPA date. The figure below represents the forecasted energy generation and energy requirements forecasted by WECS under different scenarios.

4.5.1 Result on Generation forecast and WECS forecast

The figure 4.3 below provides the energy requirement forecasted by WECS and total energy generation.

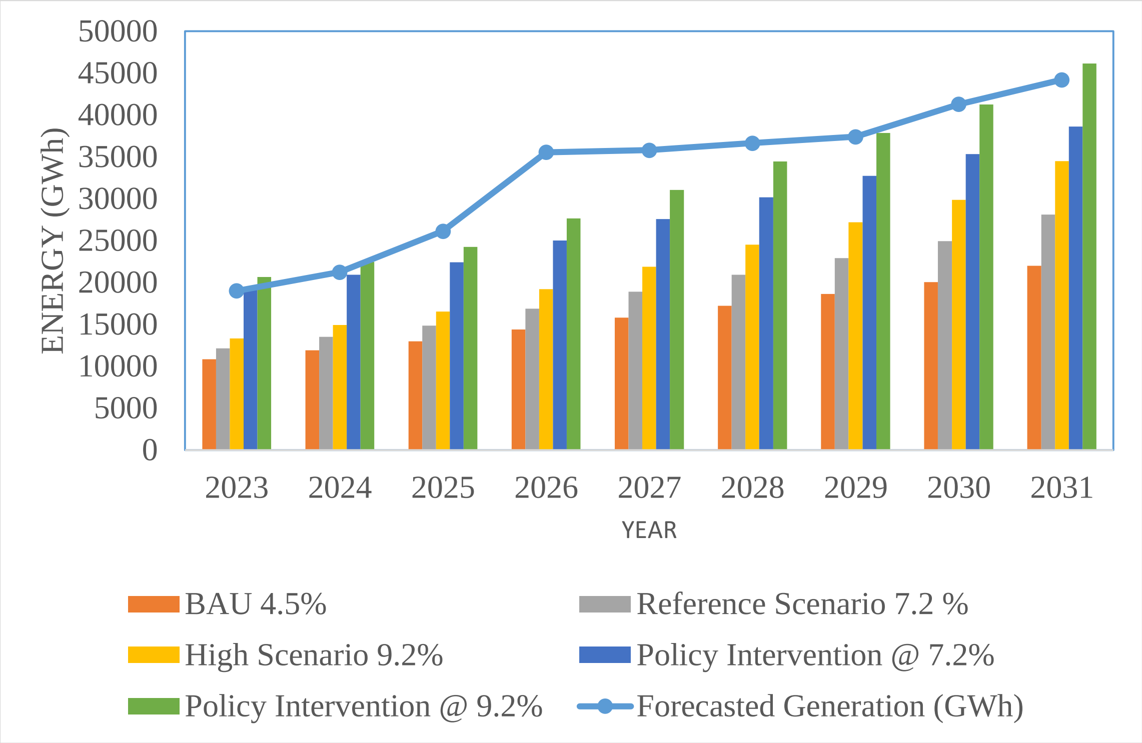


Figure 4.3 : Energy requirement forecasted by WECS and Total Energy Generation (GWh) forecast

The above chart shows the results of different scenarios for the years 2023 to 2031, focusing on energy surplus and deficit values. In the BAU 4.5% scenario, Reference scenario 7.2% and High scenario 9.2% there will be only surplus energy and no deficit energy. However, Policy Intervention @ 7.2% and Policy Intervention @ 9.2%, there will be mix of surplus and deficit energy. The details of surplus and deficit energy of different scenario for a different year is shown in following Table 4.3 and Table 4.4.

Table 4.3 : Surplus/Deficit Energy for BAU and Reference Scenarios

Year	BAU 4.5%		Reference Scenario 7.2 %		High Scenario 9.2%	
	Surplus (GWh)	Deficit (GWh)	Surplus (GWh)	Deficit (GWh)	Surplus (GWh)	Deficit (GWh)
2023	8175.01	-	6851.80	-	5677.57	-
2024	9323.58	-	7729.26	-	6301.07	-
2025	13146.42	-	11281.00	-	9598.83	-
2026	21145.18	-	18676.25	-	16349.06	-
2027	19986.42	-	16913.99	-	13941.77	-
2028	19411.00	-	15735.06	-	12117.81	-
2029	18757.37	-	14477.92	-	10215.64	-
2030	21222.98	-	16340.02	-	11432.72	-
2031	22210.77	-	16111.38	-	9730.87	-

Table 4.4 : Surplus/Deficit Energy for BAU and Policy Interventions.

Year	Policy Intervention @ 7.2%		Policy Intervention @ 9.2%	
	Surplus (GWh)	Deficit (GWh)	Surplus (GWh)	Deficit (GWh)
2023	-	393.11	-	1666.48
2024	322.80	-	-	1230.57
2025	3712.99	-	1879.62	-
2026	10546.27	-	7893.54	-
2027	8222.04	-	4749.95	-
2028	6481.13	-	2189.69	-
2029	4662.02	-	-	448.78
2030	5962.15	-	31.99	-
2031	5596.67	-	-	1924.59

4.5.2 Result on Generation forecast and Weighted Average Method of Electricity Demand Forecast

The generation forecast and weighted average method of electricity demand forecast is compared and shown in following bar chart figure 4.4.

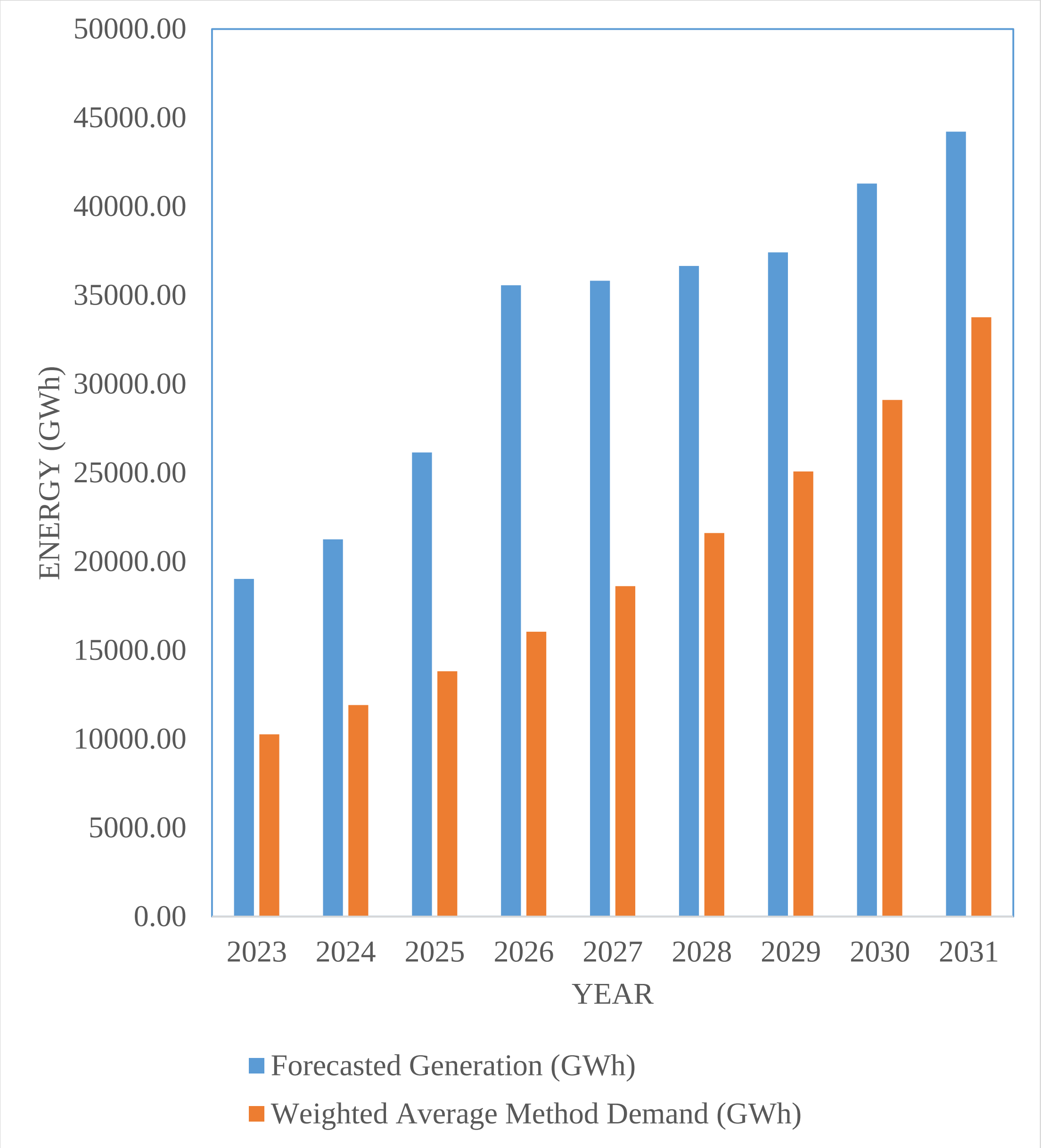


Figure 4.4 : Future energy generation and electricity demand forecast

Figure 4.4 shows the future energy generation and electricity demand forecast from 2023 to 203l. From this bar chart, it seems there will be surplus energy throughout the year and no deficit energy. The details of surplus and deficit energy for the different year is as shown in following Table 4.5.

Table 4.5 : Surplus/Deficit energy for Weighted Average Method of Electricity Demand forecast.

Year	Weighted Average Method	
	Surplus Energy(GWh)	Deficit Energy(GWh)
2023	8752.73	-
2024	9333.36	-
2025	12323.78	-
2026	19518.78	-
2027	17200.04	-
2028	15051.21	-
2029	12344.38	-
2030	12199.98	-
2031	10450.59	-

4.6 Result on Maximum Cross Border Power Flow Condition

After the analysis of demand forecast and future year energy generation, the maximum surplus energy is observed at BAU 4.5% scenario. The optimum power flow is obtained in the month of Aswin. The capacity requirement of transmission line for different year is depicted in the following Table 4.6. To determine capacity of present transmission line is considered all the cross border transmission line above 132 KV. If all the plan, proposed and under construction transmission line operate within the scheduled date, transmission lines will enough to transmit surplus energy. However, due to the delay in construction, present transmission line is not enough to transmit surplus energy in coming futures. Therefore, all the transmission lines should be commissioned in time.

Table 4.6 : Capacity Requirement of Cross Border Transmission Line.

Year	Total Installed Capacity (MW)	Maximum Energy Flow in Ashwin	Total Capacity (MW)	Transmission line Requirement (MW)
2023	3558.33	846.22	1500	1305.89
2024	3975.29	965.11	1500	1489.37
2025	4892.71	1360.82	3500	2100.03
2026	6654.42	2188.79	3500	3377.77
2027	6702.39	2068.85	3500	3192.67
2028	6859.53	2009.28	5300	3100.75
2029	7002.04	1941.63	8300	2996.34
2030	7728.28	2196.85	8300	3390.20
2031	8275.09	2299.10	8300	3547.99

From the above table, we can observe that the power transfer capacity of the transmission line requirement is greater than the available power transfer capacity of the transmission line. Between 2023 and 2024, the transmission line capacity is 1500 MW; between 2025 and 2028, the transmission capacity is 3500 MW, and between 2029 and 2031, the transmission line capacity is 8300 MW. However, the transmission line capacity requirement is less than the total available capacity (MW).

CHAPTER 5 : CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

This thesis studied the energy cross border electricity trade opportunities for different scenarios. It's concluded that the scenarios have varying impacts on the energy balance, with surpluses being predominant.

5.1.1 Conclusions on cross border electricity trade opportunities

To determine the cross border electricity trade opportunities, surplus and deficit energy for different scenario of energy consumptions is being compared with the generation forecast. The conclusions arrived from the studied are follows.

Surplus and Deficit energy for WECS demand forecast: The surplus energy is predominant with compare to the deficit energy. The policy intervention scenarios introduce deficits in some years while still maintaining surpluses in others. In BAU 4.5%, throughout the years, surplus energy is consistently present but there is no deficit energy. Similarly, in reference scenario 7.2% and high scenario 9.2% surplus energy is decreased with the increase in consumer demand although there is no deficit energy is observed. However, in policy intervention 7.2% scenario; there are mix of surplus and deficit energy in the studied years. In this scenario, deficit energy is observed only in initial year 2023 except this year surplus energy is obtained. In the policy intervention 9.2% there is mix of surplus and deficit energy is observed.

Surplus and Deficit energy for Weighted Average Method demand forecast: The percentage increase in generation energy are 11.72%, 23.08%, 36.01%, 0.72%, 2.34%, 2.08%, 10.37% and 7.08% for the year 2023, 2024, 2025, 2026, 2027, 2028, 2029,2030, 2031 respectively. However, the demand growth is only 16.05%. Hence we can conclude that there is sufficient of surplus energy for all the years.

In this thesis, only the PPA-signed projects are considered for the analysis of cross-border opportunities. However, numerous projects are undergoing the PPA process, and ongoing planned projects are in various stages of construction. Upon the completion of all projects currently under construction and those in progress, surplus energy will increase. Additionally, for the determination of future energy generation forecast, the average completion time of all under-construction hydropower projects is taken based on past project completion time. By reducing the completion time of all under-construction and planned hydropower projects, the future energy generation can be shifted to earlier years. This shift would result in increased energy generation, ultimately leading to higher surplus energy and enhance the cross border electricity trade.

5.2 Recommendation

- More than 56% of the total installed capacity in India is from thermal power, and nuclear power accounts for about 2% of this capacity. If we can lower the per unit cost of generation from hydropower projects, it would be possible to collect extra revenue through cross-border electricity trading.
- In the present situation, the existing transmission line is not sufficient to evacuate the power for cross-border trading. Only one 400 KV Dhalkebar-Muzaffarpur transmission line is currently in operation, resulting in limited power transmission capacity. Therefore, in order to evacuate the power generated from different parts of Nepal, the proposed 400 KV transmission lines need to be commissioned on schedule.
- The power sector structure of Nepal is vertically integrated. Nepal Electricity Authority owns and operates the entire transmission line infrastructure. It is necessary to involve private companies in transmission and distribution for cross border trading and to encourage internal market competition. The new electricity act, which has been pending in parliament for a long time, also includes provisions for cross-border trading and the deregulation of the electricity market in Nepal.
- In this research, the possibility of future additions of solar energy is not studied. However, the government of Nepal has identified some projects and some of IPPs solar projects that has been already signed power purchase agreement with the Nepal Electricity Authority. The future addition of solar energy will ultimately increase future energy generation. As a result, surplus energy will also increase.

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APPENDIX

Appendix A Average Plant Capacity Factor

Power Stations	Total Installed Capacity (MW)	Actual Generation(MWh)			Plant Factor		
		F/Y 2076/77	F/Y 2077/78	F/Y 2078/79	F/Y 2076/77	F/Y 2077/78	F/Y 2078/79
Kaligandaki 'A'	144	871,466.00	817,712.86	974,831.97	0.69	0.65	0.77
Mid-Marsyangdi	70	446,624.75	398,846.30	468,270.00	0.73	0.65	0.76
Marsyandi	69	443,852.10	398,920.10	464,271.50	0.73	0.66	0.77
Upper Trishuli 3A	60	407,551.15	314,767.50	432,832.50	0.78	0.60	0.82
Chameliya	30	160,811.64	151,247.41	153,981.04	0.61	0.58	0.59
Trishuli	24	128,973.11	121,211.30	137,113.27	0.61	0.58	0.65
Gandak	15	10,337.60	12,123.40	15,181.70	0.08	0.09	0.12
Modi	14.8	66,913.20	60,470.50	79,601.90	0.52	0.47	0.61
Devighat	15	92,053.14	85,429.11	98,389.60	0.70	0.65	0.75
Sunkoshi	10.05	62,245.94	55,916.73	63,524.08	0.71	0.64	0.72
Puwa	6.2	34,914.55	34,477.31	37,715.20	0.64	0.63	0.69
Total	458.05	**Avg Plant Factor**			0.62	0.56	0.66
		Three year APCF			0.61		

Appendix B Under Construction Projects

Developer	Projects	District	Installed Capacity (kWh)	PPA Date Nepali	Expected Completion Date
Lohore Khola Hydropower Co. Pvt. Ltd	Lohore Khola	Dailekh	4200	2069	2023
Abiral Hydropoer co. Pvt. ltd.	Upper Khadam	Morang	990	2070	2023
Alliance Energy Solutions Pvt.Ltd.	Upper Sit Khola	Argakhanchi	905	2075	2026
Amar Jyoti Hydro Power Pvt. Ltd.	Istul Khola	Gorkha	1506	2075	2026
Ambe Hydropower Pvt. Ltd.	Upper Bhurundi	Parbat	3750	2075	2026
Ankhu Hydropower (P.) Ltd.	Ankhu Khola	Dhading	34000	2073	2024
Annapurna Bidhyut Bikas Co. Pvt. Ltd.	Landruk Modi	Kaski	86590	2075	2026
Apex Makalu Hydro Power Pvt. Ltd.	Middle Hongu Khola A	Solukhumbu	22000	2075	2026
Api Power Company Ltd.	Upper Chameliya	Darchula	40000	2075	2026
Apolo Hydropower Pvt Ltd	Buku Khola	Solukhumbu	6000	2070	2023
Arati Power Company Ltd.	Upper Irkhuwa	Bhojpur	14500	2075	2026
Balephi Jalbidhyut Co. Ltd.	Balephi	Sindhupalchowk	23520	2067	2023
Baraha Multipower Pvt. Ltd.	Irkhuwa Khola B	Bhojpur	15524	2075	2026
Barpak Daruadi Hydropower Pvt. Ltd.	Middle Super Daraudi	Gorkha	10000	2075	2026
Beni Hydropower	Upper Solu	Solukhumbu	18236	2069	2023

Project Pvt. Ltd.					
Betrawati Hydropower Company Pvt. Ltd.	Phalanku Khola	Rasuwa	13700	2069	2023
Bhalaudi Khola Hydropower Pvt. Ltd.	Bhalaudi Khola	Kaski	2645	2076	2027
Bhujung Hydropower Pvt. Ltd.	Upper Midim	Lamjung	7500	2074	2025
Bigu Hydro Venture Pvt. Ltd.	Pegu Khola	Dolakha	3000	2079	2030
Bikash Hydropower Company Pvt Ltd.	Upgen Mashés Khole -	Gorkha	4550	2075	2026
Blue Energy Pvt. Ltd.	Super Trishuli	Gorkha and Chitwan	70000	2075	2026
Budhi Gandaki Hydropower Pvt. Ltd.	Super Machha Khola Sana	Gorkha	4600	2080	2031
Bungal Hydro Pvt. Ltd (Previously Sanigad Hydro Pvt. Ltd.)	Upper Sanigad	Bajhang	10700	2072	2023
Champawati Hydropower Pvt. Ltd	Chepe khola A	Lamjung	7000	2075	2026
Chandeshwori Mahadev Khola MH. Co. Pvt. Ltd.	Chulepu Khola	Ramechhap	8520	2071	2023
Chauri Hydropower (P.) Ltd.	Chauri Khola	Kavrepalanchowk, Ramechap, sindu, Dolakha	6000	2076	2027
Chilime Hydro Power Company Ltd.	Rasuwagadhi	Rasuwa	111000	2068	2023
Chirkhwa Hydropower Pvt. Ltd.	Upper Chirkhwa	Bhojpur	4700	2073	2024
Consortium Power	Khare Khola	Dolakha	24100	2070	2023

Developers Pvt. Ltd.					
Daram Khola Hydro Energy Ltd.	Daram Khola	Baglung and Gulmi	9600	2073	2024
Dariyal Small Hydropower Pvt.Ltd	Upper Belkhu	Dhading	996	2068	2023
Dhading Ankhu Khola Hydro Pvt. Ltd.	Upper Ankhu	Dhading	38000	2075	2026
Dhaulagiri Civil Electrical and Mechanical Engineering Pvt. Ltd.	Madhya Daram Khola A	Baglung	3000	2075	2026
Dhaulagiri Civil Electrical and Mechanical Engineering Pvt. Ltd.	Madhya Daram Khola B	Baglung	4500	2075	2026
Dhaulagiri Kalika Hydro Pvt. Ltd	Darbang Myagdi	Myagdi	25000	2072	2023
Diamond Hydropower Pvt. Ltd.	Upper Daraudi-1	Gorkha	10000	2072	2023
Dibyajyoti Hydropower Pvt. Ltd.	Marsyangdi Besi	Lamjung	50000	2075	2026
Dipjyoti Hydropower Pvt. Ltd.	Khani Khola	Dolakha	550	2078	2029
Dipsabha Hydropower Pvt. Ltd.	Sabha Khola A	Sankhuwasa bha	9990	2071	2023
Dolakha Nirman Company Pvt. Ltd.	Isuwa Khola	Sankhuwasa bha	97200	2075	2026
Dovan Hydropower Company Pvt. Ltd.	Junbesi Khola	Solukhumbu	5200	2069	2023
Dudh koshi Hydropower Private Ltd	Dudhkoshi 2 Jaleshwor	Solokhumbh u	70000	2078	2029
Dudhkoshi Power	Rawa Khola	Khotang	6500	2069	2023

Company Pvt. Ltd.					
Dudhpokhari Chepe Hydropower Pvt. Ltd.	Dudhpokhari Chepe	Gorkha	8800	2075	2026
Dynamic Hydro Energy Pvt. Ltd.	Chepe Khola Cascade	Lamjung and Gorkha	2000	2079	2030
Dynamic Hydro Energy Pvt. Ltd.	Lapche Tamakoshi	Dolakha	40000	2079	2030
Dynamic Power Pvt. Ltd.	Manahari Khola	Makwanpur	4444	2079	2030
Ekikrit Byapar Company Pvt. Ltd.	Brahamayani	Sindhupalch owk	35470	2075	2026
Energy Engineering Pvt. Ltd.	Upper Mailung A	Rasuwa	6420	2067	2023
Energy Venture Pvt. Ltd.	Upper Lapche	Dolakha	52000	2073	2024
Essel-Clean Solu Hydropower Pvt. Ltd.	Lower Solu	Solukhumbu	82000	2070	2023
Expert Hydro Investment Pvt. Ltd.	Sani Bheri	Rukum (East)	44520	2080	2031
Gaughar Ujjyalo Sana Hydropower Co. Pvt. Ltd.	Ghatte Khola Small	Sindhupalch owk	970	2074	2025
Gaurishankar Power Development Pvt. Ltd.	Middle Hyongu Khola B	Solukhumbu	22900	2074	2025
Gelun Hydropower Co.Pvt.Ltd	Gelun	Sindhupakch owk	3200	2068	2023
Global Hydropower Associate Pvt. Ltd.	Likhu-2	Solukhumbu / Ranechap	33400	2071	2023
Gorakshya Hydropower Pvt. Ltd.	Super Ankhu Khola	Dhading	23500	2074	2025

Greenlife Energy Pvt. Ltd.	Khani khola-1	Dolakha	40000	2074	2025
Gumu Khola Bhyakure Hydropower Pvt. Ltd.	Gumu Khola	Dolakha	950	2075	2026
Gurkhas Himalayan Hydro Ltd.	Upper Junbesi	Solukhumbu	4700	2080	2031
Habitat Power Company Pvt. Ltd	Hewa Khola "A"	Panchthar	5000	2075	2026
Halesi Urja Pvt. Ltd.	Madhya Rawa	Khotang	2000	2079	2030
Happy Energy Pvt. Ltd.	Mathillo Sankhuwa	Sankhuwasa bha	40000	2080	2031
Helambu Construction Pvt. Ltd	Ksumti khola	Sindhupalch owk	683	2075	2026
Hilton Hydro Energy Pvt. Ltd.	Super Kabeli	Taplejung	12000	2075	2026
Him Consult Pvt. Ltd.	Rele Khola	Myagdi	6000	2074	2025
Him Parbat Hydropower Pvt. Ltd.	Sagu Khola-1	Dolakha	5500	2075	2026
Him Parbat Hydropower Pvt. Ltd.	Sagu Khola	Dolakha	20000	2075	2026
Him River Power Pvt. Ltd.	Liping Khola	Sindhupalch owk	16260	2073	2024
Him Star Urja Co. Pvt. Ltd.	Buku Kapati	Okhaldhung a and	5000	2074	2025
Himalayan Engineering and Energy Pvt. Ltd.	Arun Khola-2	Nawalpur	2000	2080	2031
Himalayan Water Resources and Energy Development Co. Pvt. Ltd.	Upper Chauri	Kavrepalanc howk	6000	2074	2025
Himali Hydro Fund Pvt. Ltd.	Sona Khola	Taplejung	9000	2075	2026

Himali Rural Electric Co-operative Ltd.	Leguwa Khola Small	Dhankuta	640	2074	2025
Hira Ratna Hydropower P.itd	Tadi Khola	Nuwakot	5000	2067	2023
Hydro Connection Pvt. Ltd.	Rauje Khola	Solukhumbu	17712	2075	2026
Hydro Empire Pvt. Ltd.	Upper Myagdi	Myagdi	20000	2071	2023
Hydro Innovation Pvt. Ltd.	Tinekhu Khola	Dolakha	990	2069	2023
Hydro Support Pvt. Ltd.	Middle Kaligandaki	Myagdi	53539	2080	2031
Hydro Venture Private Limited	Solu Khola (Dudhkoshi)	Solukhumbu	86000	2071	2023
Hydro Village Pvt. Ltd	Myagdi Khola	Myagdi	57300	2075	2026
Ichowk Hydropower Pvt. Ltd.	Gohare Khola	Sindhupalchowk	950	2075	2026
Idi Hydropower Co. P. Ltd.	Idi Khola	Kaski	975	2070	2023
IDS Energy Pvt. Ltd.	Lower Khorunga	Terhathum	5500	2074	2025
Ingwa Hydro Power Pvt Ltd	Upper Ingwa khola	Taplejung	9700	2068	2023
Integrated Hydro Fund Nepal Pvt. Ltd.	Upper Brahamayani	Sindhupalchowk	15150	2075	2026
Isuwa Energy Pvt. Ltd	Lower Isuwa Cascade	Sankhuwasabha	40100	2075	2026
Jagadulla Hydropower Co. Ltd.	Jagadulla	Dolpa	106000	2080	2031
Jal Urja Pvt. Ltd.	Nuagad	Darchula	1000	2075	2026
Jalshakti Hydro Company Pvt. Ltd.	llep (Tatopani)	Dhading	23675	2075	2026
Jhilimili Hydropower Co. Pvt. Ltd.	Gulangdi Khola	Gulmi	980	2075	2026

Jhyamolongma Hydropower Development Company Pvt. Ltd.	Karuwa Seti	Solukhumbu	32000	2074	2025
Jumdi Hydropower Pvt. Ltd.	Jumdi Khola	Gulmi	1750	2056	2023
Jurimba Hydropower Co. Pvt. Ltd.	Jurimba Khola	Sindhupalch owk	7630	2079	2030
Kabeli Energy Limited	Kabeli- A	Panchthar and Taplejung	37600	2072	2023
Kabeli Hydropower Company Pvt.Ltd.	Kabeli-3	Taplejung	21930	2075	2026
Kalanga Hydro Pvt. Ltd.	Kalangagad	Bajhang	15330	2072	2023
Kali Gandaki Gorge Hydropower Co. Pvt. Ltd	Kaligandaki Gorge	Myagdi	180000	2079	2030
Kalika Construction Pvt. Ltd.	Upper Daraudi B	Gorkha	8300	2076	2027
Kalika Construction Pvt. Ltd.	Upper Daraudi C	Gorkha	9820	2076	2027
Kalika Energy Ltd.	Bhotekoshi-5	Sindhupalch owk	62000	2075	2026
Kalinchowk Hydropower Ltd.	Sangu (Sorun)	Dolakha	5000	2075	2026
Kasuwa Khola Hydropower Ltd.	Kasuwa Khola	Sankhuwasa bha	45000	2075	2026
Khechereswor Jal Vidhyut Pvt. Ltd.	Salubyani Gad Small	Bajhang	233	2074	2025
Khechereswor Jal Vidhyut Pvt. Ltd.	Jadari Gad Small	Bajhang	1000	2074	2025
Langtang Bhotekoshi Hydropower Company Pvt. Ltd.	Rasuwa Bhotekoshi	Rasuwa	120000	2074	2025

LC Energy Pvt. Ltd. (Prv. Chirkhwa Hydropower Pvt	Lower Chirkhwa	Bhojpur	4060	2074	2025
Lower Irkhuwa Hydropower Co. Pvt. Ltd.	Lower Irkhuwa	Shojpur	13040	2075	2026
Lower Mid Rawa Khola Hydropower Project Pvt. Ltd.	Lower Mid Rawa	Khotang	4000	2080	2031
Mabilung Energy (P) Ltd	Upper Piluwa Khola -3	Sankhuwasa bha	4950	2075	2026
Madame Khola Hydropower Pvt. Ltd.	Madame Khola	Kaski	24000	2075	2026
Madhya Midim Jalbidhyut Company P. Ltd.	Middle Midim	Lamjung	4800	2079	2030
Madhya Tara Khola Hydropower P. Ltd. (Prv. Pahadi Hydro Power Company (P.) Ltd.)	Madhya Tara Khola Small	Baglung	2200	2073	2024
Makar Jitumaya Hydropower Pvt. Ltd.	Upper Suri	Dolakha	7000	2075	2026
Makari Gad Hydropower Pvt. Ltd.	Makarigad	Darchula	10000	2072	2023
Manang Marsyangdi Hydropower Company Pvt. Ltd.	Manang Marsyangdi	Manang	135000	2077	2028
Masina Paryatan Sahakari Sanstha Ltd.	Masina	Kaski and Tanahu	891	2075	2026
Mathillo Mailung Khola Jalbidhyut Ltd.	Upper Mailun	Rasuwa	14300	2068	2023

Maulakalika Hydropower Company Pvt. Ltd.	Kalika Kaligandaki	Tanahu	38160	2079	2030
Maya Khola Hydropower Co Pvt. Ltd.	Maya Khola	Sankhuwasabha	14900	2070	2023
Melamchi Hydro Pvt.Ltd.	Ribal khola	Sindhupalchowk	998	2078	2029
Menchhiyam Hydropower Co.Ltd.	Upper Piluwa Khola 2	Sankhuwasabha	4720	2075	2026
Mewa Developers Pvt. Ltd	Siwa Khola	Taplejung	9300	2079	2030
Mewa Developers Pvt. Ltd.	Middle Mewa	Taplejung	73500	2075	2026
Middle Bhotekoshi Jalbidhyut Company Ltd.	Middle Bhotekoshi	Sindhupalchowk	102000	2068	2023
Milarepa Energy Pvt. Ltd.	Super Melamchi khola	Sindhupalchowk	23600	2080	2031
Milke Jaljale Hydropower Pvt.Ltd	Upper Piluwa Hills	Sankhuwasabha	4990	2075	2026
Modi Jalvidhyut Company Ltd.	Upper Modi 'A'	Kaski	42000	2080	2031
Moonlight Hydropower Pvt. Ltd.	Balephi A	Sindhupalchowk	22140	2077	2028
Mount Everest Power Development Pvt. Ltd.	Dudhkunda Khola	Solukhumbu	12000	2075	2026
Mount Nilgiri Hydropower Company Pvt. Ltd.	Rurubanchu-1	Kalikot	13500	2074	2025
Mount Rasuwa Hydropower Pvt. Ltd.	Midim 1 Khola	Lamjung	13424	2075	2026
Multi Energy Development Pvt. Ltd.	Langtang Khola	Rasuwa	20000	2072	2023

Myagdi Hydropower Pvt. Ltd.	Ghan Khola	Myagdi	14000	2073	2024
Nama Buddha Hydropower Pvt. Ltd.	Tinau Khola Small	Palpa	1665	2065	2023
Nasa Hydropower Pvt. Ltd.	Lapche Khola	Dolakha	99400	2074	2025
National hydro Power Co. Ltd.	Tallo Indrawati	Sindhupalch owk	4153	2079	2030
Nepal Water and Energy Development Company Pvt. Ltd.	Upper Trishuli 1	Rasuwa	216000	2074	2025
Nilgiri Khola Hydropower Co. Ltd.	Nilgiri Khola	Myagdi	38000	2073	2024
Nilgiri Khola Hydropower Co. Ltd.	Nilgiri Khola 2 Cascade	Myagdi	71000	2074	2025
North Summit Hydro Pvt. Ltd.	Nyadi Phidi	Lamjung	21400	2075	2026
Nyam Nyam Hydropower Company Pvt. Ltd.	Nyam Nyam Khola	Rasuwa	6000	2074	2025
Omega Energy Developer Pvt. Ltd.	Sunigad	Bajhang	11050	2074	2025
Orbit Energy Pvt. Ltd	Sabha Khala C	Sankhuwasa bha	4196	2075	2026
Orbit Energy Pvt. Ltd. (Previously Pokhari Hydropower Company Pvt. Ltd.)	Sabha Khola B	Sankhuwasa bha	15100	2074	2025
Paan Himalaya Energy Private Limited	Likhu-1	Solukhumbu / Ranechap	51400	2071	2023
Palum Khola Hydropower Pvt Ltd.	Palum Khola	Taplejung	21000	2075	2026
Parbat Paiyun Khola Hydropower	Set Khola	Parbat	3500	2074	2025

Company Pvt Ltd.					
Peoples Energy Ltd. (Previously Peoples Hydro Co-operative Ltd.)	Khimti-2	Dolakha and Ramechhap	48800	2072	2023
Peoples Hydropower Company Pvt. Ltd.	Super Dordi "Kha"	Lamjung	54000	2071	2023
Perfect Energy Development Pvt. Ltd	Middle Trishuli Ganga	Nuwakot	19410	2075	2026
Phedi Khola Hydropower Company Pvt. Ltd.	Phedi Khola (Thumlung)	Bhojpur	3520	2075	2026
Pike Hydropower Pvt. Ltd.	Likhu Khola	Ramechhap and Okhaldunga	30000	2075	2026
Puwa Khola-1 Hydropower Pvt. Ltd.	Aayu Malun khola	Okhaldhung a	21000	2078	2029
Raghuganga Hydropower Ltd.	Rahughat	Myagdi	40000	2075	2024
Rapti Hydro and General Construction Pvt. Ltd	Rukumgad	Rukum	5000	2073	2024
Rara Hydropower Development Co. Pvt. Ltd.	Upper Parajuli Khola	Dailekh	2150	2069	2023
Rasuwa Hydropower Pvt. Ltd	Phalanku Khola	Rasuwa	7290	2071	2023
Reliable Hydropower Co. Pvt. Ltd.	Khorunga Khola	Terhathum	4800	2069	2023
Research and Development Group Pvt. Ltd.	Rupse Khola	Myagdi	4000	2071	2023
Ridge Line Energy Pvt. Ltd	Super Chepe	Gorkha Lamjung	9050	2075	2026

Rising Hydropower Compnay Ltd.	Selang Khola	Sindhupalchowk	990	2069	2023
River Falls Hydropower Development Pvt. Ltd.	Down Piluwa	Sankhuwasabha	10300	2071	2023
River Side Hydro Energy Pvt Ltd.	Tamor Khola-5	Taplejung	37520	2075	2026
Ruby Valley Hydropower Company Ltd	Menchet Khola	Dhading	7000	2075	2026
Ruru Hydroelectric Company Pvt. Ltd.	Rurubanchu Khola-2	Kalikot	12000	2075	2026
S.K Energy Development Pvt. Ltd.	Shyam Khola	Bhojpur	7200	2079	2030
Sabha Pokhari Hydro Power (P.) Ltd.	Lankhuwa Khola	Sankhuwasabha	5000	2074	2025
Sailung Power Company Pvt. Ltd.	Bhotekoshi-1	Sindhupalchowk	40000	2075	2026
Sajha Power Development Pvt Ltd.	Lower Balephi	Sindhupalchowk	20000	2075	2026
Salankhu Khola Hydropower Pvt. Ltd.	Salankhu Khola	Nuwakot	2500	2069	2023
Salasungi Power Limited	Sanjen Khola	Rasuwa	78000	2072	2023
Samyukta Urja Pvt. Ltd.	Thulo Khola	Myagdi	21300	2075	2026
Sangrila Urja Pvt. Ltd.	Chhujung Khola	Sankhuwasabha	63000	2079	2030
Sani Bheri Hydropower Co. Pvt. Ltd	Sani Bheri 3	Rukum	46720	2078	2029
Sanigad Hydro Pvt. Ltd.	Upper Kalangagad	Bajhang	38460	2072	2023
Sanima Hydropower Ltd.	Jum Khola	Dolakha	56000	2080	2031

Sanima Middle Tamor Hydropower Ltd. (Prv. Tamor Sanima Energy Pvt. Ltd.)Sanima Energy Pvt. Ltd.)	Middle Tamor	Taplejung	73000	2073	2024
Sanjen Hydropower Co.Limited	Upper Sanjen	Rasuwa	14800	2068	2023
Sanjen Hydropower Co.Limited	Sanjen	Rasuwa	42,500	2068	2023
Sankhuwasabha Power Development Pvt. Ltd.	Super Sabha Khola	Sankhuwasabha	4100	2075	2026
Sano Milti Khola Hydropower Ltd.	Sano Milti	Ramechhap and Dolakha	3000	2073	2024
Sanvi Energy Pvt. Ltd.	Jogmai Cascade	Illam	6000	2075	2026
Saptang Hydro Power Pvt. Ltd.	Saptang Khola	Nuwakot	2500	2074	2025
Sasha Engingeering Hydropower (P). Ltd	Khani Khola(Dolakha)	Dolakha	30000	2069	2023
Seti Khola Hydropower Pvt. Ltd.	Seti Khola	Kaski	22000	2074	2025
Sewa Hydro Ltd.	Lower Selang	Sindhupalchowk	1500	2074	2025
Shaileshwari Power Nepal Pvt. Ltd.	Upper Gaddigad	Doti	1550	2075	2026
Shikhar Power Development Pvt. Ltd.	Bhim Khola	Baglung	4960	2075	2026
Siddhi Hydropower Company Pvt. Ltd.	Siddhi Khola	Illam	10000	2074	2025
Silk Power (Prv. Maa Shakti	Luja Khola	Solukhumbu	24824	2075	2026

Engineering & hydropower					
Simkosh Hydropower Pvt. Ltd.	Simkosh Khola	Myagdi	3450	2079	2030
Sindhujwala Hydropower Ltd.	Upper Nyasem	Sindhupalchowk	41400	2073	2024
Sindhujwala Hydropower Ltd.	Upper Nyasem Khola A	Sindhupalchowk	21000	2075	2026
Sisa Hydro Electric Company Pvt. Ltd.	Sisa Khola A	Solukhumbu	2800	2073	2024
Sita Hydro Power Co. Pvt. Ltd.	Nyasim Khola	Sindupalchowk	35000	2075	2026
Sita Hydropower Co. Pvt. Ltd.	Dudh Khola	Manang	65000	2075	2026
Siuri Nyadi Power Pvt. Ltd.	Super Nyadi	Lamjung	40270	2074	2025
Snow Rivers Pvt. Ltd.	Super Kabeli A	Taplejung	13500	2075	2026
Summit Energy Solution Pvt. Ltd	Bakan Khola	Sankhuwasabha	44000	2079	2030
Super Bagmati Hydropower Pvt. Ltd.	Super Tallo Bagmati	Lalitpur	41314	2080	2031
Super Ghalemdi Hydropower Pvt. Ltd.	Super Ghalemdi	Myagdi	9140	2075	2026
Super Hewa Power Company Pvt. Ltd.	Super Hewa	Sankhuwasabha	6000	2074	2025
Super Khudi Hydropower Pvt. Ltd.	Upper Khudi	Lamjung	21210	2076	2027
Super Madi Hydropower Ltd. (Previously Himal Hydro and General	Super Madi	Kaski	44000	2073	2024

Construction Ltd.)					
Suryakunda Hydroelectric Pvt. Ltd.	Upper Tadi	Nuwakot	11000	2068	2023
Sushmit Energy Pvt. Ltd.	Kunaban Khola	Myagdi	20000	2075	2026
Syarpu Power Company Limited	Syarpu Khola	Rukum	3236	2078	2029
Tallo Midim Jalbidhut Company Pvt. Ltd.	Lower Midim	Lamjung	996	2070	2023
Tamor Sanima Energy Pvt. Ltd.	Upper Tamor	Taplejung	255281	2079	2030
Tanahun Hydropower Ltd.	Tanahun	Tanahun	140000	2075	2026
Tangchhar Hydro Pvt. Ltd	Tangchhahara	Mustang	2200	2070	2023
Terhathum Power Company Ltd.	Khorunga-Tangmaya	Terhathum	2000	2079	2030
Thulo Khola Hydropower Pvt. Ltd.	Upper thulo Khola-A	Myagdi	22500	2075	2026
Trishuli Jal Vidhyut Company Ltd.	Upper Trishuli 3B	Rasuwa	37000	2074	2024
Tundi Power Pvt.Ltd	Rahughat Mangale	Myagdi	35500	2075	2026
Tundi Power Pvt.Ltd	Upper Rahughat	Myagdi	48500	2075	2026
Union Mewa Hydro Ltd.	Mewa Khola	Taplejung	23000	2075	2026
Unitech Hydropower Co. Pvt. Ltd.	Upper Phawa	Taplejung	5800	2074	2025
United Mewa Khola Hydropower Pvt. Ltd.	Mewa Khola	Taplejung	50000	2074	2025

United Modi Hydropwer Ltd.	Lower Modi 2	Parbat	10500	2072	2023
Upper Lohore Khola Hydropower Co. Pvt. Ltd.	Upper Lohore	Dailekh	4000	2074	2025
Upper Myagdi Hydropower Pvt. Ltd. (Prv. Himalayan	Upper Myagdi -1	Myagdi	53500	2080	2031
Upper Richet Hydropower Pvt. Ltd.	Upper Richet	Gorkha	2000	2074	2025
Upper Syange Hydropower Limited	Dovan khola	Gorkha	24500	2080	2031
Vision Energy and Power Pvt. Ltd.	Nupche Likhu	Ramechhap	57500	2074	2025
Vision Lumbini Ltd.	Seti Nadi	Kaski	25000	2075	2026
Vokano Hydropower Pvt. Ltd.	Teliya Khola	Dhankuta	996	2069	2023
Water and Energy Nepal Pvt. Ltd.	Bad Gad	Baglung	6600	2068	2023
Water Energy Development Pvt. Ltd.	Machha Khola	Gorkha	16000	2080	2031
Water Energy Solution Pvt. Ltd.	Upper Deumai	Ilam	8300	2079	2030
White Flower Energy Company Pvt. Ltd.	Upper Chhujung	Sankhuwasa bha	40700	2079	2030
White Lotus Power Pvt.Ltd.	Hidi Khola	Lamjung	6820	2079	2030
Yambling Hydropower Pvt. Ltd.	Yambling Khola	Sindhupalch owk	7270	2072	2023
Yaru Hydropewer Pvt. Ltd.	Yaru Khola	Gorkha	30542	2080	2031
Source: Nepal Electricity Authority					

Appendix C Expected Future Installed Capacity

Year	Total Additional Installed Capacity (MW)	Total Additional Energy (GWh)	Total Additional Installed Capacity (KW)
2023	1173.434	6270.36	1173434
2024	416.96	2228.07	416960
2025	917.423	4902.34	917423
2026	1761.71	9413.87	1761710
2027	47.975	256.36	47975
2028	157.14	839.69	157140
2029	142.504	761.48	142504
2030	726.238	3880.73	726238
2031	546.815	2921.96	546815

Appendix D Weighted Average Method Electricity Demand Forecast and WECS forecast

Year	Final Electricity Demand (GWh)						
	Forecasted Generation (GWh)	BAU 4.5%	Reference Scenario 7.2 %	High Scenario 9.2%	Policy Intervention @ 7.2%	Policy Intervention @ 9.2%	Weighted Average Method Demand (GWh)
2023	19014.27	10839.25	12162.47	13336.69	19407.38	20680.75	10261.54
2024	21242.33	11918.75	13513.07	14941.27	20919.53	22472.90	11908.97
2025	26144.67	**12998.25**	**14863.67**	**16545.84**	**22431.68**	**24265.05**	13820.90
2026	35558.55	14413.37	16882.29	19209.49	25012.28	27665.00	16039.77
2027	35814.91	15828.48	18900.92	21873.14	27592.87	31064.96	18614.87
2028	36654.60	17243.60	20919.54	24536.79	30173.47	34464.91	21603.39
2029	37416.08	18658.72	22938.17	27200.44	32754.06	37864.87	25071.70
2030	41296.81	**20073.83**	**24956.79**	**29864.09**	**35334.66**	**41264.82**	29096.83
2031	44218.77	22008.01	28107.39	34487.90	38622.10	46143.36	33768.18

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