NEPAL
MINISTRY OF ENERGY, WATER RESOURCES AND IRRIGATION

PROJECT
ON
INTEGRATED POWER SYSTEM
DEVELOPMENT PLAN
IN NEPAL

FINAL REPORT
Executive Summary

December 2024

Japan International Cooperation Agency

NEWJEC Inc.
Deloitte Tohmatsu Financial Advisory LLC
Kansai Transmission and Distribution, Inc.

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1. INTRODUCTION

1.1 BACKGROUND

The Nepal has abundant hydropower resources, with an estimated hydropower of 83GW and an economically viable hydropower of 42GW. GoN (Government of Nepal) formulated policy papers such as "Action Plan on Crisis Prevention of National Energy and 10 years, Hydropower development (2016)" and "Energy, Water Resources and Irrigation's Sector's Status and Roadmap for the Future" (commonly known as, "White Paper" in 2018) and has decided to make power development as a highly priority with a clear intention to accelerate the power development. On the other hand, the amount of development achieved is still behind the targets set by various policies. Load shedding due to insufficient supply capacity had continued until the mid-2010s. The supply and demand situation has been drastically improved owed to increase of electricity supply by import from India since 2016. However, power generation development has not progressed and Nepal has continued to rely on electricity import particularly during the dry season. The share of electricity imports reached 21.8% in 2019/20 and the outflow of foreign currency became a major issue in Nepal.

In this context, new power plants that have been under development such as Upper Tamakoshi (456 MW) began operations since 2021. Installed hydropower capacity increase 1,446.8 MW in 2021 and 2,685 MW in 2023, showing remarkable growth in recent years. In 2023, the annual power generation reached to 11,026 GWh against a domestic electricity demand of 11,546 GWh. Power imports during the dry season accounted for 1,855 GWh (15% of domestic demand), while power exports during the rainy season reached 1,333 GWh, bringing imports and exports closer to balance. Financially, NEA (Nepal Electricity Authority) has improved financial conditions and increased profits owed to the opportunity to export electricity to India since 2019. These developments are the result of the past decade of efforts and this growth is expected to continue for the next few years.

It is also important to note that Nepal still has considerable development potential and there remains a significant gap with the hydropower target of 15,000 MW by 2030 as outlined in policies such as the White Paper. Its factors are expensive costs of power generation facilities and transmission line facilities due to steep mountain terrain, constrain of national credit capability and investment capability, inadequacy of private investment utilization institution, unplanned issues of construction licenses to IPP (Independent Power Producer), poor collaboration among government, regulating agencies related to power development and power authority and so on. Also, it is issuing that comprehensive long-term power development plan which shall be shared by relevant agencies including IPP.

In order to develop power supply system systematically it is necessary that MoEWRI (Ministry of Energy, Water Resources and Irrigation) who has jurisdiction over National Energy policy shall formulate "IPSDP (Integrated Power System Development Plan)" which covers power generation method, priority of power development, scale and timing of power development, procurement method of financial resources, investment plan including sharing role between private and public funds in collaboration with JICA (Japan International Cooperation Agency).

1.2 OBJECTIVES

Objectives of IPSDP are to indicate the vision and target until 2040 to achieve stable domestic power supply and power export to neighboring countries by the development of clean energy.

1.3 BASIC APPROACHES ON IPSDP

Based on the background and objectives, the basic approaches of 3E (Energy security, Economy and Environment) + Policy on IPSDP are described as follows;

Energy Security

- *to achieve the reliable electric power supply by domestic primary energy*
- *to contribute to realize the stable power supply through the interactive and flexible power trade*

Economy :Reduction of Financial Burden and Economic Growth

- *to establish the electricity tariff at a lower financial burden*
- *to grow up the economy and earn foreign currency through the power trade*

Environment :Environmental and Social Considerations

- *to ensure that the development is acceptable and affordable to the social and ecological environment*
- *to contribute to the reduction of CO_2 emission with the supply of clean energy*

Policy : In line with the policies in the power sector

- *to be consistent with "Energy Development Roadmap and Work Plan" prepared by MoEWRI in 2023 under approval by Cabinet.*
- *to be aligned with this policy which indicates the target of hydropower development 28GW in 2035 and 86 work plans in comprehensive fields of power sector.*

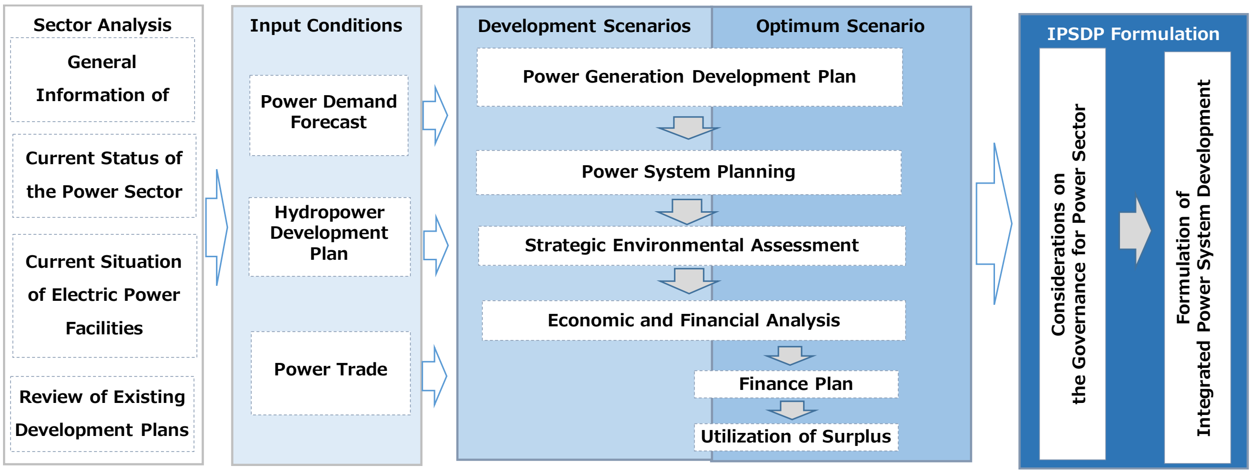
Currently, the MoEWRI is developing the "Energy Development Roadmap and Work Plan 2035" as its energy policy up to 2035 which is under discussion by the cabinet. This roadmap sets the development goals by 2035 to include a power demand consumption of 40,710 GWh (3.4 times increase), total power generation capacity of 28,713 MW (10.2 times increase), transformer capacity of 40,000 MVA (4.5 times increase), and power exports of 15,000 MW (23.7 times increase). 85 work plans are proposed in four areas: "1. Improvement of the legal system", "2. Capacity development for GoN", "3. Promotion of infrastructure development" and "4. Establishment of business function on power market". It is necessary for IPSDP to align with such higher-level policies, particularly considering the achievement of the goals set forth in this Energy Development Roadmap and Work Plan.

2. IPSDP

2.1 OUTLINE OF IPSDP

Outline of studies for IPSDP are;

- to clarify the situation of power demand forecast, hydropower development plan and power trade with neighboring countries based on power sector analysis,
- to prepare Development Scenarios which indicate the direction of development on power sector involving PGDP (Power Generation Development Planning), PSP (Power System Planning), SEA (Strategic Environmental Assessment) and economic and financial analysis
- to select Optimum Scenario from comparison of Development Scenario and update it as the main body of IPSDP considering comprehensive perspectives of power trade with neighboring countries, finance plan for investment and energy transition and
- to formulate IPSDP as the middle and long term development plan which indicates "Vision" and "Target" of power sector in Nepal.



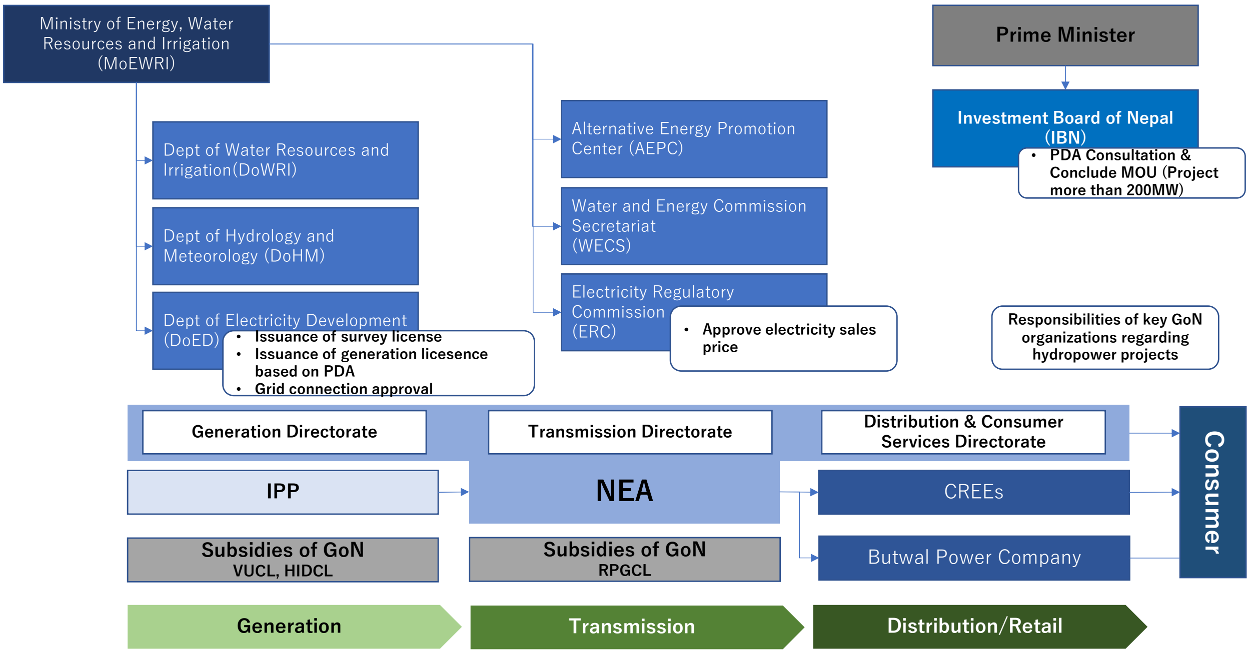
Source: JICA Study Team

Figure 2.1-1 Flowchart of IPSDP Studies

2.2 BASIC UNDERSTANDINGS OF THE DEVELOPMENT IN POWER SECTOR

2.2.1 Organizational Structure of the Power Sector

Figure 2.2-1 shows the structure of the power businesses in Nepal. Among the administrative bodies involved in the power sector in Nepal are MoEWRI, which is responsible for policies and laws related to energy development and use, DoED (Department of Electricity Development), a unit of the ministry, which is responsible for issuing licenses for power generation businesses, ERC (Electricity Regulatory Commission), which regulates and supervises power businesses, including PPA (power purchase agreement) and retail tariffs, WECS (Water and Energy Commissions) and AEPC (Alternative Energy Promotion Center).



Source: JICA Study Team

Figure 2.2-1 Structure of Power Businesses in Nepal

The country's electricity business has a vertically integrated structure, with NEA handling generation, transmission and distribution of electricity. In the generation sector, however, many IPPs have entered the market under the Electricity Act of 1992.

Other government organizations in the power sector include RPGCL (Rastriya Prasaran Grid Company Limited), VUCL (Vidhyut Utpadan Co., Ltd.), and HIDCL (Hydroelectricity Investment and Development Company Ltd.). Additionally, organizations closely related to the power sector include IBN (Investment Board of Nepal) and IPPAN (Independent Power Producers' Association, Nepal). It is important for IPSDP to proceed with discussions in collaboration with these related organizations.

2.2.2 Involvement of Existing and On-going Power Development Plans in the Power Sector

Various DPs (Development Partners) have supported development studies and planning for the power sector in Nepal. In addition, WECS, RPGCL and NEA have also formulated their development plans, leading to a situation where numerous plans coexist. IPSDP shall involve them shown in Table 2.2-1 as a foundation of studies and guidance of the direction of future overviews.

Table 2.2-1 Major Policies and Development Plans in the Power Sector

Field	Name	Date[1]	Agency	Assistance
Power Sector	Nationwide Master Plan Study on Storage-type Hydroelectric Power Development	2014	NEA	JICA
	Review in Data Collection Survey on Hydropower Development Project	2018	NEA	JICA
	Irrigation Master Plan	2019	DWRI	ADB
	Hydropower Potential of Nepal	2019	WECS	-
	World Bank/WECS: Preparation of River Basin Plans and Hydropower Development Master Plans and Strategic Environmental and Social Assessment	2024	WECS	WB
Power System	Transmission System Development Plan of Nepal	2018	RPGCL	
	The Distribution System/Rural Electrification Master Plan of Nepal	2022	NEA	ADB

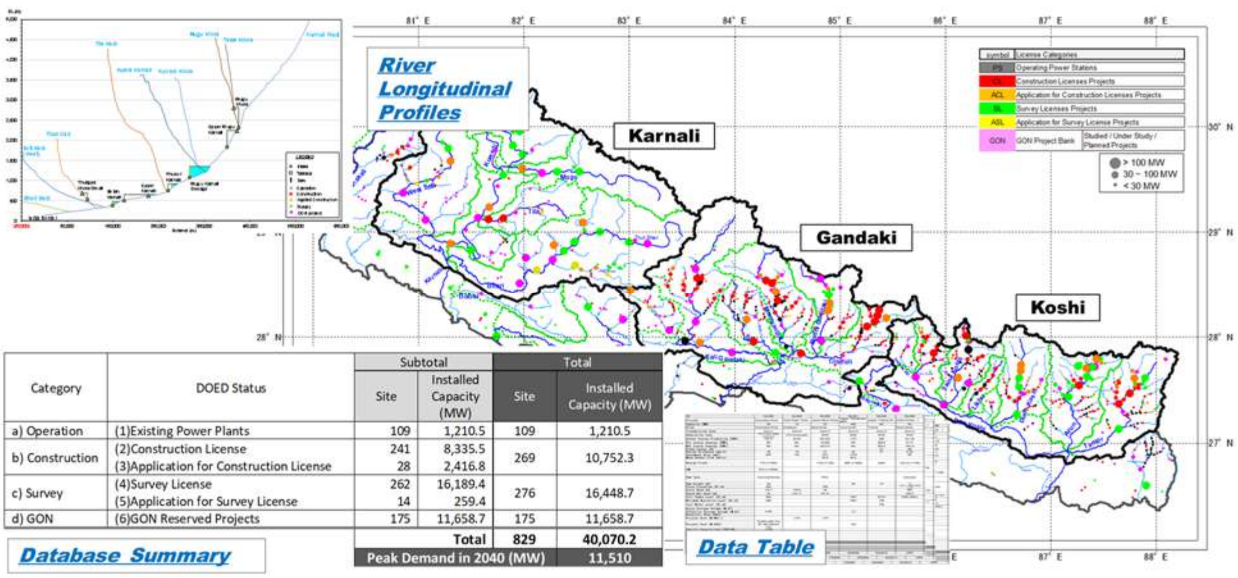
Source: JICA Study Team

2.2.3 Hydropower Development Plan

Hydropower is unique power sources which output and annual power generation are depended on natural conditions at project sites. Therefore, accuracy of these information directly affects to the quality of power generation development planning and power system planning in Nepal where hydropower is majority of the power sources. DoED of MoEWRI has been authorized to manage administrative process of generation and transmission projects over 1MW and more such as survey, construction and operation. The DoED Project list is widely recognized as the development list of generation and transmission and is assumed to be a reliable information source which is regularly updated by DoED Including the GoN Projects, the list covers almost all of identified hydropower potential in Nepal. Based on the progress of development, the projects are classified into the categories of a) Operation, b) Construction (Construction License and Application for Construction License), c) Survey (Survey License and Application for Survey License) and d) GoN. Information of irrigation and large storage hydropower projects which are excluded from DoED is also collected as much as possible.

In this study, key information such as coordinates of site, power planning, hydrological information, salient features of facilities, accessibility, environmental and social considerations and project cost are collected. Finally, hydropower database is developed including the inventory of basic information, GIS (Geographic Information System) map and river profiles (Figure 2.2-2).

[1] All dates taking effect are per the Western calendar system.



Source: JICA Study Team

Figure 2.2-2 Outline of Hydropower Database

Based on the results of considerations in this Section, lessons for power generation development planning are shown in Table 2.2-2.

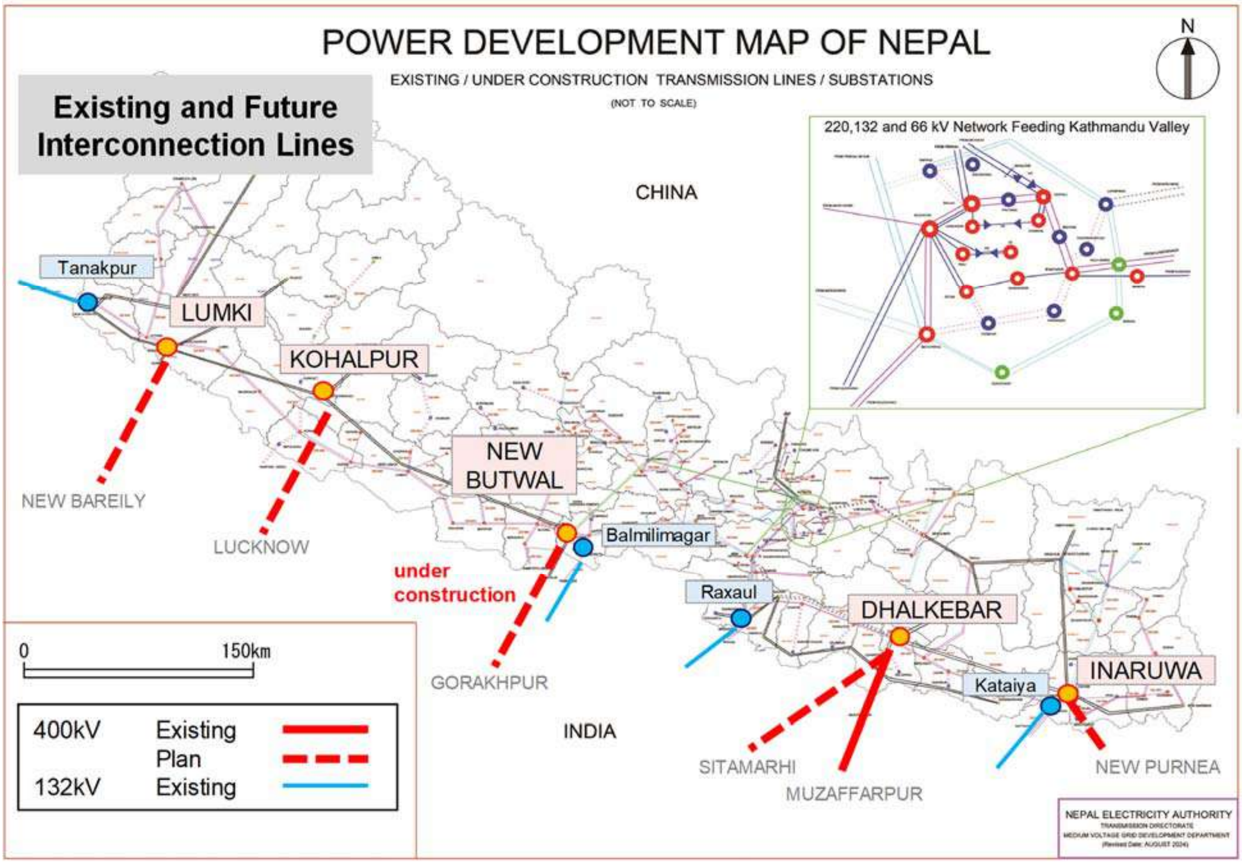
Table 2.2-2 Lessons for Power Generation Development Planning

Item	Lessons
Development Capacity (MW)	➢ The installed capacity of the DoED Project List is updated to 40,070.2 MW (829 sites) based on the information collected. It exceeds domestic power demand of 11,510MW in 2040. ➢ In addition to the consideration of significant drop of power generation in dry season, it is also important to take into account the power export in order to set appropriate development capacity.
Annual Power Generation (GWh)	➢ Power generation of ROR (Run of River), PROR (Peaking Run of River) and STO (Storage) in dry season falls to about 32.6% of the total in wet season. It is important to utilize reservoir and cascade operations but it is still difficult to resolve the difference and planning should be based on these seasonal fluctuations. ➢ Based on past experience, the annual power generation in a drought year falls by approximately 20% from the design value. Thus, it is necessary to set an appropriate reserve margins to ensure supply reliability. ➢ With regard to the amount of power generation, development of only b) Construction will require electricity imports except June, July and August. If c) Survey is developed, the shortfall will be largely eliminated. Finally, if GoN is also developed, it will be possible to supply electricity on its own, including during drought years. ➢ If hydropower is developed, surplus electricity will need to be exported, mainly during the rainy season. If not developed, the shortfall will need to be imported, mainly during the dry season.
Levelized Cost of Energy (cents/kWh)	➢ The average LCOE (Levelized Cost of Energy) are ROR: 4.0 cents/kWh, PROR: 5.0 cents/kWh and STO: 9.2 cents/kWh which are competitive power sources compared to thermal power plants, even taking into account the increase of project costs. ➢ NEA wholesale price for domestic consumers (8.2 cents/kWh) and the Indian electricity market IEX wholesale price (5.0 cents/kWh) are above LCOE of most of sites. ➢ In addition to domestic supply, it is necessary to consider power export to neighboring countries such as India and Bangladesh. It is also required to maximize values of hydropower and improve wholesale economics, such as improving day and year round regulating capacity.

Source: JICA Study Team

2.2.4 Power Trade

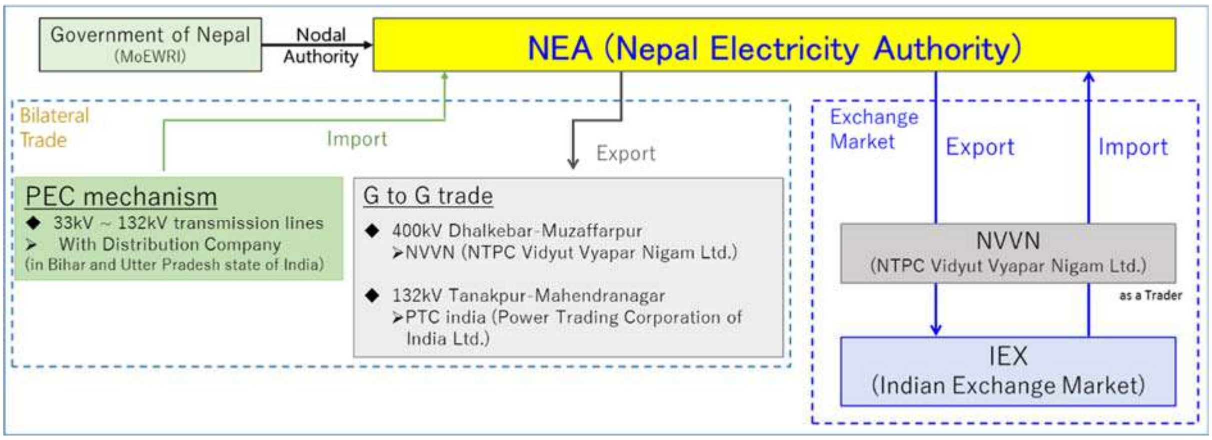
Figure 2.2-3 shows the current status and future plans for interconnection lines. Nepal has been exchanging electricity with India, and there are interconnection lines between Nepal and India such as 400kV Dhalkebar - Muzaffarpur transmission line, 132kV, 33kV and 11kV transmission lines. Each interconnection line is used for both imports and exports. There are plans to construct five(5) 400kV interconnection lines between Nepal and India for 2040.



Source: JICA Study Team based on NEA documents

Figure 2.2-3 Current Status and Future Plans for Interconnection Lines

Nepal trades electricity almost exclusively with India, either through Bilateral trade or through the IEX (Indian Exchange Market). With regard to power imports from India, Nepal is importing power through long-term contracts with NVVN (NTPC Vidyut Vyapar Nigam Ltd.) based on India's power trading guidelines and through IEX. On the other hand, the Day Ahead Market in IEX is the main source of income for power export, however, in order to secure stable income for power development, medium- and long-term PPAs with future price prospects are needed.



Source: JICA Study Team

Figure 2.2-4 Current Power Trade Scheme between Nepal and India

2.3 THE STUDY FOR DEVELOPMENT SCENARIOS

In this Section, Development Scenarios for the power generation mix are developed and the direction of the power sector is considered based on several perspectives, including the legal systems, policies, natural conditions, current status of primary energy.

2.3.1 Direction of Development Scenarios

Based on the results and analysis on Section 2.2, the following approaches are assumed to be important for the study of the future power generation mix. Several Development Scenarios will be composed with obvious concepts in order to explore the direction of the power sector in which Nepal aims based on 3E (Energy Security, Economy and Environment) + Policy.

- PGDP in Nepal will basically be dominated by hydropower and the power generation mix will depend on its possibility to be developed. In other words, the success or failure of hydropower development will determine the direction of the power sector.

- If the hydropower developments on the DoED Project List are fully developed, how much surplus power will be generated compared to electricity demand, whether export is feasible in terms of generation costs, flexibility and timing, and whether financing the development costs is feasible.

- What action will be required if the planned hydropower development is not realized? In case of the shortfall, what is the scale of required amount of power trade imported from neighboring countries, mainly India and how much is necessary for the expense of it?

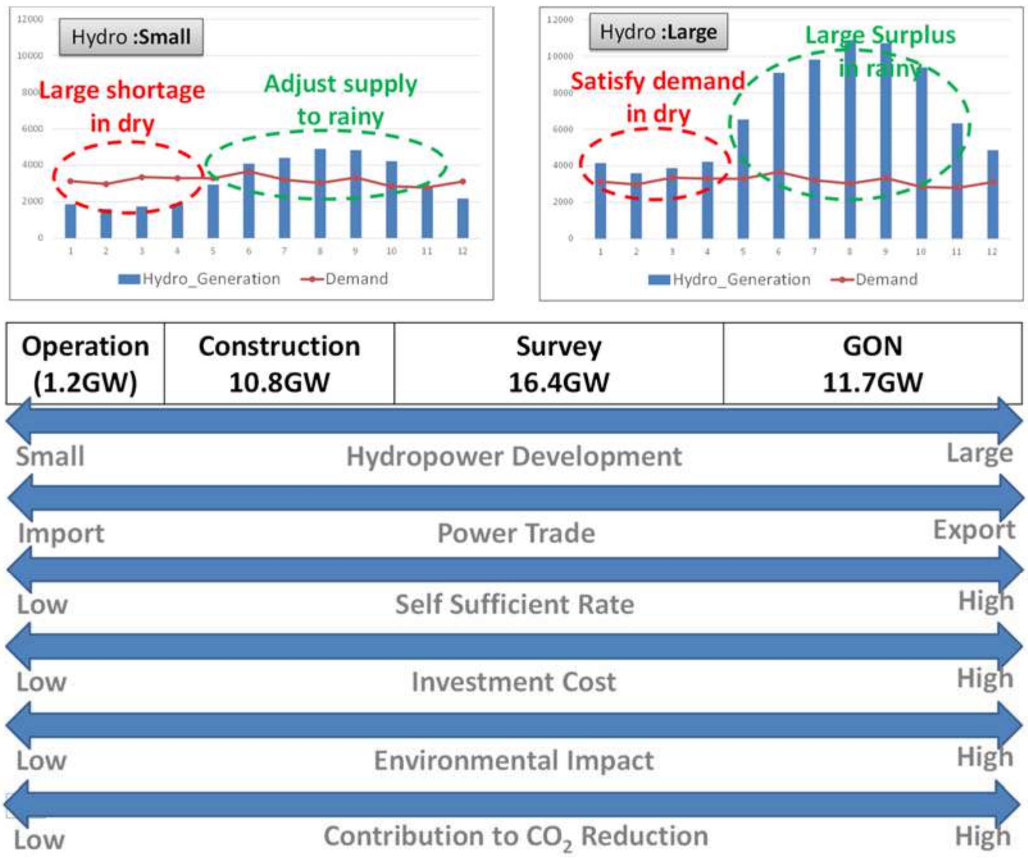
- Will renewable energy such as solar power contribute to the power generation mix? What is the impact on imports and exports in terms of power trade and supply capacity on peak time?

Understandings above imply that the supply and demand of power is balanced by hydropower and power trade in Nepal. Therefore the capacity of hydropower development determine the direction of the power generation development planning.

(i) Development capacity of hydropower is small
- *Hydropower is developed in order to meet peak demand in rainy season*
- *Shortages are supplemented by power import in dry season.*

(ii) Development capacity of hydropower is large
- *Hydropower is developed to meet peak demand in dry season and excessed electricity generated is exported.*

It is important to consider two overall approaches for the future direction: (i) Restrict hydropower development and accept power import in dry season or (ii) Promote hydropower development and power export. It is necessary to recognize the trade-off of hydropower development in amount of power trade, capital investment cost and environmental and social impacts in order to respond growing power demand in Nepal. These concepts are summarized in Figure 2.3-1.



Source: JICA Study Team

Figure 2.3-1 Direction by the Development Capacity of Hydropower[2]

In terms of 3E + Policy, if the development capacity of hydropower is large, energy security is improved owed to the increase of self-sufficiency rated of electric power and export to neighbouring countries. Increase of export also contribute to the economy in Nepal by earning foreign currency and climate change through the reduction of CO_2 emission. At the same time, it is also essential to consider the feasibility of financing, the selection of economically viable projects and negative environmental impacts.

If the development capacity of hydropower does not meet demand, it is necessary to prepare

[2] Operation :Commissioned projects, Construction :Projects holding or applying Construction Licenses, Survey ; Projects holding or applying Survey Licenses and GoN: Projects without Licenses

options to supplement shortages by the introduction of renewable energy or power trade. There are also benefits in terms of environmental impacts and lower capital investment costs in the development with small scale. These impacts need to be assessed from various perspectives in comparison of Development Scenarios.

2.3.2 Setting of Development Scenarios

Four Development Scenarios in PGDP will be set up: Scenario 1: Power Import, Scenario 2: Renewable and Scenario 3: Hydro Middle and Scenario 4: Hydro Maximum. The concepts of these scenarios are as follows.

Table 2.3-1 Setting Conditions of each Scenario

Item	Scenario 1 Power Import	Scenario 2 Renewable	Scenario 3 Hydro Middle	Scenario 4 Hydro Maximum
New Hydropower	a) Operation b) Construction	a) Operation b) Construction	a) Operation b) Construction c) Survey	a) Operation b) Construction c) Survey d) GoN
Renewable Ration against Power Demand (GWh)	10%	25%	10%	10%
Power Trade	Dry :Import Rainy :Export	Dry :Import Rainy :Export	Dry :Import Rainy :Import	Dry :Import Rainy :Import

Source: JICA Study Team

(Scenario 1 :Power Import)
- ✓ **Only committed hydropower projects** with Construction License are developed.
- ✓ Shortage of electricity is supplemented **by import** in dry season. Surplus is partially exported in rainy season.

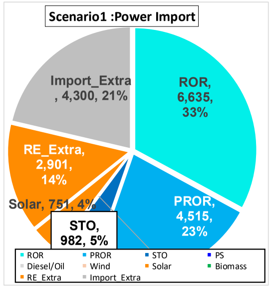
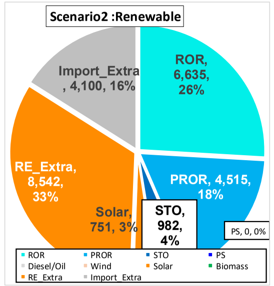
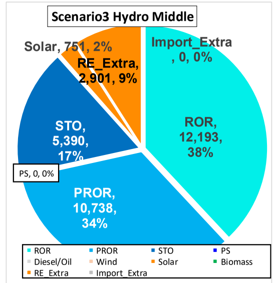
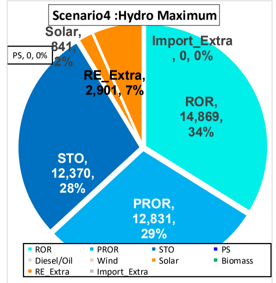
(Scenario 2 :Renewable)
- ✓ **Only committed hydropower projects** with Construction License are developed.
- ✓ Shortage of electricity is supplemented **by import and solar** in dry season. Surplus is partially exported in rainy season.

(Scenario 3 :Hydro Middle)
- ✓ **Committed and promising hydropower projects** with Construction License and Survey License are developed.
- ✓ Surplus electricity is exported. In drought year, it may be necessary to import electricity in dry season.

(Scenario 4 :Hydro Maximum)
- ✓ **All hydropower projects** which are proposed in DOED List are developed.
- ✓ Surplus electricity is exported.

Scenarios 1 and 2 correspond to (i) small hydropower development, setting scenarios when the demand in dry season is supplied by hydropower and power import from India. Scenario 2 increases the introduction of renewable energy compared to Scenario 1 in order to verify whether renewable energy contributes to improvement of the balance between power supply and demand. Scenarios 3 and 4 correspond to (ii) large hydropower development, setting scenarios with power supply throughout the year by hydropower. The scenarios compare the power supply and demand balance, export volumes and investment costs between the developments of hydropower in intermediate or maximum levels. Summary of comparison of Development Scenarios are shown in Table 2.3-2.

Table 2.3-2 Summary of the Evaluation of Development Scenarios

Evaluation Items		Scenario 1 Power Import	Scenario 2 Renewable	Scenario 3 Hydro Middle	Scenario 4 Hydro Maximum
Generation Mix					
		20,158MW	25,599MW	32,048MW	43,887MW
(1) Energy Security	Self Sufficiency Rate of Power Generation (%)	85.4%	99.7%	188.2%	230.1%
	International Issues	Interruption of power imports		Interruption of power exports	
	Grid Stability	None	Impacts by VRE	None	
(2) Economy	Cumulated Investment Cost	19,138 MUSD (1,015MUSD/year)	24,838 MUSD (1,307MUSD/year)	48,345 MUSD (2,544MUSD/year)	70,531 MUSD (3,712MUSD/year)
	Cumulated Balance of Power Trade	7,360MUSD	10,820MUSD	30,366MUSD	41,270MUSD
	Vulnerability for Fuel Cost	Fuel Inflation in India		None	
(3) Environmental and Social considerations	Natural and Social Impacts	Relatively small		Intermediate	Large
	Cumulated CO_2 Emissions (million ton)	69.1 million ton	52.4 million ton	39.5 million ton	44.5 million ton
	CO_2 Emissions Rate ($g\text{-}CO_2$ /kWh)	172.5 $g\text{-}CO_2$/kWh	111.4 $g\text{-}CO_2$/kWh	27.0 $g\text{-}CO_2$/kWh	25.0 $g\text{-}CO_2$/kWh
	Cumulated Reduction of CO_2 Emissions by Power Export (million ton)	169.1 million ton	205.7 million ton	505.7 million ton	684.3 million ton
Policy	Target of 15000MW in 2030	Not achieved		Achieved	
	Introduction of ARE	Achieved			

Source: JICA Study Team

2.3.3 Analysis Results of Development Scenarios and Selection of Optimum Scenario

The future direction of the power generation development planning in Nepal is discussed by comparing each scenario based on 3E + Policy. The results of the comparative study of each Scenario based on 3E + Policy are summarized in Table 2.3-3.

Table 2.3-3 Comparison of Development Scenarios based on 3E + Policy

Scenarios	Considerations
Scenario 1 Power Import	Power Import is assumed to be a feasible Scenario with low capital investment and environmental impact. However, it has low energy self-sufficiency in 2040, supply risks of power import interruptions and cost escalation risks such as fuel inflation. It is also difficult to achieve the goals set out in the policy of power sector.
Scenario 2 Renewable	Renewable as same as Scenario 1, the capital investment cost and environmental impact is relatively lower and the import dependency is also low owed to the generation of renewable energy. On the other hand, it is necessary to include the regulation capacity from neighbouring countries against the intermittency of VRE (Variable Renewable Energy) mainly derived from solar in order to secure the grid stability.
Scenario 3 Hydro Middle	Hydro Middle requires power imports only during February but it is possible to supply power to domestic demand and neighbouring countries even in drought years. Although the capital investment required is high, it is assumed to be feasible in case of power trade promoted. The environmental impact is also significant and measures to reduce the impact based on the results of the SEA are important.
Scenario 4 Hydro Maximum	Hydro Maximum can secure to supply power to domestic demand and neighbouring countries even in the drought year. Compared to Scenario 3, the capital investment and environmental impact would also be very high and feasibility needs to be fully considered.

Source: JICA Study Team

Based on the results of the comparative study of Development Scenarios described above taking into account the evaluation of 3E and consistency with the Policy, Scenario 3: Hydro Middle is selected as the base case for Optimum Scenario which development scale can be optimized.

Direction of future development by IPSDP suggest that basic strategy of power sector is to satisfy the domestic demand in dry season and to export surplus electricity to neighbouring countries in rainy season by domestic clean energy of hydropower and renewable energy.

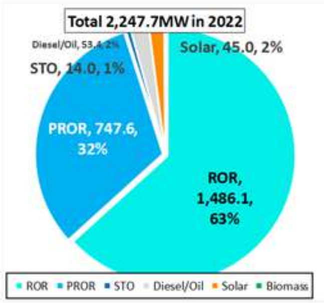
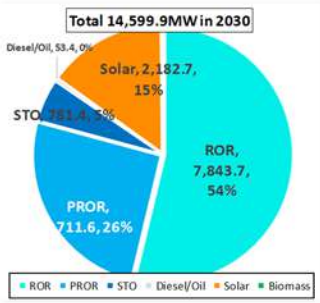
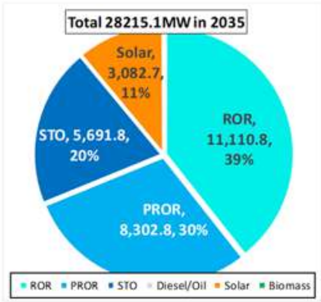
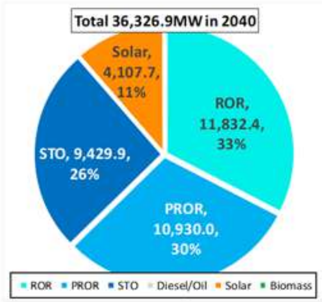
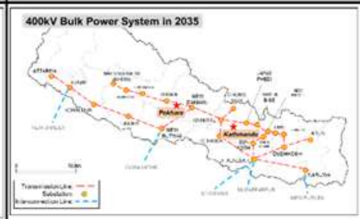
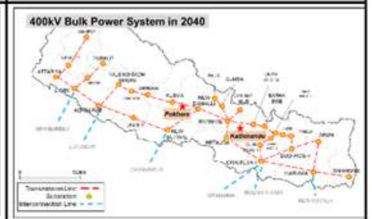
2.4 FORMULATION OF OPTIMUM SCENARIO

This section updates Scenario 3: Hydropower Middle which is selected as the Optimum Scenario and formulates the PGDP, PSP, SEA, economic and financial analysis, financing and utilization of surplus energy in IPSDP. The Optimum Scenario analysis reflects the following updates of three input conditions:

- Power Demand Forecast (Update the input conditions from 2021 to 2023)
- Generation Project List (Update DoED List from May, 2021 to March 2023 and execution of screening of hydropower projects)
- CO_2 Emission Factor of India in Power Trade (820g-CO_2/kWh→716 g-CO_2/kWh)

Analysis results of Optimum Scenario is summarized in and major study items are described below;

Table 2.4-1 Summary of Optimum Scenario

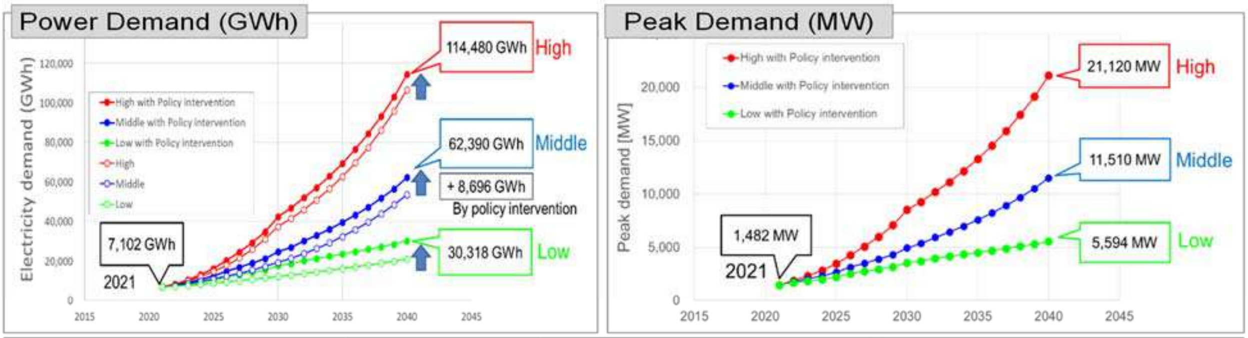
Item	2022/23	2030	2035	2040
Power Demand Forecast				
Power Consumption (GWh)	9,347GWh	24,737GWh	39,638GWh	62,390GWh
Power Demand (MW)	1,986W	4,949MW	7,581MW	11,510MW
Energy Consumption Per capita	320.5kWh/capita	774kWh/capita	1,184kWh/capita	1,779kWh/capita
Power Generation Development Planning				
Installed Capacity				
Annual Power Generation (Power Trade)	10,693GWh (-521GWh)	56,737GWh (25,859GWh)	102,527GWh (55,233GWh)	133,185GWh (61,370GWh)
Self Sufficient Rate	86.3%	183.7%	216.8%	185.5%
CO2 Emission	128.3kg-CO_2/kWh	31.8kg-CO_2/kWh	25.4kg-CO_2/kWh	29.0kg-CO_2/kWh
Power System Planning				
Power System				
Total Length of Transmission Line	400kV 78 km and 220&132kV 4,068km	400kV 1,149 km and 220&132kV 4,988km	400kV 1,818km and 220&132kV 5,563km	400kV 2,487 km and 220&132kV 6,138 km
Total Capacity of Transformer	400kV 945 MVA / 220&132kV 4,917 MVA	400kV 9,625 MVA / 220&132kV 13,317 MVA	400kV 15,050 MVA / 220&132kV 18,567 MVA	400kV 20,475 MVA / 220&132kV 23,817 MVA
Economic and Financial Analysis				
Accumulated Investment (Generation)	-	23,207MUSD	42,642MUSD	53,063MUSD
Accumulated Investment (Transmission)	-	3,573MUSD	5,970MUSD	8,687MUSD
Total Cost	-	26,780MUSD	48,612MUSD	61,750MUSD

Source: JICA Study Team

2.4.1 Power Demand Forecast

The results of the power demand forecast and the per capita electricity consumption (kWh/capita) × GDP (Gross Domestic Product) (USD/capita) comparison for various countries are shown in Figure 2.4-1 and Figure 2.4-2, respectively. The power demand forecast, taking into account various policies such as EV (Electric Vehicle), E-cooking, and SEZ (Special Economic Zones), assumes that the power demand (GWh) and peak demand (MW) will grow from 7,102 GWh and 1,482 MW in 2021 to 62,390 GWh (8.8 times) and 11,510 MW (7.8 times) respectively by 2040.

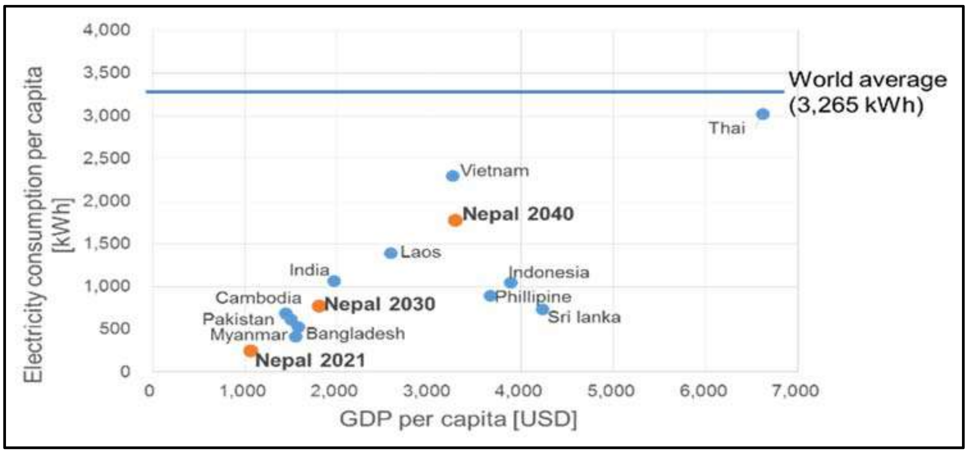
Per capita electricity consumption is expected to grow from 242 kWh/capita in 2021 to 1,779 kWh/capita by 2040. While the growth rate indicates a significant increase, the demand forecast results are generally reasonable and not excessive when compared to the world average of 3,265 kWh/capita and other countries in South Asia and Southeast Asia. It remains necessary to continue efforts to stimulate further demand, such as through industrial development and energy transition.



Middle Case	Unit	Year				
		2021 (Current)	2025	2030	2035	2040
Electricity Consumption	[GWh]	7,102	12,590	24,737	39,638	62,390
Growth rate	%/year	-	10.19	11.25	5.86	5.09
X times of 2021	-	-	1.77	3.48	5.58	8.78
Peak Demand	[MW]	1,482	2,675	4,949	7,581	11,510
Growth rate	%/year	-	15.40	14.49	9.89	9.50
X times of 2021	-	-	1.81	3.34	5.12	7.77
kWh per capita	[kWh/capita]	242	413	774	1,184	1,779
Growth rate	%/year	-	23.12	21.19	10.28	10.50
X times of 2021	-	-	1.71	3.20	4.90	7.37

Source: JICA Study Team

Figure 2.4-1 Power Demand Forecast (Left :Power Demand (GWh), Right :Peak Demand (MW))



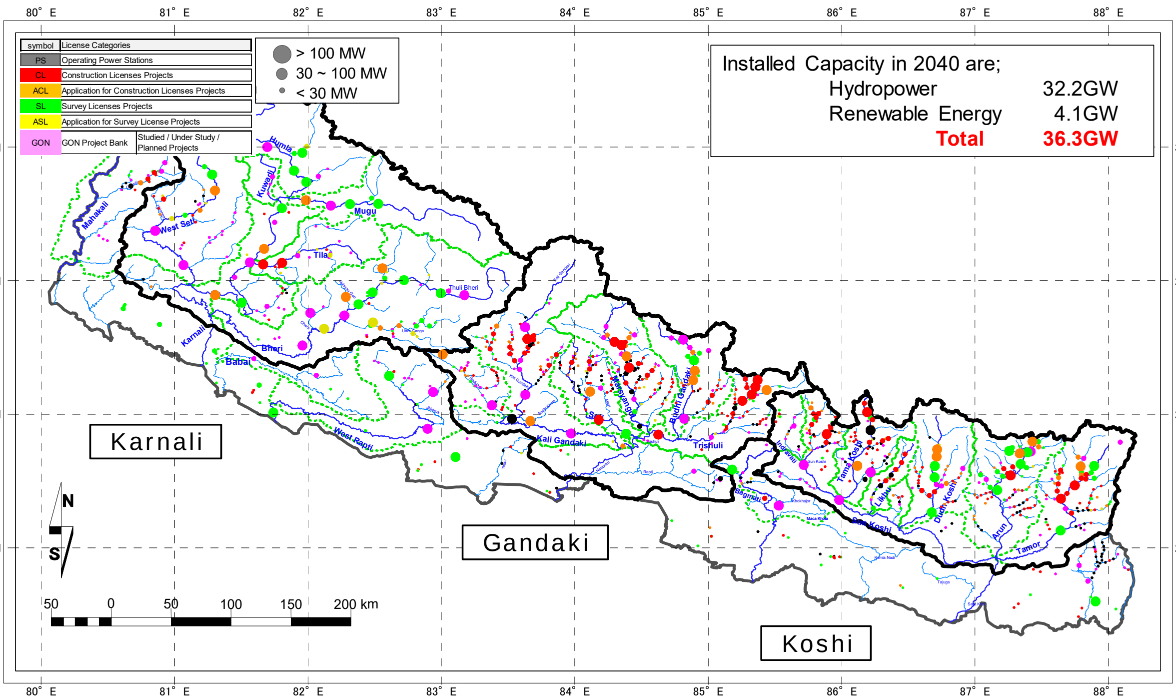
Source: JICA Study Team

Figure 2.4-2 The Relationship Between GDP Per Capita and Electricity Consumption Per Capita for Each Country in South and Southeast Asia

2.4.2 Power Generation Development Planning

(1) Installed Capacity (MW)

PGDP focused on the development of clean energy of hydropower and other renewables, assessed hydropower potential of major river basins in Nepal and clarified required capacity through rainy and dry seasons. The installed capacity, which was 2.7 GW as of 2023, is expected to reach the development target of 28 GW by 2035 as indicated in the Energy Development Roadmap and Work Plan and further increase to 36.3 GW by 2040. The generation mix in 2040 will be as follows: ROR: 13.3 GW (37%), PROR: 10.1 GW (28%), STO: 8.1 GW (23%) and renewable energy: 4.1 GW (12%).



Source: JICA Study Team

Figure 2.4-3 Hydropower Sites and Installed Capacity (GW)

Table 2.4-2 organizes the installed capacity and progress of hydropower development sites in each river basins listed in IPSDP. The gray hatch indicates over 50% completion in categories a) + b), highlighting river systems with substantial progress in operation and construction.

Among the three major rivers, development have been relatively advanced in Gandaki and Koshi rivers. Particularly, Gandaki River with Seti, Marshandhi, and Trishuli has many sites under construction. Conversely, there are many river systems undeveloped such as Karnali River, West Seti River, Bheri River, Dudhkoshi River and Tamor River despite having abundant hydropower potential. These underdeveloped river basin account for 53% of the total development capacity and it is an important and urgent issue to realize the development outlined in IPSDP.

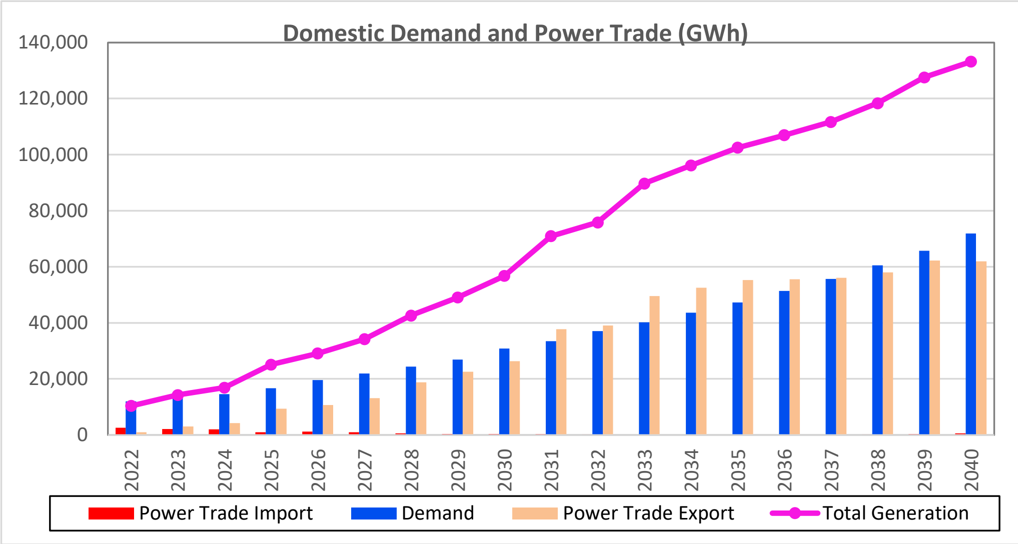
Table 2.4-2 Capacity of Hydropower Development Sites by River System and Progress in IPSDP (MW)

	River	a) Existing (Operation)		b) Committed (Construction)		c) Prioritized (Survery)		d) Optimized (GON)		Total
Karnali	Karnali	11.9	0.2%	1,068.4	22.3%	2,888.5	60.3%	821.1	17.1%	4,789.9
	Tiala Nadi	0.0	0.0%	621.7	83.1%	126.6	16.9%	0.0	0.0%	748.3
	Seti	12.0	0.7%	385.5	22.8%	236.4	14.0%	1,059.0	62.6%	1,692.9
	Bheri	0.0	0.0%	644.3	22.7%	1,569.1	55.4%	618.8	21.8%	2,832.1
Gandaki	Kali Gandaki	217.5	20.8%	819.0	78.5%	6.7	0.6%	0.0	0.0%	1,043.2
	Modi Khola	45.0	20.1%	175.0	78.2%	3.8	1.7%	0.0	0.0%	223.8
	Badigad Khola	7.5	0.6%	898.1	68.0%	35.0	2.7%	380.3	28.8%	1,321.0
	Myagdi Khola	0.0	0.0%	250.7	86.1%	40.4	13.9%	0.0	0.0%	291.0
	Seti Gandaki	94.5	10.0%	621.5	66.0%	225.1	23.9%	0.0	0.0%	941.1
	Marshandi	255.3	13.4%	1,509.8	79.3%	139.7	7.3%	0.0	0.0%	1,904.8
	Budhi Gandaki	13.5	0.6%	950.4	40.6%	174.6	7.5%	1,200.0	51.3%	2,338.4
	Trishuli	134.5	10.1%	1,075.0	80.6%	123.5	9.3%	0.0	0.0%	1,333.0
	Other Tributaries	76.4	76.2%	7.0	7.0%	16.8	16.8%	0.0	0.0%	100.2
Koshi	Sun Koshi	17.5	2.3%	38.5	5.1%	19.3	2.6%	680.0	90.0%	755.3
	Indrawati Nadi	10.5	20.8%	29.1	57.6%	10.9	21.6%	0.0	0.0%	50.4
	Balephi Khola	4.2	1.2%	307.7	89.8%	30.8	9.0%	0.0	0.0%	342.7
	Bhote Koshi	89.3	27.3%	233.4	71.5%	3.7	1.1%	0.0	0.0%	326.3
	Likhu Khola	131.8	33.9%	239.0	61.5%	18.0	4.6%	0.0	0.0%	388.8
	Tama Koshi	603.4	26.2%	1,249.2	54.3%	51.0	2.2%	396.5	17.2%	2,300.0
	Dudh Koshi	27.1	1.2%	857.8	38.9%	971.1	44.0%	350.0	15.9%	2,206.0
	Arun	33.2	1.0%	1,915.9	55.1%	1,525.9	43.9%	0.0	0.0%	3,475.1
	Tamor	95.3	5.2%	1,331.9	73.2%	392.9	21.6%	0.0	0.0%	1,820.2
	Koshi DS	155.5	28.3%	59.3	10.8%	335.0	60.9%	0.0	0.0%	549.8
Other Rivers		173.6	9.1%	309.7	16.3%	1,088.6	57.1%	334.0	17.5%	1,905.9
Total		2,209.5	6.6%	15,597.8	46.3%	10,033.4	29.8%	5,839.7	17.3%	33,680.4

*Gray hatch indicate river basins over 50% by a) Existing + b) Committed   Source: JICA Study Team

(2) Power Generation (GWh)

The domestic power demand, power generation and power trade until 2040 are shown in Figure 2.4-4. The power generation is expected to increase from 10,693GWh in 2023 to 133,185GWh by 2040. In terms of power trade, the export volume will steadily increase from 2024 onwards. It is expected to account for about 50% of the total power generation from 2030 onwards. Additionally, since main electricity export destinations, India and Bangladesh, primarily rely on thermal power generation, it is expected to contribute to the improvement of power supply reliability and the reduction of CO_2 emissions in these countries, potentially contributing to a reduction of 44,351 thousand tons of CO_2 emissions by 2040.



Source: JICA Study Team

Figure 2.4-4 Domestic Power Demand, Power Generation and Power Trade until 2040 (GWh)

(3) Hydropower Priority Projects

This section selects priority projects from among the hydropower development sites introduced in the Optimum Scenario to accelerate future hydropower development. Evaluation criteria for selection of hydropower priority projects are installed capacity, power generation scheme, governmental developers, contribution to cascade operation, results of screening, consistency with policy, power trade, commitment of DPs and negative impacts on environment.

Out of the 643 sites to be elaborated in Optimum Scenario excluding 140 existing power plants, 503 sites were scored using the above selection criteria. Analysis results were confirmed between Nepalese side and JICA Study Team. As a result, the top 26 sites with scores of 5 or higher were selected as priority hydropower projects. The list of hydropower priority projects is shown in Table 2.4-3.

It should be noted that projects in this list are selected within the scope of this study and the possibility of each site must be ultimately determined through F/S (Feasibility Studies) and ESIA (Environmental Impact Assessments). In particular, ESIA requires comprehensive studies for individual site conditions and this report does not guarantee the implementation of each site.

Furthermore, the list includes sites where development rights are held by government entities such as NEA and VUCL, as well as those held by private companies, considering all as important projects regardless of the developer's attributes.

Table 2.4-3 List of Hydropower Priority Projects

Status in DoED List	Commis-sioning	Name	River System	Generation Scheme	Installed Capacity (MW)	Annual Power Generation (GWh)
Construction	2026	Tanahu HEP	Trishuli	STO	140	503
	2025	Arun 3	Arun	PROR	900	3,466
	2030	Tila-1 Hydropower Project	Karnali	PROR	299	
	2030	Tila-2 Hydropower Project	Karnali	PROR	297	
	2030	Upper Marsyangdi 1	Trishuli	PROR	102	587
Application for Construction License	2029	Budhi Gandaki Ka	Trishuli	PROR	226	641
	2038	Adhikhola Storage HEP	Kaligandaki	STO	180	693
	2038	Betan Karnali HEP	Karnali	PROR	442	2,319
	2032	Phukot Karnali HEP	Karnali	PROR	480	2,448
	2034	Chainpur Seti HEP	Karnali	PROR	210	1,158
	2039	Kimathanka Arun HEP	Arun	PROR	450	2,558
	2035	Begnas- Rupa Storage HEP	Trishuli	STO	150	206
	2032	Nalsyau Gad Storage HEP	Karnali	STO	417	1,232
Survey	2030	Tamor Storage	Tamor	STO	200	1,079
	2030	Jagdulla HEP	Karnali	PROR	106	615
	2031	Lower Seti (Tanahu) HEP	Trishuli	STO	126	521
	2037	Bajhang Upper Seti HEP	Karnali	PROR	216	1,245
	2034	Dudhkoshi Storage HEP	Sunkoshi	STO	635	3,362
	2028	Madi Storage HEP	Others	STO	156	456
	2033	Upper Arun HEP	Arun	PROR	1,061	4,478
	2035	Kulekhani Sisneri Pumped Storage HEP	Others	STO	100	317
	2031	Budhigandaki Prok-1 HEP	Trishuli	PROR	103	
Application for Survey License	2030	Bheri 4 HEP	Bheri	STO	271	1,593
GON Projects	2038	Bharbung HEP	Bheri	STO	470	1,339
	2033	SR-06 Storage	Karnali	STO	309	1,684
	2035	Sunkoshi 3	Sunkoshi	STO	680	2,300
	2033	West Seti Storage HPP	Karnali	STO	750	2,876

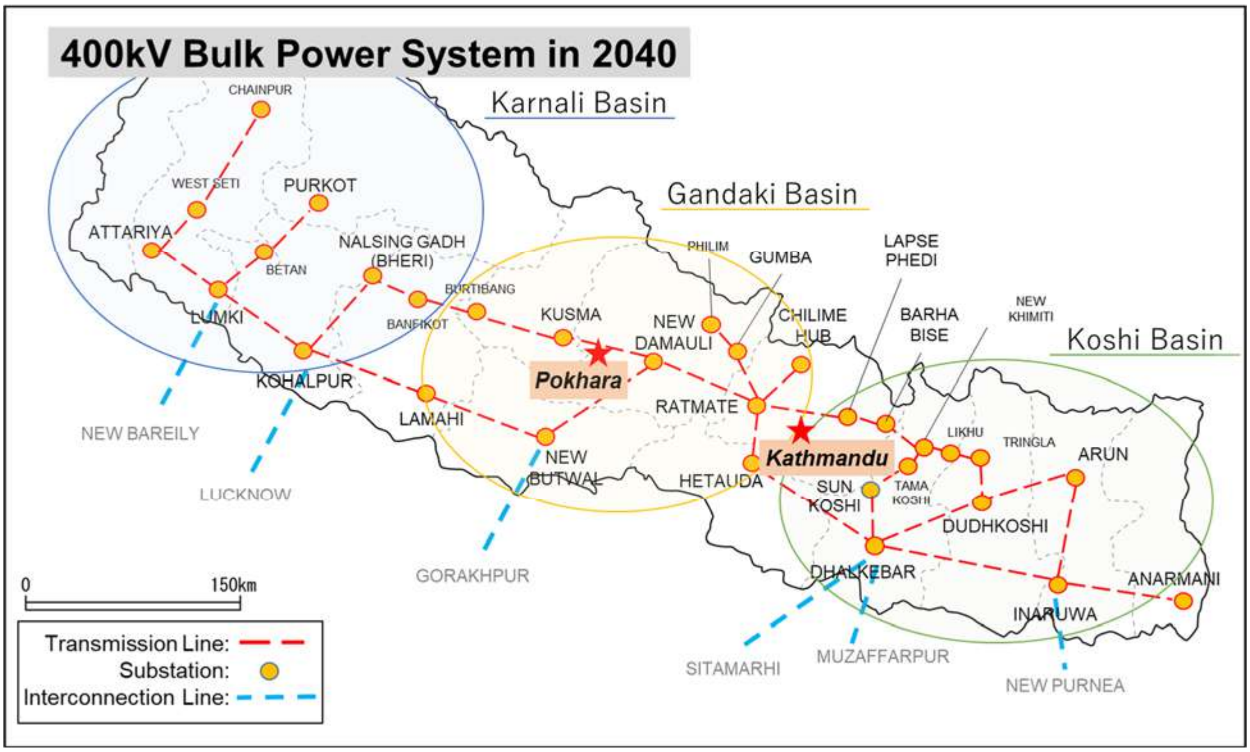
Source: JICA Study Team

2.4.3 The Power System Plan (PSP) and power trade with neigh boring countries

(1) Power System Plan (PSP)

The PSP considered the 400kV backbone system, the lower-level systems around major cities, and the interconnection line with India. The results are shown in Figure 2.4-5. The 400kV backbone system is projected to grow from a transmission line length of 78 km and transformer capacity of 945 MVA in 2023 to 2,487 km and 20,475 MVA by 2040. It will form a grid consisting of two east-west 400kV routes across the country and north-south routes developed along major rivers. Additionally, domestic 220kV/132kV/66kV systems, including the urban distribution networks in Kathmandu, Pokhara, and Butwal, will also be reinforced.

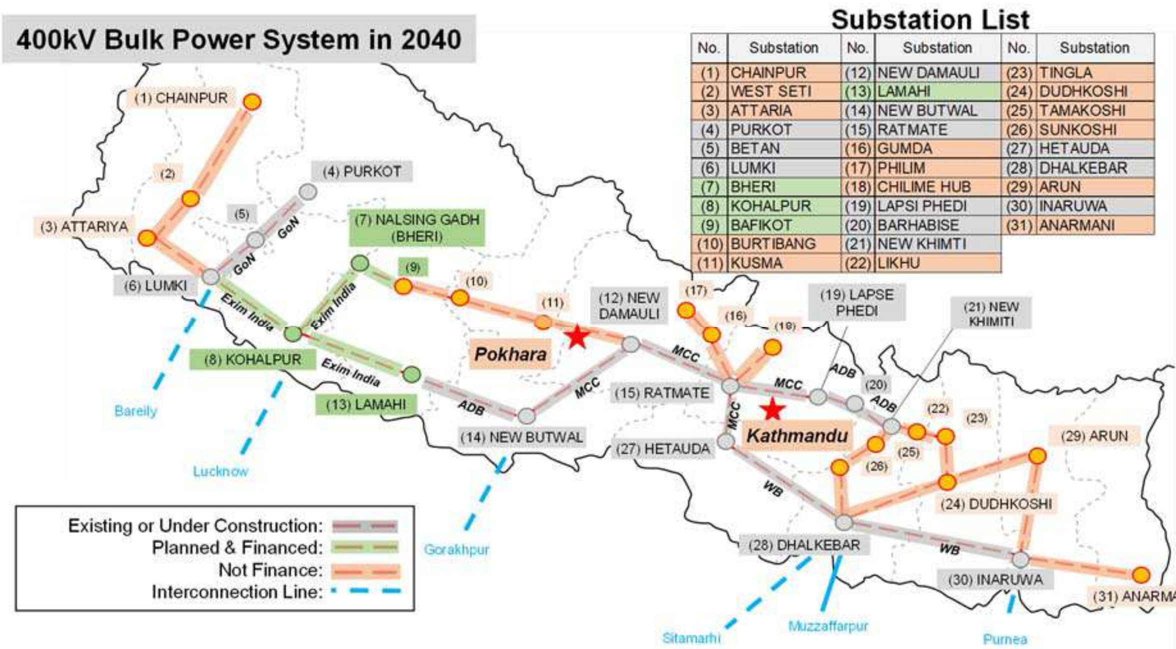
Power trade with neighboring countries will be conducted via India, with six 400kV interconnection lines planned. For development sites beyond 2035, direct exports through dedicated interconnection lines will be required to ensure stable and efficient system operation.



Source: JICA Study Team

Figure 2.4-5 Major backbone systems and international interconnection lines in 2040

Figure 2.4-6 summarizes the development status of the 400 kV domestic grid.



Source: Prepared by JICA Study Team

Figure 2.4-6 Current status of development plans for 400kV grid and interconnection lines

With the support of MCC, WB, ADB, etc., the 400 kV domestic grid is under construction or planned for most of the major cities in the country, including Kathmandu and Pokhara. As for the interconnection lines, the existing Dhalkebar-Muzzaffapur interconnection line and the New

Butwal-Gorakhpur interconnection line under construction are capable of handling power imports to major cities in the country and hydropower exports in the Gandaki water system and western Koshi water system, both of which are already under construction.

On the other hand, in consideration of future export expansion, it will be necessary to develop 400 kV domestic grids and interconnection lines for water systems that will be developed in the future, such as the West Seti, Karnali, Bheri, Dudhokoshi, Arun, and Tamor water systems. Based on this recognition, the issues of grid development for power export are summarized.

Table 2.4-4 Future 400kV interconnection line and target water system

400kV Interconnection line	400kV Nepal grid	Target water system	Operators
Lumki – Bareily	Chaipur Seti – West Seti – Attariya	West Seti	RPGCL (Only West Seti – Attariya)
	Phurkot – Betan – Lumki	Karnali	RPGCL
Kohalpur – Lucknow	Bheri – Kohalpur	Bheri	NEA
Dhalkebar – Sitamarhi	New-Khimti – Tamakoshi – Sunkoshi – Dalkebar	Sunkoshi, Tamakoshi, Dudhokoshi	NEA
Inaruwa – Purnea	Arun – Inaruwa	Arun, Tamor	NEA、RPGCL

Source: JICA Study Team

These domestic and interconnection lines will be developed in a north-south direction, connecting each water system to India rather than building a conventional east-west grid connecting domestic demand centres. It is also important to promote the development of power sources and systems from the perspective of integrated development of water systems, regarding the future development of power transmission lines as a single package.

(2) Power Trade

In addition to infrastructure development, it is also important to establish institutional arrangements such as establishing distribution channel between power trading companies and IPPs and power companies/customers in India and Bangladesh, granting preferential treatment for clean energy, and applying for power grid connection in each country in order to mitigate the concentration of wholesale to NEA.

1) Wholesale scheme of electricity from the viewpoint of power generators

Table 2.4-5 and Table 2.4-6 show the possible future power trade scheme and a comparison of each scheme of wholesaling from the viewpoint of power generators. 1) is a conventional trade and 2), 3) are new trading schemes assuming power exports.

Table 2.4-5 Wholesale suppliers of electricity from the viewpoint of power generators

Wholesale customer	Content
1) NEA	This is a conventional scheme of trading that is completed through domestic transactions with NEA. Since NEA distributes the purchased power to the domestic retail market and the surplus to India, the generators are not directly involved in power trade. Although the purchase price will be lower for the generator, it is assumed that this will continue to be the mainstream scheme for small and medium-sized power generation projects in Nepal, as it does not require any administrative procedures such as grid connection applications or PPAs with customers in other countries.
2) Power trading company	This is a scheme through power trading companies. In the future, Nepal's Electricity Act will be amended to allow power trading business, and it is expected that the function of power distribution, which NEA is responsible for, will be partially transferred to Nepal Trading Companies. NEA has established NPTCL (Nepal Power Trading Company Ltd.), the first trading company in Nepal, in 2021, and NPTCL is expected to operate this trading business for the time being. The power generation companies will be able to choose whether to use the PPA with the power trading companies as the price at which they sell electricity, or whether the price will be linked to the market.
3) Direct trade with DISCO/Customer in India/Bangladesh	This is a scheme in which power generation companies deal directly with power distribution companies and major customers in India and Bangladesh, and it offers economies of scale in structuring project financing with the participation of investors from various countries.

Source: JICA Study Team

Table 2.4-6 Comparison of Electricity Suppliers from the Power Generator's Perspective

Scheme	1) NEA	2) Trading Company	3) Direct Trade
Purchaser	NEA	Trading Company	Large consumers in overseas
Selling Price	PPA with NEA	PPA with Trading Company Market Price	PPA with Consumers
Pros	- Purchase volume and price are secured. - There are transmission costs only with Nepal.	<PPA> - Purchase volume and price are secured. <Market> - Electricity can be sold when surplus power is generated.	- Purchase volume and price are secured. - IPP can chose the customer with the best contract conditions by themselves.
Cons	- Limited amount of NEA purchases.	- The purpose and function of the Trading Company has not yet been determined.	- IPPs need to secure their own customers - Transmission costs are incurred outside of the Nepal in addition to within Nepal

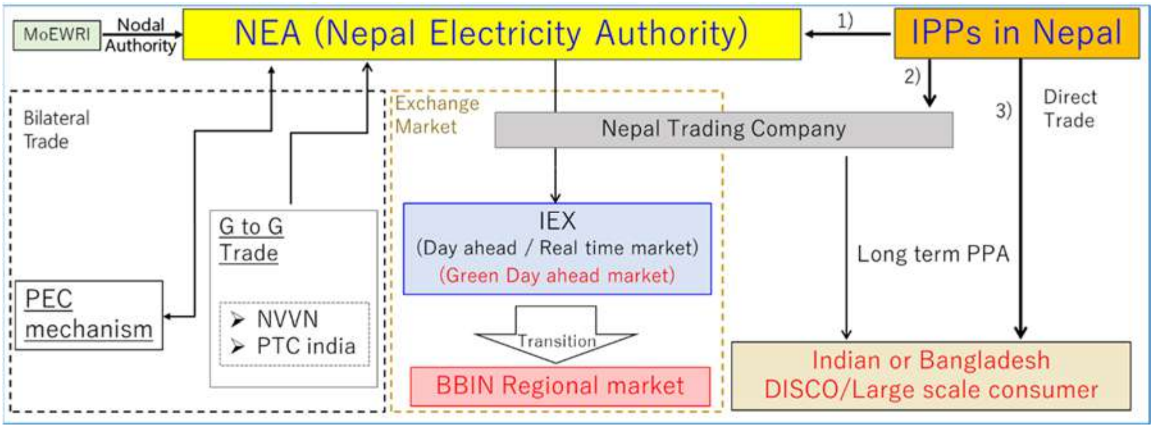
Source: JICA Study Team

When looking at power trade from the perspective of a power generator, wholesale customers and the wholesale price are important factors in considering business feasibility. PPA's electricity selling price is 5.68 NRs/kWh (4.4 cents/kWh) on average in 2023/24 for NEA domestic trade, and 8.77 NRs/kWh (6.6 cents/kWh) for export, with the latter being higher. It is desirable for power generators to have a scheme that allows them to consider both domestic trading and exports as wholesale customers. There is no restriction on each power generator to choose only one form of trading for these 1), 2), and 3), and flexible combinations are expected to be possible.

For example, during the dry season, power could be sold to Nepal through NEA in the scheme of 1), and during the rainy season, power could be sold to India and Bangladesh in the scheme of 2) and 3). If this type of trade is possible, the power generation plans required, especially for medium to large scale projects, are expected to change.

2) Proposed power trading scheme

Figure 2.4-7 shows the proposed trading scheme from the perspective of both the NEA and the power generator.



Source: JICA Study Team

Figure 2.4-7 Proposed power trading scheme

As mentioned above, the diversification of wholesale customers for power generators is expected to reduce NEA's financial risk and promote the participation of Indian and Bangladesh generators.

It is also expected to add value to hydropower, a clean energy source. IEX also has a green market for renewable energy, which is traded at about 10% higher than the regular market. If NEA can conclude an agreement with the Indian government to participate in the green market, it will lead to increase earnings for NEA. As mentioned above, India plans to increase its procurement of electricity derived from renewable energy sources, and the market is expected to expand in the future. In addition to IEX, it will also be necessary to conclude long-term relative contracts (PPAs) with power distribution companies and large customers in India and Bangladesh in order to secure long-term stable power export.

In addition, the proposal to build an interconnection line directly between Nepal and Bangladesh and the proposal for Bangladesh to participate in IEX, as India foresees a potential of IEX's development as a broad-based power exchange market in South Asia, would contribute to increasing the volume of electricity trade between Nepal and Bangladesh.

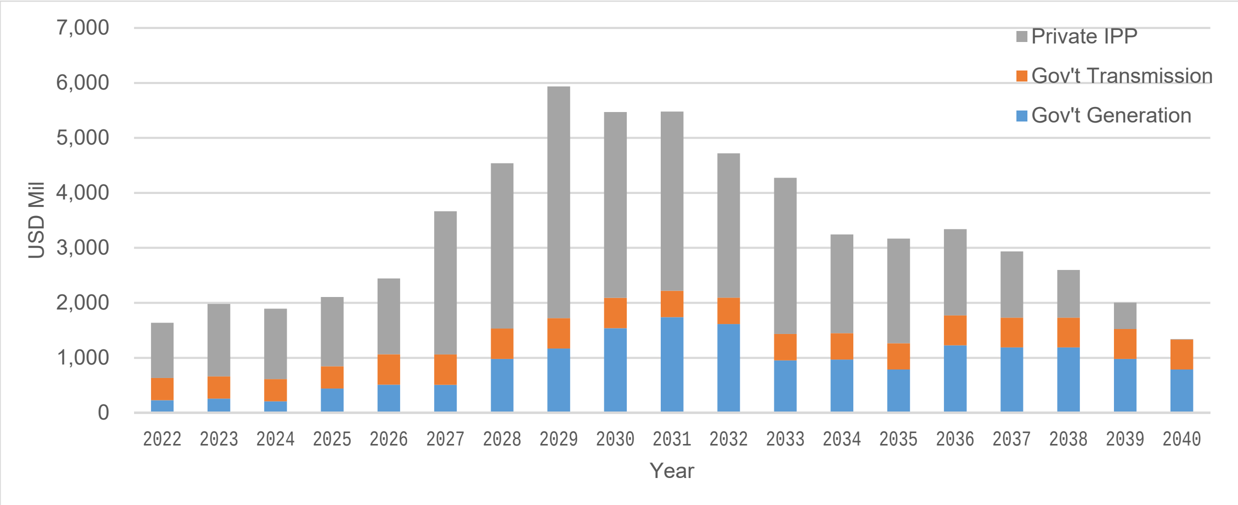
However, in order to ensure the supply of electricity to the domestic market, it will also be necessary to require a certain amount of domestic supply throughout the year when granting licenses to power generators. This will require improvement of NEA's capacity to plan for supply and demand, coordination with the DoED, which issues development rights, or the ERC, which evaluates PPAs, as well as coordination with power generators and trading companies.

2.4.4 Financial Analysis of IPSDP

As shown in Figure 2.4-8, the IPSDP requires a large capital investment of 61,750 MUSD cumulatively, or 3,431 MUSD per year on average, until 2040 for power generation, transmission, and distribution. In order for Nepal's power sector to implement the IPSDP, the plan is evaluated from the following two perspectives.

i) Financially sustainable operation of the sector at reasonable electricity tariff levels
ii) Financing plan considering Nepal's domestic and international fund raising capacity

Regarding i), the government-related organizations that will be implementing the IPSDP as the government is firstly analyzed, creating a cash flow table for the IPSDP period for that organization, and analyzing the fundraising required for investment and the level of electricity tariffs. Then, the impact on the macro economy based on the results of the financial analysis is conducted. Regarding ii), the attributes of operators and fundraising assumed from the scale of development and profitability are categorized and an outlook for capital demand and investment and financing during the IPSDP period based on the characteristics of investors and lenders is presented.



Note: The classification of government (estimated)/private (estimated) was made by the JICA Study Team after confirming the proponents of each target project. Projects that were clearly being promoted by the Nepalese government were classified as "Investment by the Nepalese government (estimated)" and all others as "Investment by the private sector (estimated)". PPPs (Public Private Partnership) were classified as the latter.

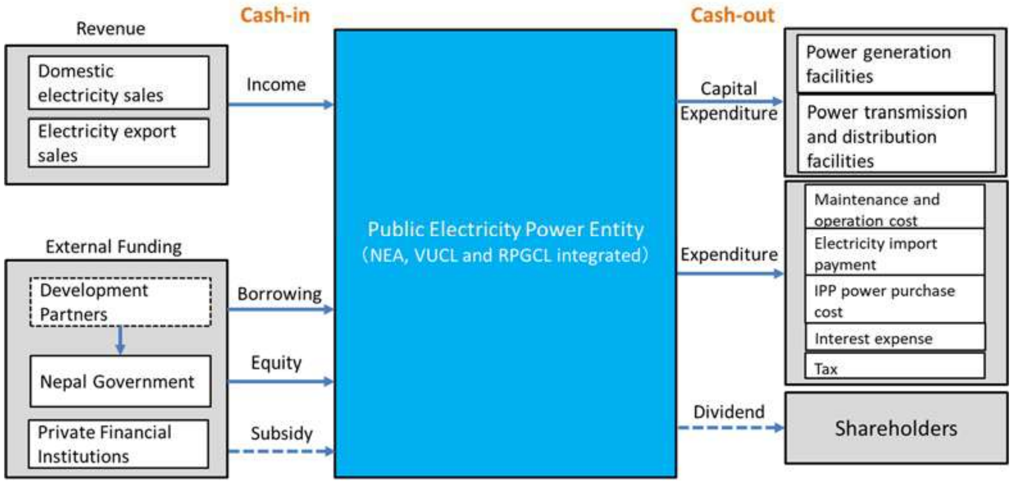
Source: JICA Study Team

Figure 2.4-8 IPSDP funding needs

(1) Financial Analysis of IPSDP

1) Financial Flow involved in Public Electric Power Company

In financial analysis, a public electric power company which consists of NEA, VUCL and RPGCL is analyzed. The financial flow involved in the public power is shown in the Table 2.4-9.



Source: JICA Study Team

Figure 2.4-9 Basic Funding Flows in Nepal's Electricity Sector

2) Cash Flow analysis

In this section, a cash flow analysis will be carried out based on the three cases shown in the following table. The amount obtained by deducting the repayment amount of the loan from the income obtained through business activities will be reserved as funds in the hands of the public power utility and used as the source of investment for the following years. If the above funds are insufficient for the amount required for investment, the necessary funds for investment will be covered by borrowing and shareholder investment. The ratio of borrowing to shareholder investment will be 7:3. The borrowing interest rate applied 5.0%, which is the current average fundraising interest rate of NEA, and 10.0%, which is the average interest rate of commercial banks in Nepal.

Table 2.4-7 Cases of Cash Flow Analysis

Cases	Assumptions
Benchmark Case (Based on the current electricity price)	The current electricity tariffs, electricity export selling prices, and purchase prices from IPPs are maintained at the current pricing levels.
Case 1 (Cash Short)	In Case 1, the domestic electricity tariff level at which public electric power utilities will have a negative cash balance in any year after 2023. This is the electricity tariff level at which a cash shortfall will occur even if the funds necessary for investment are procured through borrowing and investment.
Case 2 (Without loan and shareholder investment)	The domestic electricity tariff level is set so that the funds saved through business activities over the analysis period exceed the funds required for investment. In this case, all of the funds required for capital investment can be covered by business revenues.

Source: JICA Study Team

The electricity tariff levels and the profit level of the public entities ROE (Return on Equity) and ROA (Return On Asset) for each case are shown in Table 2.4-8.

Table 2.4-8 The level of electricity tariffs

Electricity Tariffs and Profit Level		Interest Rate (%)	
		5.0%	10.0%
Case	Case 1	0.054 dollars/kWh (ROE:3.0% ROA:1.0%)	0.058 dollars/kWh (ROE:2.0% ROA:0.0%)
	Benchmark Case[3]	0.070 dollars/kWh (ROE:10.0% ROA:5.0%)	0.070 dollars/kWh (ROE:8.0% ROA:4.0%)
	Case 2	0.130 dollars/kWh (ROE:18.0% ROA:15.0%)	0,132 dollars/kWh (ROE:18.0% ROA:15.0%)

Source: JICA Study Team

The results suggest the electricity tariffs can be suppressed to \$0.055/kWh considering cash position perspective alone. However, the suppressed electricity tariff forced the GoN to raise funding externally, hence increasing uncertainty of procurement and the government's financial burden. On the other hand, if all capital investment funds are covered by the revenues of public electric power utilities, electricity tariffs need to raise double from the current level, which would increase the burden on citizens. If IPSPD is implemented maintaining the current electricity tariff level of \$0.070/kWh, capital investment can be promoted using the revenues of public electric power utilities combined with borrowing and investment. The results also suggest that applying current tariff could avoid an over-burden of citizens due to a significant increase of electricity tariffs.

3) Sensitivity analysis of electricity export sales prices

In addition to examining domestic electricity rates, the selling price of electricity exports is also examined. The benchmark case applies an electricity selling price of \$0.070/kWh based on the performance of IEX. The electricity sales price setting will have a significant impact on the business operations of the power sector in Nepal. Therefore, the study examines the changes of electricity sales prices' impact to the profit margins and financial status of public power utilities in Nepal.

The analysis uses 0.030 dollars/kWh, 0.040 dollars/kWh, 0.050 dollars/kWh, and 0.060 dollars/kWh to set prices that have fallen from 0.070 dollars/kWh. The lowest price of 0.030 dollars/kWh was set based on the 2020 IEX annual average trading fee of 0.031 dollars/kWh, assuming that the selling price of electricity exports falls to this level. Note that conditions other than the selling price of electricity exports are the same as those used in the benchmark case. The results calculated using the above variable settings are shown in the table below.

Table 2.4-9 Result of sensitivity analysis of electricity export sales prices

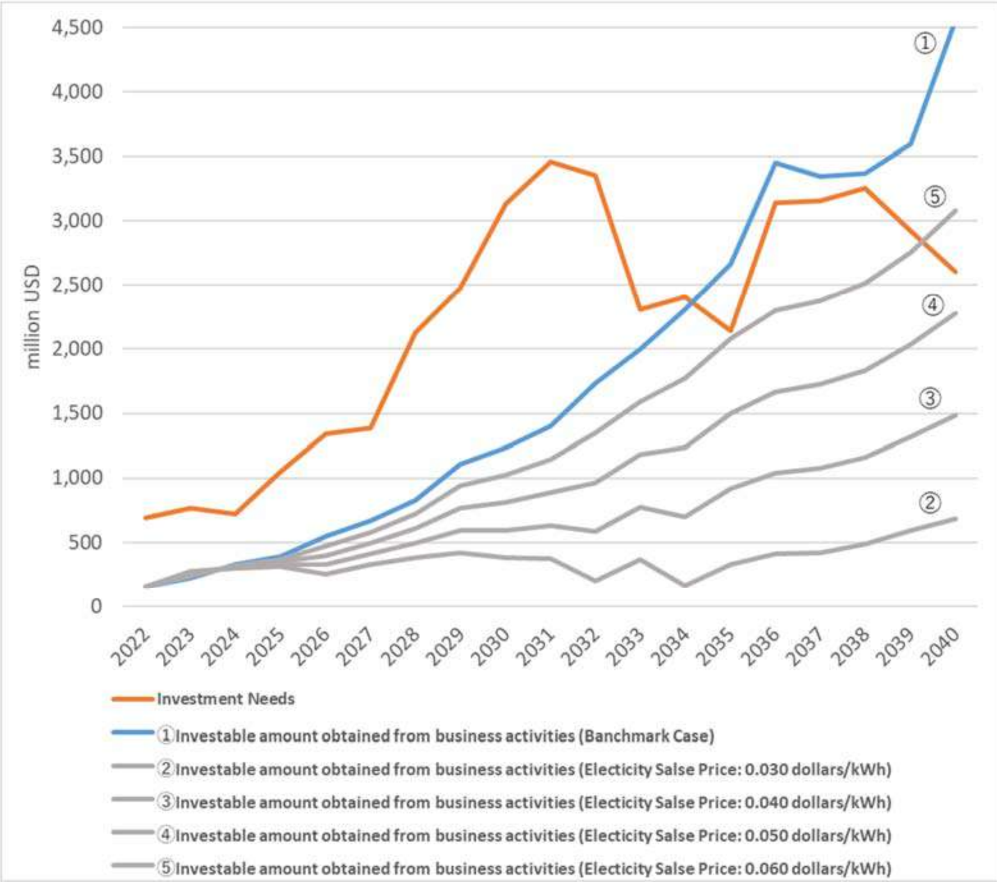
Result of Analysis		Electricity Export Sales Prices（dollars/kWh）				
		0.030 dollars/kWh	0.040 dollars/kWh	0.050 dollars/kWh	0.060 dollars/kWh	0.070 dollars/kWh
Profit Level	ROE	-39.0%	-4.0%	4.0%	7.0%	10.0%
	ROA	-3.0%	0.0%	2.0%	4.0%	5.0%
Financial Status	Cash Short	No	No	No	No	No
	Insolvency	Yes	No	No	No	No

Source: JICA Study Team

Even if the selling price for electricity exports falls to \$0.030/kWh, Nepalese power sector will barely be able to avoid a cash shortfall, but as a result of the accumulation of deficits, their net assets will become negative and will become insolvent. In addition to the public power utility

[3] In the cash flow analysis in the previous section, an interest rate of 5.0% is used as the benchmark case.

having a significant shortage of cash on hand, power sector needs to raise more external funds (loans and shareholder contributions) for capital investment than in the benchmark case. As capital contributions from the Nepalese government will increase, there is a possibility that the public power utility will go bankrupt due to insolvency (profit margins are ROE: -39.0% and ROA: -3.0%). Figure 2.4-10 indicates relationship between available investment amount from cash on hand and the amount of capital investment need.



Source: JICA Study Team

Figure 2.4-10 Relationship between available investment amount from cash on hand and capital investment amount

One possible way to make up for the loss of revenue from electricity exports would be to raise domestic electricity tariffs, but this would increase the burden on the public. Therefore, if the selling price of electricity exports falls, it may become necessary to reconsider the plans envisaged in the IPSDP by taking measures such as discontinuing unprofitable projects through careful review of the projects, improving the profitability of projects by reviewing the costs of new projects, and increasing the added value of electricity sales. However, there are limits to how much a business profitability can be reviewed, and in reality, if the selling price of electricity exports falls to a level where ROE and ROA become negative (below 0.050 dollars/kWh), it is expected that a review of the development plan itself will be necessary. Considering the current electricity situation in neighboring countries, it is unlikely that the selling price for electricity exports will deviate significantly from $0.070/kWh. However, it is necessary to update periodically a medium- to long-term plan such as the IPSDP in response to business environment's changes.

(2) Impact on the macro economy

This section considers the impact of implementing the IPSDP on Nepal's macro economy. Specifically, we consider the impact on external debt, foreign exchange reserves, trade balance due to electricity exports, GDP due to electricity exports, and domestic employment. Note that the cash flow of public power utilities in the following analysis is based on the benchmark case of domestic electricity selling price (0.070 dollars/kWh) and borrowing interest rate (5%). However, since the GDP growth rate described below is based on real GDP, the inflation rate of 3% considered in the financial analysis is not taken into account. The results of the impact on the macro economy are shown in Table 2.4-10.

Regarding the analysis of the impact on the macro economy, the study estimated the impact of borrowing and shareholder investments by public power utilities in capital investment under the IPSDP on external debt and foreign exchange reserves. As a result, it was confirmed that external debt will increase as capital investment increases, peaking in the early 2030s, but is not significantly higher than other countries. In addition, the effect of electricity exports is a maximum 5% increase in GDP and a maximum 14% improvement in the trade deficit. Furthermore, hydropower development is expected to create jobs, and IPSDP development is expected to contribute to economic growth.

Table 2.4-10 Impact on the macro economy

Indicators	Analysis Result
External Debt	The impact of capital investment in the IPSDP on external debt was analyzed in two cases: 15% (Case 1) and 100% (Case 2) of the external debt of borrowings and shareholder contributions accepted by public power utilities based on the current Nepalese government budget structure. The results show that the external debt-to-GDP ratio will rise to a maximum of 21.4% in Case 1 and 32.5% in Case 2 from around 2031 to 2032, when capital demand is high. However, these figures are not particularly high compared to other developing countries in Asia.
Foreign Exchange Reserves	We estimated the ratio of foreign exchange reserves to external debt and how many months' worth of imports the foreign exchange reserves are equivalent to. The foreign exchange reserve ratio was 1.44 in Case 1 of the analysis of external debt, and 1.01 in Case 2, both of which exceeded the benchmark of 1. In terms of the value of imports, foreign exchange reserves equivalent to more than 10 months' worth of imports were secured throughout the analysis period, exceeding the benchmark level of 3 months.
Impact of electricity exports on the trade balance	If the average trade deficit of 32% of GDP over the past 10 years is taken as the baseline trade deficit, it is estimated that electricity exports could improve the trade deficit by up to 14%.
The impact of electricity exports on GDP	The amount of revenue from electricity export sales is expected to grow year by year, and it is estimated that it will increase GDP by up to about 5% compared to a situation without IPSDP exports.
Job Creation	The number of unemployed people in 2022/2023 is estimated to be around 980,000, but based on rough estimates of job creation through IPSDP, it is expected that up to 85,000 jobs will be created per 1,000 MW hydropower plant, which could lead to a reduction in the number of unemployed people of around 9%.

Source: JICA Study Team

2.4.5 Investment Plan

In this section, how to finance the individual projects included in the IPSDP is considered.

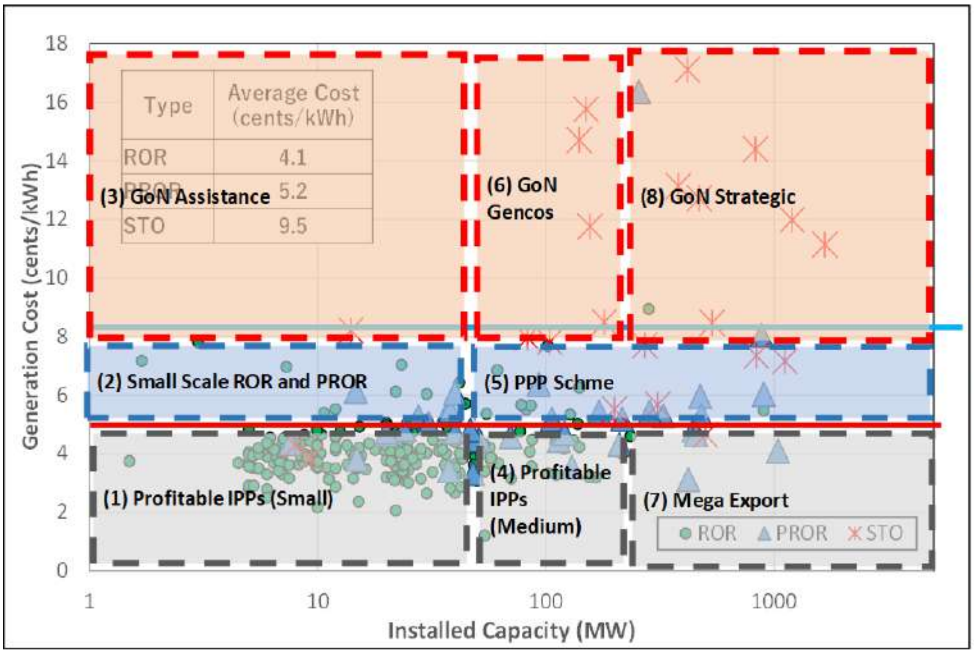
(1) Considerations regarding fund procurement based on business scale and profitability

Power development projects are likely to have different investors and lenders depending on the project scale, profitability, and the composition of participating entities. In particular, in hydroelectric power projects, the scale of the project determines the development period and required investment amount, so the composition of investors and lenders varies.

Regarding the size of the hydroelectric power projects to be analyzed, small-scale generally refers to projects of less than 1 MW, but in this study, considering the situation in Nepal and projects in other countries, it is assumed that the projects of 50 MW or less are assumed to be small-scale, which can be funded within Nepal mainly through corporate finance. Medium scale broadly refers to projects up to 200 MW that do not require IBN investment permission, and both corporate and project finance are assumed. Hydroelectric power plants over 200 MW are subject to IBN approval, and mainly project finance is assumed. Public support, including the use of ODA (Official Development Assistance), is expected to be applied to projects of medium or larger scale.

Power transmission and distribution projects need to be operated as an entire power system, not as individual business units like power generation projects, and profitability varies greatly depending on the business unit. In the future, the Electricity Act is expected to be amended to open up the power transmission and distribution business to the private sector, but as this is a highly public-interest business that aims to provide a stable supply of electricity to the people of Nepal, there is a strong tendency for the financing associated with the construction of power transmission lines to be mainly provided by public funds.

In this study, as shown in Figure 2.4-11 and Table 2.4-11, hydropower projects that should be developed in the IPSDP were evaluated based on the axis of generation cost and business scale (installed capacity) and classified into eight categories. The generation cost was considered based on the LCOE described in Section 2.2.3. In the analysis, projects with an LCOE of 5.0 cents/kWh or less were classified into a category that is highly profitable and can be funded by private funds, and those with an LCOE of 5.0-8.0 cents/kWh were classified into a category that is medium profitable and therefore should be borrowed under more favorable conditions than the private sector, such as partial PPP loans, for which private financing is insufficient. Furthermore, projects with an LCOE exceeding 8.0 cents/kWh are classified as requiring loans from development aid agencies because they are not profitable.



Source: JICA Study Team

Figure 2.4-11 Distribution of IPSDP Priority Development Projects

Table 2.4-11 Basic Concept of Project Categories and Financing Methods in IPSDP

Profitability	Category	Capacity	Sites	Output	Investment Amount	Source of Finance	
				(MW)	(USD Mil	Gov't	Private
High	(1) Profitable IPPs (Small)	Less than 50MW	493	5,915.40	8,975.20	―	◎
	(4) Profitable IPPs (Medium)	50～200MW	60	5,614.10	8,652.00	△	◎
	(7) Mega Export	More than 200MW				○	◎
Medium	(2) Small Scale ROR and PROR	Less than 50MW	24	434.4	889.7	△	○
	(5) PPP Scheme	More than 50MW	24	6,658.40	12,822.40	○	○
Low	(3) GoN Assistance	Less than 50MW	8	88	139.5	○	△
	(6) GoN PROR/STO Projects	50～200MW	8	1,128.00	2,351.80	◎	―
	(8) GoN Strategic Project	More than 200MZ	11	6,811.90	15,279.40	◎	―
-	(9)Others (inc Solar)	-	82	4,188.10	4,213.50	―	◎
	(10) Power System	-	-	-	9,496	◎	△

Source: JICA Study Team

For projects in categories (1), (4), and (7) with relatively high profitability, private funds are expected to be utilized to the maximum extent possible. Small-scale projects are expected to be corporate financed, but since there are many sites, it is desirable to speed up the loan and various approval processes. For medium to large-scale projects, project finance from domestic and foreign investors and operators is expected, and private financing from development financial institutions is also expected to be utilized. Since the operators who can participate in large-scale projects are particularly limited, it is expected that they will be implemented by an SPC (Special Purpose Company) consisting of government-affiliated operators such as NEA, major domestic conglomerates, major international developers, and Indian power companies.

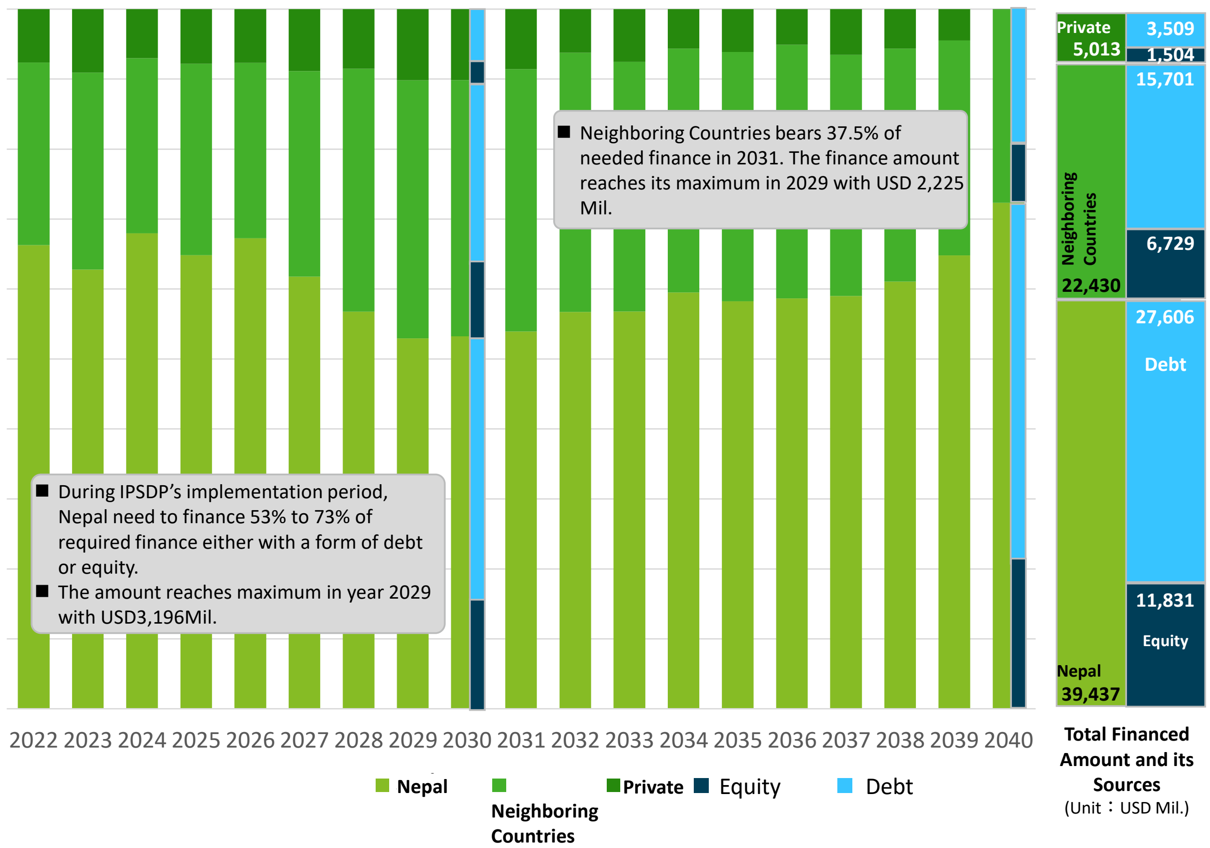
For projects in categories (2) and (5) with medium profitability, if the project is small and cannot be expected to be profitable on its own, it is expected that support will be provided in bulk through funds, or that government-affiliated operators such as HIDCL will join in support. For medium to large-scale projects, in addition to various power generation formats such as ROR, PROR, and STO, it is expected that a variety of players will participate as developers, including medium to large-scale domestic and foreign developers, government-affiliated operators, and Indian power companies. Financing needs to be structured for each project, and it is expected that there will be a wide variety of support methods. It is necessary to consider a flexible structure that combines support measures that can be applied to each player.

Low-profit projects in project categories (3), (6), and (8) with relatively low profitability include regulated power sources such as STO. It is difficult to evaluate the business value of STO power sources based solely on hourly value such as LCOE, and many locations do not show feasibility or profitability through financial analysis. Therefore, development by government-affiliated businesses with the support of development aid agencies or joint development with IPPs is expected. In addition to utilizing support schemes such as EBF (Equity Backed Finance) and overseas investment and loans, it will be important to utilize ODA budgets not only for Nepal, but also for neighboring countries that are potential destinations for electricity.

(2) Investment Plan for IPSDP Implementation

This section examines the outlook for financiers and investors for projects that were prioritized in the IPSDP, based on the characteristics of the projects, and shows the trends in capital demand and the amount of investment and loans during the IPSDP period. Based on this distribution and characteristics, a model of the investors and loan providers for the projects was envisaged, and an attempt was made to allocate investors and lenders based on this model. As shown in Figure 2.4-12 and Table 2.4-12, capital demand during the IPSDP period will peak between 2029 and 2032, when construction of many projects will be concentrated, and then gradually decline.

Debt will also peak at USD 4,225 million in 2029, decrease to USD 2,411 million by 2034, increase to USD 2,481 million in 2036, and decrease gradually thereafter. This projection is for hydropower projects currently captured in the IPSDP. It is expected that investment trends through 2030 will attract private sector investment, noting that figures presented below does not depict the inflow of stimulated private sector investment.



Source: JICA Study Team

Figure 2.4-12 Proportional trend and Source of Finance

Table 2.4-12 Trend of Finances by Sources during IPSDP period

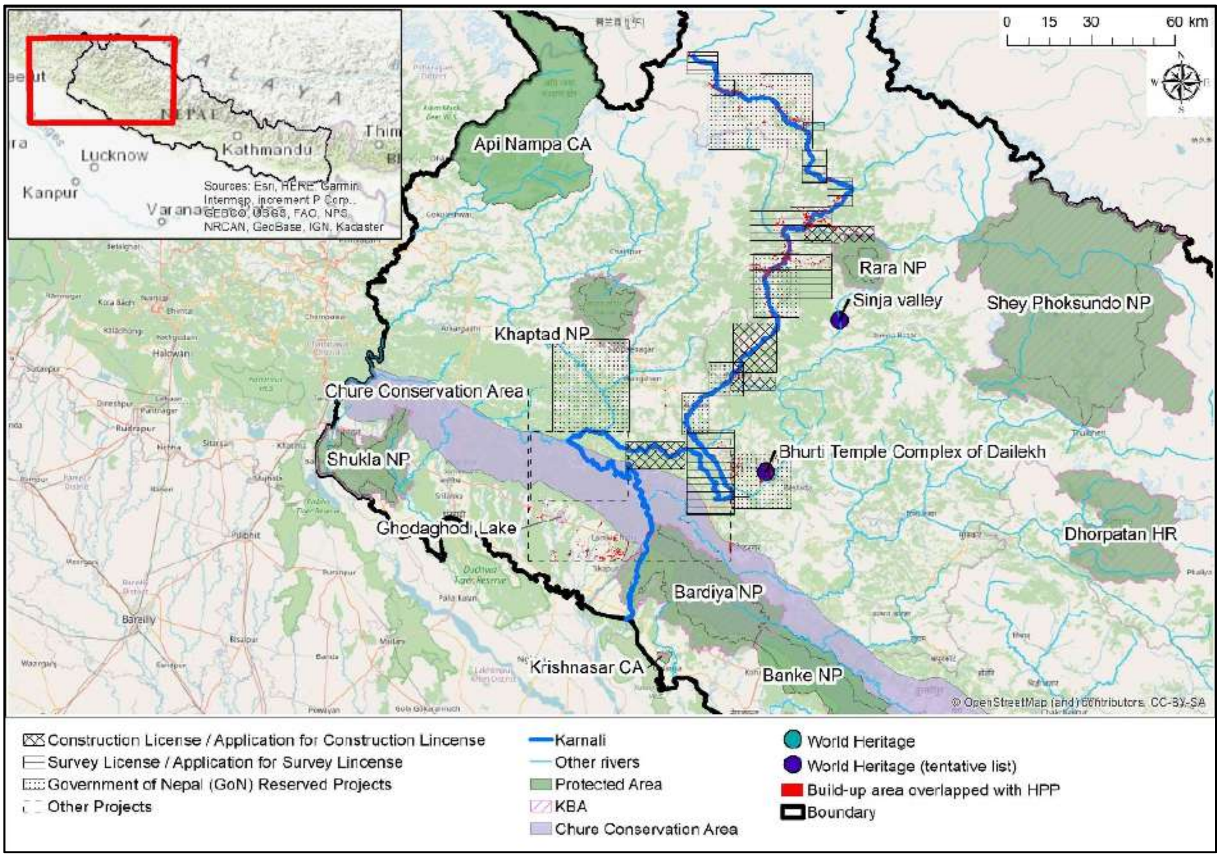
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Nepal	5,194	5,992	6,185	6,498	7,427	9,785	10,675	13,207	12,353	12,405	11,077	10,286	8,314	8,166	8,470	7,763	7,151	6,070	4,635
Neighboring Countries	978	1,381	1,371	1,562	1,833	2,914	3,362	4,651	4,271	4,248	3,524	3,222	2,348	2,357	2,451	2,185	1,873	1,363	678
Private	217	301	251	267	295	549	639	805	617	645	497	501	307	296	277	245	186	123	480

(Unit : USD Mil)

Source: JICA Study Team

2.4.6 Strategic Environmental Assessment

The optimal scenario selected in this master plan was evaluated from environmental and social viewpoints. The points to be considered, such as cumulative impacts, for hydropower development for each river and river basin were analyzed. Then, the impacts on protected areas (national parks, areas important from the biodiversity perspective KBA (Key Biodiversity Area), ecosystems (both aquatic and terrestrial ecosystems, especially migratory fish and rare species listed in the IUCN (International Union for Conservation of Nature) Red List), cultural heritage, etc. were examined; and points to be considered for environmental and social considerations, such as mitigation measures for the anticipated impacts, were also considered.



Source: JICA Study Team

Figure 2.4-13 Evaluation of Optimum Scenarios (Example) - Karnali River

It is recommended to avoid as much as possible environmental and social impacts caused by projects in line with the mitigation hierarchy, and then to examine measures to minimize, reduce, and mitigate those impacts that cannot be avoided. In the process, it is important to provide opportunities for stakeholders, such as the central government, provincial governments, and affected people, to express their opinions and to hold meaningful consultations. In addition, appropriate monitoring should be carried out; and if any concerns are identified during the monitoring, corrective measures should be taken. The main points to keep in mind are as follows.

Table 2.4-13 Points for Environmental and Social Considerations in SEA (Mitigation Measures etc.)

Items	Points for Environmental and Social Considerations in SEA (Mitigation Measures etc.)
Basin-wide cumulative impact assessment / Cooperation and collaboration between project developers	• In Nepal, the progress of development plans varies from river basin to river basin and cumulative impacts can be significant in some river basins due to multiple hydropower projects; therefore, it is necessary to evaluate the cumulative impacts for each river basin and consider appropriate mitigation measures from the perspective of river basin management. In particular, in river basins where development plans would be concentrated, such as the Gandaki River basin (where many existing power plants are located near demand areas and development is progressing), it is recommended to carry out development that takes cumulative impacts into account at an early stage. In addition, it is recommended that Nepal strategically consider free-flowing rivers in order to avoid significant cumulative impacts on each river system and to conserve the flow rate and continuity of the river basins. • Environmental management is also sometimes not properly implemented from the perspective of watershed management in Nepal; and there are cases that environmental measures (such as the installation of fish passages to allow migratory fish to move around) are not carried out effectively in multiple hydropower projects located along the same river basin. It is recommended that cooperation and collaboration among project developers along the basin, including private hydropower developers, be promoted in order to properly conduct river basin management.

Items	Points for Environmental and Social Considerations in SEA (Mitigation Measures etc.)
E flow	• Hydropower projects may affect E flow (environmental flow), including minimum water flow, and may cause changes in the flow rate of the entire river and downstream areas, as well as habitat fragmentation. If adverse effects are anticipated by hydropower development, it is advisable to refer to guidelines such as "IFC Good practice handbook - Environmental flows for hydropower projects (2018)" and to develop and implement an E flow management plan based on evaluation of E flows.
Protected areas	• When developing a project within a protected area (national park, wildlife sanctuary, hunting reserve, conservation area, buffer zone) defined in the local country's National Parks and Wildlife Conservation Act (2029/1973), permission from the authorities must be obtained prior to development. Damming or modifying the flow of rivers is prohibited, and restrictions such as maintenance flow are required for hydropower development. In addition, when implementing within a Ramsar site based on an international treaty, the project must be carried out in accordance with the management plan of each Ramsar site. It is advisable to plan and implement the project in accordance with the mitigation hierarchy.
Ecosystem / Forest	• Water intake, storage, and discharge associated with hydroelectric power generation projects may change river flow rates and water levels, potentially affecting ecosystems such as aquatic organisms and waterfowl. There is also a concern that the construction of dams and intake weirs could cut off river channels and impede the upstream migration of migratory fish. When such impacts are anticipated, it is necessary to evaluate the impact on E flow and aquatic ecosystems and reflect them in environmental management plans and monitoring plans. • In addition, deforestation due to hydroelectric development is expected to have permanent or temporary effects on flora and fauna. In particular, when a project is planned within a KBA or critical habitat is identified, the consideration should be given to minimizing the impact in the layout of the project plan, including access roads and other ancillary facilities. In addition, when local residents rely on forest use for timber and NTFPs (Non-timber Forest Products) as a source of income and adverse effects from the project are expected, it is recommended that livelihood restoration plans be formulated and implemented based on discussions with affected people.
Appropriate compensation for land acquisition, involuntary resettlement, and loss of livelihood, distribution of benefits, etc.	• One of the challenges facing hydropower development in Nepal is compensation for projects involving resettlement and land acquisition, which has led to criticism from NGOs (Non-Governmental Organizations) and complaints from residents. It is desirable to formulate and implement a resettlement action plan that includes payment of compensation at replacement cost. In particular, when large-scale resettlement is required for reservoir-type hydroelectric power plants or power transmission lines, it is important to secure sufficient budgets and implementation systems. • In addition to physical resettlement, if economic resettlement such as loss of livelihood occurs, it is recommended that livelihood restoration plans be formulated and implemented in accordance with procedures stipulated in local national laws (Land Acquisition Act (2034/1977), Real Estate Expropriation Act (2013/1956)), and with reference to good practices of hydropower projects in Nepal undertaken by the World Bank and other international donors. • Looking at the country as a whole, the benefits of power development are concentrated in the urban areas of Kathmandu and Pokhara, while the areas directly affected by the development are those surrounding the site. It is desirable to consider correcting these disparities in benefits.
Indigenous Peoples	• The National Foundation for Development of Indigenous Nationalities Act defines 59 ethnic groups as indigenous peoples, and they are widely distributed in the mountainous areas where hydroelectric power projects are planned. In addition, Nepal has ratified the ILO (International Labor Organization) Convention on Indigenous and Tribal Peoples in Independent Countries (No. 169). If adverse effects on indigenous peoples are anticipated, it is recommended that meaningful consultations be held with indigenous peoples affected by the projects from an early planning stage and that their consent be obtained based on the principle of FPIC (Free, Prior and Informed Consent). In addition, if indigenous peoples are included among the affected peoples, it is advisable to formulate an IPP (Indigenous Peoples Plan) and implement measures accordingly.
Natural hazards	• Natural disasters in Nepal include landslides caused by heavy rains during the monsoon season. In addition, projects may suffer significant physical damage due to GLOFs (glacial lake outburst floods). When selecting project sites, it is advisable to avoid areas with high disaster risks such as landslides and GLOFs, and to develop emergency response plans in the event of a disasters etc.
Climate change	• Nepal has formulated policies such as the National Climate Change Policy (2076/2019), and hydropower is considered to be a desirable form of power generation in terms of greenhouse gas emissions. However, as mentioned above, it is recommended to evaluate physical risks associated with climate change in relation to the risks of GLOFs, etc., and to consider alternatives and incorporate them into the design.

Source: JICA Study Team

3. DEVELOPMENT MILLSTONES AND FUTURE OUTLOOK FOR IPSDP

This Chapter consolidates the results of IPSDP studies cross-sectionally, presents the milestones and pathway towards realizing IPSDP and indicates the necessary transformations and future outlook of power sector. Finally, challenges and recommendations to carry out IPSDP are summarized.

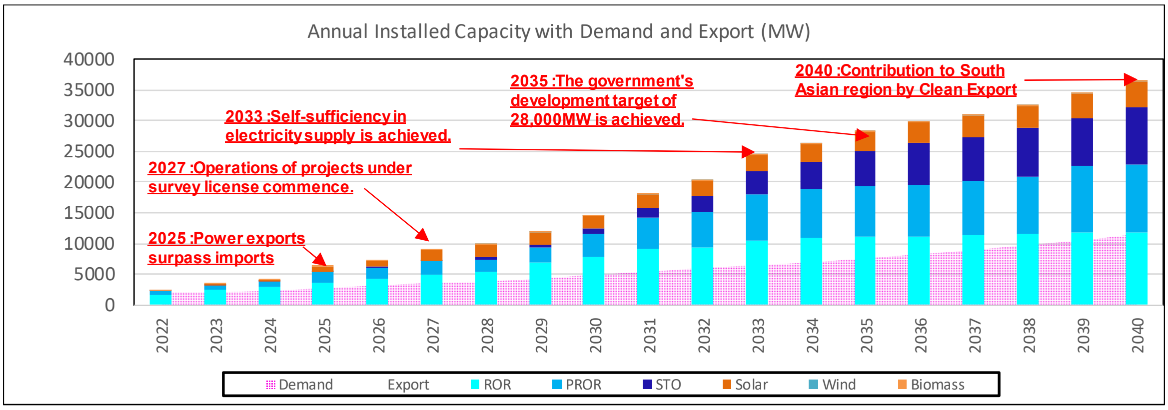
3.1 DEVELOPMENT MILESTONES AND PATHWAYS TOWARDS 2040 IN IPSDP

Figure 3.1-1 summarize the installed capacity, domestic demand, power trade and major milestones towards 2040 in IPSDP. Development milestones of IPSDP are; achieving net-zero in power trade (2025), commencement of operation of power generation projects currently under survey (2027), achieving self-sufficiency through a year (2033), meeting government targets in roadmap (2035) and contributing to stable power supply to domestic and neighboring countries (2040).

From 2023 to 2025, 4,110.2MW of installed capacity will have been developed. It is important to steadily implement the projects currently under construction that have already obtained a Construction License. From 2026 to 2030, 8,250.6MW of installed capacity will have been developed. The projects currently under construction are expected to commence operations between 2026 and 2027. From 2028 onwards, projects currently with a Survey License or identified by GoN will also start operations. Active participation from international developers, investors, and banks including those from India and Bangladesh is facilitated.

From 2031 to 2035, 13,669.0MW of installed capacity will have been developed. Development will shift from small and medium ROR to large-scale PROR and STO projects over 200MW. In this period, commencement of major projects under Survey License will reach the peak of development, achieving power self-sufficiency including the dry season by 2033. As surplus electricity is available through the year after 2030, energy transition initiatives will advance the utilization of low-carbon fuels like hydrogen and ammonia. These continuous efforts will lead the achievement of development target indicated in the Energy Development Roadmap and Work Plan 2035.From 2036 to 2040, 8,112.0MW of installed capacity will have been developed. Large-scale STO HPPs (Hydro Power Plant) and development of upstream areas in each river basin will progress. As domestic power supply is stable year-round, new power sources will be developed for direct export to neighboring countries.

Achieving these milestones requires the implementation of various measures, including technical considerations, finance, institutional and legal frameworks and human resource development. Considering the timeline and the progress of each project, it is assumed that projects currently under construction with a Construction License will be required to commence operations by 2027. Ensuring the steady execution and progress monitoring of these projects is essential. Conversely, numerous projects with a Survey License and GoN projects need to be proceeded towards commercialization. To achieve the MoEWRI development target of 28GW by 2035, these projects need to commence operations between 2031 and 2035. Therefore, construction works of them are required to start by 2026-2030. These are urgent issues in various fields to be carried out in few years involving not only the power sector but also other sectors.



Item			~2025	2026 -2030	2031 - 2035	2036 - 2040
Generation	Hydro	GoN Entities	Rasuwagadhi (111MW), Sanjen (42.5MW), Upper Modi A (42MW), Rahughat (40MW), Upper Trishuli 3B (37MW), Madhya Bhotekoshi (102MW)	Tanahu HEP (140MW), Tamor Storage (200MW), Madi Storage HEP (156MW)	Lower Seti(126MW), Uttarganga STO (828MW), Phukot Karnali (480MW), Nalsyau Gad STO (417MW), Upper Arun (1061MW), Chainpur Seti (210MW), Dudhkoshi STO (635MW), Sunkoshi 3 STO (680MW)	Betan Karnali (442MW) Kimathanka Arun (450MW), Bharbung (470MW), Mugu Karnali STO (1670MW)
			408MW (509MUSD)	**1113MW (2216MUSD)**	**4900MW (8558MUSD)**	**2969MW (6130MUSD)**
		IPPs	Upper Trishuli-1 (216MW), Arun 3 (900MW)	Manang Marsyangdi (282MW), Budhi Gandaki Ka (226MW), Bheri 4 HEP (271MW), Tila-1 (299MW), Tila-2 (297MW)	Lower Badigad STO (380MW), Budhi Gandaki (340MW), Upper Marsyangdi -2 (327MW), Dudh Koshi-IV (350MW), Upper Tamor (285MW), Bheri-2 (270MW), West Seti STO (750MW), SR-06 STO (309MW) Tamakoshi 3 (650MW), Khimti Shivalaya STO (396MW)	Bajhang Upper Seti (216MW), Naumure STO (218MW), Upper Mugu Karnali (240MW), Bheri-1 (270MW), Humla Karnali-Cascade (637MW)
			2902MW (4267MUSD)	**5782MW (9661MUSD)**	**7869MW (14776MUSD)**	**4118MW (7963MUSD)**
	RE		**800.2MW (823MUSD)**	**1355.6MW (1363MUSD)**	**900MW (950MUSD)**	**1025MW (925MUSD)**
	Technical Studies		Planning for Cascade Operation utilizing STO; Considerations of access road for hydropower corridors	Introduction of pumped storage; Innovation of generation planning considering export		
	Construction		**1) HPPs in Construction Licenses**	**2) HPPs in Survey Licenses**	**3) HPPs in GoN categories**	
Power System	400kV Bulk Power System		NEW BUTWAL - NEW DAMAULI - RATMATE - LAPSI PHEDI, RATMATE – HETAUDA – DHALKEBAR – INARUWA	LUMKI – KOHALPUR – LAMAHI - NEW BUTWAL, DHALKEBAR - NEW KHIMTI - DUDHKOSHI, DHALKEBAR – DUDHKOSHI – ARUN	ATTARIA - LUMKI, NALSING GADH - NEW DAMAULI, LAPSI PHEDI - NEW KHIMTI	CHAINPUR - ATTARIA, PURKOT - LUMKI, NALSING GADH - KOHALPUR, PHILIM – RATMATE - CHILIME HUB, ARUN – INARUWA - ANARMANI
	Interconnection Lines		NEW BUTWAL - GORAKHPUR	LUMKI - BAREILY, INARUWA - PURNEA	DHALKEBAR 2 - MUZAFFARPUR	KOHALPUR - LUCKNOW
	Major Cities Demand		Kathmandu 506 MW (LAPSI PHEDI, RATMATE) Birgunj 302 MW (HETAUDA) Pokhara 195 MW (NEW DAMAULI) Dhalkebar 126 MW (DHALKEBAR)	Kathmandu 935 MW (LAPSI PHEDI, RATMATE) Birgunj 570 MW (HETAUDA) Pokhara 371 MW (NEW DAMAULI) Dhalkebar 368 MW (DHALKEBAR) Lumbini 637 MW (NEW BUTWAL)	Kathmandu 1,329 MW (LAPSI PHEDI, RATMATE) Birgunj 873 MW (HETAUDA) Pokhara 403 MW (NEW DAMAULI) Dhalkebar 564 MW (DHALKEBAR) Lumbini 975 MW (NEW BUTWAL)	Kathmandu 2,017 MW (LAPSI PHEDI, RATMATE) Birgunj 1,326 MW (HETAUDA) Pokhara 612 MW (NEW DAMAULI) Dhalkebar 856MW (DHALKEBAR) Lumbini 1,481 MW (NEW BUTWAL)
	Cost		**1213MUSD**	**2765MUSD**	**2397MUSD**	**2717MUSD**
	Technical Studies		Power system operation planning with power trade; Interconnection studies with neighboring countries	Harmonization between power system and VRE; Power System Planning for Western Province		
	Construction		**Reinforcement of Interconnection Lines and Domestic Bulk Power System**	**Establishment of 400kV Bulk Power System**		**Operation of Transmission Lines for Direct Export**
Developer			Matching between domestic HPPs and potential developers; Facilitation of involvement of foreign developers	Establishment of SPCs		
Finance			Enhancing the finance capacity of domestic finance	Involvement of Indian/Bangladesh Investors; Utilization of Sovereign or PPP loans for Nepal, India and Bangladesh		
Rule & Regulation			Establishment of modality of power trade in PPA, grid interconnection and related regulations			
Capacity Development			Restructuring the Power Sector	Scale-up of governmental entities in quantity and quality		
Energy Transition			Facilitation of electrification by EV, E-cooking or Heat pumps; Research and development for green hydrogen or ammonia		Energy transition by utilizing surplus electricity	

Source: JICA Study Team

Figure 3.1-1 Development Milestones and Pathways in IPSDP

3.2 CHALLENGES OF IPSDP

To realize IPSDP, it is crucial to steadily execute the currently ongoing projects by 2026. From 2027 onwards, it will be necessary to develop the currently surveyed projects. Many of these new developments lack established implementation structures and financing. Feedback from local private and government operators indicates that it is difficult for individual license-holding developers to undertake large-scale projects alone. Meanwhile, domestic resources are already being utilized, making the promotion of participation by foreign developers, investors, banks, and development aid agencies an urgent task. To achieve development post-2027, issues such as integrated river basin development, access road development, securing transmission routes, and promoting power trade must be addressed. Additionally, enhancing the capacity of government organizations and the entire power sector is also necessary.

Many of these challenges need to be addressed promptly to achieve development post-2028. However, as the various fields are closely related, it is difficult to solve them through the efforts of individual government organizations alone. Inter-organizational cooperation is crucial. For instance, while NEA's risk in expanding power trade does not directly affect the technical considerations of power sources and systems as an electrical phenomenon, it is closely related to financial aspects, such as who bears the financial risk in power trade, institutional aspects, such as whether organizations other than NEA will be involved in the power trade, and governance aspects, such as adjusting interests among various stakeholders, including neighboring countries.

This section organizes the major challenges, summarizing knowledge and experiences of JICA Study Team through IPSDP studies and comments obtained from various stakeholders. Although issues of power sector are closely related each other, these are classified into the following five categories;

(1) Clean export
(2) Expansion of the Nepal power system
(3) Business structure of power sector
(4) Finance / Private Investment
(5) Energy Transition

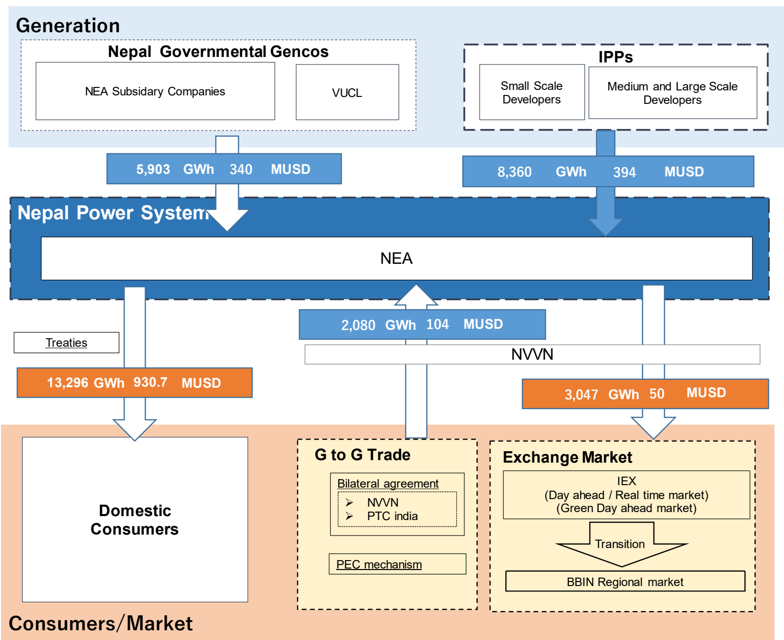
Major topics and relation with generation, power system, finance, legal framework and governance are integrated in Table 3.2-1.

Table 3.2-1 Challenges in the Five Necessary Transformations in the Nepalese Power Sector

Item	Generation	Power System	Finance	Institutional / Legal	Governance
1.Clean Export					
Concentration of risks on NEA for expansion of clean export	✓	✓	✓	✓	✓
Securement of power supply reliability for domestic demand	✓	✓		✓	✓
Technical issues on expansion of power trade		✓			
Development scheme on interconnection lines		✓		✓	✓
Issues on legal framework for power trade	✓	✓		✓	
Insufficient experiences on export oriented hydropower projects by Nepalese developers	✓	✓	✓	✓	
2.Expansion of the Nepal Power System					
Necessary adaptation measures against climate change risks.	✓	✓		✓	
Necessity of integrated river basin development	✓			✓	✓
Capacity development on tunnel design and construction	✓			✓	
Need to improve system planning capabilities.		✓		✓	
Interconnection of VRE		✓		✓	
Mitigation of environmental and social impacts	✓	✓	✓	✓	
3.Business Structure of Power Sector					
Necessity of capacity development of GoN	✓	✓		✓	
Clarification of role of government organizations and sector reforms.	✓	✓		✓	✓
Shortage of domestic contractors	✓	✓		✓	
Necessity of international standard PPA	✓			✓	✓
4.Finance/Private Investment					
Finance from domestic investors or lenders	✓	✓	✓	✓	
Necessity of promotion of FDI	✓	✓	✓	✓	
Enhancement of assistance by development partners	✓	✓	✓	✓	
5.Energy Transition					
Promotion of electrification	✓	✓	✓	✓	
Establishment of legal framework and supply chain in Green Hydrogen	✓	✓	✓	✓	

3.3 REQUIRED TRANSFORMATIONS AND FUTURE OUTLOOK FOR THE POWER SECTOR

Figure 3.3-1 illustrates the current business structure of power sector in 2023.



- ➢Financial risk is concentrated in NEA, as it functions as the single buyer.
- ➢NEA's dual roles in generation and transmission/distribution lack transparency in decision-making processes and financial performance.
- ➢There is unclear role distribution between NEA and public power entities like VUCL and RPGCL,
- ➢NEA's near-monopoly in transmission/distribution results in a lack of competition, potentially increasing costs.
- ➢A strategic and speedy decision-making organizational structure is required for power trade.

Source: JICA Study Team

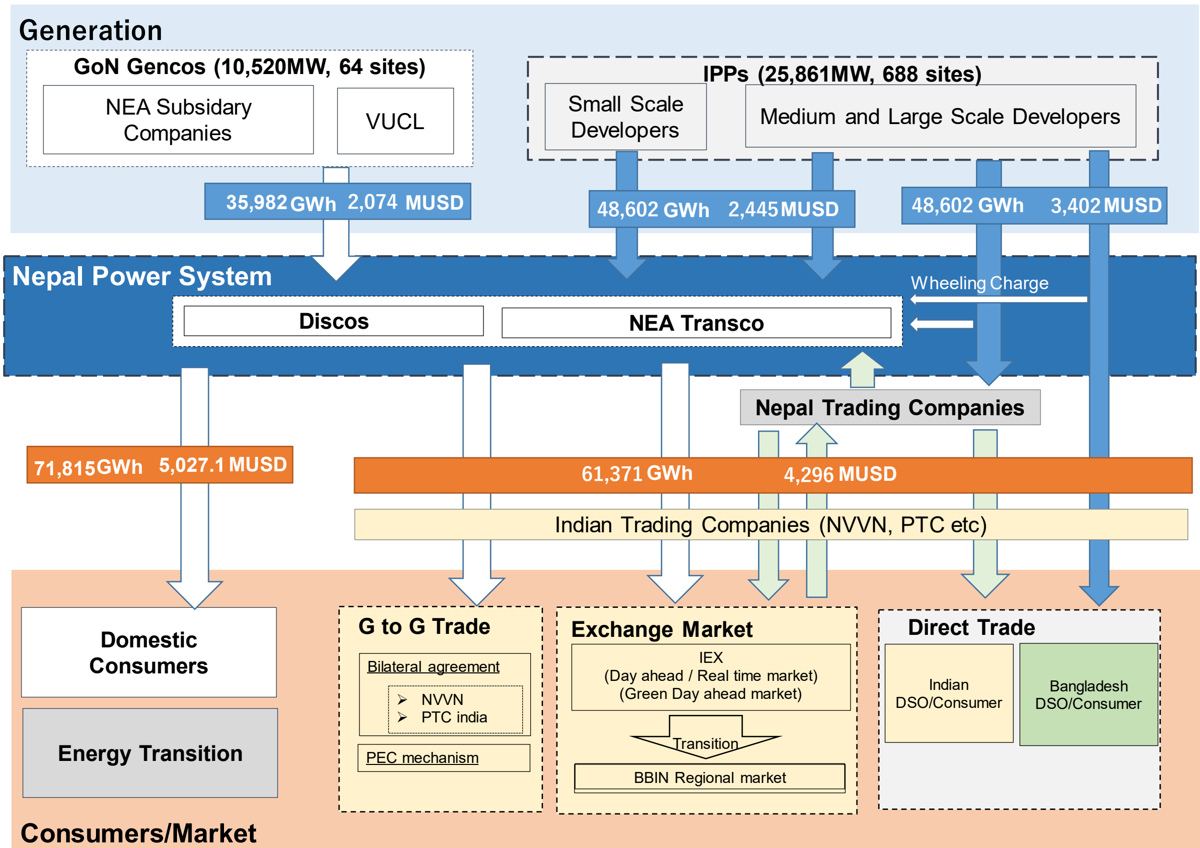
Figure 3.3-1 Business Structure of the Power Sector in 2023

As of 2024, the power sector has achieved stable power supply and better financial conditions owed to development over the past decade. However, to achieve the development outlined in IPSDP, the following transformations are required:

(1) Expansion of Clean Export
(2) Significant Scale Expansion of the Power System
(3) Reform of the Power Sector
(4) Expansion of Finance/Private Investment
(5) Energy Transition

Figure 3.3-2 illustrates the envisioned business structure of the power sector in 2035, reflecting the five required transformations.

In 2035, power sector in Nepal will see dramatic expansion in terms of supply-demand scale, clean export, institutional structure and cash flow. The installed capacity and number of power plant sites will be 7,497 MW and 58 sites for government entities such as NEA and VUCL, and 20,718 MW and 654 sites for IPPs. The power system will have a 400 kV backbone transmission lines from east to west across the country with a total length of 1,818 km and six 400 kV international interconnection lines.



Source: JICA Study Team

Figure 3.3-2 Future Outlook for the Power Sector in 2035

The amount of power market business and sales revenue will also increase significantly. Domestic consumption will be 39,966 GWh (44.3%) with a revenue of 3,311 MUSD and Clean Export will be 50,259 GWh (55.7%) with a revenue of 3,518 MUSD, out of the total sales volume of 90,224 GWh. Clean Export will particularly account for 6% of the national GDP, developing into an export industry that would earn foreign currency. The institutional structure of power sector will also be significantly transformed with the establishment of power trading companies alongside NEA unbundling to generation, transmission, and distribution.

Nepal has substantial potential for energy transition including CO_2 reduction in neighboring countries through Clean Export. It is also expected to promote electrification of energy derived from fossil fuels and the utilization of green hydrogen and ammonia.

3.4 CHALLENGES AND RECOMMENDATIONS FOR IPSDP

The milestones and pathways suggest that technical studies for Clean Export, strengthening and attracting IPPs, securing domestic and international financing, power system planning and capacity development of human resources must be completed within the next few years to achieve large-scale development beyond 2030. In other words, immediate actions are required to realize massive expansion of power sector. It is critical to deal with these issues but these tasks involve various fields and domestic stakeholders and international agencies. It seems to be challenging to achieve solely through the activities of individual agencies and requiring various adjustments. Considering the limited resources of relevant agencies such as MoEWRI, DoED, ERC, NEA, and development partners, it is also important to focus on priority issues that Nepal must address urgently. In this context, following five pilot projects are proposed;

- Sunkoshi-3 HPP for Clean Export
- Phukot Karnali HPP as Pioneer of Karnali River Basin
- Transaction Advisory Services for Capacity Development
- Assistance of Domestic Financial Capacity
- Implementation of Pilot Project for Energy Transition

To resolve these situations, implementation of pilot projects is expected to be effective, encompassing many of the identified issues. Once pilot projects indicate solution of these issues such as PPA, interconnection with foreign grid, setting of transmission wheeling charge or physical infrastructure development, these could be good benchmarks for subsequent projects.

As these pilot projects are required to explore various new fields with a lot of issues or unforeseeable risks, it supposed to be challenging for IPPs or private sector to deal with these pilot projects. Therefore, it might be reasonable to select GoN entities such as NEA or VUCL as implementing agencies and to execute these pilot projects under the assistance from GoN and development partners.

Based on understandings above, issues and recommendation of pilot projects are summarized in Table 3.4-1.

Table 3.4-1 Challenges and Recommendations on IPSDP

Item	Sunkoshi-3 HPP	Phukot Karnali HPP	Transactionary Advisory Service	Enhancemen of HIDCL	Energy Transition
1.Expansion of Clean Export					
Concentration of risks on NEA for expansion of clean export	Establish direct trade scheme with India and BPDB				
Securement of power supply reliability for domestic demand	Improve dry season supply capacity	Improve dry season supply capacity			
Technical issues on expansion of power trade	Review and establish generation plans considering three-country interconnection	Promote development of Lumki-Bareily interconnection line			
Development scheme on interconnection lines	Establish and operate three-country interconnection				
Issues on legal framework for power trade	Facilitate smooth expansion of power trade by involving India and BPDB				
Insufficient experiences on export oriented hydropower projects by Nepalese developers	Project implementation by NEA	Participation of VUCL	Advisory support for NEA and/or VUCL		
2.Significant Expansion of the Nepalese Power System,					
Necessary adaptation measures against climate change risks.	Develop 400kV substations and transmission lines in Sunkoshi basin	Develop access roads in Surkhet to Karnali basin Phukot - Lumki 400kV T/L			
Necessity of integrated river basin development		Promote development of Karnali main river and Tila river basin			
Capacity development on tunnel design and construction		Undertake the first large-scale tunnel construction in Karnali basins			
Need to improve system planning capabilities.	Develop three-country interconnection plan	Develop power system plan for western area			
Interconnection of VRE					
Mitigation of environmental and social impacts	Implement study of international standards including transmission lines	Implement study of international standards including transmission lines			
3.Reforming the Electricity Sector					
Necessity of capacity development of GoN	Improve NEA's capabilities	Improve VUCL's capabilities	Strengthen organizational structure of the power sector and coordination with other ministries		
Clarification of role of government organizations and sector reforms.			Promote organizational restructuring along with power law revision		
Shortage of domestic contractors	Involve Indian developers and BPDB	Involve NHPC	Expand the sector to include contractors, equipment suppliers, construction consultants, legal advisors		
Necessity of international standard PPA	Consider PPAs with India and Bangladesh	Consider PPAs with India			
4.Expanding Finance/Private Investment					
Finance from domestic investors or lenders				Strengthen HIDCL and private banks	
Necessity of promotion of FDI	Encourage entry of developers and financial institutions from India and Bangladesh	Promote financing by NHPC		Matchmaking between foreign and domestic businesses on India and Bangladesh Expand clean energy use in energy-intensive industries	
Enhancement of assistance by development partners	Ensure cross-regional involvement of development partners including India and Bangladesh	Support VUCL		Propose finance promotion measures such as loans, PPPs, sector loans, TSLs"	
5.Energy Transition					
Promotion of electrification					Propose new electrification promotion measures such as heat pumps
Establishment of legal framework and supply chain in Green Hydrogen					Propose pilot projects for green hydrogen and ammonia

Source: JICA Study Team