

Chapter 3

A Resilient Power System and Power Market in Lao PDR

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1. Introduction

1.1. Power System

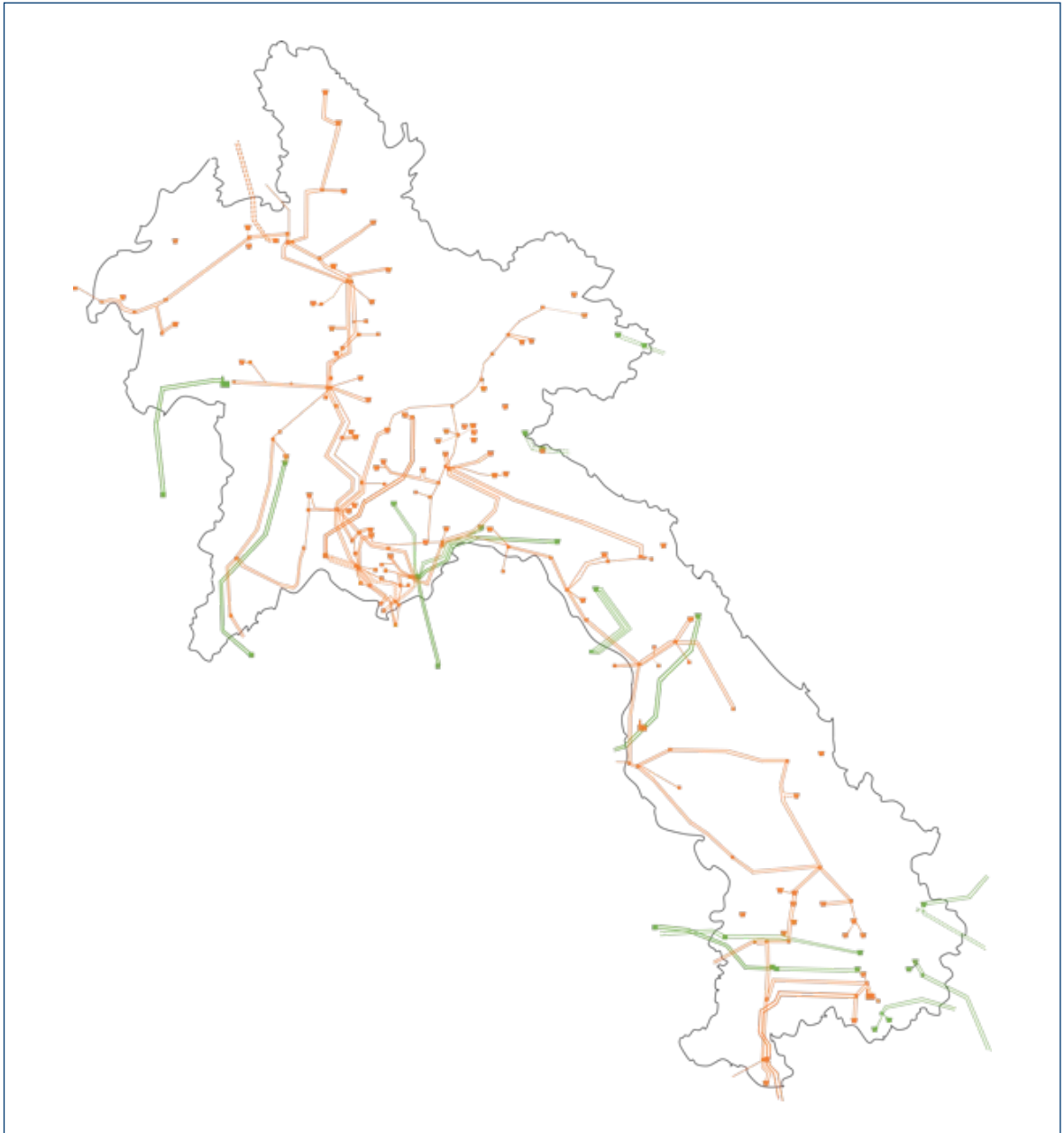
Lao People's Democratic Republic (Lao PDR) covers a land area of 236,800 square kilometres – approximately 1,000 kilometres from north to south – with a population of approximately 7.5 million (MNRE, 2020). It borders five countries – Cambodia, China, Myanmar, Thailand, and Viet Nam. Forests cover approximately 70% of the country's land area, and the country has abundant potential for renewable energy sources such as hydropower, solar, wind, and biomass, as well as coal mining, which greatly exceeds the country's energy consumption. Thus, electricity generated in Lao PDR can be supplied domestically as well as exported to neighbouring countries.

The power transmission system of Lao PDR is divided into two types of transmission lines – one for domestic supply and one for export, where power plants are directly connected to neighbouring countries. Each is not connected to the other within the borders of Lao PDR. The voltage classes are 500 kilovolts (kV), 230 kV, and 115 kV. The transmission system for domestic supply is connected to the systems of China, Myanmar, and Thailand by 115-kV interconnection lines and to the system of Cambodia by 230-kV and 115-kV interconnection lines. To avoid synchronous interconnection between neighbouring countries, the transmission systems for domestic supply that are interconnected with each neighbouring country are divided domestically.

The 500-kV and 230-kV transmission systems for domestic supply are mostly operated by Électricité du Laos Transmission Company (EDL-T), and the 115-kV line by Électricité du Laos (EDL). Some sections are operated by other transmission operators.

Export-dedicated transmission lines transmit electricity from export-dedicated independent power producers (IPPs) to neighbouring countries. Thailand and Viet Nam are directly connected to transmission lines from IPPs in Lao PDR. To Cambodia, the power lines of EDL and transmission operators are directly connected, and power from the power producers procured by EDL is transmitted to Cambodia. The electricity system of Lao PDR is depicted in Figure 3.1.

Figure 3.1. Electricity System of Lao PDR

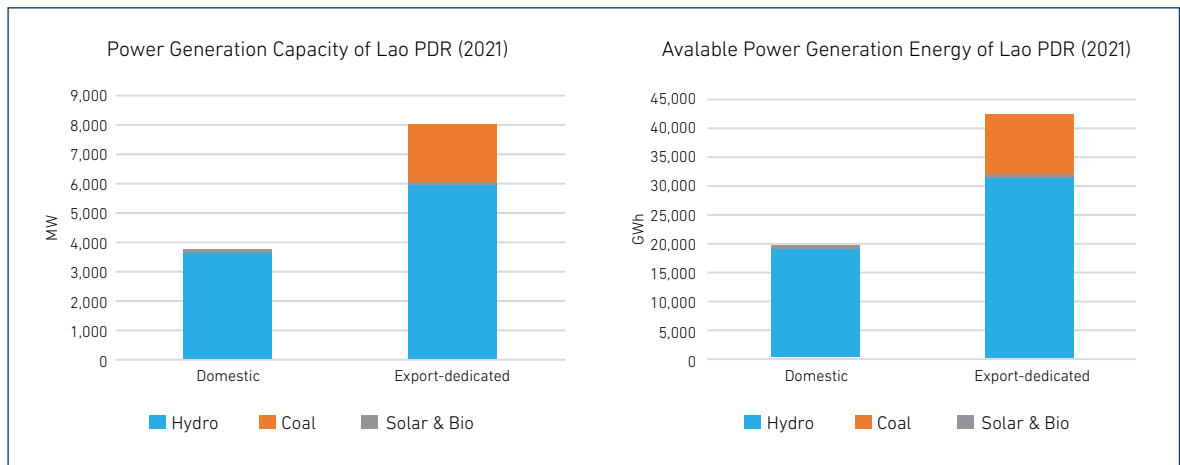


Green: export-only transmission lines; orange: domestic grid.

Source: MEM and EDL.

In 2021, Lao PDR's power generation was 11,661.14 megawatts (MW), with a generation potential of 58,813.42 gigawatt-hours (GWh) per year (Lao Statistics Bureau, 2022). Figure 3.2 shows Lao PDR's installed power generation capacity and available power generation capacity above 1 MW. Hydropower plants account for 94% of the installed capacity of power plants in the electricity system for domestic supply. There is one coal-fired power plant, Hongsa, with an installed capacity of 1,878 MW and whose installed generating capacity for export is 1,803 MW.

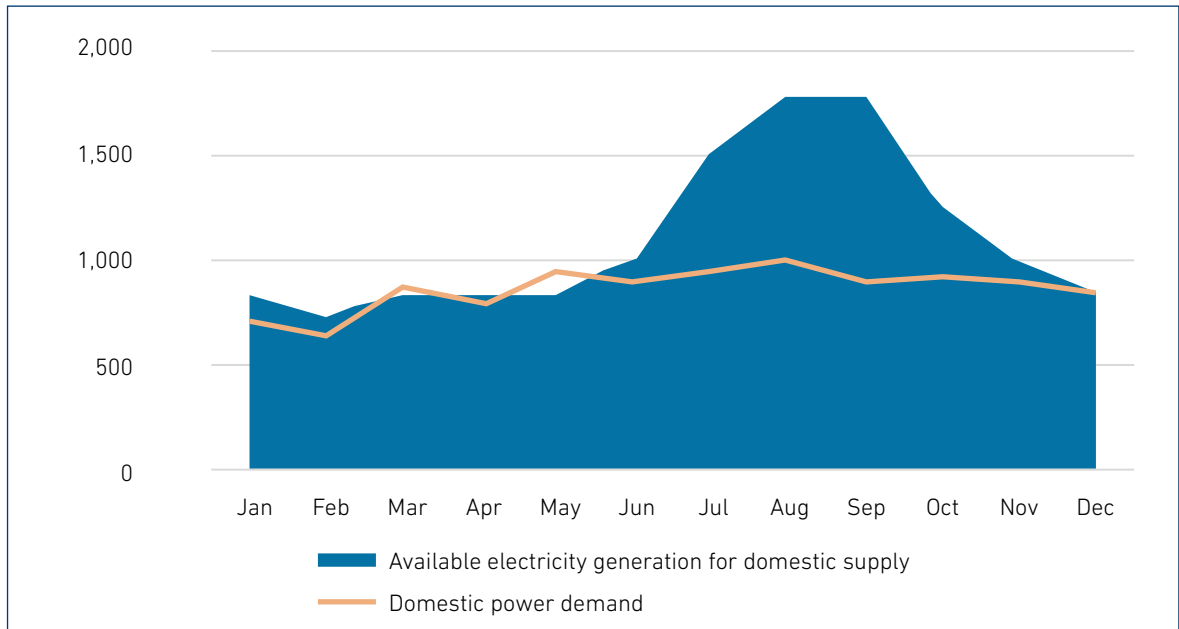
Figure 3.2. Power Generation Installed Capacity and Available Power Generation Energy



Source: Statistical Yearbook Energy and Mines 2022, DPC, MEM, 2022.

A graph overlaying the amount of electricity and electricity demand in 2022 is shown in Figure 3.3. The amount of electricity available for generation was 13,390 GWh/year. The amount of electricity available for generation in each month of the wet season (i.e. August–September) was around 1,800 GWh, while the amount of electricity available for generation in each month of the dry season (i.e. December–May) was 800–900 GWh. This fluctuation in the amount of electricity during the wet and dry seasons poses various challenges for the power system for domestic supply.

Figure 3.3. Monthly Electric Power Demand in Terms of Available Power Generation Energy, 2022



Source: Author.

The maximum demand for domestic generators in 2022 was recorded at about 1,800 MW on 4 August, or about 10,500 GWh/year, with a generation surplus of about 800–900 GWh in August and September 2022. The amount of this surplus exceeds the capacity of the current interconnection line with Thailand (i.e. around 600 GWh/month on average), but the entire amount cannot be exported to Thailand. In the dry season, the amount of electricity that can be generated is roughly balanced against domestic demand, but due to stability transmission constraints on the 230-kV transmission line connecting the northern part of the country to Vientiane, all of this electricity cannot be transmitted; thus, the supply of the missing electricity is dependent on imports from Thailand.

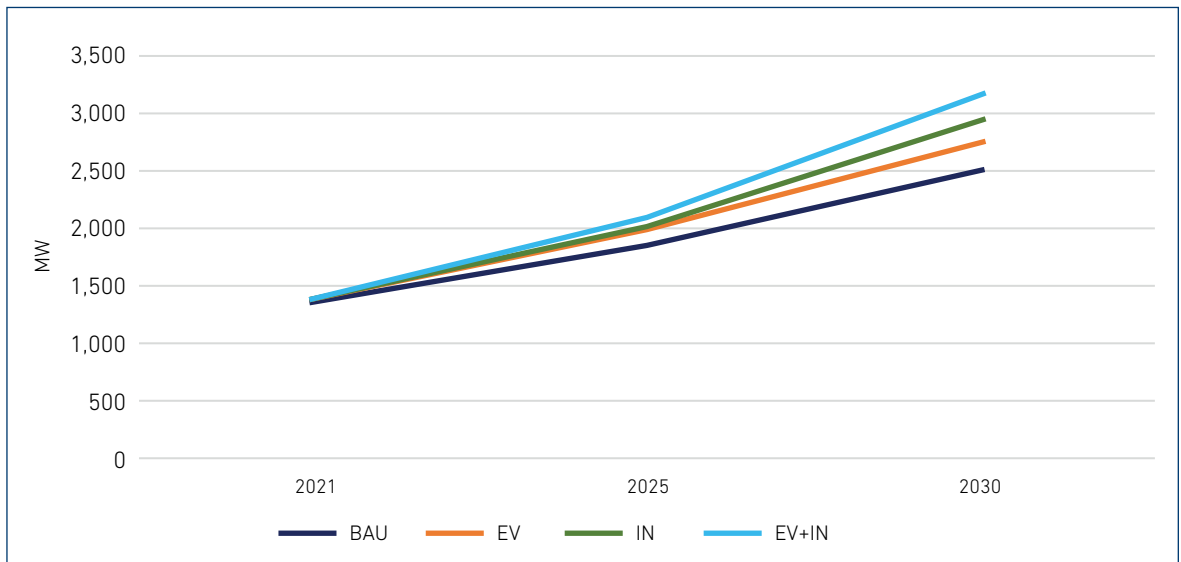
The *National Power Development Strategy, 2021–2023*, developed by the Ministry of Energy and Mines (MEM) and approved by the National Assembly in 2021, forecasts domestic electric power demand to 2030 (MEM, 2021b). The power demand forecast assumed a business-as-usual (BAU) case, electric vehicle penetration case, and industrial demand development case. The power supply plan for domestic supply was developed in accordance with the following policies:

- (i) The power supply mix for domestic supply is to be diversified, with a target share of 75% hydropower (with an emphasis on reservoir-based hydropower), 14% coal, and 11% other renewable energy sources.

- (ii) Hydropower plants will optimise the use of water resources and ensure that the amount of electricity generated meets the demand during the dry season. This will also reduce the costs of importing electricity from neighbouring countries. Coal-fired power plants also play an important role in providing a stable supply of electricity to the electricity grid, especially during the dry season.
- (iii) Renewable energy power plants, including solar power and biomass, must be price-competitive, maintain retail prices, and have technical guarantees of grid connection.
- (iv) The basic policy is ultimately to ensure that, even in the dry season, supply is available without having to rely on imports.

The following figures show the maximum electric power demand forecast, installed generation capacity, monthly available electricity generation, and electric power demand for the BAU case to 2030. The maximum electricity demand is 2,541 MW, and the installed generation capacity is 5,784 MW, which is 2.3 times the maximum electric power demand to ensure that domestic generation facilities can supply demand even during the dry season.

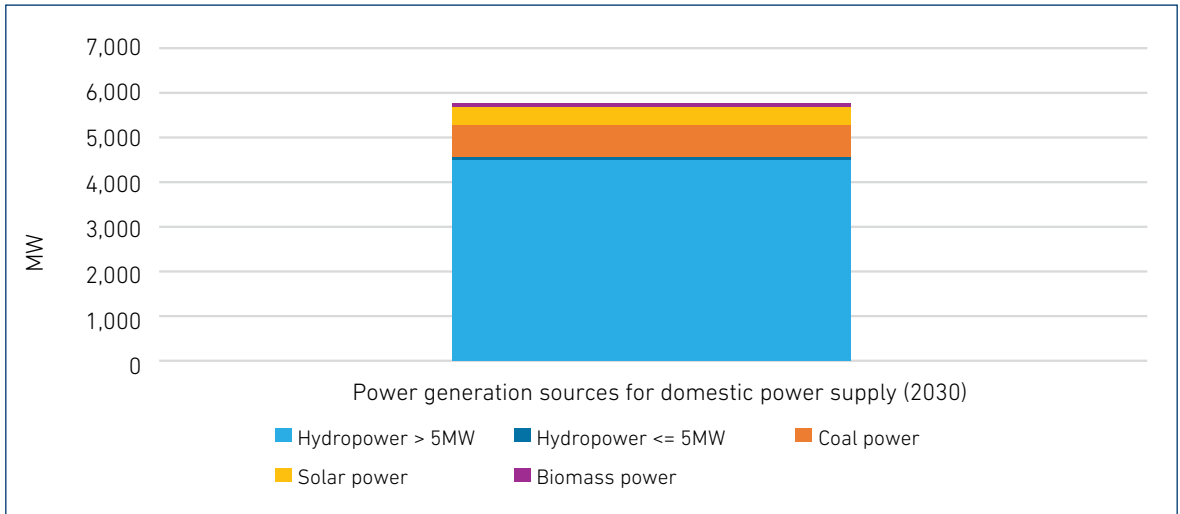
Figure 3.4. Maximum Domestic Power Demand Forecast, 2021–2030
(megawatts)



BAU = business as usual, EV = electric vehicle penetration case, IN = industrial demand development case.

Source: MEM (2021b).

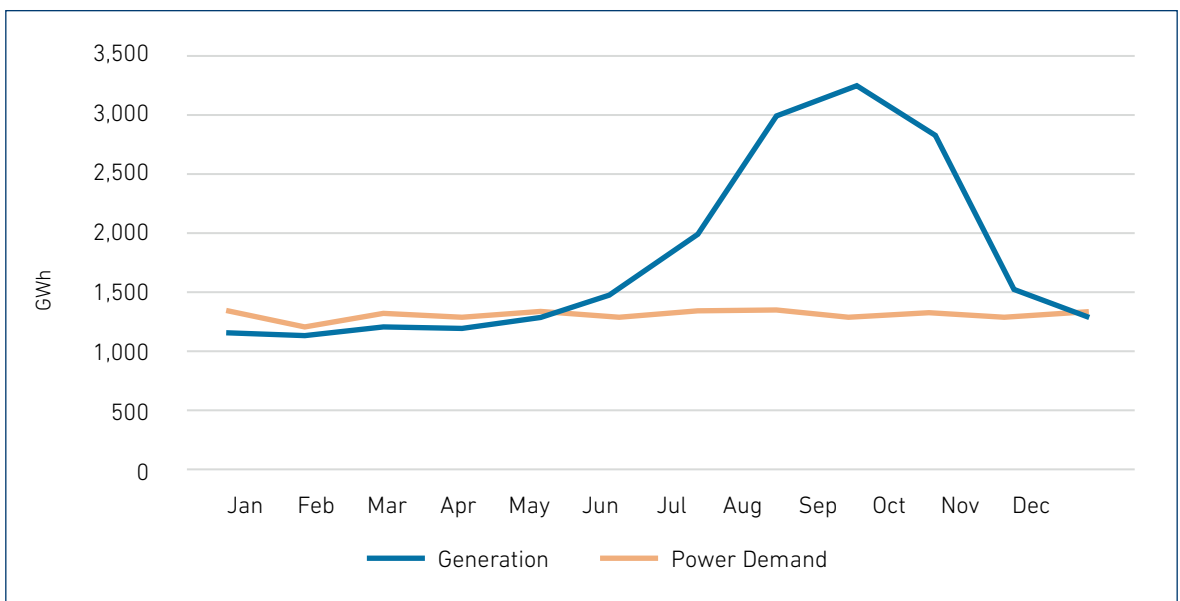
Figure 3.5. Power Generation Sources for Domestic Power Supply, 2030
(megawatts)



MW = megawatt.

Source: MEM (2021b).

Figure 3.6. Monthly Available Electric Power Generation and Electric Power Demand, BAU
(gigawatt-hours)



BAU = business as usual.

Source: MEM (2021b).

1.2. Power Market

The power sector in Lao PDR is governed by MEM. The power system generators for domestic supply are the IPPs and EDL-Generation Public Company (EDL-Gen). The domestic transmission and distribution company (i.e. 115-kV and distribution lines) is EDL, and the domestic transmission company (i.e. 500-kV and 230-kV lines) is EDL-T. There are also individual transmission companies, with a railway transmission company and a transmission company operating a 230-kV (i.e. 500-kV design) transmission line near the Cambodian border.

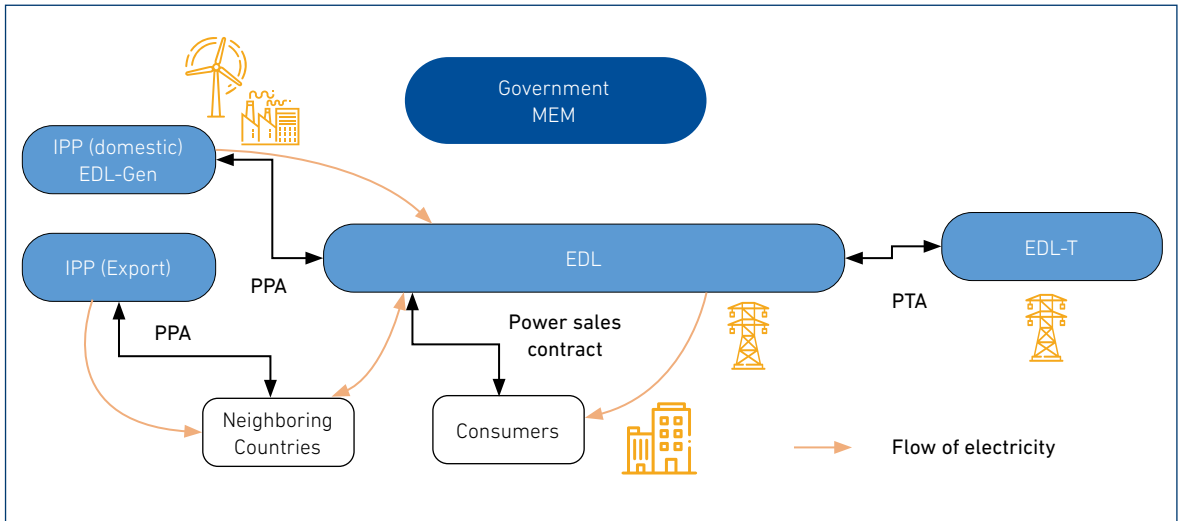
The business of selling electricity in Lao PDR is regulated by the Electricity Law, with one state-owned company – EDL – selling domestic electricity. EDL procures the electricity that it sells from IPPs and EDL-Gen, the domestic power producers.

The transmission system for domestic supply is connected to the China, Thailand, and Myanmar grids by 115-kV interconnection lines, and to the Cambodia grid by 115-kV and 230-kV interconnection lines.

Power purchase agreements and power transmission agreements in the transmission system of Lao PDR power sector take the following forms: (i) contracts between IPPs and the various EDLs for domestic supply, (ii) contracts between IPPs and the Electricity Generating Authority of Thailand (EGAT) and Vietnam Electricity (EVN) for power export, (iii) contract between EDL and EGAT for power sharing, (iv) contract with China Southern Power Grid Company Limited (CSG) for power sharing, (v) contract between EDL and Électricité du Cambodia (EDC) for power export, and (vi) power transmission services agreement between EDL and EDL-T and other transmission companies.

Under the contract with EGAT in Thailand, prices for both imports and exports are relatively low, and the price difference between exports and imports is small. This makes it convenient for EDL to have EGAT adjust for excesses and deficiencies in the wet and dry seasons during the year. Yet if there is an annual excess of exports, electricity is sold to Thailand at a lower price; if there is an excess of imports, the unit price is higher. It is therefore advantageous for Lao PDR to ensure that imports and exports are balanced in this contract and to have Thailand make the adjustment. Figure 3.7 shows the players in Lao PDR power sector.

Figure 3.7. Power Sector Players



EDL = Électricité du Laos, EDL-Gen = Électricité du Laos Generation Public Company, EDL-T = Électricité du Laos Transmission Company, IPP = independent power producer, MEM = Ministry of Energy and Mines, PPA = power purchasing agreement, PTA = power transfer agreement.

Source: Authors.

2. Strengths, Weaknesses, Opportunities, and Threats to Energy Security

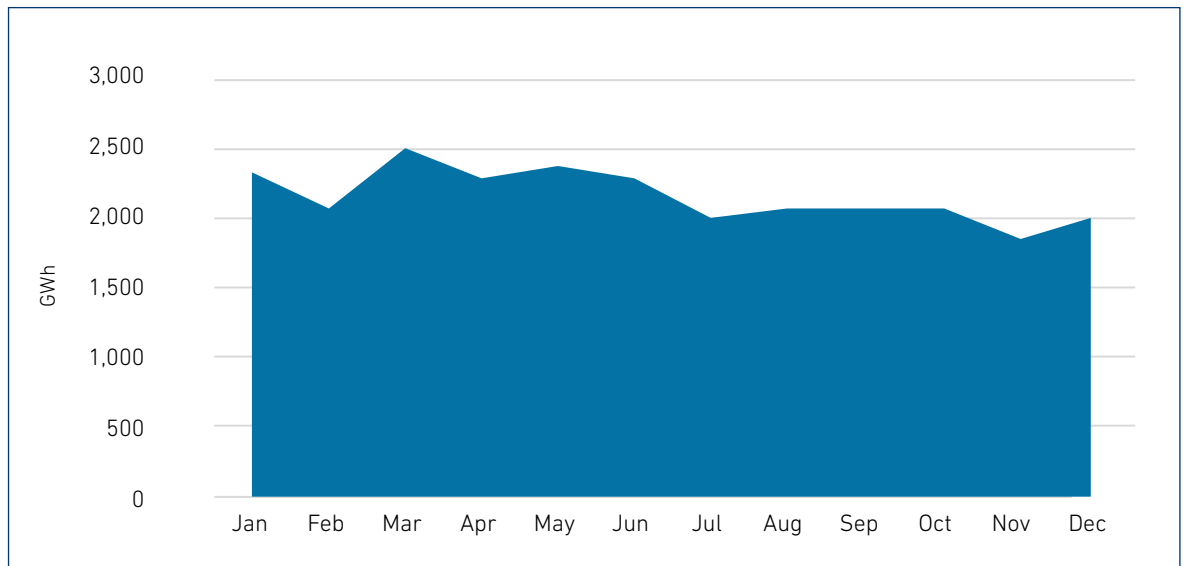
2.1. Strengths and Opportunities

Lao PDR shares borders with five countries, and renewable energy – including hydropower – can be exported to them all year round, regardless of the season.

Export-only power generation projects are operating well. Hydroelectric energy is well utilised, contributing to the security of the supply in neighbouring countries and fuel reduction in thermal power. The amount of electricity available for export-only power generation remains somewhat constant throughout the year. This may be due to the fact that many power plants, such as Nam Ten 2, have large reservoirs to store water between seasons, allowing for seasonal adjustments, and the Mekong River-

flowing Sayaburi power plant ensures that its export-only generating capacity is at a level that allows for some generation during the dry season. Export-only hydropower, which is exported via export-only transmission lines, is also used to save on generation fuel, as the main source of electricity in Cambodia, Thailand, and Viet Nam is thermal power. Therefore, Lao PDR hydropower generation is almost fully utilised throughout the year in neighbouring countries. The monthly electricity generation of export-only hydropower plants in Lao PDR in 2022 is shown in Figure 3.8.

Figure 3.8. Monthly Electric Power Energy Available from Export-Dedicated Hydropower Plants, 2022 (gigawatt-hours)



Source: EDL.

Opportunities exist in Lao PDR to enhance regional energy security through deep integration with neighbouring countries' power grids through the transmission network of the Association of Southeast Asian Nations (ASEAN).

2.2. Weaknesses and Threats

Available electricity generation during the rainy season from the electricity system for domestic supply exceeds domestic electricity demand in Lao PDR. Some of this surplus power is exported through EDL and the interconnection lines in China, Myanmar, and Thailand. However, the grid is not designed to export the surplus from power plants far from the interconnection lines, and there are constraints on the capacity of the interconnection lines and domestic transmission lines, resulting in surplus power that cannot be consumed.¹

The power system for domestic supply may experience shortages during the dry season. In this case, imports are made through the interconnection lines with Thailand. EDL – in charge of domestic electricity supply – imports this electricity from Thailand at a higher unit price, which has caused the financial situation of EDL to deteriorate. In particular, in 2023, annual imports exceeded exports for the first time.

Hydropower producers for domestic supply often enter into take-or-pay contracts, setting the unit cost of electricity generation so that the revenue from the sale of the electricity that can be generated covers project costs. As a result, if surplus electricity is not used during the rainy season, EDL's financial situation worsens, as EDL does not receive payment for it. It thus becomes difficult to pay the cost of generating electricity for domestic supply, discouraging investment in power generation projects. Moreover, Lao PDR has few domestic funds and relies on foreign capital to fund power generation and transmission projects.

The electricity system for domestic supply must secure non-hydropower generation to compensate for the lower hydropower generation potential during the dry season. Coal-fired power plants; solar, wind, or biomass power plants; or electricity imports are candidates. However, coal-fired power plants run counter to carbon neutrality. In addition, power plants set up only for the dry season have high fixed costs per unit of electricity. Solar and wind power plants have large output fluctuations during the day and night and due to changes in weather conditions, which can lead to instability in the electricity system.

¹ Until the early 2000s, the scale of electricity generated for domestic use was such that the capacity of the interconnection lines was sufficient to export any surplus to Thailand. However, the capacity of the interconnection lines has not changed significantly since then, resulting in a surplus of electricity that cannot be exported.

3. Key Directions for the Power System and Market

An energy transition should be planned to increase the resilience of the energy supply, taking into account stability, sustainability, and restoration of supply in emergencies. Lao PDR is rich in renewable energy resources such as hydropower, solar, wind, and biomass, which – in addition to its own supply – can be exported to neighbouring countries and have the potential to contribute to carbon neutrality throughout the region. Lao PDR can utilise its abundant renewable energy resources to secure its own energy supply and to improve the electricity resilience of neighbouring countries as well.

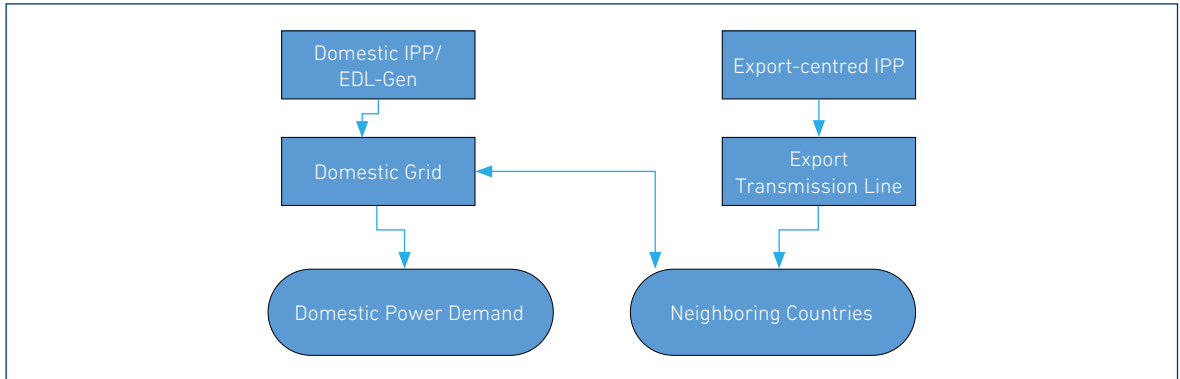
However, there are many challenges to overcome, including the establishment of a transmission network and grid operation system to efficiently and stably supply sufficient amounts of renewable energy to Lao PDR and its neighbours, prevention of power system instability due to fluctuations in renewable energy generation output, and development of appropriate power market mechanisms. The main directions are considered to be the development of an investment environment for renewable energy, transmission, and substation facilities as well as the establishment of an appropriate grid operation regime. These measures would address the challenges in the power system to achieve energy transition in Lao DPR, while maintaining and improving resilience in terms of generation, transmission, and power markets. The following actions are recommended.

- (i) **Develop renewable energy power plants.** In addition to hydropower plants, solar and wind power plants should be developed in sufficient quantities and to ensure power supply capacity to meet domestic demand and needs of neighbouring countries. Investments in solar, wind, and biomass will diversify the energy mix and reduce dependence on hydropower. In addition, the electricity system should be able to cope with fluctuations in renewable energy output, which are influenced by inter-seasonal, day/night, and weather changes.
- (ii) **Integrate the power system for domestic supply with the export-only power system.** Although Lao PDR's export-only power is effectively utilised and the export-only power projects are operating well, the financial situation of the domestic supply power projects is deteriorating due to power surpluses and excess imports during the dry season. To supply domestic demand and to export to neighbouring countries the electricity surplus generated in Lao PDR, IPPs should be able to transmit electricity domestically and to neighbouring countries by integrating the export-only transmission lines and domestic supply power system. The domestic grid and transmission lines of the export-only IPPs should operate as a single unit, and the IPPs should be able to sell power on the integrated power system.

To integrate the domestic and export-only power systems, two contractual arrangements are possible. In the first, the power producer IPP – EDL-Gen – would simultaneously sell electricity to the domestic utility EDL and to electricity producers in neighbouring countries through fixed contracts. IPPs, domestic electricity producers, and electricity producers in neighbouring countries could also participate in the creation of a power market and sell power through a market mechanism. In the second, the power producers, IPPs, and EDL-Gen would sell power to a single organisation, Single Buyer, which in turn would sell power to the domestic electricity utility, EDL, and to electricity producers in neighbouring countries. The domestic electricity utility would purchase electricity at the same price as the electricity utility in the neighbouring country, however.

The current contracts with IPPs are shaped to correspond to the system shown in Figure 3.9, and it is difficult to supply electricity through an integrated system within the performance period of the original contract.

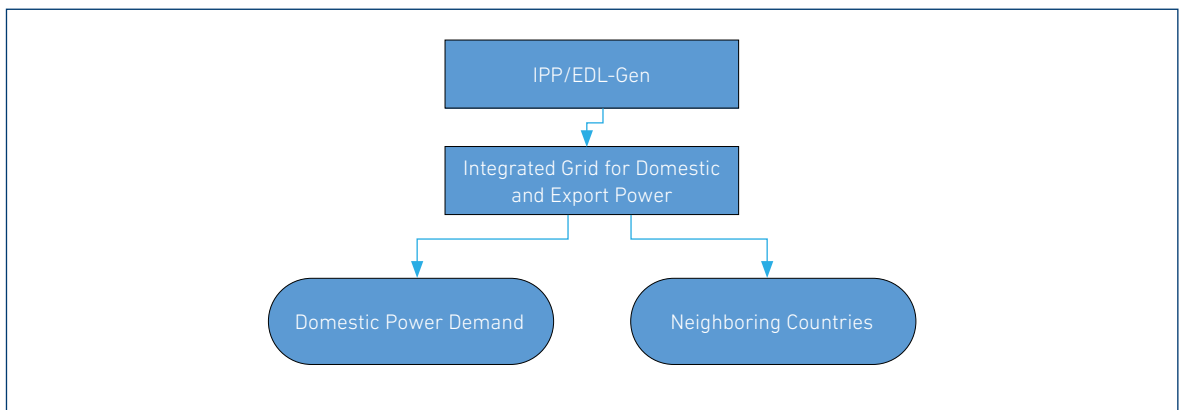
Figure 3.9. Current Electric Power System



EDL-Gen = Électricité du Laos Generation Public Company, IPP = independent power producer.
Source: Author.

An opportunity could be to switch contracts and to supply electricity through an integrated system at the end of the build–operate–transfer contracts for the Houay Ho hydropower plant in 2029 and the Nam Theun 2 hydropower plant in 2035. The supply of electricity could then be provided by an integrated system as shown in Figure 3.10.

Figure 3.10. Proposed Electric Power System



EDL-Gen = Électricité du Laos Generation Public Company, IPP = independent power producer.
Source: Author.

Along with the integration of the domestic and export power systems, it is necessary to strengthen the wide-area interconnected transmission network that links Lao PDR with neighbouring countries and to establish an appropriate operation system. The following must be considered: (i) development of the investment environment (e.g. development of guidelines on financing schemes and procedures for planning and construction); (ii) development of market mechanisms; (iii) establishment of the scope of synchronous interconnection; (iv) development of a wide-area grid operation system (e.g. supply–demand and frequency adjustment methods, utilisation of the regulating capacity of reservoir hydropower plants, response to fluctuations in renewable energy output, and emergency response); and (v) establishment of grid codes (e.g. conditions for interconnection line operation, requirements for generator connection, and information and data sharing rules)

4. Conclusions and Policy Recommendations

4.1. Development of Renewable Energy Power Plants

In addition to hydropower plants, the country should strive to develop renewable energy sources such as solar and wind power plants in sufficient quantity and efficiency to ensure power supply capacity for domestic demand and to meet the needs of neighbouring countries.

Lao PDR's aims to diversify its power sources for domestic supply by developing hydropower, coal-fired power, and other renewable resources. Although coal-fired power generation makes use of domestic coal, the country has to proceed cautiously with its development due to its carbon-neutral orientation and the difficulty of financing it. In addition, the cost of wind and solar power generation has been decreasing in recent years thanks to their global spread, and if such energy can be utilised without waste and output fluctuations on the electricity system can be well controlled, these can be alternatives to coal-fired power plants. For this reason, it is expected that Lao PDR will shift its policy emphasis to the development of renewable energy sources such as hydropower, solar, and wind power as a source of power in the country.

These renewable energy sources are also carbon-neutral and are in high demand from neighbouring countries, where thermal power plants still account for a large share of electrical energy supply. Exports can make the region carbon-neutral, improve the security of the energy supply, and increase the efficiency of the supply. Monetising the export production of renewable energy – which is at surplus levels domestically – is also important for Lao PDR. In addition to optimising electricity export contracts, measures to develop a certification system for renewable energy and to promote sales to neighbouring countries should be considered.

The government should develop a master plan for hydropower, solar, wind, and their power systems, including both domestic supply and exports, with priorities, implementation plans, processes, and indicative funding and cost-sharing.

4.2. Integration of the Electricity System

To effectively supply Lao PDR-generated electricity domestically and for export to neighbouring countries without any surplus, the power system for domestic supply should be integrated and operated with dedicated transmission lines for export. The integration of these power systems would enable the transmission of electricity from the power producers to neighbouring countries as well as domestically. The domestic grid and the transmission lines of the export-only power producers should be operated as an integrated unit, and the power producers should sell their electricity on the integrated power system.

To promote the integration of the power grids and strengthening of wide-area transmission networks that are interconnected with neighbouring countries, guidelines should be developed that will govern the planning process and the selection of the entities to implement transmission line projects.

When integrating power systems for domestic supply and those dedicated to export, a transmission system operator is required to operate both the power supply for domestic supply and export from the power producers to neighbouring countries. If a market is created, it will be necessary to carry out a wide range of grid operations tasks, such as balancing supply and demand based on the amount of electricity traded on the market, as well as responding to accidents. The required power system facilities should be identified, and transmission network plans should be developed. It is also necessary to develop a grid code to operate, plan, and build an integrated power system of renewable energy and domestic and international interconnected lines efficiently and with a high degree of supply reliability.

For renewables, studies should be carried out on the adjustment of output fluctuations due to weather and seasonal changes and on the standards and control of inverter equipment used for grid connection and its operational methods, which should be reflected in grid codes, guidelines, and manuals.

4.3. Development of Market Mechanisms

When integrating the power system for domestic supply and that for export, there are two possible forms of power sales contracts that the power producers can use. A power producer can sell power to both the domestic electricity provider, EDL, and the electricity provider in the neighbouring country; or, the power producer can sell power to a single organisation, Single Buyer, which in turn sells power to EDL and the electricity provider in the neighbouring country.

In the former case, there are examples of power generators in countries with well-developed international electricity markets that are selling electricity to their own countries as well as exporting it across borders. As the network expands from Lao PDR to neighbouring countries, this approach is likely to require an organisation to manage the intra-regional market operator and export process, as multiple power generators would be selling electricity domestically as well as to neighbouring countries. If the integrated system develops into a market with multiple power producers, cooperation between market participant entities and with neighbouring countries is essential to ensure smooth operation, including agreement on the intra-market pricing mechanism, securing priority for domestic electricity supply, and managing the intra-regional electricity market and international interconnection lines.

In addition to long-term contracts between two parties, there are several market formats – ranging from contracting for delivery in advance (e.g. the day-ahead market) to spot markets – where the seller and buyer each identify and contract with the other party in real time through a price mechanism. However, from the point of view of ensuring reliability in grid operation, it is preferable to proceed from a long-term contract between two parties where the amount of supply is determined in advance or from a market with a large day-ahead market. A way to apply this form to Lao PDR would be to start by limiting it to small-scale transactions in one area or with one power producer, and then gradually expanding the scope of application.

There are examples of EDL purchasing electricity from power producers in the south of the country and exporting it to Cambodia.² EDL could expand and apply the scope of its exports in this way, but the scale of electricity that it handles would be several times larger than that of domestic electricity sales, which would be considered too risky given the scale of EDL's operations. Considerable capital and funding would be required. Therefore, as the scale increases, it is envisaged that the role of Single Buyer would be taken up by another entity that can control more funds.

² EDL and EDC have an agreement to export electricity; the contract between EDL and EGAT provides for the flexible exchange of electricity.

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