Energy Security White Paper: Policy Directions for Inclusive and Sustainable Development for Lao PDR and the Implications for ASEAN

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ASEAN: Enhancing Connectivity and Resilience

ERIA
Economic Research Institute for ASEAN and East Asia

Energy Security White Paper:
Policy Directions for Inclusive and Sustainable Development for Lao PDR and the Implications for ASEAN

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Sepon Mine Vilabouly district, Savannakhet Province, Southern Lao

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Hongsa Coal Fired Power Plant
Ban Han, Hongsa, Sainyabuli, Lao

Foreword

Saleumxay Kommasith
Deputy Prime Minister and Minister of Foreign Affairs
Lao People's Democratic Republic

Over the past decades, rapid economic development has transformed Southeast Asia, preparing the region to join the international production network. This transformation has enabled vibrant exports of manufacturing products, textiles, and other high-valued-added goods, including energy, from the Association of Southeast Asia Nations (ASEAN) to the global market. This success is largely due to global investments attracted by the region's favourable labour force, growing connectivity, innovation, and regional political stability driven by ASEAN's vision.

This achievement reflects the collective efforts of ten Southeast Asian countries to promote mutual trust and cooperation, broadening collaboration with nations worldwide for regional prosperity. However, the ASEAN region, like others, faces numerous challenges, including maintaining economic growth, addressing climate change, managing natural disasters, and tackling both traditional and non-traditional security issues. Lao PDR, in particular, must broaden its macroeconomic structure and policies to address current economic issues – such as inflation, currency depreciation, and employment – and future challenges related to green growth for sustainable development.

In 2024, Lao PDR has set the theme for its ASEAN Chairmanship as 'ASEAN: Enhancing Connectivity and Resilience.' Under this theme, energy security remains a key priority for ASEAN, supporting inclusive ad sustainable economic growth in the region.

ASEAN countries are parties to the Paris Agreement, committing to reducing global greenhouse gas emissions (GHGs) as outlined in each country's Nationally Determined Contributions (NDCs). To achieve the carbon neutrality target by mid-century, countries must pursue alternative fuel pathways, shifting from fossil fuel-based energy systems to cleaner energy systems. Multiple decarbonisation pathways are essential. Amongst the policies and measures encouraging investment in a sustainable energy system and energy security, energy efficiency and conservation are considered low-hanging fruits for curbing energy consumption and reducing CO_2 emissions.

Many ASEAN countries are rich in natural resources and renewable energy, including solar, wind, biomass, geothermal, and hydropower. With the right policies, the region can accelerate the deployment of these renewable resources to green its energy system. Lao PDR, in particular, can play a significant role in contributing renewable electricity to help decarbonise the ASEAN grid through power connectivity and trade. The gradual adoption of hydrogen and ammonia as fuel presents untapped potential for clean energy, converting surplus renewable energy from hydropower, solar, wind, and biomass into clean fuel molecules like hydrogen and ammonia. These could be used in transportation, power generation, and industries, benefiting countries that can produce green hydrogen and ammonia. Lao PDR stands to gain significantly from this, given its abundant renewable resources.

Despite exporting electricity to neighbouring countries, Lao PDR has a high dependency on imported finished petroleum products such as gasoline, diesel, liquefied petroleum gas (LPG), and kerosene for domestic consumption in transportation, commercial, and residential sectors. This dependency makes Lao PDR's energy supply security vulnerable, necessitating an appropriate energy security strategy to mitigate potential risks.

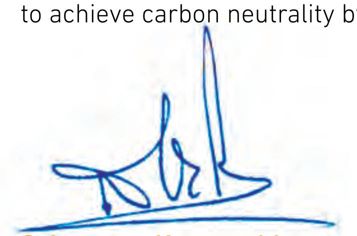
This White Paper provides key policy directions for all involved sectors, emphasising the importance of cooperation, collaboration, and investment in creating a resilient, inclusive, and sustainable energy system. Sustainable finance, through investments in clean technologies, renewables, energy efficiency, ecotowns, smart grids, electric vehicles, and battery energy storage, can drive sustainable development and decarbonisation in the region.

While policies are advancing to support clean and renewable energy development, unnecessary energy subsidies must be scrutinised. These subsidies place an economic burden on many countries, particularly developing economies in ASEAN, deter investment in energy infrastructure and efficient technologies, and undermine renewable energy initiatives. Although some ASEAN countries have acted to remove these subsidies, governments must do so cautiously, as removing subsidies can be politically sensitive. Inefficient subsidies can lead to increased energy demand, fiscal pressure, harmful emissions, and hinder sustainable green growth. However, targeted subsidies are essential to support the energy poor.

Financing clean technologies and renewables is a critical issue in Lao PDR and ASEAN. Innovative financing mechanisms, including blended finance, can help make renewable projects and clean energy development technologies bankable. New sources of capital mobilisation through green bonds, sustainable bonds, social bonds, and climate transition bonds can accelerate the deployment of clean and renewable technologies in the region.

ASEAN must enhance cooperation under its three community pillars: promoting infrastructure connectivity, narrowing the development gap, promoting greater economic integration and people-to-people exchanges, and strengthening relations with external partners. This approach will maintain ASEAN's relevance and centrality in the evolving regional architecture. Regional and international cooperation can facilitate technological transfers and lower the cost of clean and renewable energy deployment in ASEAN. Under Lao PDR's ASEAN Chairmanship, the country aims to expand ASEAN's external relations, strengthen ASEAN's centrality and unity, and construct a regional architecture for stability, peace, and development.

Promoting carbon neutrality and ensuring national and regional energy are critical for inclusive and sustainable development. This energy policy white paper calls for cooperation from all stakeholders in policy design and implementation at all levels. Lao PDR is ready to support the development of policies and measures suggested in the White Paper and to collaborate bilaterally, regionally, and internationally to achieve carbon neutrality by 2050.



Saleumxay Kommasith

Deputy Prime Minister and Minister of Foreign Affairs
Lao People's Democratic Republic

Preface

Chansaveng Boungnong
Deputy Minister, Ministry of Energy and Mines
Lao People's Democratic Republic

I am very delighted to see the comprehensive development of the Energy Policy White Paper on 'Energy Security Policy Directions for Inclusive and Sustainable Development for Lao PDR and the Implications for ASEAN.' This White Paper has been developed through careful processes, including two extensive stakeholder consultations to gather views and feedback from line ministries, involved agencies, embassies, and experts on key issues around energy security, inclusive growth, and sustainability of the energy system.

The White Paper reflects the commitment of both parties, 'The Ministry of Energy and Mines (MEM), Lao PDR, and the Economic Research Institute for ASEAN and East Asia,' as outlined in the signed 3-year Memorandum of Understanding (MoU). Under this MoU, ERIA provides technical support to MEM during Lao PDR ASEAN Chairmanship and follows up on the Energy Security White Paper. I am also very pleased that ERIA plays critical role in supporting ASEAN countries in the energy transition. As you may be aware, Lao PDR, as well as the rest of ASEAN, are facing tremendous challenges regarding the future energy landscape and how the energy transition will embrace a new architecture, including sound policies and technologies to ensure energy access with affordability, energy security, and energy sustainability. Pathways towards carbon neutrality could be diverse amongst countries. Availability, accessibility, and affordability of energy supply are the most fundamental requirements for Lao PDR with respect to the energy security and sustainable development.

Lao PDR's high potential renewable energy resources, such as hydro, solar, wind, and biomass, could be utilised at optimum levels to accelerate the share of renewables in the energy mix. These renewable resources could allow Lao PDR to build a green and resilient economy. Lao PDR is in a good position not only to achieve the decarbonisation of its own energy system, but also to help green the ASEAN Grid through power exchange and the future power market of ASEAN.

In the context of energy security, Lao PDR could be more resilient if all end-use sectors move towards electricity usage. The adoption of electric vehicles (EV) could be a good strategy, as it would reduce the import of petroleum products such as gasoline, diesel, LPG, and kerosene. Accelerating the use of electricity in all sectors will bring about new opportunities for developing clean fuels such as ammonia and hydrogen, which could be used for industries and heavy-duty transport modes for both inland and waterway transportation. Furthermore, green ammonia will provide a new opportunity for producing green agricultural fertilisers domestically, reducing the need to import fertilisers and petroleum products.

Although Lao PDR is expected to have a high share of renewables, some petroleum products will continue to play roles in the energy mix. Therefore, it is crucial for Lao PDR to leverage energy cooperation through existing ASEAN mechanisms such as the ASEAN Petroleum Security Agreement (APSA) to ensure mutual assistance during times of distress when energy supplies are disrupted by extreme weather conditions or terrorist attacks. Nonetheless, Lao PDR must also have systems in place to respond to supply disruptions, requiring reserve capacity and the ability to act in emergencies.

The next steps involve accelerating energy cooperation to ensure that Lao PDR is equipped with the human resources needed to handle required technologies for the transition and future challenges. This includes gaining knowledge of smart grids, the Internet of Things, possibly Artificial Intelligent (AI) and automation in the power sector, as well as understanding EVs and recycling if transportation shifts towards electricity and hydrogen fuel. Closing knowledge gaps in technology know-how for energy transitions and future technologies is paramount.

The Ministry of Energy and Mines, Lao PDR (MEM), seeks cooperation at all levels within the government, line ministries, agencies, and involved stakeholders to participate in the process of building strategic policies to safeguard Lao PDR's energy security while ensuring inclusiveness and sustainable development. I extend my sincere appreciation to ERIA and the experts led by Dr Han Phoumin, my senior staff such as Permanent Secretary Mr Khamso Kouphokham, Director General of the Research Institute for Energy and Mines Dr Anousak Phongsavath, and all DGs and key staff for their strong collaboration and hard work in shaping this important policy direction on energy security for inclusiveness and sustainable development for Lao PDR, with significant implications for ASEAN.

Chansaveng Boungnong

Deputy Minister, Ministry of Energy and Mines
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Preface

Tetsuya Watanabe
President of Economic Research Institute for ASEAN and East Asia (ERIA)

Since the 2020s, the world has navigated complex socio-political challenges, including the Covid-19 pandemic, the prolonged Russia–Ukraine war, Middle East tensions, and the ongoing economic conflict between the United States and China. Amongst the numerous issues arising from these black swan events, high energy costs have the potential to divert countries from long-term decarbonisation efforts. These events have also served as a wake-up call for countries to secure their energy sources while maintaining commitments to achieve carbon neutrality by 2050.

The Economic Research Institute for ASEAN and East Asia (ERIA) has actively supported the Association of Southeast Asia Nations (ASEAN) by crafting a regional decarbonisation roadmap and providing perspectives on energy transition technologies. These efforts help countries embark on the right paths for a smooth energy transition. Moving towards a green and clean energy system will depend on clean technologies, fuels, and the deployment of renewable energy resources. In this regard, energy policy and planning must facilitate and accommodate investments in clean technologies and renewables, providing new opportunities for investment and adding value to the economy.

Technically, ASEAN is rich in solar photovoltaic (solar PV) resources, though only a few countries, such as Viet Nam, Indonesia, and the Philippines, have significant offshore wind resources. The Mekong subregion countries (Thailand, Myanmar, Lao PDR, Cambodia, and Viet Nam) are abundant in hydropower resources. High penetration of hydropower, solar PV, wind, and biomass power generation in ASEAN could be facilitated by future power connectivity and trade within the entire region. If the ASEAN electricity market gradually evolves into a multilateral electricity market, hydropower resources from the Mekong subregion could play a significant role as baseload power, complementing the high penetration of solar and wind energy. In the absence of thermal power plants, large capacity electrical discharge 'battery energy storage' will be needed to back up power shortages during periods of low sunshine and wind. Battery energy storage, hydrogen fuel, and ammonia could be considered as they can be produced from excess electricity generated by hydropower, solar PV, wind, and biomass.

To support Lao PDR's ASEAN Chairmanship, ERIA and the Ministry of Energy and Mines, Lao PDR, signed a Memorandum of Understanding (MoU) to conduct a study and develop a Strategic White Paper on 'Energy Security for Inclusiveness and Sustainable Development for Lao PDR and the Implications for ASEAN.' This study is significant for ASEAN countries as it examines energy security while providing a direction for inclusive growth and sustainable development. The study aligns energy security objectives with countries' long-term climate commitments as reflected in their Nationally Determined Contributions (NDCs) and carbon neutrality goals by mid-century.

ERIA's experts, together with experts from the Ministry of Energy and Mines, approached this task diligently, including a scoping analysis of key energy issues and stakeholder involvement. Key energy issues were identified by analysing the entire energy system of Lao PDR in relation to neighbouring countries. These issues related to energy security include fossil fuel import dependency, energy efficiency, power grid connectivity, power systems, transportation (including the introduction of electric vehicles), carbon credits and mechanisms, carbon markets, regional and international cooperation for innovative technological transfer, financing sustainable energy infrastructure, and closing knowledge gaps. Experts used Strength, Weakness, Opportunity, and Threat (SWOT) analysis to understand the detailed aspects of opportunities and challenges, such as establishing energy security mechanisms, scaling up renewable penetration into the energy system, introducing electric vehicles and hydrogen fuel, and developing the carbon market.

This Energy White Paper provides broad policy directions with options best suited to various energy systems. Importantly, the White Paper is based on evidence-based research findings conducted by energy experts with input from a wide range of stakeholders. I am very pleased with the entire process of developing the 'White Paper on Energy Security Policy Directions for Inclusive and Sustainable Development for Lao PDR and the Implications for ASEAN.'

I hope this White Paper will open up new opportunities for developing detailed policies to support investment in clean technologies and the uptake of renewable resources. Fast-tracking energy finance for the energy transition is critical to ensure countries can secure enough funds for their energy transformation while maintaining energy security. I also want to thank all experts, especially Dr Han Phoumin, the Senior Energy Economist who led the team of experts in this important task. I also thank Mr Khamso Kouphokham, the Permanent Secretary; Dr Anousak Phongsavath, Director General of Research Institute for Energy and Mines; and all other key stakeholders involved in developing the White Paper. Additionally, I thank the Mekong River Commission Secretariat (MRCS) for deploying their experts to contribute to the analysis of sustainable hydropower development in the Mekong subregion.

Tetsuya Watanabe

President of ERIA

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The Energy Security White Paper was developed by a working group consisting of teams from Lao PDR and the Economic Research Institute for ASEAN and East Asia (ERIA). Laotian team included experts from the Ministry of Energy and Mines (MEM), while the ERIA team brought together specialists in energy economics and policy, power systems, sustainable transport, energy efficiency and conservation, green financing, and capacity-building training. Extensive consultations were conducted with various local experts in Lao PDR's energy sector, whose feedback greatly informed the international experts on the policy directions necessary to achieve energy security in the country.

This White Paper was led by Dr Han Phoumin, Senior Energy Economist at ERIA, and co-led by Dr Anousak Phongsavath, Director General of the Research Institute of Energy and Mines (RIEM), MEM, Lao PDR.

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List of Abbreviations

ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
CCS	carbon capture and storage
CCUS	carbon capture, utilisation, and storage
CN2050	Carbon Neutral Scenario 2050
CO_2	carbon dioxide
EDL	Électricité du Laos (Electricity of Lao PDR)
EE	energy efficiency
EEC	Energy efficiency and conservation
EGAT	Electricity Generating Authority of Thailand
EnMS	Energy management system
EPC	energy performance contract
ESCO	Energy Services Companies
EV	electric vehicle
FDI	Foreign direct investment
GCGS	green credit guarantee scheme
GDP	gross domestic product
GHG	greenhouse gas
IPP	Independent Power Producers
JCM	Joint Credit Mechanism
kWH	kilowatt hour
Lao PDR	The People's Republic of Lao
LCR	Lao–China Railway
LPG	liquefied petroleum gas

IPP	Independent Power Producers
MEM	Government of Lao PDR, Ministry of Energy and Mines
MEPS	minimum energy performance standard
MONRE	Ministry of Natural Resources and Environment
MRC	Mekong River Commission
Mtoe	millions tonnes of oil equivalent
MRV	Measuring, reporting, and verification
NDC	Nationally Determined Contribution
PNPCA	Procedures for Notification, Prior Consultation, and Agreement
R&D	research and development
SEZ	special economic zone?
TTO	technology transfer offices
TWH	terawatt-hour
VCM	voluntary carbon market

Part 1:

Energy Security White Paper: Policy Directions for Inclusive and Sustainable Development for Lao People's Democratic Republic and the Implications for the Association of Southeast Asian Nations

1. Overview of Energy Policy Directions

The Lao People's Democratic Republic (Lao PDR) along with the rest of the Association of Southeast Asian Nations (ASEAN) has pledged to comply with the goals to cut carbon dioxide (CO_2) emissions and find pathways to reach carbon neutrality by 2050 that are set out in the Paris Agreement. Meeting the carbon neutrality goals will require all nations to achieve large-scale reductions in greenhouse gas (GHG) emissions through fundamental transformation of energy systems — the decarbonisation of the power sector, followed by electrification or decarbonisation of energy consumption other than electricity, and offsetting the remaining CO_2 emissions using negative-emission technologies. However, the availability of power systems or low-carbon energy and the possibility of using alternative energy varies significantly across countries and regions, and energy transition cannot be accomplished uniformly. While numerous opportunities exist to reduce emissions in the ASEAN and East Asia region to meet the carbon neutrality targets by 2050, the transition to carbon neutrality must safeguard energy supplies against this backdrop, recognising that some cannot leap suddenly to renewable energy due to economic constraints and their inability to pay the huge costs of decarbonisation.

Lao PDR's energy primarily comes from coal, oil, hydropower, and other sources, including biomass, solar, and electricity for export. The energy supply of Lao PDR is predicted to double from 6.29 million tonnes of oil equivalent (Mtoe) in 2020 to 12.78 Mtoe in 2030, and it will triple by 2050 (18.57 Mtoe). Combined coal and oil constituted the largest share (60%) of the total supply in 2017. However, coal and oil combined are expected to reduce to about 20% by 2050 in the carbon neutrality scenario (CN2050). Hydro, solar, wind, and biomass have large potential in Lao PDR. They could allow the country to maximise its electricity net export on the ASEAN grid with the following expected capacity and schedule: 45 terawatt-hours (TWh) by 2030; 73 TWh by 2040; and 161 TWh by 2050. Renewable energy such as hydropower, solar photovoltaic, wind, and biomass will be the dominant fuel sources by 2050. Other clean fuels such as ammonia also play a role in decarbonising the power sector through coal/ammonia co-combustion. Electricity export could generate about $121 billion in cross revenue by 2050 – that excludes the potential from carbon credits generated from renewable carbon offsetting energy projects and the forest-reserves.

In 2024, Lao PDR is exporting electricty to neigbouring countries, but it has high import dependency (100% import of finished old products such as gasoline, diesel, and kerosene) for transportation, commercial, and residential consumption. In the medium term, import levels of these finished fuel products will continue to increase in Lao PDR, putting pressure on energy security. It is expected that there will be an increasing energy demand in Lao PDR for all sectors until 2050. This increasing energy demand poses a threat to supply security, and Lao PDR is yet to develop energy security measures to cope with unexpected supply disruption.

For end-use sectors, electricity is expected to comprise the largest share of final energy consumption by 2050. Its share is predicted to increase from a low base of 13% in 2017 to 42% by 2050 (Chapter 2). The increasing share of electricity consumption in end-use sectors will be key for decarbonisation. According to CN2050, In the final energy demand, oil and biomass will remain the dominant energy fuel sources until 2050. Lao PDR can do more to accelerate the use of electricity in transportation to reduce oil consumption. In fact, the transportation sector could embrace further acceleration of electric vehicles (EV) by 2050. Industries could also embrace the use of electricity or green hydrogen, as Lao PDR has the potential to develop substantial amounts of green electricity from hydropower, solar, wind, and biomass.

Lao PDR has a long journey ahead to decarbonise its whole energy system, as it needs to deal with the currently operational, 1,878 megawatts (MW) Hongsa coal-fired power plant, as well as a few more fleets of coal-fired power plants in the southern part of Lao PDR that the government has already committed to building (Chapter 1). It will need to find an appropriate strategy to deal with all of them. One solution could be to use clean coal technology combined with carbon capture, utilisation, and storage (CCUS). Since Lao PDR will have clean hydrogen production, the carbon from the power plant could be used to produce the synthetic fuels for transportation uses. Lao PDR has huge potential to decarbonise the energy system if the coal-fired power plants are put into retirement by 2050 and no additional coal power plants are built, except for those that the government has already committed to. If coal continues to be used during the energy transition, it will need to be co-combusted with ammonia and be integrated with CCUS for the CN2050.

Lao PDR has a broad policy direction for the inclusive and sustainable development of its energy security. It has explored the entire energy system and produced a set of policy recommendations and suggestions to ensure that the transformation of the energy system can be financed, the technology can be transferred; the energy cost is affordable; and the human resources and capacity can be built along the required technologies.

Due to renewable resource potentials, Lao PDR and ASEAN may need to accelerate the penetration of variable renewable energy and other carbon-free technologies (hydro, geothermal, biomass, nuclear, CO_2 free hydrogen, and CCUS) and negative-emission technologies, such as forest carbon sinks. All these renewable and clean technologies should contribute to carbon neutrality by 2050 and promote sustainable economic development. However, during energy transition periods, fuel switching from coal to natural gas, deployment of more efficient turbines, and co-firing with hydrogen or ammonia all play important roles in decarbonisation and energy security. While affordable technologies will be deployed in the mid-term, more niche but expensive technologies will be required in the last stage of complete carbon neutrality, including CCUS, hydrogen, and ammonia. The cost of decarbonisation is one of the most important concerns for Lao PDR and ASEAN as it could affect their affordability. In this regard, mitigation costs must be reduced through technological innovation, large-scale deployment of low-carbon technologies, and regional and international cooperation.

While multiple pathways for decarbonisation have been agreed, there are three important steps involving technological development and transformation that could allow developing countries such as Lao PDR, as well as ASEAN as a whole, to ensure smooth energy transitions.

i. Early decarbonisation transition technologies: These technologies involve the immediate switching from coal to natural gas power generation, waste to energy power plants in the power sector, and leak detection for fugitive emission reduction upstream. These technologies can be deployed in the early phases of a country's transition pathway and may be retired before reaching net-zero emissions.
ii. Partial emissions reduction transition technologies: These technologies include the co-combustion of coal-fired power generation with biomass, or ammonia, and the co-combustion of gas-fired power generation with hydrogen fuel. The share of biomass, ammonia, and hydrogen to the power generation mix must increase over time. For the upstream sector, introducing electrification in gas production and processing is highly recommended.
iii. Deep decarbonisation transition technologies: These technologies include CCUS combined with coal/gas power generation, blue hydrogen, blue ammonia, and CCUS in gas processing. Countries must embrace technologies that involve the power sector and the end-use sector as part of their pathway to carbon neutrality.

Financing clean technologies and renewables is still one of the most critical issues in Lao PDR and

ASEAN. Striving for a circular economy may offer environmental benefits and save resources through recirculating a larger share of materials, reducing waste in production, lightweighting products and structures, and extending the lifetime of products. All these activities also offer the opportunity for new business models. In addition, digitisation will give all countries the opportunity to transform the efficiency of their economies by ensuring that all economic activities become more energy saving and more energy efficient. This could contribute to overall emission reduction and particularly a reduction in energy intensity for the economy. Lao PDR and ASEAN countries will need to undertake as much technological innovation as possible, as well as helping to integrate nature-based carbon sinks into the solutions for emission reduction.

2. Energy Supply Security

Lao PDR, being a net importer of finished oil products, acknowledges that its oil consumption has increased over the past decade, however there are no substitute fuels available to balance this increase. Its continued reliance on oil imports and petroleum products (liquefied petroleum gas (LPG) and oil) and its growing electricity consumption means that to protect its energy security, the country must begin to plan its fuel and power reserves. Lao PDR should consider two options when designing a strategic oil reserve: i) a Strategic Petroleum Reserve, which the government will establish and control and where commercial stocks remain unaffected, and ii) a Mandatory Petroleum Reserve with enforcing laws that mandate oil traders to maintain certain levels of stock.

Lao PDR may need to designate a responsible party to oversee and evaluate the risk and determine the amount of oil reserves that will be required. This may be a subcommittee or an existing department within the Ministry of Energy and Mines (MEM) or related ministries. The party should consider the establishment of an oil reserve within Lao PDR and also assess any ongoing risks, such as those related to geopolitics and the supply and demand of oil outside of Lao PDR. The task should encompass the protocols for determining the triggering point (supply disruption level or amount of time in distress) at which the government must intervene when the situation reaches a predetermined level of oil supply insecurity. In this case, Lao PDR may need to develop multiple scenarios that might influence the oil security of the country, analyse the risks associated with each scenario, and determine its probability and impact. This planning includes how action plans are formatted to manage various incidents and other emergencies that may arise in Lao PDR or its neighbouring countries that could disrupt the supply of oil imports into the country. The incidents could occur domestically; in nearby countries; or present geopolitical risks, such as the emergency closure of domestic oil terminals, an emergency shutdown of refineries in countries that supply oil, such as Thailand and others, the crisis between Israel and Hamas, or the conflict between the US and Iran. Risk analysis should be undertaken simultaneously and spontaneously to assess the likelihood of potential damage and the seriousness of the emergencies. The government can evaluate an oil shortage incident in advance and use planned countermeasures to mitigate the effects by analysing the appropriate strategic fuel reserve during a crisis or unusual circumstance. It is recommended that a qualitative risk assessment should be developed by professionals in the oil and related industries to determine the risk factors relating to the supply and demand sides, the degree of severity of the impact, and the probability of an event occurring.

Oil logistics play a crucial role in the integration of the oil supply network, significantly influencing the distribution of oil to end-users. A well-designed and functional oil logistics system helps to facilitate timely and efficient oil transport from suppliers to customers in the appropriate quantity and at the proper time. If oil logistics are not operating at maximum efficiency, they can have a negative effect and seriously harm both the country's transportation system and its economy. Within the oil supply chain, oil logistics plays a pivotal role in enabling the nation to adapt to changes in the global economy. It is recommended that Lao PDR investigate ways to enhance the oil supply logistics system to improve the security of the oil supply, as oil logistics play a critical role in supporting the oil security system. It is also recommended that Lao PDR begin the analysis immediately by compiling information on the tankage facilities (tank capacities and fuel services) across Lao PDR's provinces and regions and compares the tankage capacity with the local demand. It should be noted that the scope of this exercise could be expanded to include monitoring the effects of seasonal variations in demand. Moreover, tankage-to-consumption ratios should be examined to ascertain the optimal ratio for every area. Lao PDR should determine the proper ratio or index for major cities and rural provinces, then design the corresponding facilities to ensure the quantity of reserves and storage meets demand. Lao PDR could also consider constructing an integrated oil logistics network or an oil hub to connect its oil terminals to the pipeline system in the northern region of Thailand to facilitate the oil distribution from Thailand to Lao PDR for a quick supply in an emergency, The oil supply could then be redistributed to the remaining regions of Lao PDR.

Those looking for better fuel for their homes are increasingly adopting LPG in residential settings to replace biomass. LPG can be the preferred choice because it offers a superior heating solution in many applications. It generates consistent heat as opposed to burning biomass, which is also less convenient, Because it is convenient and clean, LPG has become the standard fuel in the industrial sector. Monitoring of LPG consumption in the country should be a priority, considering that LPG consumption has been rising over the past few years and this is a trend that is continuing. It should be noted, however, that the reserves of LPG and oil do not always have to be the same due to their differing types of use. LPG is primarily used in the residential sector, whereas oil is primarily used in the transportation sector. Lao PDR should also consider the fact that, unlike LPG users in households who have options and may choose to switch back to biomass in the event of a shortage, oil consumers in the transportation sector lack alternative fuel sources as a backup. In contrast, most industrial plants have backup alternative fuel sources. Therefore, it is important to consider potential differences in the urgency of demand use when determining the rate of reserve for LPG versus oil.

It is recommended that the following specific procedures be designed to enable the petroleum reserve design strategy for Lao PDR to be conducted:

i. evaluate the reserve alternatives and their pros and cons;
ii. delegate a responsible party to oversee and evaluate the risk and determine the amount of oil reserves required;
iii. plan for a variety of scenarios that could impact Lao PDR's oil security;
iv. conduct a risk analysis of each scenario and assess its impact and likelihood of occurring;
v. calculate the quantity of oil to be reserved for emergencies in terms of percentages of monthly oil consumption or the number of days Lao PDR must maintain oil in storage;
vi. design the logistics system to keep the oil reserve in secure locations ready to be further distributed to support the whole oil system in Lao PDR; and
vii. apply this systematic approach to electricity and other electricity dependent sectors, such as EVs if the need arises.

3. Resilient Power Systems and Power Market

3.1. Grids and Mini Grids

Countries and companies are currently facing a volatile, uncertain, and rapidly evolving global energy landscape. Meeting the growing demand for electricity while pursuing GHG emission reductions in ASEAN will require huge investments in power generation capacity from decarbonisation strategies such as renewable energy and power system expansion. To address these challenges, it is necessary to implement a range of mechanisms and technologies, and from a grid perspective, it is believed that one of the keys is the development of multilateral power trading in ASEAN, known as the ASEAN Power Grid. Multilateral power trading focuses on optimising resources on a regional, rather than a national, basis to meet electricity demand across the region at the lowest possible cost. Potential benefits of multilateral power trading are:

i. more efficient use of the region's energy resources, leading to lower overall production costs in the ASEAN Power Grid, as optimal investments can be made at the regional level, rather than suboptimal solutions in each country;
ii. assistance for utilities in the region to balance their excess supply and demand, improve access to energy services, and reduce the cost of developing energy infrastructure;
iii. increased development and integration of renewable energy capacity into the regional grid; and
iv. reduced need for investment in power reserves to meet peak demand, thereby reducing operating costs and system losses, while achieving more reliable supply.

There have been significant, albeit slow, developments within ASEAN to increase regional trade based on bilateral agreements and to use existing infrastructure to move electricity throughout the subregion. However, there is still a long way to go before a fully-fledged ASEAN regional electricity market is established. One of the reasons for the slow progress is the variety of power sector structures and markets across ASEAN, which creates problems and barriers at all levels of cooperation. To address this issue, there is a need to accelerate close discussions amongst ASEAN-related sectoral energy bodies to establish a regional regulatory framework and technical standards. This should include institutional arrangements with clearly defined roles, responsibilities, and coordination mechanisms (including regional institutions); a comprehensive vision for decarbonisation that highlights the multiple benefits of multilateral power trading; and an identification of minimum technical requirements.

While aiming to develop an efficient power supply system between national grids by promoting multilateral power trading, it should be noted that there are still areas with no or low electrification in the islands and remote areas of the ASEAN region. In such areas, it is often unprofitable to connect to a large grid such as a national grid due to the cost of installing mountain and undersea transmission lines. As a result, small-scale diesel generation systems are popular, but diesel generation is also expensive and has a high environmental impact. Therefore, the introduction of renewable energy is expected, and when the cost of batteries becomes affordable, a combined battery/renewable energy system is expected to complement the intermittency of renewable energy, thereby reducing reliance on diesel generation. In a future phase, replacing existing diesel generators with power generation systems fuelled by liquefied natural gas, biofuels, and blue or green hydrogen would also be an effective approach. As they have a lower environmental impact than diesel generation, it is expected that their introduction will be promoted in areas where it is feasible to do so, considering profitability.

There is a growing need to adopt the emerging new technologies. The shift to cleaner energy requires smarter grids to manage the variability of renewables and to integrate distributed energy resources. For example, smart grid technologies such as real-time monitoring, data analytics, and advanced control systems will improve grid stability and enable efficient integration of variable renewable energy sources such as solar and wind. Artificial intelligence also plays a crucial role in this evolution, enhancing smart grids with predictive analytics for demand forecasting, fault detection, and optimised grid operation. In addition, an energy management system (EMS) combined with batteries and other energy storage solutions, are becoming essential to balance supply and demand and improve grid resilience. This confluence of innovative technologies can be an enabler, paving the way for a more decentralised, intelligent, and sustainable energy future.

3.2 Development of Renewable Energy Power Plants

In addition to hydropower plants, there is a need 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 development plan aims to diversify its power sources for domestic supply by developing hydropower, coal-fired power, and other renewable energies. Although coal-fired power generation makes use of home-grown coal, the country must proceed cautiously with its development in the future 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 the energy can be utilised without waste and the output fluctuations and characteristics of the electricity system can be well controlled, wind and solar power can be an alternative 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 energy in the country.

These renewable energy sources also have carbon-neutral value and are in high demand from neighbouring countries, where thermal power plants still account for a large share of the electrical energy supply. Renewable energy exports can make the region carbon neutral, improve the security of the energy supply, and increase its efficiency of supply. Monetising the export production of surplus renewable energy 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 also be considered. The Government of Lao PDR needs to develop a comprehensive plan for hydropower, solar, and wind, and their power systems, including both domestic supply and exports, with priorities, implementation plans, processes, and indicative funding and cost-sharing.

3.3 Integration of the Electricity System for Domestic Supply and the Electricity System Dedicated to Export

To effectively supply electricity generated in Lao PDR for domestic demand and to export to neighbouring countries without any surplus, the power system for domestic supply will be integrated and operated with a dedicated transmission line for export. The integration of the power systems will enable the transmission of electricity from the power producers to both domestic users and neighbouring countries. The domestic grid and the transmission lines of the export-only power producers will operate as an integrated unit, and the power producers will sell their electricity on the integrated power system.

To promote the integration of power grids and the strengthening of wide-area transmission networks that are interconnected with neighbouring countries, guidelines should be developed for the planning process and the selection of the entities to implement the transmission line projects. When integrating power systems for domestic supply and those dedicated to export, a transmission system operator is required to coordinate the power supply from the producer to both the domestic market and the export supply in neighbouring countries.

If a market is created, a wide range of grid operations tasks should be carried out, from balancing supply and demand based on the amount of electricity traded on the market, to responding to accidents. Transmission system operators could identify the required power system facilities and participate in, or lead in, the formulation of transmission network plans. It is essential to optimise the planning process and to develop a grid code to operate, plan, and build an efficient, integrated, renewable energy power system with a high degree of supply reliability and with domestic and international interconnected lines. For renewable energies, 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. The findings should be reflected in grid codes, guidelines, and manuals.

3.4 Development of Market Mechanisms

When integrating a power system for domestic supply and a power system exclusively for export, there are two possible forms of power sales contracts that the power producer can conclude: either the power producer sells power to both the domestic electricity provider, Électricité du Laos (Electricity of Lao PDR) (EDL), and the electricity provider in the neighbouring country; or the power producer sells power to a single organisation, Single Buyer, which in turn sells power to EDL and the electricity provider in the neighbouring country. In the first case, there are examples of power generators in areas with well-developed international electricity markets, such as the European Union and North America, Here, countries sell electricity to their own domestic markets as well as exporting it across borders to other countries. As the network expands from Lao PDR to neighbouring countries, this approach is likely to require an organisation to manage the intraregional market operator and export process, as multiple power generators will be selling electricity not only to their own country, but also to neighbouring countries. If the integrated system develops into a market with multiple power producers, cooperation between market participant entities and cooperation with neighbouring countries will be essential to ensure the smooth operation of the market, including agreement on the intramarket pricing mechanism, securing priority for domestic electricity supply, and managing the intraregional electricity market and international interconnection lines.

In addition to long-term contracts between two parties, there are several other market formats, ranging from contracting for delivery some time in advance, such as in 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, to ensure reliability in grid operation, it is preferable to proceed from a long-term contract between two parties where the amount of supply is determined some time in advance, or from a contract with a large day-ahead market. This could be applied in Lao PDR by starting with small-scale transactions in one area or with one power producer, and then gradually expanding the scope of application.

When considering the Single Buyer scenario, there are examples of EDL purchasing electricity from power producers in the south and exporting it to Cambodia[1]. It is conceivable that the EDL could expand and apply the scope of its exports in this way, but the scale of electricity it manages would be several times larger than that of the domestic electricity sales, which would be considered too risky given the scale of the EDL's operations. Considerable capital and funding would be required. Therefore, as the scale increases, it is expected that the role of Single Buyer will be taken up by another entity that can control more funds.

[1] The EDL and Electricite du Cambodge (Electricity of Cambodia) have an agreement to export electricity from Lao PDR; the contract between the EDL and the Electricity Generating Authority of Thailand (EGAT) provides for the flexible exchange of electricity between them.

4. Sustainable Transportation Systems

Transitioning to a sustainable transport system in Lao PDR has the potential to not only reduce CO_2 emission levels but also improve energy security and economic impacts. Lao PDR aims to achieve a 30% EV share by 2030, with supporting factors such as abundant hydropower, technological adaptability, and international collaboration, including proximity to China's EV industry. However, challenges include low infrastructure development, limited financing schemes and technical resources, and policy and regulation gaps. Although developing EV is crucial, transitioning towards sustainable transport may need to go beyond EV only. Other alternatives are biofuel development, public transport improvements, intercity rail enhancements, and logistics and distribution centre advancements. To achieve a sustainable transport system in Lao PDR, the country should develop a series of implementation programmes and policies over a short, medium, and long timeframe.

4.1. Short-Term Plan (2–5 Years)

i. EV acceleration strategies:
   - *Provide regulatory frameworks specifically for EV.*
     Policies such as incentives, standardisation, charging tariff, charging infrastructure, and vehicle registration should be created to increase the attractiveness of EVs, both on the demand and supply side.
   - *Expand EV-use in public transport i.e. electric buses, electric minibuses, or electric minivans.*
     Incentives should be provided to private companies willing to invest in EV public transport, to enable those in suburban areas (mainly on low incomes) to access public services in the urban areas or urban centres.
   - *Prioritise electric motorcycles for private EVs.*
     Motorcycles constitute a more affordable mode of private vehicle than cars. They also make up a higher share of private vehicles overall.

ii. Biofuel development:
   - *Incentivise private sectors willing to implement biofuel production on an industrial scale.*
     Fiscal incentives may be provided to increase the attractiveness and profitability of the biofuel business. Other non-fiscal support may be provided such as training and capacity building for smaller scale business in rural areas.

iii. Public transport improvement:
   - *Renew old bus fleets.*
     Inefficient, high-CO_2 emitting bus fleets should be replaced with newer fleets to improve the reliability of the whole bus transport system.
   - *Improve transit system governance.*
     The efficiency, punctuality, reliability, and convenience of the current bus transit system should be improved.

iv. Intercity passenger and freight rail development:
   - *Develop new special economic zones (SEZs) in regions along the railway systems.*
     This will accelerate the economic impact of the rail network and will attract new opportunities to the country.

v. Domestic fuel price adjustment:
   - Adjust domestic gasoline/diesel price to reflect international oil prices.
     Strategically reducing subsidies will lessens the dependency on oil consumption and make transition to EVs, or alternative transport modes other than private vehicles with internal combustion engines, more appealing. However, it will need to be done carefully to avoid a big impact on the economy.

vi. Transportation systems integration and intramodality:
   - *Integrate different modes of transportation to establish a smooth and uninterrupted travel experience for all.*
     The availability of multimodal hubs will facilitate seamless transfers between trains, buses, and other transportation modes.

vii. Sustainable tourism development:
   - *Implement regulations and incentives to encourage sustainable practices in the tourism industry.*
     This could include the use of eco-friendly transport options, such as bicycles, electric scooters, and walking paths within tourist destinations.

viii. Community engagement development:
   - *Engage with local communities in transportation planning and decision-making processes.*
     The aim would be to effectively address community needs and align with their priorities and preferences.

4.2. Medium-Term Plan (5–10 Years)

i. Electric vehicle industries development:
   - *Prepare an area for the EV industry in a SEZ.*
     Providing a specific area for EV industry will attract investments. Situating a SEZ near Lao–China Railway (LCR) would be ideal, given the connectivity with China, which will secure the supply chain of components.
   - *Create a transfer of technology policy for foreign investors.*
     The policy will stimulate the development of the domestic EV industry and accelerate research and development (R&D) with smaller state budget spending.

ii. Biofuel Development:
   - *Ensure integration of the biofuel market with the international supply chain.*
     Ensuring the international market for biofuel products will increase profitability for local businesses. However, certain policies will be required to ensure domestic demand is securely provided.

iii. Intercity passenger and freight development:
  - *Develop new logistic hubs near LCR and SEZs.*
    New logistic hubs will improve freight transport coverage as well as increase economic activity in regions close to LCR, especially in SEZs.
  - *Modernise the cargo transport sector in Lao PDR.*
    This will include the increased functional integration of supply chains and the growing role of distribution centres.

iv. Public transport expansion:
  - *Expand urban public transport systems in other emerging cities.*

v. Logistics and distribution centres development:
  - *Open the country to integrate to the global supply chain.*
    Lao PDR should start unlocking its market and distribution potential by developing a more geographically integrated system, not only at national level but also at a broader regional level. While the country may not currently be the main destination or origin of the commodities trade, it needs to explore its potential as an intermediate location in the regional distribution network. This will be fundamental to the geography of freight circulation as Lao PDR provides connectivity between corridors of circulation in the region. With this involvement in the global supply chain, the internal logistics and distribution centres of Lao PDR should be developed. This, in turn will bring the local production centres into the network.
  - *Improve integration between transport and inventory control through the promotion of major coordinators and integrators (logistics providers) in the logistics industry.*
    Freight distribution in Lao PDR should start to shift from the paradigm of inventory-based to replenishment-based logistics where manufacturers will play a dominant role in matching the commodity demand by taking advantage of more integrated and efficient suppliers, manufacturers, and distributors.

4.3. Long-Term Plan (10–20 Years)

i. Railway expansion across the country:
  - *Enhance connectivity between different regions of Lao PDR.*
    This will boost cross-border commerce, promote regional integration, and strengthen Lao PDR's position as transit hub. Expansion should be focused on connecting the southern part of Lao PDR.

ii. EV development with a focus on accessibility and low-cost travel:
  - *Expand public transport services through development of EVs.*
    Electric buses, electric minibuses, or electric vans should be used to enable people in suburban areas, mostly those on low incomes, to access public services in urban centres.
  - *Provide fiscal and non-fiscal facilities for private sector development of EV public transport, including the development of the charging infrastructure and systems.*
    If EVs are introduced as private vehicles, then priority should be given to electric motorcycles that constitute a more affordable private vehicle than cars.

iii. Logistic and distribution centre development:
- *Integrate functionality into supply chains.*
  After an initial short-term period where supply and logistics chains in Lao PDR have become more integrated, in the longer term, a more functional integration should be achieved. This should include the emergence of large logistics operators that control many segments of the supply chain, developed economies of scale in distribution supported by advanced information technology, and intermodal transport integration.
- *Develop distribution centres that provide a more fundamental link between production and consumption.*
  In this phase, distribution centres should provide an interface between the industrial and retail geographies of the supply chain concerned. Distribution centres can then perform numerous value-added activities, ranging from simple tasks, such as warehousing, packaging, and labelling, to complex processes, such as providing some level of final assembly and taking returns.

5. Securing Affordable Energy for the Growing Industrial, Commercial, and Residential Sectors

Access to affordable energy is vital for the economy and wellbeing of the people of Lao PDR and is crucial for promoting economic growth across all sectors (industrial, commercial, and residential). However, reliance on heavy subsidies can lead to economic losses and put pressure on government budgets. The current energy price setting (especially the electricity tariff) has several challenges. First, electricity price setting does not follow a market-based approach. It relies on government policies to provide cheap energy for the residential and private sectors to improve livelihoods and industrial development. As a result, electricity prices in Lao PDR are lower than those in other ASEAN countries. Second, price setting is not based on supply and demand. There is an overproduction of electricity during the rainy season and an underproduction during the dry season. More than 80% of Lao PDR's electricity for domestic use comes from hydropower plants and some electricity power plants do not have the necessary reservoirs to store water for the dry season. Because EDL needs to buy electricity from the Electricity Generating Authority of Thailand (EGAT) at high prices during the dry season, it is important to set the price based on the market approach. EDL purchases electricity from the Independent Power Producers (IPPs) and others at high prices, but then sells the electricity (especially for the residential sectors) at low prices. To sell at the low prices set by the Government of Lao PDR and enforced by the MEM, EDL must subsidise the electricity to its consumers, leading to financial difficulties for the company that creates debts and deficits. To provide a reliable and cost-effective electricity supply, Lao PDR should consider the following key recommendations:

i. Electricity prices should be calculated on a market-based approach. As mentioned above, electricity prices in Lao PDR are lower than in other ASEAN countries. Electricity tariffs should be restructured to cover costs and to be based on supply and demand that incorporates seasonal adjustment for the rainy season and dry season. On average, EDL has purchased electricity from IPPs at around $0.62/kilowatt hour (kWh). In 2023, approximately 11.5 billion kWh was purchased for domestic electricity and in 2024, the figure was around 14 billion kWh. EDL must subsidise approximately $0.04–$0.05 cents/kWh, which is estimated to equate to $500–$600 million in 2024.
ii. Electricity sources should be secured during the dry season. Exploring and promoting more solar, wind, and biomass energy is crucial and an effective approach is to develop solar energy in the reservoirs of hydropower plants. Negotiations with IPPs and EGAT on purchasing price settings and price adjustments for electricity are necessary. The IPPs need to lower prices during the dry season. Without implementing changes now, the electricity prices will gradually increase in the medium- and long-term.
iii. The electricity system should be improved. This can be achieved through reducing electricity loss and promoting energy efficiency and conservation (EEC). The existing electricity infrastructure is inefficient, leading to high distribution losses in the national power grid between 2014 and 2024. The average electricity loss was 13% in 2014, 8.80% in 2022, and 6.8% in 2023.Although efficiency figures are improving, the process must be accelerated to secure the energy supply.
iv. There should be greater flexibility to negotiate with IPPs to use electricity to meet the growing domestic demand and to charge affordable prices. At present, more than 90% of the electricity from IPP hydropower projects is exported. It is crucial for EDL to have flexibility to negotiate with IPPs to meet the domestic demand.
v. Energy subsidies should be overhauled and targeted to groups that need energy for their basic needs, such as cooking, lighting, and transportation. The electricity price reform should fulfil the following requirements:
   - *Transparency*. The government should publicise the gradual removal of electricity subsidies. Transparency will help to garner public support during the reform process. Public campaigns and education outreach will be needed to clearly show how energy subsidies impact welfare, discourage investment, and reduce competition.
   - *Consistency*. Well-established programmes to monitor progress and mitigate any negative impacts will be needed. Reporting, monitoring, and disseminating information on the reform process with clear timeframes, sector-by-sector, will allow all stakeholders to envisage the costs they and their businesses will incur in the future. This will ensure greater success for the reform programme. The reform process will benefit welfare, investments, and future growth, so government strategies need to build on these arguments and facts to show the public the benefits in a transparent and timely manner.
   - *Policy support*. Policy support and investment in efficient technologies, including environmental technologies, are key to promoting competitiveness due to lower energy consumption and higher savings.

6. Energy Efficiency in End-Use Sectors

EEC implementation will bring about multiple benefits to Lao PDR such as enhancing energy security; improving the affordability of, and access to, the energy supply; supporting economic growth; and contributing towards decarbonisation and climate change mitigation. Policy directions for immediate- and long-term planning and implementation of energy efficiency strategies and programmes have been identified to be a prudent measure for achieving energy security and sustainable development for Lao PDR. However, the journey to implementing the EEC implementation plan must commence with a government directive, i.e. a top-down approach, while the EEC implementation programmes listed below will constitute a bottom-up approach. Therefore, it is recommended that the implementation programmes for accelerating EEC agenda in Lao PDR are executed in two stages as set out below.

6.1 Short-Term Plan within 2–3 Years from the Start of the Energy Efficiency and Conservation Implementation Plan

i. *Establish an implementing agency/department for the implementation plan:*
   - This agency/department is empowered with authority, manpower, and financial resources to implement, collect energy data, monitor and analyse energy performance, disseminate information, promote EEC activities, and provide guidance to end-use sectors.
   - It will be responsible to execute other EEC programmes listed below.

ii. *Execute the EEC programmes: EEC programmes to be developed will comprise the following:*
   - EEC guidelines to be developed and published for commercial and industrial sectors. These include:
     - EnMS: Procedural guides will establish an EnMS that is based on a systematic Plan-Do-Check-Act concept. EnMS should also include guides on best practices in maintenance to achieve energy efficiency.
     - Decarbonisation: EEC implantation will contribute significantly to carbon emission reduction and decarbonisation.
     - Computation of energy efficiency indicators and establishment of benchmarking for respective commercial and industrial sub-sectors.
     - Digitalisation: Application of state-of-the-art digital technologies will enable greater control, flexibility, optimisation, and savings in equipment capital investments due to energy optimisation, and energy-efficient plant operation.
     - Categories of EEC measures, i.e. low, medium, and high investment initiatives.
     - Passive and active design measures for the commercial building sector.
     - Significant Energy Users complete and specific energy consumption and guides on best practices in selection, optimisation, design, installation, testing and commissioning, and operation and maintenance.

- Energy efficiency indicators, e.g. Building Energy Intensity for the commercial building sector, and Energy Use Intensity for the industrial sector with statistical benchmarking values to be established.
- Implementation of energy saving measures for industrial and commercial building sectors with the establishment and participation of Energy Services Companies (ESCO).
- Minimum Energy Performance Standard (MEPS) for energy-efficient electrical appliances and equipment which are primarily used in the residential sector. Some of these appliances and equipment are also used in other sectors.

iii. *Develop and implement EEC partnering programmes*: The partnering programme is a consultative programme which is designed to involve pre-identified stakeholder organisations, such as industrial and commercial subsector associations, professional bodies, academia, research institutions, and other government departments. The objectives of the partnering programme are:
- to obtain stakeholders' input for greater effectiveness and coverage of EEC programmes;
- to facilitate the dissemination of information about EEC programmes; and
- to improve the stakeholders' 'buy-in' process and gain immediate nationwide acceptance and participation of EEC programmes.

iv. *Develop and implement capacity building programmes*: Capacity building is an important part of the EEC implementation. Expertise and resources within ASEAN should be sourced to provide assistance, guidance and to expedite the programme. The development and implementation of capacity building should cover the following areas:
- Immediate measures:
  - o professional training courses at elementary, intermediate, and advanced levels, for the development of expertise and skills in energy efficient design, systems operation and energy management, and energy audits;
  - o continuous professional development to update participants on latest developments and practices; and
  - o awareness campaigns through roadshows, seminars, workshops, social media, and other publicity drives.
- Long-term measure
  - o Educational curricula for high schools and universities.

6.2 Long-Term Plans within 4–5 Years from the Start of the Energy Efficiency and Conservation Implementation

If Lao PDR were to embark on a programme to accelerate the uptake of EEC measures in line with the Joint Ministerial Statement declared at the 41st ASEAN Ministers of Energy Meeting in 2023, it would become necessary to establish an EEC legislative framework The development and enactment of a legislative framework will take time, but it will enable Lao PDR to accelerate the EEC programmes as part of the country's sustainable development policy.

The requirements given in EEC programmes will become mandatory for large consumers who exceed a predetermined yearly threshold value of energy consumption in industrial and commercial building sectors, and this threshold value of yearly energy consumption will be defined in Lao PDR's EEC laws. The laws will also stipulate compliance requirements and penalties for repeated non-compliance.

Once an EEC legislative framework is established, manpower resources to enforce EEC legislative requirements will need to increase. This increase will include more skilled manpower resources in commercial and industrial sectors to be available and ready for EEC implementation.

By implementing policy direction to implement EEC plans as soon as possible, Lao PDR will be in the best position to develop and establish an EEC legislative framework for the country's long-term sustainable energy plan.

7. Energy Management and Energy Service Companies

To reap the vast potential of energy savings through the implementation of efficient EnMs and ESCOs and taking into consideration the lengthy gestation period needed to develop effective national policies, it is recommended that policies be implemented from year one (short-term policies), year three (medium-term policies), and year four (long-term policies).

7.1. Short-Term Policies

i. *Issue a special order or ministerial directive to implement EnMS*: The directive will compel all government buildings, institutional buildings, government-owned manufacturing plants, and installations consuming more than 500,000 kWh per month of electricity, to implement EnMs. Private sector buildings consuming similar thresholds may be requested to comply with this directive.

ii. *Fast-track registration of ESCOs*: This fast-track registration scheme will be available to local engineering consultancy companies, practicing engineers and architects who have experience in providing energy services locally and/or working with Registered Foreign Professional Engineers, or registered ESCOs from any of the ASEAN economies on transfer of energy efficiency (EE) knowledge. This policy allows Lao PDR to register an initial pool of ESCOs and the corresponding professionals to conduct energy audits, EE consultancy, buildings or facilities retrofitting, and Energy Performance Contract (EPC) services.

iii. *Implement a national demonstration project*. A government-owned buildings or factory that has high energy consumption should be chosen to trial an EE demonstration project to be implemented by the maintenance staff of the building and a registered ESCO. The scope of works for the demonstration project should include: i) an energy Investment Grade Audit; iii) implementation of energy saving practices that range from no-cost to high-cost measures; iii) implementation of medium- and high-cost measures with either an EPC Shared Saving Model or the EPC Guaranteed Saving Model; and iv) implementation of an EnMS. The project should run for 2 to 3 years with a monthly energy performance report being sent to MEM.

iv. *Build the capacity of energy efficiency professionals through structured training*: A Strengths, Weaknesses, Opportunities, and Threats analysis identified one of the areas of weaknesses in Lao PDR's energy management structure as the low capacity of the EE professionals who are the energy auditors, energy managers, and measurement and verification professionals. Since it is these professionals who will support the effective implementation of the EnMS and the long-term national plans for EEC, it is vital that they are given effective, structured training to achieve this.

v. *Promote EEC nationally through a communication plan*: Awareness of EEC is crucial to lower maximum demand and final energy use and to achieve a slower increase in energy supply and installed capacity. The communication plan should cut across all sectors, including industrial, commercial, residential, agricultural, and other non-energy use sectors. Stakeholder engagement seminars and workshops are necessary to impart information about EEC. There should be a focus on educating the public on EEC and energy conservation through simple acts, such as switching off unused equipment (lights, TVs, air-conditioners, etc) rather than leaving them on standby mode, which is a waste of energy. The promotion and awareness campaigns should achieve behavioural and mindset change.

7.2. Medium- to Long-Term Policies

One of Lao PDR's key EEC policies will be the eventual enactment of a holistic, national EEC decree or legislation and the subsidiary legislation to support it. As with other ASEAN nations, the process of developing the act takes considerable time. The following are the recommended medium- to long-term policy areas that should be covered:

i. *Legislate a national EEC act*: The act shall have the following provisions:
   - prescribed premises relating EE to the industrial, commercial, and residential sectors;
   - prescribed energy-using products;
   - operational requirements for prescribed premises to implement EnMS and conduct energy audits;
   - establishment of a national implementation agency under MEM;
   - registration of ESCOs, energy managers, energy auditors, and training providers;
   - provision of a sustainable EE funding mechanism.
   - information gathering power and enforcement provisions; and
   - general provisions such as publication of information, the power of ministers to make regulations, and the power of authorities to make rules and issue guidelines.

ii. *Legislate EEC regulations*: While the EEC act stipulates broad provisions through laws for EEC, regulations are required to cater for the dynamic changes to the ecosystems of EEC such as lowering the threshold of prescribed premises to capture more energy consumers and others. The regulation shall include the following key provisions:

- an obligation to submit information on EnMS;
- qualification requirements for EE professionals;
- a certificate of registration;
- a description of the function and duties of ESCO and EE professionals;
- the fee structure for ESCO and EE professionals;
- the type of report for EnMS; and
- a declaration by registered EE professionals.

iii. Equip the implementation agency: The main functions of the implementation agency as empowered by the proposed act shall be to i) effectively coordinate with prescribed premises and to collaborate with government agencies and other bodies to recognise and utilise existing resources and infrastructure; and ii) to perform such functions and exercise such powers as may be assigned to it. The functions and powers include to:

- prescribe measures including guidelines for factories;
- prescribe measures including guidelines for buildings;
- register ESCO and EE professionals;
- prescribe measures including guidelines for energy-using equipment;
- promote measures for consumers;
- prescribe common measures including to disseminate financial assistance and incentives;
- create data and information repository centre; and
- create regional offices.

The existing EE department of MEM can be expanded into a national implementation agency with adequate human, technical, technological, and financial resources to effectively manage all provisions of the EE act and regulations.

iv. *Establish a sustainable funding mechanism*: The success of any project depends on timeliness and adequate financial resources to meet the yearly budget requirements. The mechanism should, amongst other things, be independent of the fiscal budget and sufficiently sustainable to meet the operational budget of the implementation agency, the expenditure of EE campaigns, and the incentives to implement high-cost energy saving measures.

v. *Enhance capacity building through structured training*: With growth in gross domestic product (GDP) and population in the near future, it is inevitable that final energy demand will increase. But it is hoped that with effective implementation of an EE legislative framework, an EnMS, and the competent work of ESCO, the final energy demand will decouple from the business-as-usual scenario. There will be a growing need for EE professionals to support implementation of the act and the regulations and it is worth noting that capacity building of ESCO and EE professionals is a process of nurturing and takes time. The following are some proposed courses to be conducted for capacity building of ESCO and EE professionals to achieve this goal:

- ISO 50001 EnMS;
- energy audit processes;
- measurement and verification;
- EPC mechanisms: the Guaranteed and Shared Saving Models;
- registration, functions, and roles of ESCO;
- project management; and
- energy saving measures for electrical and thermal systems.

8. Minimum Energy Performance Standards

The implementation of MEPS is expected to take a considerable amount of time due to the requirements of capacity building, the wide range of equipment and appliances available in the market, insufficient test facilities, and insufficient performance standards.

Implementation of MEPS will happen in stages, given the factors already discussed, but gives Lao PDR great potential to reduce energy consumption.

8.1. Short-Term Plan within 2–3 years of the Start of Minimum Energy Performance Standards Implementation

i. *Create EE awareness*: Lack of EE awareness prevents consumer from 'buying-in' to the concept of energy savings. An EE awareness programme should be set up to raise awareness of the importance of reducing energy consumption. The EE awareness programme could be conducted through an educational school curriculum, public road shows, and promotion through seminars and workshops.

ii. *Establish an implementing agency*: An implementing agency or department will be established to lead and execute the MEPS implementation plan. This agency or department shall develop the necessary product specifications and test procedures, manage the certification bodies, and set up the registration bodies.

iii. *Develop performance and testing standards*: This shall be conducted through a consultative programme. Stakeholders, such as professional bodies, industrial and commercial associations, academics, and research institutions whose involvement are crucial to the implementation of MEPS shall be identified and invited to join this programme.
Engagement with these stakeholders will improve the impact of targeted products related to the energy reduction objectives and will establish the EE levels that are achievable, based on manufacturers' readiness and the best available technologies.

8.2. Long-Term Plan within 4–5 Years of the Start of Minimum Energy Performance Standards Implementation

Setting up testing facilities is an important long-term element of MEPS and they are required to conduct product compliance tests.

In the absence of accredited testing laboratories, an interim measure would be to accept independent, third-party testing for EE verification. International and regional laboratories are available to ensure that testing conforms to the standards set.

9. Renewable Electricity and the Opportunity of Green Hydrogen and Ammonia

To make hydrogen a feasible alternative in ASEAN, it is imperative to implement specific policies such as subsidies, tax incentives, and international collaboration for infrastructure development. Implementing these will effectively reduce the financial disparity and improve the competitiveness of hydrogen technologies, especially during the initial phases of implementation.

Lao PDR is aggressively investigating the potential of hydrogen energy as a key component of its renewable energy plan. The country possesses a substantial capacity for renewable energy, particularly hydropower, which can be used to generate hydrogen. Lao PDR has the potential to become a significant participant in the regional hydrogen economy by exporting hydrogen generated from the country's renewable resources. The Government of Lao PDR continues to rely on the electricity sector as a major driver of growth and development and as a source of increased revenue through exports to neighbouring countries. With the huge potential of renewable energy sources, Lao PDR also has an opportunity to produce green hydrogen and ammonia from clean sources of electricity. To realise the future potential of green hydrogen and ammonia, Lao PDR may consider the following recommendations:

i. *Form a national task force* responsible for coordinating the development of the green hydrogen and ammonia industry. The task force would include government agencies, industry associations, and experts, to monitor and help implement the national strategy and action plan for green hydrogen and ammonia. The task force would facilitate policy and regulatory discussions, evaluate infrastructure development, and promote public-private partnerships.

ii. *Establish a centre of excellence* as a trusted source of data and analysis, integrate Lao PDR ministry research institutes and the National University of Lao PDR with a mandated focus on hydrogen and ammonia research development, and select a site for a hydrogen-ammonia pilot plant.

iii. *Establish a green hydrogen and ammonia industry association* to represent the interests of industry stakeholders, enabling collaboration between the public and private sectors and development partners.

iv. *Negotiate and formalise international carbon credit trading networks*, a legal and statutory property rights framework for hydrogen and ammonia carbon offsets, and tradable renewable energy certificates based on green hydrogen and ammonia production in Lao PDR. The distribution of revenue from carbon trading will need to be specified in contractual arrangements with foreign entities investing in hydrogen-ammonia production and distribution. The proposed hydrogen and ammonia association could also play an active role in negotiations.

v. *Adapt existing special economic zone tax breaks* including subsidies and import duty exemptions for hydrogen and ammonia capital goods as part of a wider push to create incentives for developing a green hydrogen and green ammonia industry.

vi. *Create strong collaborative frameworks* to accelerate the uptake of emerging hydrogen and ammonia technologies by fostering knowledge transfer, promoting economies of scale, and identifying costly mistakes and failures. Weak cooperation mechanisms can slow down the deployment of technologies in the demonstration phase by up to ten years or more.

vii. Access international *expertise* and training to support sound energy and financial analysis of hydrogen and ammonia investments and trends.

viii. Actively *collaborate with regional neighbours* to expand information sharing with Lao PDR's neighbours and to build relations with the Greater Mekong Subregion regarding hydrogen and ammonia production, safety, transport, and utilisation.

Multiple endeavours are currently in progress to foster the growth of the hydrogen industry in Lao PDR. For instance, the government is collaborating with international partners such as the Asian Development Bank (ADB) and the Global Environment Centre Foundation to develop a power-to-gas masterplan. The purpose of this strategy is to delineate the necessary procedures for implementing hydrogen production and utilisation on a large-scale, commercial level. This involves implementing regulations, infrastructure, and business plans to facilitate the growth of the hydrogen economy, as recommended by ADB and the Climate Technology Centre & Network.

In addition, Lao PDR is pursuing collaboration with EGAT, Mitsubishi, and the Government of Thailand to look into the establishment of green hydrogen and ammonia production plants. These facilities will harness the country's renewable energy potential to produce hydrogen. This programme is a component of a wider plan aimed at increasing the proportion of renewable energy sources in the energy composition mix and decreasing dependence on imported fossil fuels. Lao PDR shows significant potential to develop green hydrogen in the future, as the potential of its hydropower capacity is predicted to be approximately 26.5 GW, which is far more than its present energy requirements. The country can leverage this excess to generate hydrogen, establishing itself as a prominent player in the hydrogen supply chain.

10. Optimising Sustainable Hydropower Development on the Mekong: What Direction Should Lao PDR Take?

To navigate the challenges and fortify Lao PDR's journey towards sustainable hydropower development, four strategic actions and policy directions are suggested.

10.1. Implementation of Planned Options and Identification of New Options for Joint Investment Projects

i. Lao PDR should raise the importance of the proposed mainstream hydropower dams projects, planned along the border between Lao PDR and Thailand (i.e. Pak Chom and Ban Khoum), and develop them as national joint projects with the Government of Thailand. Both countries can then work on the pre-feasibility and feasibility stages, with the technical and facilitating support of the Mekong River Commission (MRC) Secretariat. This will ensure good quality reports and studies that illustrate clear impact assessments and mitigation measures. This pre-prior consultation engagement with the MRC Secretariat will help when it comes to the eventual submission and application of the prior consultation process within the MRC framework while both countries could jointly submit these proposed hydropower dam to the MRC.

ii. Lao PDR should solidifying the work with the MRC and other Mekong–Lancang countries to identify potential new joint investment projects in the MRC Adaptive Basin Plan. The MRC would like to formulate this with other member countries under proactive regional planning by the end 2024, with projects completed by 2027. These projects can be invested in, operated, or managed by two or more riparian countries to implement, or support the implementation of, those projects that have been identified to tackle flood and drought, optimise energy production, and secure food production for the Mekong basin and region.

10.2. Identification and Implementation of Alternative and Complementary Cost-Effective Energy/Water System Integration Options

i. The government should identify and implement projects to develop alternative renewable energy sources, such as solar and wind. Aligning with Lao PDR's energy development plans and leveraging advancements in technology, these alternative energy sources offer the potential for reduced investment and greater energy resilience, as well as saving the river environment for future generations. Embracing such diversification also addresses the pressing challenges to water security at Lao PDR's arsenal of hydropower dams, posed by climate change.

ii. Lao PDR should then identify other water-related, alternative energy infrastructure projects, such as floating solar and pumped storage hydropower development and implement the projects to supplement the energy supply available from existing hydropower projects.

10.3. Strengthening and Applying Mekong River Commission Procedures, Tools, and Guidelines

i. The government should strengthen early and effective application and use of the MRC procedures, tools, and guidelines, as well as data and studies, such as the Procedures for Notification, Prior Consultation, and Agreement (PNPCA), and the Transboundary Environmental Impact Assessment (Chapter 10). They should further the uptake of these documents into the national process of hydropower project development through dissemination to relevant line agencies (especially environmental impact assessment authorities) and companies and through targeted capacity building. Doing this will enable Lao PDR to conduct high-quality feasibility studies and reliable environmental and social impact assessments as well as proposed mitigation measures to avoid, minimise, and mitigate potential adverse impacts at both national and transboundary levels.

ii. Further work should be done to strengthen the implementation of the post-PNPCA process including the Joint Action Plan agreed at the completion of the PNPCA prior consultation process of the hydropower projects. These joint action plans are considered a mechanism for dialogue amongst the MRC Member Counties and other stakeholders, as the agreements keep them informed about the development of the submitted hydropower projects. Improvements in the implementation of the joint action plans will demonstrate Lao PDR's commitment to transparency and openness and its willingness to cooperate. In return, Lao PDR will win more trust and support for its future hydropower developments.

10.4. Working towards Coordinated Water Infrastructure Operation and Communication in Mekong River Basin for Multiple Benefits Including Disaster Mitigation and Management

i. It is important to further the work on national regulations and platforms to establish dam coordination and management centres to facilitate data and information sharing amongst the different dam operators. Good data and information sharing is crucial, considering that dams in the region are operated by many different operators. A coordination and monitoring centre could help support such coordinated operation and management for energy (and water) optimisation, as well as backup disaster mitigation and management efforts. The centre could be hosted by MEM with active participation of the Ministry of Natural Resources and Environment (MONRE) and connection to the MRC.

ii. There should be a focus on working under the MRC platform to share the operational data relating to the hydropower dams amongst MRC member countries and other basin countries to improve data, share information, and increase transboundary coordination in the basin regarding management of flow, sediment, and emergency procedures.

11. Voluntary Carbon Markets and Mechanisms

The following are the policy directions and recommendations for the development of carbon market initiatives in Lao PDR's energy sector.

11.1. Aligning the Policy Objectives of Carbon Markets Initiatives

Policymakers in Lao PDR need to establish objectives and prioritise the roles of carbon markets and crediting. This step is crucial to shape the ecosystem of the carbon market in the country and its participation in the international voluntary carbon market (VCM). Potential policy objectives are set out below.

i. Reduce GHG Emissions and contribute to meeting NDC Targets
A domestic crediting mechanism not only assists in GHG emissions abatement but also contributes to Lao PDR's Nationally Determined Contribution (NDC) targets. However, international cooperation under Article 6 of the Paris Agreement might not provide substantial benefits to meet the host country's NDC targets. This is because the mitigation outcomes from the project will need corresponding adjustments. Under Article 6.2, the sharing ratio of mitigation outcomes will depend on the agreement between the host and acquiring countries. For instance, the Government of Japan shared at least 80% of the issued credits for most of the Joint Credit Mechanism (JCM) projects (Chapter 11). Similarly, with international carbon trading through Article 6.4 – The Paris Agreement Crediting Mechanism – participating countries will need to adjust their national GHG emissions inventories, accordingly, based on the traded credits when accounting for the host country's GHG emissions inventory.

ii. Generate government revenue and capitalise debt swaps with creditors
The 9th National Socio-Economic Development Plan Financing Strategy (2023–2025) acknowledges that emissions trading schemes could generate a significant amount of revenue for Lao PDR (Chapter 11). However, implementing such schemes will require the development of guidelines, procedures, systems, and capacity building, and hence regional-level consideration, to be cost-effective. Nevertheless, mandating carbon or emissions trading projects to register and trade under the administration of a national registry will generate revenue for the government, irrespective of whether it is a mandatory emissions trading system or a voluntary carbon crediting mechanism. Additionally, the strategy also considers debt-for-nature swaps as an innovative fiscal policy. This concept can be applied to the Article 6.2 approach by cooperating with creditor countries. For instance, generated credits for interest repayments can be integrated into negotiation strategies to alleviate the debt burden. However, this might be more suitable for nature-based activities due to lower costs compared to energy-related activities.

iii. Mobilise green investment and measure the benefits
The VCMs and crediting mechanisms can channel private or foreign investments into mitigation activities. For instance, foreign investors can invest in specific projects to obtain carbon credits through Article 6 approaches or independent crediting mechanisms. Additionally, the methodologies used in crediting mechanisms can be used by governments and private investors to estimate the GHG emissions reduction value of a particular measure or to understand the GHG emissions reduction impact of a financial investment. This approach is used in results-based climate finance, which relies on the ability to measure the actual GHG performance of a specific investment in a cost-effective way. Consequently, it provides a tangible investment opportunity that can attract investments from a broad range of financial players. As the issued carbon credits are used as a metric of carbon performance for results-based climate finance, but not for meeting the financial providers' NDCs, these credits are defined as Mitigation Contribution Units under Article 6.4 and are not obliged to corresponding adjustments.

iv. Promote low-carbon development and local environmental benefits
In many developing countries, prioritising the development of emerging economic sectors or addressing local environmental issues often takes precedence over emissions mitigation. Carbon crediting mechanisms offer the potential to generate additional benefits beyond simply reducing emissions. They can serve as a financial incentive for businesses to adopt cleaner technologies, thereby facilitating climate change mitigation alongside other objectives such as enhancing air quality,

safeguarding water resources, promoting soil health and biodiversity, and increasing productivity. Additionally, there are social and economic advantages, including improved energy access, job creation through the implementation of new technologies, enhanced livelihoods, and support for the early commercialisation of emissions reduction technologies or products. Furthermore, while Article 6 may not be the primary approach for meeting a host country's NDCs, activities undertaken within its framework must ensure environmental integrity and promote sustainable development, thus yielding environmental benefits.

v. Gauge the market response to carbon-pricing signals

According to the 9th National Socio-Economic Development Plan Financing Strategy (2023–2025), one of the agreed actions that Lao PDR will take to finance environmental and climate priorities is to study the feasibility of environmental fiscal reform, including introducing a carbon tax (Chapter 11). In this context, a crediting mechanism could be a useful option if there are barriers, such as legal hurdles or political resistance, to implementing a mandatory emissions trading system or carbon tax. Thus, a crediting mechanism may serve as a good starting point to send a carbon-pricing signal and build familiarity with market mechanisms. Furthermore, by assessing the market sensitivity to carbon-pricing signals, Lao PDR may further evaluate whether there will be sufficient supply and demand for credits before embarking on a mandatory or voluntary domestic emissions trading scheme.

vi. Provide offset options for corporate climate objectives and compliance obligations

The VCMs and crediting mechanisms can facilitate stronger voluntary commitments to emissions abatement, particularly where mandatory carbon pricing is absent or for entities not subject to mandatory policies or emission constraints. These approaches provide a source of credible emissions reductions that businesses and other organisations can use to voluntarily offset their emissions. Moreover, Lao PDR is considering a carbon tax as one of the options for financing environmental and climate priorities. Therefore, if a carbon tax is introduced, VCM and crediting mechanisms can offer additional flexibility to compliance options by allowing offsets in addition to tax payments.

However, in this context, to ensure there is sufficient supply for the domestic carbon market, jurisdictions may limit the domestic carbon credits to trade at international markets. Additionally, most jurisdictions that allow the use of offsets, limit them to either credits from domestic carbon markets or carbon trading that apply corresponding adjustments to ensure the outcomes contribute to achieving their NDCs. For instance, Singapore is the first country to implement a carbon tax with an offsetting mechanism that aligns with the requirements of Article 6 under the Paris Agreement. By establishing offsetting criteria compliant with Article 6, all emissions offset through international platforms contribute to its national GHG emissions reduction. These carbon credits are compulsory for corresponding adjustments, making them eligible for claiming emissions reductions toward meeting NDCs (Chapter 11).

In contrast, internationally transferred carbon credits that do not undergo corresponding adjustments should not be used to meet NDCs. Singapore's offsetting mechanism could serve as an example for other ASEAN countries on how to benefit from international cooperation and meet their NDCs through Article 6.

11.2. Enhancing the Regulatory Framework and Market Infrastructure

As the national focal point for climate change, the MONRE is aggressively strengthening Lao PDR's participation in VCMs, including the introduction of regulatory frameworks and market infrastructure for carbon trading, and the development of governance frameworks for Article 6. However, these efforts focus on nature-based activities. If Lao PDR plans to explore the potential of carbon trading beyond forest contributions, the regulatory framework will need to expand in the future to cover other sectors. Establishing clear guidelines for project approval, monitoring, and verification, is crucial to ensure effective governance of carbon trading. Additionally, Lao PDR may consider setting a threshold to limit international carbon trading from domestic mitigation activities. This is to ensure that mitigation actions contribute to achieving NDC targets by 2030 and net-zero by 2050.

Another indicator of capitalising on carbon market opportunities is the establishment of a carbon credits exchange platforms in ASEAN countries. Countries such as Indonesia, Malaysia, Singapore, and Thailand have launched carbon trading platforms, with Viet Nam expected to follow suit in 2025. These platforms serve similar functions, including auctions and facilitating international and domestic carbon trading mechanisms. This marks a positive beginning, especially for countries planning a mandatory emissions trading scheme or carbon pricing with an offsetting mechanism.

11.3. Strengthening the Measuring, Reporting, and Verification System

Establishing a comprehensive measuring, reporting, and verification (MRV) system to generate accurate and reliable data is fundamental for any carbon-pricing instrument, including voluntary carbon credit mechanisms. Reliable baselines for emissions reduction projects under VCM and crediting mechanisms are essential for determining additionality and accurately quantifying emission reductions. Defining baselines for these projects can be complex and may require extensive data collection and analysis. Therefore, an effective MRV system not only enhances efficiency in managing emissions information but also serves as a database for establishing baseline information.

Most importantly, regardless of whether the energy sector is included in the carbon trading framework, an MRV system is helpful to policymakers when shaping climate change mitigation policy and measures. Therefore, establishing standard guidelines for MRV should be a priority. Advantages of doing this are:

i. establishing databases for carbon crediting mechanisms;
ii. accounting for the national GHG emissions inventory for United Nations Framework Convention on Climate Change reporting;
iii. tracking progress toward NDC and net-zero targets;
iv. evaluating the effectiveness of mitigation policies and measures; and
v. assessing the potential for carbon-pricing compliance.

11.4. Enhancing International Cooperation

Collaborating with international partners, including neighbouring countries and international organisations, to align Lao PDR's carbon market initiatives with global standards and best practices could enhance the country's credibility and facilitate access to international markets. For example, the Government of Lao PDR, the Government of Australia, and the Global Green Growth Institute are partnering to support the development of the carbon market in Lao PDR, aligning with the principles outlined in Article 6 of the Paris Agreement. Moreover, to bolster knowledge and capacity, the Governments of Lao PDR and the Republic of Korea, henceforth 'Korea', conducted a knowledge-sharing workshop focused on 'Establishing a Master Plan for Implementing a Carbon Trading System in Laos.' This workshop marks a crucial starting point for the potential revitalisation of carbon emissions trading between Korea and Lao PDR in the future. Furthermore, Lao PDR may encourage public and private sectors to explore potential collaborations with the Government of Japan through JCM projects by disseminating information on JCM's crediting mechanism and benefits gained from previous JCM projects.

In addition to bilateral cooperation, Lao PDR could capitalise on opportunities for capacity building and regional policy frameworks under ASEAN cooperation, for instance, actively participating in the development of guidelines and standards that benefit Lao PDR and the region. These developed guidelines and standards can be adopted according to the local context, which is not only more cost-effective, but also crucial to ensure Lao PDR remains competitive in the ASEAN energy market.

12. Regional and International Cooperation for Advancing Innovative Technology Transfer

It is key to identify factors propelling technology transfer and the intricate policy landscape essential for fostering a sustainable and low-carbon future in ASEAN countries including Lao PDR. The plausible enabling factors for advancing technology transfer underscore the significance of effective communication, motivation, research collaboration, and the pivotal role played by technology transfer offices (TTOs), incubators, and management support. These factors collectively contribute to the journey from laboratory innovations to market applications, emphasising the intricate interplay required for successful technology transfer.

The policy implications for technology transfer in ASEAN countries toward achieving net-zero emissions require a comprehensive framework encompassing strategic measures aimed at cultivating sustainable practices. The delineated policies cover renewable energy transitions, EE measures, decentralised energy systems, carbon-pricing mechanisms, sustainable transportation incentives, R&D support, international collaboration, capacity building, education, and adaptation and resilience policies. This holistic framework, if implemented cohesively, serves as a strategic guide to realise the net-zero emissions target, promoting sustainability within the region and contributing substantively to global climate change mitigation efforts, given technology transfer as an enabler.

Advancing technology transfer and attaining net-zero emissions targets in ASEAN countries demands a systematic integration of plausible enabling factors and strategic policy measures. This imperative underscores the need for a concerted effort from diverse stakeholders, including academic institutions, industry entities, policymakers, and the broader community. There are several key enabling factors for Lao PDR and other ASEAN countries to consider for successful technology transfer that will guide the region toward a more sustainable, resilient, and low-carbon future.

i. Strengthening collaboration and communication:
   - Lao PDR should advocate for the creation of collaborative platforms that facilitate effective communication and knowledge dissemination amongst academia, industry, and policymakers; and
   - Interdisciplinary collaboration is important to address intricate challenges and amplify the impact of technology transfer initiatives.

ii. Motivating engagement:
   - Targeted strategies should be implemented to augment motivation, recognising their pivotal role as drivers in technology transfer; and
   - Reward mechanisms, recognition programmes, and career development opportunities should be instituted for personnel actively engaged in technology transfer activities.

iii. Enhancing team competence:
   - There should be judicious Investment in continuous training programmes aimed at enhancing the competence of technology transfer teams within innovation alliances; and
   - Cross-functional teams should be promoted, amalgamating diverse expertise for a comprehensive approach to technology transfer.

iv. Optimising the technology transfer office and incubators:
   - Research-oriented and market-oriented TTOs should be reinforced, ensuring their proactive involvement in facilitating licensing activities; and
   - The catalytic potential of incubators should be harnessed for fostering new product development, economic growth, and the transition to a low-carbon economy.

v. Promoting management support:
   - There should be strong advocacy for robust management support for researchers involved in technology transfer, recognising its pivotal role in overcoming barriers; and
   - Technology transfer should be incorporated more into institutional management strategies.

vi. Investing in R&D:
   - Strategic investment in R&D should be prioritised for clean energy technologies, fostering innovation aligned with sustainability goals; and
   - Funding mechanisms should be initiated to support startups and research institutions dedicated to clean energy solutions.

vii. Fostering international collaboration:
   - Collaborative ties with international partners should be strengthened to promote joint research, technology transfer, and knowledge exchange; and
   - There should be active participate in global initiatives focusing on sustainable development and technology transfer for climate mitigation.

viii. Capacity building and education initiatives:
- Targeted policies for capacity building at institutional, industrial, and workforce levels should be developed and implemented; and
- Educational programmes and training initiatives should be expanded to equip the workforce with the requisite skills for transitioning to a low-carbon economy.

ix. Climate adaptation and resilience policies:
- Climate adaptation and resilience measures should be integrated into technology transfer policies, considering potential climate change impacts on energy infrastructure; and
- Comprehensive strategies to enhance the resilience of clean energy systems to changing environmental conditions should be developed.

x. Fiscal and Financial Incentives for Clean Energy Investments:
- Well-targeted fiscal and financial incentives should be provided,, including subsidies, grants, and low-interest loans, to attract private sector engagement in clean energy projects; and
- Financial incentives should be aligned with broader goals, emphasising the attainment of net-zero emissions and sustainable economic growth.

The successful integration of these strategies requires a collaborative and adaptive approach, marked by continuous monitoring and evaluation. This adaptive approach will ensure the refinement of policies based on evolving technological landscapes and socio-economic conditions.

13. The Development of Carbon Capture Utilisation and Storage

CCUS will be one of the avenues for Lao PDR to reach a carbon neutral future and enabling it will require substantial efforts. Several key directions could be adopted to develop CCUS technologies:

i. *Conduct a national carbon dioxide storage resource assessment*. To fully understand the total potential amount of CO_2 which can be stored in Lao PDR, an assessment should be conducted. At present, due to its limited data on the CO_2 storage resources in depleted oil wells and saline aquifers, Lao PDR will be overlooked as a potential storage site for CO_2. Collating the data will be the first step towards enabling CCUS projects and activities. However, this kind of study will require a substantial amount of investment, hence, cooperation schemes and international support will be required.

ii. *Develop regulatory frameworks for carbon capture and storage (CCS)/CCUS Activities*. Regulating CCS/CCUS projects and activities will be the next key step to provide greater certainty, which may attract more investment to enable the development of CCS/CCUS projects. The example of Indonesia can be emulated, where regulations began with enhanced oil and gas recovery activities (CCUS), which then expanded to storage in saline aquifers (CCS). Specific regulations on capture, transport, storage, MRV, and post-closure should also be addressed in the later stages of the development of a regulatory framework.

iii. *Pilot Project Development*. CCUS pilot projects will be crucial to demonstrate their economic viability and to improve the effective and efficient technology around CO_2 storage. The pilot project will also showcase and inform the community regarding the environmental benefits of CO_2 injections. The successful implementation of the pilot project will also signal investors to support and develop more CCUS projects in the country.

iv. *Financing CCUS*. To fully develop CCUS as a viable business, the price of emitting CO_2 needs to be higher than that of capturing and storing it. This can be done in several ways: increasing the price of emitting CO_2 (carbon pricing), prohibition or mandating mechanisms, reducing the cost to private sector investors of CCS (e.g. through capital grants or concessional finance), and increasing the revenue created through CCS (e.g. through payments per tonne of CO_2 stored or operational subsidies). In terms of financing CCUS technology deployment, Lao PDR can tap into multilateral development banks (e.g., The World Bank or ADB), VCMs, and sustainable financing such as green and climate bonds.

v. *Develop Interconnected CCUS Networks.* Connecting with ASEAN countries to develop a regional CCUS network will be beneficial, especially for countries with limited amounts of storage. In the long-term, Lao PDR should aim to tap into these networks to gain access to lower-cost CO_2 storage options. Cross-border mechanisms should be addressed at the national, bilateral, or regional level to enable this. It will, however, need high-level coordination and streamlining in terms of planning and development within the countries in the region.

14. Financing Sustainable Energy Infrastructure

Securing investment for financing energy infrastructure that is sufficient to support the transition from the current heavy reliance on fossil fuel towards a cleaner and more resilient energy system is one of the great challenges of our time. The solution must ensure a smooth energy transition that leaves no one behind and takes into consideration energy affordability, accessibility, and security, while simultaneously achieving the Paris Agreement goal of keeping temperature increases to well below 2° Celsius, preferably to 1.5° Celsius compared to pre-industrial levels. Fast-tracking energy finance for the energy transition is critical to ensure that countries can secure enough funds to finance their energy transformation. Annual investment in renewables and clean energy has grown steadily since the 2015 announcement of the Paris Agreement on climate goals. 'The ASEAN Renewable Energy Outlook 2021', published by the ASEAN Centre for Energy, estimates that the region will require around $360 billion of investment in the power sector alone, to achieve the targets of 23% renewable energy share in total primary energy supply, as well as a 35% share in installed power capacity by 2025. In 2023, an estimated $1.7 trillion was invested in renewables and clean technologies, while $1 trillion was invested in fossil fuels. The increasing share of investment in clean energy outpaced fossil fuel investment for the first time between 2016 and 2023. This new ASEAN trend reflects global investor sentiment towards cleaner energy systems. However, attention will need to be paid to how developing countries can finance the energy transition.

Lao PDR and ASEAN will need secure finances to support their sustainable energy infrastructure. Lao PDR has the potential to become a key player in the advancement of sustainable energy. This will help enhance energy security in the region and support the worldwide shift towards a sustainable future. It is generally accepted that tax revenue generated from the infrastructure expansion should be used to incentivise the investment around clean energy and technologies. It is further recommended that green credit guarantee schemes (GCGS) should play a crucial role in financing renewable energy and sustainable infrastructure through guaranteed schemes that share risk amongst stakeholders. Using domestic savings for investments is also highly encouraged to reduce dependence on foreign direct investment (FDI). FDI is, however, crucial and Lao PDR needs to have a sound investment environment to attract it. Below are key suggestions to achieve this.

14.1. Utilising the Spillover Effect in the Form of Tax Refunds to Private Investors

To increase the investment incentives crucial for funding sustainable energy development, the Government of Lao PDR will need to utilise the 'spillover effects' created by energy supplies and refund the tax revenues to investors of the energy projects. This is suggested since the government often regulates electricity tariffs, and private financial institutions struggle to finance these infrastructural projects.

There are three significant reasons why utilising the spillover effects will benefit Lao PDR. First, private investors are given further incentives to invest in sustainable energy initiatives by leveraging the spillover effect of energy projects such as tax revenues and business development. This leads to higher rates of return on investments, and projects that are more attractive to private investors. Second, utilising the effect will mitigate risks associated with sustainable energy investments. There is less risk to private investors by providing sources of additional revenue through increased sales and property tax revenue, making investment more attractive. Third, the spillover effect generated by sustainable energy projects potentially contributes to energy development in the region by creating jobs, increasing employment opportunities, and stimulating the business economy. Not only will this benefit the energy sector of Lao PDR, but it will also positively impact the overall economic stability in the long-term.

14.2. Green Credit Guarantee Scheme

The establishment of a tailored GCGS should reduce risk in investment and information asymmetry associated with sustainable energy projects. The GCGS is crucial to improve the creditworthiness of low-carbon projects which lack physical collateral and tend to have weak credit standings. Hence, the GCGS serves as a safeguard by covering a portion of the risk and facilitating access to private financial institutions' financing, increasing investor confidence in unlocking private capital for sustainable energy projects.

The green credit guarantee for low-carbon projects will reduce information asymmetry and the expected default losses because the credit guarantee corporation – the government – guarantees a portion of loan default. Therefore, banks want to lend money to those guaranteed low-carbon projects.

The GCGS covers the credit risk of green projects that suffer from a shortage of physical collateral or have weak credit standing in Lao PDR and other ASEAN Member States. By reducing the risks, this scheme helps private financial institutions finance projects. The boosted access to financing stimulates the flow of money from financial institutions to incorporated projects, thus eliminating obstacles to financing and funding sustainable energy projects. The GCGS is, therefore, an essential accelerator to create and promote renewable energy infrastructure projects in Lao PDR and other ASEAN Member States. To achieve financial sustainability for GCGS, several key points should be considered.

i. *Sufficient Capital*: GCGS must possess adequate capital to guarantee projects for the energy transition. This ensures that they can support a wide range of projects, providing the necessary financial backing to foster growth and development in the energy sector.
ii. *Independent Assessment Body*: The assessment body should operate independently from GCGS to ensure impartial evaluation of projects. This independence is crucial to maintain objectivity and fairness in the selection process.
iii. *Importance of Assessment*: The role of the assessment process is pivotal to select projects with higher creditworthiness and a greater likelihood of success. Accurate and thorough assessments help mitigate risks and ensure that only viable projects receive support.
iv. *Variable Guarantee Fees*: GCGS should vary guarantee fees based on the soundness and creditworthiness of projects. Projects demonstrating higher soundness and lower risk should be charged lower fees, incentivising quality and reliability in project proposals.
v. *Local Offices*: GCGS needs to establish local offices nationwide or in major cities. This local presence allows GCGS to have direct access to information and to closely monitor the progress of projects. It also facilitates better communication and support for regional initiatives, ensuring projects are on track and meeting their goals.

By addressing these points, GCGS can build a robust framework for financial sustainability, supporting the successful transition to sustainable energy solutions.

14.3. Maximising Non-Debt Financing

Regarding sustainable energy development, strategic initiatives to achieve long-term energy security and economic growth focus on diversifying financing sources and securing financial stability. Relying on external debt for energy generation makes Lao PDR vulnerable to global financial market changes and fluctuations in currency exchange rates. Additionally, the accumulation of foreign debt might create economic and political risks for the country. Lao PDR would develop its sustainable energy sector without heavy external borrowing by maximising non-debt financing modalities, such as FDI and remittances, and relying more on domestic savings. Notably, apart from financial capital, FDI often implies technology transfer, managerial expertise, and direct and indirect access to foreign markets; thus, it boosts the competitiveness of renewable energy. Remittances represent a stable source of income and, if channelled into sustainable energy projects, may substantially reduce the country's external debt. Additionally, the circulation of domestic finance and savings into investments will align with economic stability objectives by retaining capital within the country and stimulating economic activity.

There should be a focus on effective instruments such as green bonds and credit guarantee schemes to ensure an adequate level of finance and funding for development without the need to compromise the financial stability of Lao PDR. Green bonds are debt instruments dedicated solely to funding projects that offer environmental benefits, including renewable energy projects. Through expanding the green bond market, Lao PDR gains access to a new source of funding that supports its sustainability goals and is attractive to socially conscious investors. At the same time, credit guarantee schemes address the reluctance of private financial institutions to lend the necessary funds because of perceived risks. They function as an insurance policy against default on the loans covering renewable energy projects. To sum up, the integrated approach grants access to financial resources for renewable energy projects and increases the nation's economic resilience. Using various financial instruments from multiple sources reduces the dependence on volatile external debt markets and ensures adequate investment. By maximising the use of non-debt financing sources, such as FDI and remittances, and tapping into financial instruments, such as green bonds and credit guarantees, Lao PDR minimises the contribution of overseas finance to risks, decreases the impact of external debt, and secures the inflow of funds for energy projects. The integrated approach, therefore, enhances energy and environmental security and fosters long-term economic growth and financial stability.

14.4. Institutional Investors

Institutional investors such as insurance companies and pension funds hold large pools of capital and desire long-term investments with stable returns. Given that the investment requirement for renewable projects needs to be those that are long-term, have relatively stable cash flow, and adhere to sustainability goals, institutional investors appear well-suited to play a substantial role in financing them. As a result, investing institutional capital in the renewable energy sector represents a strategic option for Lao PDR to mobilise a considerable amount of capital during the energy transition. Collaboration between the government, financial institutions, and institutional investors is critical to realise the potential of institutional capital in financing renewable energy projects. These partnerships may come in different forms, such as joint ventures, co-investment arrangements, or specialised investment funds tailored to renewable energy infrastructure, which could be used to leverage the expertise and resources provided by institutional investors. Through this, project viability, mitigation of risks, and acceleration of deployment of renewable energy infrastructure could be made possible. Therefore, Lao PDR and other ASEAN Member States need to have more robust insurance companies and pension funds.

Furthermore, designing investment vehicles that cater to institutional investors' preferences and risk profiles is indispensable to attract participation. Typically, institutional investors prioritise stable returns, long investment horizons, and low levels of risk. Therefore, investment vehicles such as renewable energy funds, infrastructure bonds, or asset-backed securities may be deemed appealing to institutional investors by offering them exposure to renewable energy projects while addressing risk-return preferences. Incorporating and involving institutional investors is critical to securing long-term financial support for large-scale infrastructure projects. Institutional investors contribute to the financial sustainability of renewable energy ventures by providing stable, patient, capital thereby enhancing energy security and facilitating sustainable development goals. Moreover, their involvement can attract additional private capital, catalysing further investment in renewable energy projects and fostering a vibrant renewable energy market ecosystem in Lao PDR.

Although most recommended policies concern Lao PDR specifically, with a focus on their difficulty in attracting private investment for sustainable projects and the issue of limited energy supply due to regulatory barriers and lack of financial assets, the spillover effect can be implemented in other ASEAN nations. In the form of tax refunds, the spillover effect can be used to close financial gaps in energy sectors to attract investors to build financial blocks for infrastructure. Therefore, ASEAN countries expecting similar issues to Lao PDR can apply this policy to commit to sustainable expansion. Moreover, the recommended establishment of the GCGSs facilitates mitigating risks for green investments and enhances access to finance for sustainable energy projects. The scheme can present a blueprint across ASEAN for promoting green finance instruments as a tool for regional collaboration and supporting sustainable energy development. Furthermore, broader participation in institutional investors within ASEAN will promote stable and long-term sustainable energy initiatives in the region. The expertise, significant capital, and long-term investment horizons can contribute to the region's energy transition and foster energy supply security while simultaneously building a culture of sustainable energy practices.

Overall, the policies tailored to Lao PDR focus on expanding the energy sector through green finance mechanisms and strategic partnerships to bring in investment. Through showcasing the successful use of risk-mitigating financial instruments, incentivising green investments, and diversifying financial sources, Lao PDR can lead as an example for other ASEAN nations and collaborate with neighbouring nations to advance regional energy security and financial stability.

15. Capacity Building Needs

This White Paper outlines the priorities to establish energy security in Lao PDR. Capacity building is an ongoing affair rather than a one-time event. Further, capacity building does not come in a single format but is wide-ranging, taking varying forms at different times along a temporal path. While some technical skills needed can be identified in advance, implementation requires the agility to react and adapt to changing circumstances, both at the technical skills level and to changing social, political, and economic contexts. This is especially true of policies that are many years in the making, from design to fruition. Capacity building, therefore, has an inherent dynamic to it. It is neither a simple, predetermined checklist of trainings to be provided, nor an exercise detached from real-time feedback loops, affecting policy implantation.

Capacity building is more than specific skills needed to conduct particular technical tasks. It is needed through the whole policy ecosystem to support a desired outcome. Identifying technical skills needed for a specific task can often be done with ease. However, identifying the skills needed for the policy environment rather than the more scientific and technical training needs can be more difficult. Thus, for example, imparting knowledge about how to run an infrastructure facility must run in parallel with the need to ensure the facility compliant with local and national laws and regulations and international obligations. This requires a distinct set of skills and understanding.

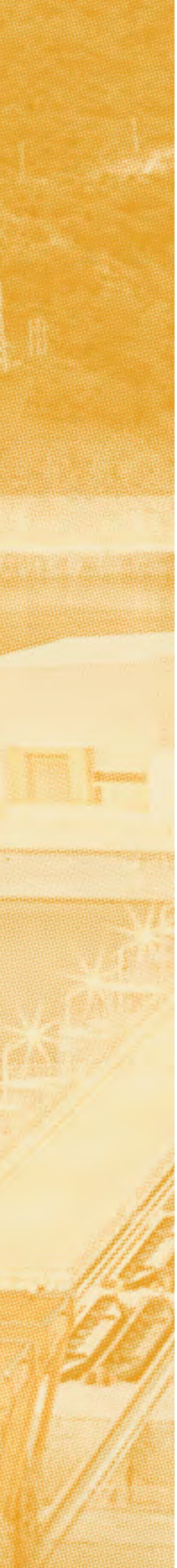
Capacity building cannot be an afterthought but must be integral to the design and adoption of policy. While not a silver bullet to ensure policy success, it can contribute to forestalling pitfalls at a later stage. Thinking through the types of support likely to be needed is important because what may appear on paper to be an ideal policy, on a more thorough evaluation, may reveal a potential level of complexity and support that was not anticipated when the policy idea was first originated; ideal policies may not be practical policies if they demand levels of human (and capital) resources beyond the means available for implementation. This brings into focus further important aspects of capacity building planning. First, policy planning must include not only cost–benefit analysis of expected outcomes, but also the cost of capacity building support. Flowing from this, it may be necessary to develop different sets of options to support implementation. These options should be considered as part of the decision-making process. Such planning for capacity building helps ensure that an outcome being pursued has a reasonable chance of success, and available resources are equal to those required for implementation.

Capacity building takes various forms, is targeted towards different stakeholders, will need to be provided by different experts, and takes place at various times along the policy development/implementation lifecycle. The most common types of capacity building are:

i. policy-modelling/cost–benefit analysis support;
ii. domestic regulatory mapping: to understand which laws and regulations may need to be reformed, to implement new policies, or remove regulations acting as a barrier to more dynamic reform and regulatory compliance;
iii. international regulatory mapping, for example, of non-tariff measures that may be faced;
iv. advocacy: support for stakeholders to know how to effectively share their findings on a particular issue with each other;
v. provision of issue-specific technical training;
vi. developing implementation work plans;
vii. developing monitoring and evaluation frameworks;
viii. monitoring policy implementation;
ix. outreach and awareness-raising; and
x. lessons learned/comparative experiences.

Specific capacity building and training is suggested in each chapter this White Paper. There is no need to discuss each type of capacity building as their potential role and importance will become apparent when thinking through policy implementation in detail. However, it is beneficial to bear in mind the range of support that exists. From this menu of capacity building activities, certain amounts of knowledge and competency will already exist and be institutionalised amongst sets of stakeholders long experienced with working in a particular field. However, any new policy or effort to innovate is likely to necessitate increased numbers of people who need to be brought into the project circle. Thus, certain requisite skills, whether in relation to policy development amongst policy officials, or technical staff in relation to policy roll out, will need to be taught. Neither the resources, nor the time needed for this, should be underestimated.

With capacity building likely to be needed for a wide range and considerable number of stakeholders, including government officials, legislators, independent regulators, oversight agencies, state owned enterprises, private sector, and community groups, the burden of who is responsible for providing the capacity building to different target audiences must also be considered. This is why it is also incumbent on government, which establishes policy, to be aware not only of its own resource limitations, but also those of counterpart stakeholders who will play a vital role in the success of the policy.



Part 2:

Evidence-Based Findings to Support the Energy Security White Paper

Chapter 1

Energy Landscape of Lao PDR

Han Phoumin

1. Introduction

Lao People's Democratic Republic (Lao PDR) – as well as the rest of Association of Southeast Asia Nations (ASEAN) Member States – is facing tremendous challenges regarding its future energy landscape. Lao PDR must embrace a new architecture, including sound policies and technologies, to ensure energy access as well as affordability, security, and sustainability. Moreover, increasing energy demand in every ASEAN Member State threatens the region's energy security and environment; hence, investment in sustainable energy infrastructure – such as clean technologies; energy efficiency; clean use of fossil fuels and renewable energy; and development and adoption of ecotowns, smart grids, and electric vehicles – is needed.

Although Lao PDR exports electricity to neighbouring countries, it still has a very high importation dependency for transport as well as commercial and residential consumption (e.g. 100% importation of finished oil products like gasoline, diesel, and kerosene). For the medium term, Lao PDR will continue to increase this importation, putting pressure on its energy security; thus, it is imperative that emergency response and preparedness at the national level regarding energy security be established.

Although Lao PDR is landlocked, it is in the middle of the Greater Mekong Subregion and is surrounded by three large economies – China, Thailand, and Viet Nam – and two medium economies – Cambodia and Myanmar.[1] As a result, Lao PDR can position itself as a 'land-linked' country and leverage the advantages thereof. Accordingly, building on its longstanding history of trading electricity with Thailand, Lao PDR has now expanded its policy to export electricity to neighbouring countries such as Cambodia and Viet Nam, and within ASEAN through the ASEAN Power Grid.[2]

This chapter uses existing data from *Decarbonisation of Energy Systems: Optimum Technology Selection Model Analysis up to 2060*, from the Economic Research Institute of ASEAN and East Asia (ERIA), to help analyse the energy landscape of Lao PDR (Kimura et al., 2022). This linear programming model helps minimise the total cost of an energy system when various constraints – such as emissions and power supply–demand balance – are supplied to examine the maximum contribution of all available clean technologies and renewables in various scenarios, including a decarbonisation scenario for Lao PDR. The key findings will help show policymakers how Lao PDR can scale up its renewables and associated technologies in an affordable manner given the barriers and costs associated with deep decarbonisation. This chapter also provides policy directions towards a secure, reliable, and sustainable energy system that meets the country's unique socio-economic environment.

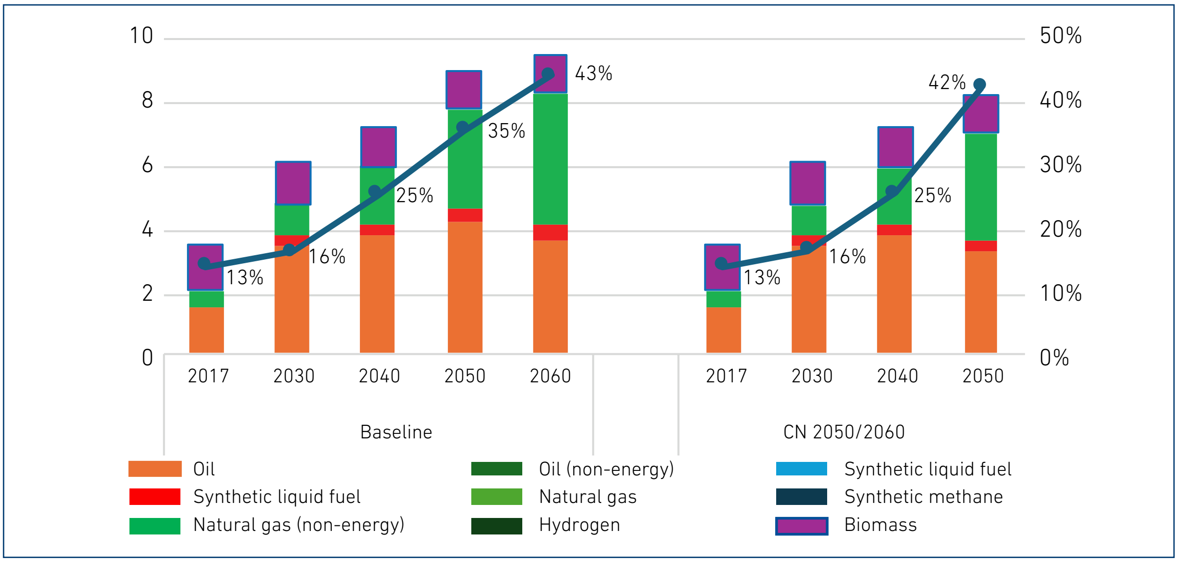
[1] Energy policy in Lao PDR has gained much public attention since the establishment of the Ministry of Energy and Mines (MEM) in 2006. Under MEM, the country's energy policy has evolved from a singular power sector policy to broader policies supporting the development of a sustainable and environmentally friendly energy sector.

[2] The ASEAN Power Grid is an initiative to construct regional power interconnection, first through cross-border bilateral terms and then on a sub-regional basis, leading to a totally integrated South-east Asian power grid system.

2. Lao PDR's Energy Demand

As shown in Figure 1.1., electricity will have the largest share in the final energy consumption of Lao PDR by 2050 under both the baseline and carbon-neutral scenarios. Electricity's share is expected to increase from 13% in 2017 to 42% or 43% by 2050. Oil and biomass would remain dominant fuel sources in 2050 under the carbon-neutral scenario. Oil would be the second-most used fuel in end-use sectors, such as transport and some industries, with 3.15 million tonnes of oil equivalent (Mtoe) or a 39% share. Biomass would be the third-largest fuel source, with a 15% share of total final energy consumption.

Figure 1.1. Final Energy Demand by Fuel Sources, Baseline versus Carbon-Neutral 2050 Scenarios (Mtoe)



CN = carbon-neutral, Mtoe = million tonnes of oil equivalent.

Source: Author's calculations.

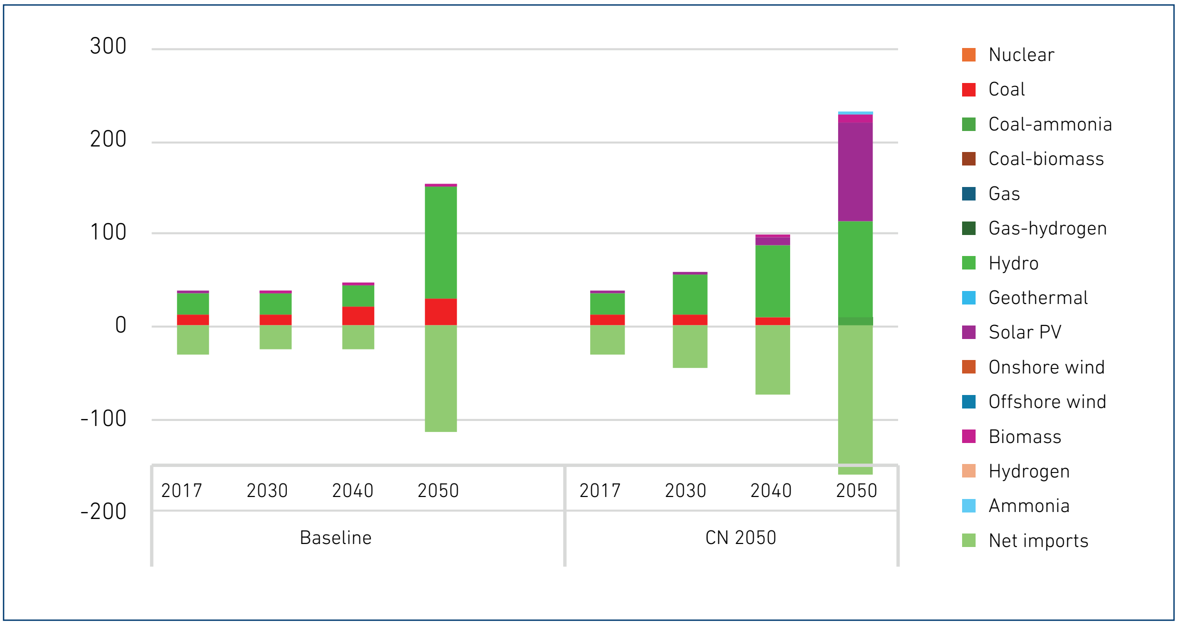
Although oil would remain the second-largest fuel source in final energy consumption by 2025 under both scenarios, the use of electricity, biomass, and clean fuels are key to decarbonise end-use sectors. Lao PDR can do more to accelerate the use of electricity in transport to reduce oil consumption, by, for example, embracing electric vehicles by 2050. Industries could also move towards the use of electricity or green hydrogen; Lao PDR has much potential for green electricity from hydropower, solar, wind, and biomass. It could use these resources to help decarbonise its own system, and the excess electricity could be traded on the ASEAN Power Grid, helping decarbonise neighbouring countries. The excess electricity could also be converted into hydrogen or battery storage.

Meanwhile, green hydrogen could also help decrease petroleum product imports as well as the use of fertilizer in agriculture. Lao PDR could produce green fertilizer from green hydrogen – the secret of which is green electricity – to help guide Lao PDR into a green and resilient economy.

3. Lao PDR's Power Generation

The country's great potential for hydro, solar, wind, and biomass could allow Lao PDR to maximise its electricity net export on the ASEAN Power Grid. It could have 45 terawatt-hours (TWh) of expected capacity by 2030, 73 TWh by 2040, and 161 TWh by 2050 under the carbon-neutral scenario (Figure 1.2). Renewables – such as hydropower, solar, wind, and biomass – would then be the dominant fuel source by 2050. Other clean fuels, such as ammonia, could also help decarbonise the power sector through coal/ammonia co-combustion.

Figure 1.2. Power Generation by Fuel Sources, Baseline versus Carbon-Neutral 2050 Scenarios (TWh)



CN = carbon-neutral, PV = photovoltaic, TWh = terawatt-hour.

Source: Author's calculations.

Exportation of electricity could bring about US$121 billion in cross-revenue by 2050, excluding the potential of carbon credits from renewable energy projects of carbon off-setting and forest reserves.[3] Lao PDR could also earn foreign exchange through electricity export, cutting the cost of imported petroleum products and fertilizer. As electricity is key to Lao PDR's current and future economy, appropriate strategies to drive investment into this sector are crucial. High-grade infrastructure, a transparent investment climate, and good governance are necessary to attract investment into Lao PDR as well.

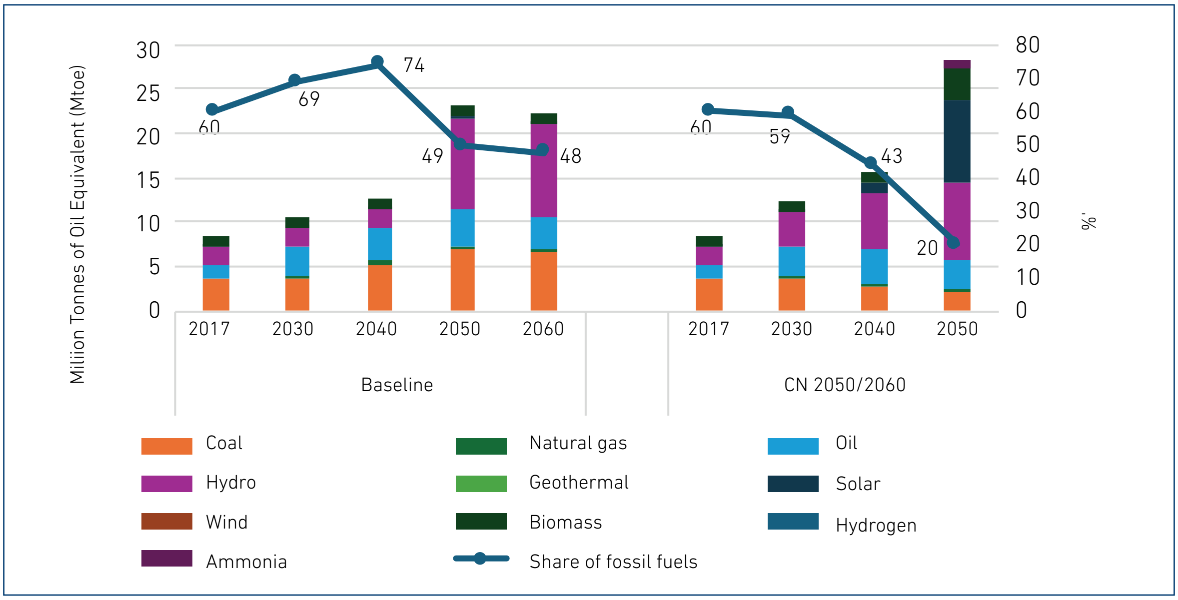
[3] Note that this is the author's calculation from the estimated power purchasing agreement and is not a net-present value.

4. Lao PDR's Primary Energy Supply

As shown in Figure 1.3, coal and oil combined constituted the largest share – 60% – of the total energy supply of Lao PDR in 2017. However, these are expected to fall to about 20% by 2050 under the carbon-neutral scenario. In 2017, hydropower had the second-largest share of the total energy supply after coal, and the combined share of both renewables and clean fuels would increase from 40% in 2017 to 80% in 2050 under the carbon-neutral scenario.

The demand for oil is forecasted to increase 2.4-fold from 2017 to 2050 under both scenarios, implying that oil will remain a key fuel for transport and industries. However, this forecast assumes that the transport and industrial sectors will continue to primarily use oil. This could change if Lao PDR's policy shifts towards electric vehicles, battery storage, and hydrogen fuels.

Figure 1.3. Primary Energy Supply by Fuel Source, Baseline versus Carbon-Neutral 2050 Scenarios



CN = carbon-neutral.

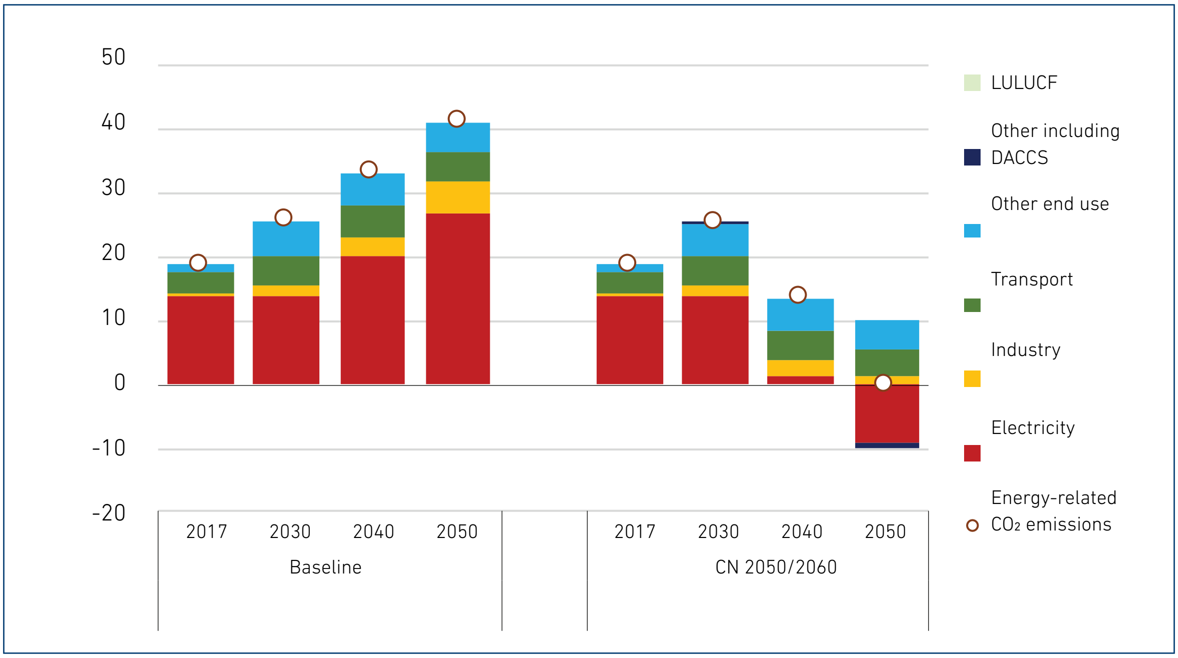
Source: Author's calculations.

Under the carbon-neutral scenario, solar and hydropower would constitute the largest share in the primary energy supply (Figure 1.3). Lao PDR also has great potential for wind and biomass; however, this depends on policies to promote this potential as well as investment. The government did sign an agreement with Savan Vayu Renewable Energy (SVARE) in February 2024 for the development of a 1,200-megawatt (MW) wind power project, which will be the largest of its kind in South-east Asia (Lao News Agency, 2024).

5. Lao PDR's Emissions and Abatement Costs

Lao PDR has a long journey ahead in decarbonising its whole energy system; it has the current 1,878-MW Hongsa coal-fired power plant as well as additional already-committed coal-fired power plants in the southern part of the country. Lao PDR must find appropriate strategies to deal with these current and committed coal-based power plants in the pipeline. One may be to combine clean coal technology with carbon capture, utilisation, and storage (CCUS). Since Lao PDR will produce clean hydrogen, carbon from power plants could be used to produce synthetic fuels for transport.

Figure 1.4. Emissions, Baseline versus Carbon-Neutral 2050 Scenarios ($MtCO_2$)



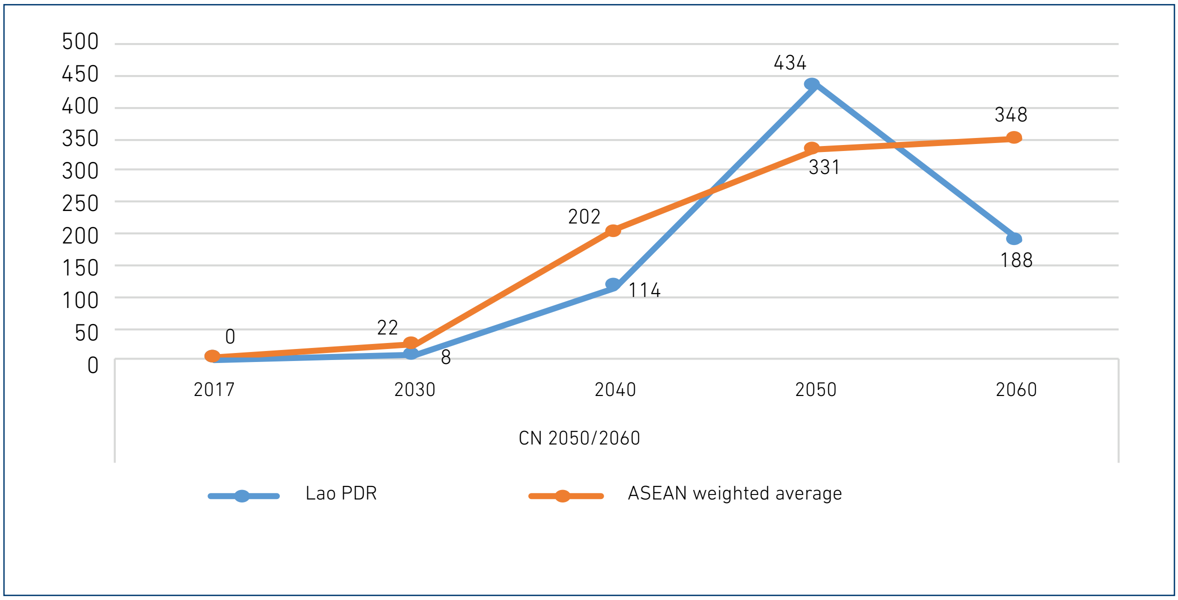
CN = carbon-neutral, CO_2 = carbon dioxide; DACCS = direct air capture with carbon storage; LULUCF = land use, land-use change, and forestry; $MtCO_2$ = million tonnes of carbon dioxide.

Source: Author's calculations.

Under the carbon-neutral scenario, emissions from the power sector will be mostly decarbonised through technologies such as CCUS (Figure 1.4). Only emissions from transport, industries, and 'other end use' will still need to be captured, as those sectors will continue to use fossil fuels. Thus, it is best to have a policy to replace fossil fuels with synthetic fuels. Moreover, Lao PDR has the potential of green hydrogen production as well as carbon capture from existing coal-fired power plants, which could further help decarbonise the sectors.

The best means to decarbonise the energy system is to retire coal-fired power plants by 2050 and to cease the development of additional coal-fired power plants by 2050. Coal should also be co-combusted with ammonia and be integrated with CCUS under the carbon-neutral scenario.

Figure 1.5. Marginal Abatement Cost of Emissions, Baseline versus Carbon-Neutral 2050 Scenarios ($US\$/tCO_2$)



ASEAN = Association of Southeast Asian Nations, CN = carbon-neutral, tCO_2 = tonne of carbon dioxide.

Source: Author's calculations.

For Lao PDR, the marginal abatement cost is predicted to drop from US$434/tonne of carbon dioxide (tCO_2) in 2050 to US$188/$tCO_2$ in 2060. In general, this decarbonisation cost is lower than that of the ASEAN average almost by half (Figure 1.5). Considering the potential of carbon credits from forests and carbon-offsetting from renewables, Lao PDR could be in the position of economic gain from selling carbon credits.

6. Conclusion and Policy Implications

Meeting a carbon-neutral goal requires a country to achieve large-scale emissions reduction through fundamental transformation of its energy system – the decarbonisation of the power sector, followed by the electrification or decarbonisation of energy consumption, and offsetting of remaining emissions using negative-emissions technologies. However, the availability of power systems or low-carbon energy and the possibility of using alternative energy vary significantly across countries and regions; energy transition cannot be accomplished uniformly across the globe. While numerous opportunities to reduce emissions exist, the transition to carbon neutrality must safeguard energy supplies and recognise some countries' limited ability to fully embrace renewables due to economic constraints and huge decarbonisation costs.

Lao PDR's energy primarily comes from coal, oil, hydropower, and 'others' (including biomass, solar, and electricity for export). The combined shares of coal and oil are expected to fall to about 20% of the primary energy supply by 2050 under the carbon-neutral scenario. As Lao PDR has great potential towards hydro, solar, wind, and biomass, this could allow the country to maximise its electricity net exports on the ASEAN Power Grid and to make renewable energy the dominant fuel source by 2050. Other clean fuels, such as ammonia, could also play a role in decarbonising the power sector through coal/ammonia co-combustion.

For end-use sectors, it is expected that electricity will comprise the largest share of Lao PDR's final energy consumption by 2050. The increasing share of electricity consumption in end-use sectors will be key for decarbonisation as well. However, oil and biomass will remain the dominant fuel sources of energy by 2050 even under the carbon-neutral scenario. Lao PDR can do more to accelerate the use of electricity in transport to reduce oil consumption by, for example, embracing electric vehicles. Further, the industrial sector could use electricity or green hydrogen much more, as Lao PDR also has great potential towards green electricity from hydropower, solar, wind, and biomass.

Lao PDR faces many challenges towards decarbonisation, including its reliance and commitment to large coal-fired power plants. It could, however, encourage clean coal technology with CCUS as well as using carbon to produce synthetic fuels for transport. The country is also encouraged to retire coal-fired power plants by 2050 and to stop their development outside of the existing pipeline. Coal should also be co-combusted with ammonia for the energy transition and be integrated with CCUS.

Broad policy directions include (i) energy supply security; (ii) a resilient power system and power market; (iii) sustainable transport systems; (iv) affordable energy for all; (v) energy efficiency improvement and electrification in end-use sectors, promotion of the energy management system and energy service companies, and creation of energy performance standards; (vi) alternative energy, especially renewables and clean technologies; (vii) sustainable hydropower development; (viii) carbon market and carbon credit mechanisms; (xi) regional and international cooperation for energy technological transfer; (x) bridging knowledge gaps; and (xi) financing sustainable energy infrastructure for Lao PDR and ASEAN.

Lao PDR should accelerate the penetration of variable renewables as well as other carbon-free (e.g. hydro, geothermal, biomass, nuclear, carbon dioxide-free hydrogen, and CCUS) and negative emissions technologies and forest carbon sinks. All should contribute to the country's carbon neutrality by the 2050 goal and promote sustainable economic development. During the energy transition period, fuel switching from coal to natural gas, deployment of more efficient turbines, and co-firing with hydrogen or ammonia will play important roles in decarbonisation and energy security. While affordable technologies must be deployed in the mid-term, more niche – and expensive – technologies are required in the last stage of carbon neutrality, including those concerning CCUS, hydrogen, and ammonia. The cost of decarbonisation remains a concern; in this regard, costs must be reduced through technology innovation, large-scale deployment of low-carbon technologies, and regional and international cooperation.

There are three important steps to ensure a smooth energy transition:

(i) **Early decarbonisation transition technologies**. These technologies involve immediate switching from coal to natural gas power generation, waste to energy plants in the power sector, and leak detection for fugitive emissions reduction upstream. These technologies can be deployed in the early phases of a country's transition pathway and may be retired before reaching net-zero emissions.

(ii) **Partial emissions reduction transition technologies.** These technologies include the co-combustion of coal-fired power generation with biomass or ammonia and the co-combustion of gas-fired power generation with hydrogen fuel. The share of biomass, ammonia, and hydrogen to the power generation mix must increase over time. For the upstream sector, electrification in gas production and processing should be introduced.

(iii) **Deep decarbonisation transition technologies.** These technologies include CCUS combined with coal/gas power generation, blue hydrogen, blue ammonia, and CCUS in gas processing. More technologies that involve the power and end-use sectors should also be embraced.

Financing clean technologies and renewables is still a critical issue in Lao PDR. Striving for a circular economy may help – as well as offer environmental benefits – through recirculating a larger share of materials, reducing waste in production, lightweighting products and structures, and extending the lifetime of products. All of these activities also offer the opportunity for new business models. In addition, the role of digitalisation will help the economy become more efficient through energy savings and efficiency, which, in turn, contributes to overall emissions and cost reduction, particularly the energy intensity reduction.

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Annex

Table 1.A1. Final Energy Demand of Lao PDR
(Mtoe)

	Baseline					Carbon-Neutral 2050/2060			
	2017	2030	2040	2050	2060	2017	2030	2040	2050
Coal	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.00
Oil	1.47	3.38	3.65	4.12	3.50	1.47	3.38	3.65	3.15
Oil (non-energy)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Synthetic liquid fuel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural gas	0.00	0.32	0.41	0.41	0.55	0.00	0.27	0.36	0.36
Natural gas (non-energy)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Synthetic methane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electricity	0.47	0.96	1.79	3.14	4.10	0.47	0.97	1.79	3.36
Hydrogen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biomass	1.44	1.34	1.27	1.21	1.21	1.44	1.34	1.27	1.21
Total	**3.49**	**6.11**	**7.22**	**8.97**	**9.46**	**3.49**	**6.07**	**7.18**	**8.08**
Share of electricity	**0.13**	**0.16**	**0.25**	**0.35**	**0.43**	**0.13**	**0.16**	**0.25**	**0.42**

Lao PDR = Lao People's Democratic Republic, Mtoe = million tonnes of oil equivalent.

Source: Author's calculations.

Table 1.A2. Power Generation of Lao PDR
(TWh)

	Baseline					Carbon-Neutral 2050			
	2017	2030	2040	2050	2060	2017	2030	2040	2050
Nuclear	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coal	13.66	13.66	22.04	29.65	29.15	13.66	13.66	10.35	0.00
Coal-ammonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.35
Coal-biomass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Baseline					Carbon-Neutral 2050			
	2017	2030	2040	2050	2060	2017	2030	2040	2050
Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gas-hydrogen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydro	23.04	23.24	23.24	120.71	120.71	23.04	43.51	76.61	103.06
Geothermal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solar PV	0.01	0.01	0.01	0.62	0.74	0.01	0.01	10.89	107.24
Onshore wind	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Offshore wind	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biomass	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.06	8.76
Hydrogen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ammonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.86
Net imports	–30.97	–25.10	–23.37	–112.55	–100.40	–30.97	–45.24	–72.93	–161.13

Lao PDR = Lao People's Democratic Republic, PV = photovoltaic, TWh = terawatt-hour.

Source: Author's calculations.

Table 1.A3. Primary Energy Supply of Lao PDR

(Mtoe)

	Baseline					Carbon-Neutral 2050			
	2017	2030	2040	2050	2060	2017	2030	2040	2050
Nuclear	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coal	3.60	3.60	5.22	6.83	6.49	3.60	3.60	2.75	2.12
Natural gas	0.00	0.32	0.41	0.41	0.55	0.00	0.27	0.36	0.36
Oil	1.47	3.38	3.65	4.12	3.50	1.47	3.38	3.65	3.15
Hydro	1.98	2.00	2.00	10.38	10.38	1.98	3.74	6.59	8.86
Geothermal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solar	0.00	0.00	0.00	0.05	0.06	0.00	0.00	0.94	9.22

	Baseline					Carbon-Neutral 2050			
	2017	2030	2040	2050	2060	2017	2030	2040	2050
Wind	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biomass	1.44	1.34	1.27	1.21	1.21	1.44	1.34	1.29	3.62
Hydrogen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ammonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95
Share of fossil fuel	59.69	68.62	73.94	49.38	47.50	59.68	58.80	43.42	19.90
Share of renewables and clean fuels	40.31	31.38	26.06	50.62	52.50	40.32	41.20	56.58	80.10

Lao PDR = Lao People's Democratic Republic, Mtoe = million tonnes of oil equivalent.

Source: Author's calculations.

Table 1.A4. Emissions of Lao PDR
(MtC)

	Baseline					Carbon-Neutral 2050			
	2017	2030	2040	2050	2060	2017	2030	2040	2050
Electricity	13.84	13.84	20.27	26.63	25.30	13.84	13.84	1.26	–9.32
Industry	0.59	1.73	2.94	5.08	5.86	0.59	1.59	2.47	1.25
Transport	3.15	4.50	4.61	4.69	3.78	3.15	4.50	4.61	4.39
Other end use	1.23	5.46	5.26	4.57	3.15	1.23	5.35	5.14	4.46
Other including DACCS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–0.77
LULUCF						0.00	0.00	0.00	0.00
Energy-related emissions	18.80	25.54	33.07	40.98	38.09	18.80	25.28	13.47	0.00

DACCS = direct air capture with carbon storage; Lao PDR = Lao People's Democratic Republic; LULUCF = land use, land-use change, and forestry; MtC = million tonnes of carbon.

Source: Author's calculations.

Chapter 2

Energy Supply Security of Lao PDR and Implications for ASEAN

Ruengsak Thitirasakul

1. Lao PDR's Primary Energy Supply

The heavy reliance of Lao People's Democratic Republic (Lao PDR) on fossil fuels made oil and coal account for 64% of the country's total energy supply mix in 2020 (Figure 2.1).

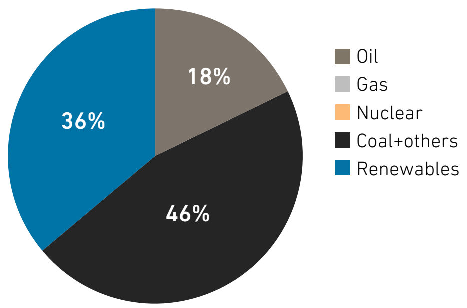
Figure 2.1. Lao PDR's Total Energy Supply

Total Energy Supply (TES)

Total Energy Supply (TES)	2015	2020
Non-renewable (TJ)	95 192	162 506
Renewable (TJ)	85 638	90 940
Total (TJ)	180 830	253 445
Renewable share (%)	47	36

Growth in TES	2015-20	2019-20
Non-renewable (%)	+70.7	-6.2
Renewable (%)	+6.2	-8.6
Total (%)	+40.2	-7.1

Total Energy Supply in 2020



TJ = terajoule.

Source: IRENA (2023).

The country's abundant coal reserves, which have a reserves–production ratio of more than 100 years (Table 2.1), contribute to the country's high coal supply security. Coal serves as Lao PDR's major additional source of electricity generation, supplementing hydroelectric power.

Table 2.1. Lao PDR's Coal Reserve Status

Type	Tonnes	Global Rank
Coal Reserves	554,461,930	37
Coal Production	5,330,918	31
Coal Consumption	5,247,934	47
Yearly Surplus	82,984	
Coal Imports	8,732	
Coal Exports	24,000	
Net Exports	15,268	

Source: Worldometer, Laos Coal, https://www.worldometers.info/coal/laos-coal/ (accessed 21 June 2024)

Based on Kimura, Phoumin, and Purwanto (2023), coal accounted for 3.93 million tonnes of oil equivalent (Mtoe) in Lao PDR's energy supply mix for 2020. Hydropower came in second at 2.24 Mtoe, biomass at 1.62 Mtoe, and oil at 1.04 Mtoe. The high rate of coal consumption is primarily due to the Hongsa coal-fired power plant, and plans are underway to build additional coal-fired power plants for exportation purposes, with a 4.2% increase in consumption projected between 2020 and 2050. It is estimated that coal's total primary energy supply share will rise from 62.4% in 2020 to 71.5% in 2050 (Kimura, Phoumin, Purwanto, 2023).

Lao PDR lacks domestic oil reserves; however, it uses oil extensively, which necessitates importing all finished oil products. Oil has consistently been the primary fuel in the country, and this trend is still present – although Lao PDR plans to phase out fossil fuels with renewables as a part of its efforts to reach carbon neutrality by 2050. However, the oil supply is still projected to more than double from 1.04 Mtoe in 2020 to 3.56 Mtoe in 2050 in the business-as-usual scenario (Kimura, Phoumin, Purwanto, 2023). The share of oil in the final energy demand would also increase from 32% in 2020 to 42% in 2050.

Lao PDR acknowledges that its oil consumption has increased over the past decade; however, there are no substitute fuels available. Given that one of the primary risks to the country's energy security stems from its reliance on oil imports, this chapter highlights potential strategies to help Lao PDR enhance its oil security status, which will ultimately raise the country's overall energy security.

Indeed, Lao PDR's energy supply security will remain vulnerable for an extended period, as its increasing oil consumption suggests that Lao PDR's 100% reliance on oil imports for finished fuel products may persist well past 2050 (Kimura, Phoumin, Purwanto, 2023). Therefore, the country should develop energy security measures to cope with unanticipated supply disruptions, which can originate from external sources like geopolitics and conflicts, disasters, accidents, and terrorist attacks on the oil logistics system. Establishing a national emergency response and preparedness protocol is essential.

Integrating various measures that make up emergency response measures is the fundamental concept behind an emergency response design. These strategies include supply and demand response plans, strategic petroleum reserves (SPR) or oil stockpiling, interruptible contracts, and fuel switching. SPR, sometimes referred to as emergency stocks, is the most crucial of the aforementioned requirements.

2. Petroleum Reserve Design Strategy for Lao PDR

To carry out a petroleum reserve design strategy for Lao PDR, it is recommended that these specific procedures be followed:

(i) evaluate the reserve alternatives and their pros and cons;
(ii) delegate a responsible party to evaluate the risk to and to determine the amount of oil reserves;
(iii) design different scenarios that can impact Lao PDR's oil security;
(iv) conduct a risk analysis of each scenario, and assess its impact and probability;
(v) calculate the quantity of oil to be reserved for emergencies in terms of percentages of monthly oil consumption or the number of days that Lao PDR must always have oil in storage;
(vi) design the logistics system to keep the oil reserves in secure locations, which are ready to be distributed; and
(vii) apply this systematic approach to electricity and other energies used in Lao PDR if the need arises.

3. Strategic Petroleum Reserves versus Mandatory Petroleum Reserves

Lao PDR must begin to design its fuel and power reserves due to the country's continued reliance on petroleum products and its growing electricity consumption. For oil, Lao PDR must choose between (i) establishing a national SPR, which the government would control and would not affect the commercial stock; or (ii) enforcing laws of reserve and mandating that oil traders always keep certain stock for national mandatory petroleum reserves (MPR). Note that the cost of the fuel to be reserved will rise in proportion to the amount reserved. In theory, the expenses will be borne by customers and accumulated.

Despite having a legal reserve already in place, Lao PDR should conduct an assessment to determine whether to implement a full-scale SPR or to maintain an MPR. Table 2.2 shows MPRs across the Association of Southeast Asian Nations (ASEAN) region.

Table 2.2. ASEAN Mandatory Oil Stockpiles

Country	Global Rank
Brunei Darussalam	31 days for refineries
Cambodia	30 days for companies importing oil
Indonesia	14 days (crude oil) 23 days (oil products) for the national oil company
Lao PDR	21 days for companies importing oil 10 days for distributors
Malaysia	30 days for the national oil company
Myanmar	6 day for oil companies
Philippines	30 days (crude oil) for refineries 15 days (oil products) for companies importing oil
Singapore	90 days (oil products) for power companies
Thailand	21.5 days (crude oil) 3.5 days (oil products) for refineries and traders
Viet Nam	10 days (crude oil) 40 days (oil products) for oil companies

Source: IEA (2022).

If Lao PDR decides to set up an SPR, the government must fund its construction; that is, the government would possess ownership of the tank terminals entirely. Oil traders would conduct normal business using their commercial stock and report their commercial reserve as additional to the SPR.

It is challenging to justify an SPR because it is very costly, requiring the government to fund the establishment of SPR facilities, provide operational staff training, establish a department to oversee reserve inventory, and purchase oil products using the government budget or taxpayer money. The government must also consider the financial complications if oil prices change, particularly if oil prices drop and there is a potential stock loss.

The government has the option to rent SPR through 'ticketing' once the oil volume to be reserved has been decided. Ticketing is an alternative for a country without significant infrastructure to store a physical reserve. Lao PDR could pay a rental fee to another country that can store stock outside of Lao PDR's borders rather than holding a reserve on site according to a bilateral agreement.

If Lao PDR confirms that the MPR will remain, however, then the responsible party must ascertain the reserve requirement that is suitable for the oil value chain environment in Lao PDR. The MPR option is less complicated because the reserve is controlled by the government rather than owned by the government. The government may establish legal reserve laws to draw on the necessary inventory in an emergency, although the government is not the actual owner of the stock. By law, Lao PDR does have the authority to obligate oil companies to stockpile a certain amount of oil for national security. Yet to address all aspects of oil supply security, Lao PDR must determine whether it has other, adequate measures to handle an emergency. These measures would go beyond the legal reserve and should, at the very least, involve demand and supply response strategies.

4. Evaluating Risk and Determining the Reserves

Lao PDR should designate a responsible party to evaluate risk and to determine the actual amount of oil reserves necessary. The responsible party may be a subcommittee or an existing department within the Ministry of Energy and Mines or related ministries. This body should also assess any ongoing risks, such as those related to geopolitics and the supply and demand of oil outside of Lao PDR. It should also define the protocols for determining the trigger point at which the government must intervene when a situation reaches a predetermined level of oil supply insecurity.

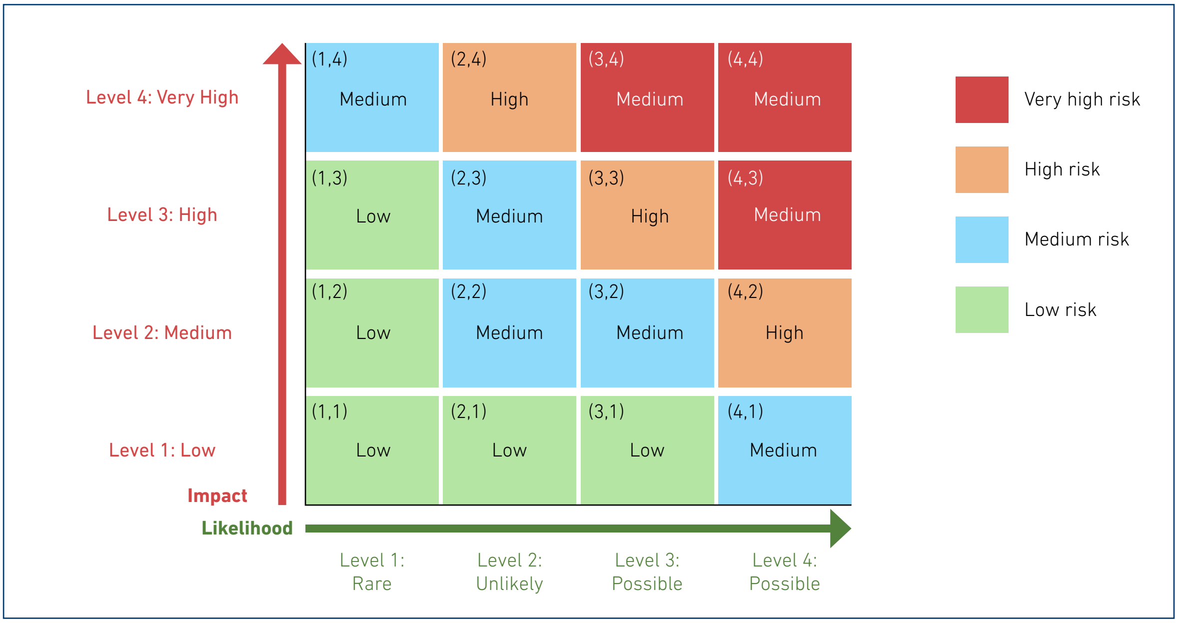
5. Scenarios Influencing the Oil Security of Lao PDR

Multiple scenarios should be developed that may influence the oil security of Lao PDR, the risks associated with each scenario should be analysed, and their probability and impact should be determined. These actions include formatting action plans to manage various incidents and other emergencies that may arise in Lao PDR or its neighbours that could disrupt the supply of oil imports into Lao PDR. Incidents can occur domestically or in nearby countries or be due to geopolitical risks, such as the emergency closure of domestic oil terminals, emergency shutdown of refineries in countries that supply oil (e.g. Thailand), the crisis between Israel and Hamas, or the conflict between the United States and Iran.

Risk analysis should be undertaken simultaneously and spontaneously to assess the likelihood of potential damage and the seriousness of the emergencies. The government can evaluate an oil shortage incident in advance and use planned countermeasures to mitigate the effects by analysing the appropriate reserves during a crisis or unusual circumstance.

It is recommended that a qualitative risk assessment be developed by professionals in the oil and related industries to determine the risk factors on the supply and demand sides, degree of severity of the impact, and probability of an event occurring. An example of a table of risk analysis is shown in Figure 2.2.

Figure 2.2. Risk Analysis to Evaluate Energy-Related Emergencies



Source: PTIT (2024).

Furthermore, Lao PDR should conduct routine emergency response drills to update the scenarios as needed. Establishing an emergency response team or committee and creating an annual tabletop exercise schedule are important.

6. Lao PDR's Oil Logistics

Oil logistics play a crucial role in the integration of the oil supply network, significantly influencing the distribution of oil to end-users. A well-designed and functional oil logistics system helps facilitate timely, efficient oil transport from suppliers to customers in the appropriate quantity at the proper time. If oil logistics are not operating at maximum efficiency, they can harm both the country's transport system and its economy.

It is recommended that Lao PDR investigate how the oil supply logistics system can be enhanced to improve the security of the oil supply. It is also recommended that Lao PDR begin the analysis immediately by compiling information on the tank facilities (i.e. tank capacities and fuel services) across provinces and regions and comparing the tank capacities with local demand. The scope of this exercise could be expanded to include monitoring the effects of seasonal variations in demand. Moreover, tank–consumption ratios should be examined to ascertain the optimal ratio for every area. The proper ratio or index for major cities and rural provinces must be determined, and corresponding facilities must be designed to ensure that the quantity of reserves and storage meets demand.

Lao PDR could also construct an integrated oil logistics network or oil hub to connect its oil terminals to the pipeline system in the northern region of Thailand to facilitate oil distribution from Thailand to Lao PDR for quick supply in an emergency.

7. Lao PDR's Online Oil Inventory System

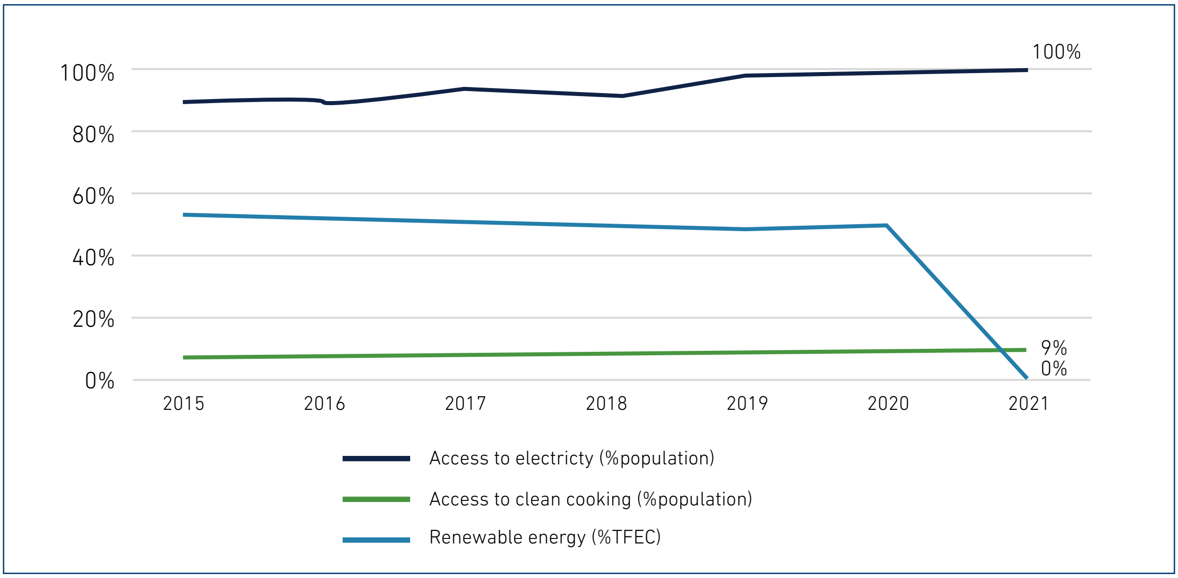
Lao PDR already has a system to track the country's oil inventory, but because all of the oil in Lao PDR is imported, this inventory system must be strengthened. The current oil inventory system could be transformed into an online monitoring system. As a result, Lao PDR would be in a better position to assess possible crises, respond to situational changes, and adjust the oil inventory to address any future energy crisis more spontaneously. Lao PDR should conduct regular and systematic reviews of the mandatory reserve requirement as well.

8. LPG Strategic Reserves

Those seeking better fuel for their homes are increasingly adopting liquefied petroleum gas (LPG) to replace biomass in Lao PDR. Figure 2.3 shows the growth of access to clean cooking, which in part refers to the use of LPG. LPG is sometimes the preferred choice because it generates consistent heat as opposed to unevenly burning biomass, which is also less convenient. Because it is convenient and clean, LPG has become the standard fuel in the industrial sector.

As LPG consumption seems to be rising recently, LPG consumption in Lao PDR should be better monitored. It is recommended that Lao PDR investigate the quantity of LPG that should be reserved for future supply security.

Figure 2.3. Lao PDR's Access to Clean Cooking



TFEC = total final energy consumption.

Source: IRENA (2023).

The strategy for reserving LPG can be developed similar to that for oil:

(i) evaluate the reserve requirement based on different scenarios that may impact LPG security;

(ii) conduct a risk analysis of each scenario, and assess its impact and probability;

(iii) determine how much LPG should be reserved for emergencies, either as a percentage of monthly LPG consumption or as the number of days needed in storage; and

(iv) establish a logistics system to keep LPG reserves in secure locations ready to be distributed to support the entire LPG system throughout Lao PDR.

It should be noted, however, that the reserves of LPG and oil do not have to be the same due to their different types of use. LPG is primarily used in the residential sector, whereas oil is primarily used in the transport sector. Lao PDR must also consider the fact that, unlike LPG users in households who may choose to switch back to biomass in the event of a shortage, oil consumers in the transport sector lack alternative fuel sources as a backup. Yet most industrial plants have backup alternative fuel sources. Therefore, it is important to consider potential differences in the urgency of demand use when determining the rate of reserve for LPG versus oil.

9. Oil Demand Shift

Lao PDR's decision to pursue a net-zero emissions target for 2050 should be considered when projecting oil demand (Table 2.3). Based on the government's decisions regarding the pathway towards net-zero emissions, it is possible to evaluate the amount of fossil fuels, including oil, that will be phased out. The amount of oil required for consumption will establish how much oil makes up Lao PDR's fuel mix and assist in determining how serious the oil security issue is to the country's overall energy security. This will thus help the government determine the appropriate level of oil inventory to be set aside. The reserve quantity can be calculated by assessing the risk of any possible threats following the determination of demand.

Table 2.3. Lao PDR's National Determined Contribution and Net-Zero Emissions Target

Target	Details
Energy access	Achieve electrification rate of 98% by 2025
Efficiency	Reduce final energy consumption for 10% from the BAU level
Renewable energy	Reach 30% share of renewable energy in total primary energy consumption by 2025.
Climate change	Reach net-zero missions conditionally in 2050.

BAU = business as usual.

Source: IEA (2022).

10. Recommendations

Oil security is a major threat to overall energy security in Lao PDR; coal and hydroelectric power generation are massive, but their security is not threatened. Enhancing the security of supply for coal and electricity is less complicated than improving the supply security for oil, as imports account for all of the supply. Therefore, it is imperative that Lao PDR concentrate on and discuss an oil security strategy urgently. Based on this analysis, it is advised that Lao PDR undertake the following actions:

(i) Design a petroleum reserve strategy with specific implementation protocols that include an assessment of reserve alternatives, scenarios, a risk analysis, oil reserve calculation, improvement of the logistics system, and oil inventory system review.

(ii) Apply this systematic approach to determine whether to improve the supply security of electricity and other energies as well.

(iii) Assess Lao PDR's oil security status to determine whether to maintain the MPR in its current form or implement a full-scale SPR.

(iv) Appoint a responsible party to supervise the reserve requirements appropriate for the oil value chain environment, assess risk, and calculate the quantity of oil reserves. The accountable entity could manifest as a standing department or subcommittee within the Ministry of Energy and Mines or affiliated ministries.

(v) Develop multiple scenarios that could affect the oil security of Lao PDR, analyse the risks associated with each scenario, and assess their probability and impact.

(vi) Establish the point at which the government must intervene when a certain degree of insecurity in the oil supply occurs.

(vii) Investigate how the oil supply logistics system can be improved to increase the supply's security.

(viii) Compile information on the tank facilities located throughout the provinces and regions of Lao PDR, compare these tank capacities with local demand, and monitor the tank–consumption ratios to determine the ideal ratio for the country's oil supply chain.

(ix) Determine further steps that can be taken to deal with the oil shortage in addition to an oil reserve; these steps should, at the very least, include supply and demand response measures.

(x) Consider modifying the current oil inventory system into an online system.

(xi) Establish protocol and requirements for LPG reserves using a strategy similar to those used for oil reserves.

(xii) Evaluate how much oil and other fossil fuels should be phased out by 2050 based on the government's pathway towards net-zero emissions.

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Chapter 3

A Resilient Power System and Power Market in Lao PDR

Masaharu Yogo
Kei Sudo

1. Introduction

1.1. Power System

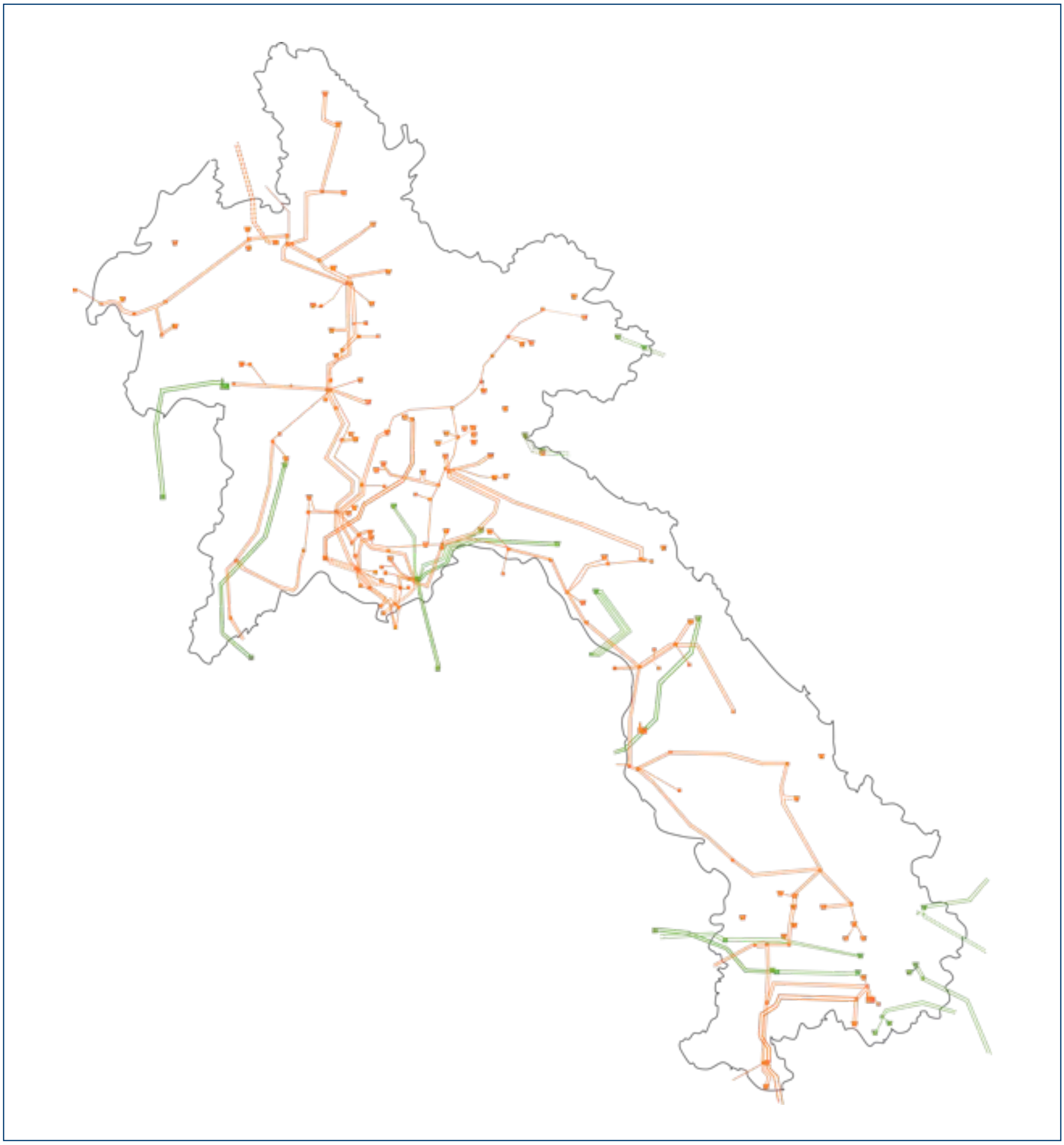
Lao People's Democratic Republic (Lao PDR) covers a land area of 236,800 square kilometres – approximately 1,000 kilometres from north to south – with a population of approximately 7.5 million (MNRE, 2020). It borders five countries – Cambodia, China, Myanmar, Thailand, and Viet Nam. Forests cover approximately 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

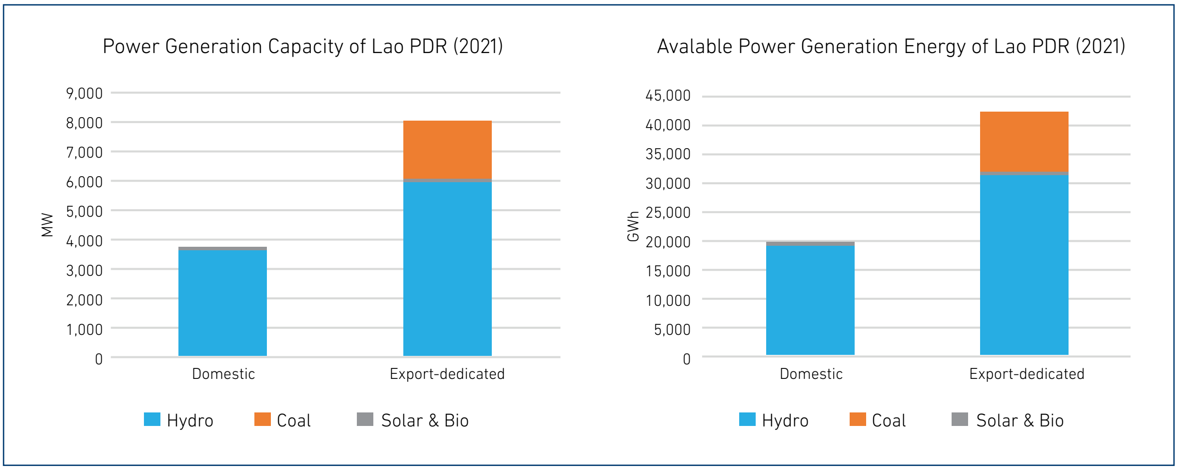


Green: export-only transmission lines; orange: domestic grid.

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.

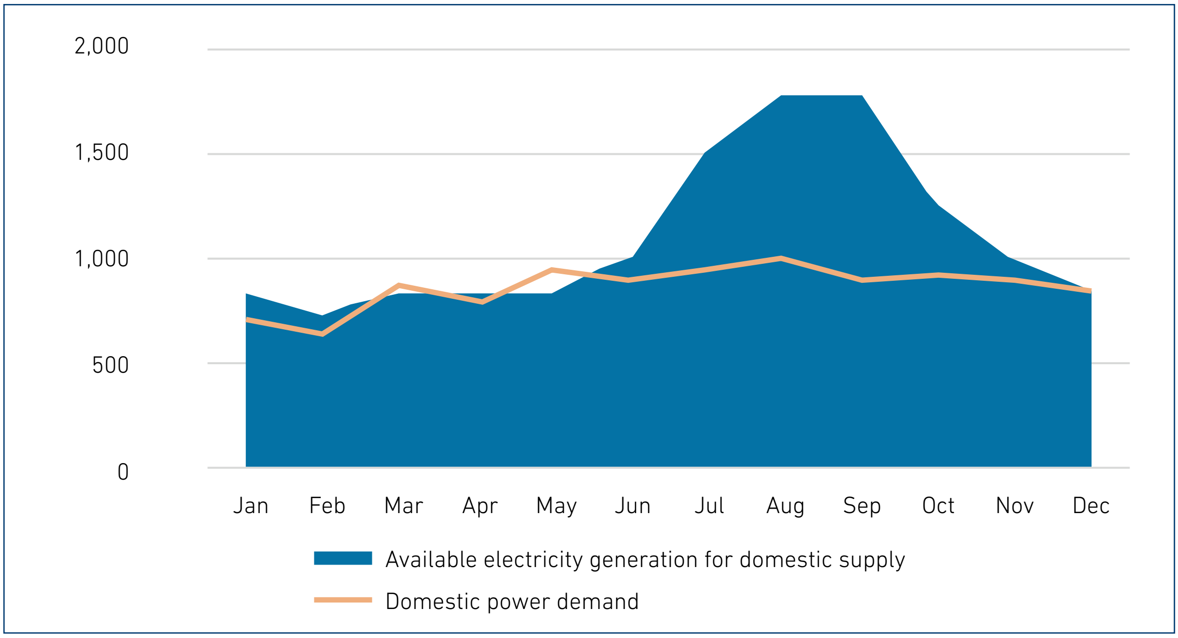
Figure 3.2. Power Generation Installed Capacity and Available Power Generation Energy



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.

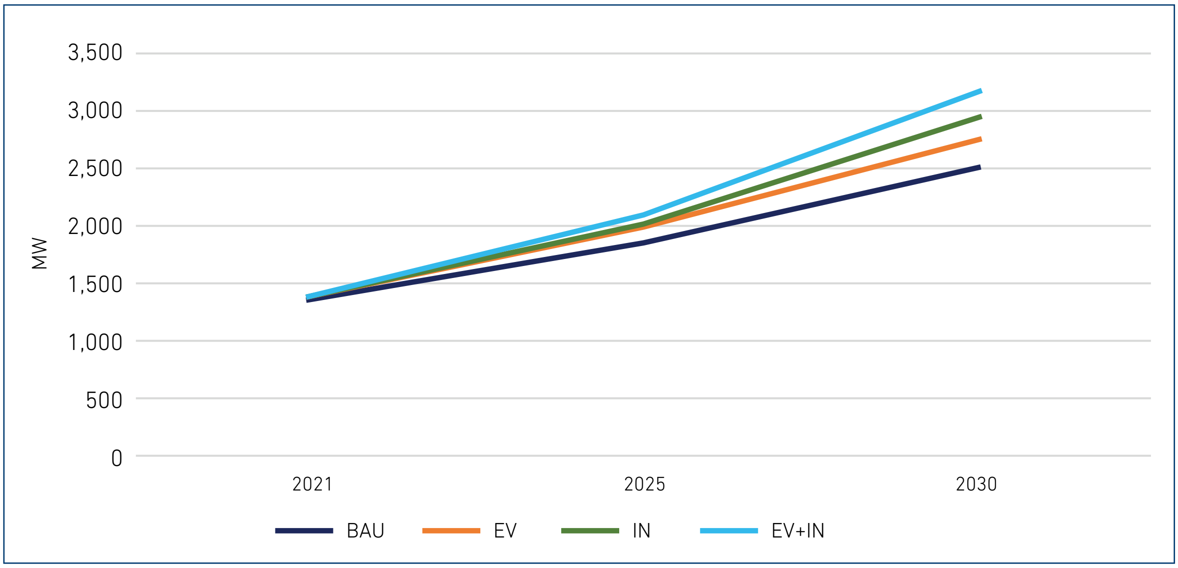
The *National Power Development Strategy*, 2021–2023, developed by the Ministry of Energy and Mines (MEM) and approved by the National Assembly in 2021, forecasts domestic electric power demand to 2030 (MEM, 2021b). The power demand forecast assumed a business-as-usual (BAU) case, electric vehicle penetration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

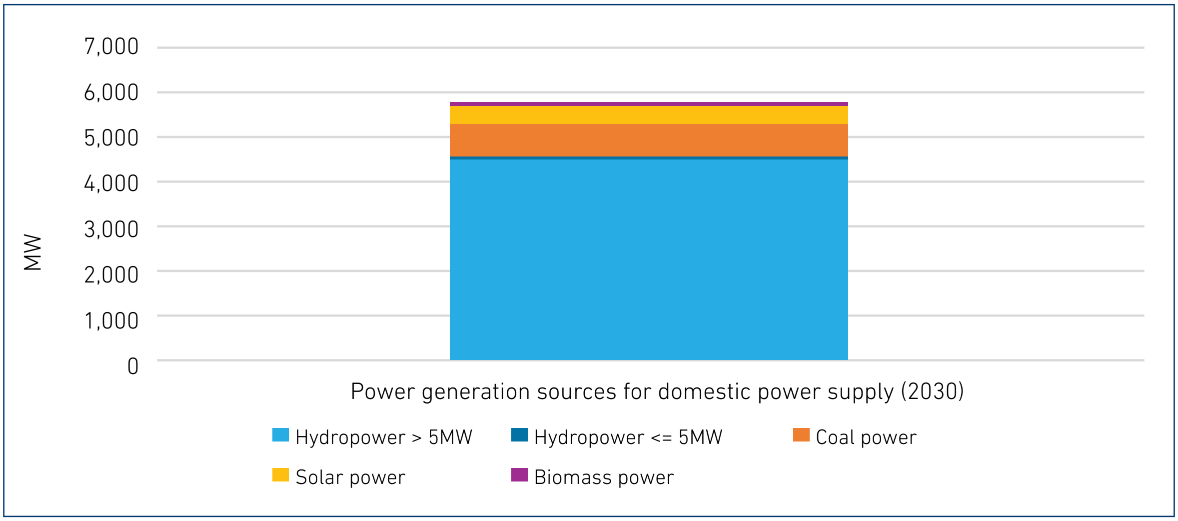
The following figures show the maximum electric power demand forecast, installed generation capacity, monthly available electricity generation, and electric power demand for the BAU case to 2030. The maximum electricity demand is 2,541 MW, and the installed generation capacity is 5,784 MW, which is 2.3 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)



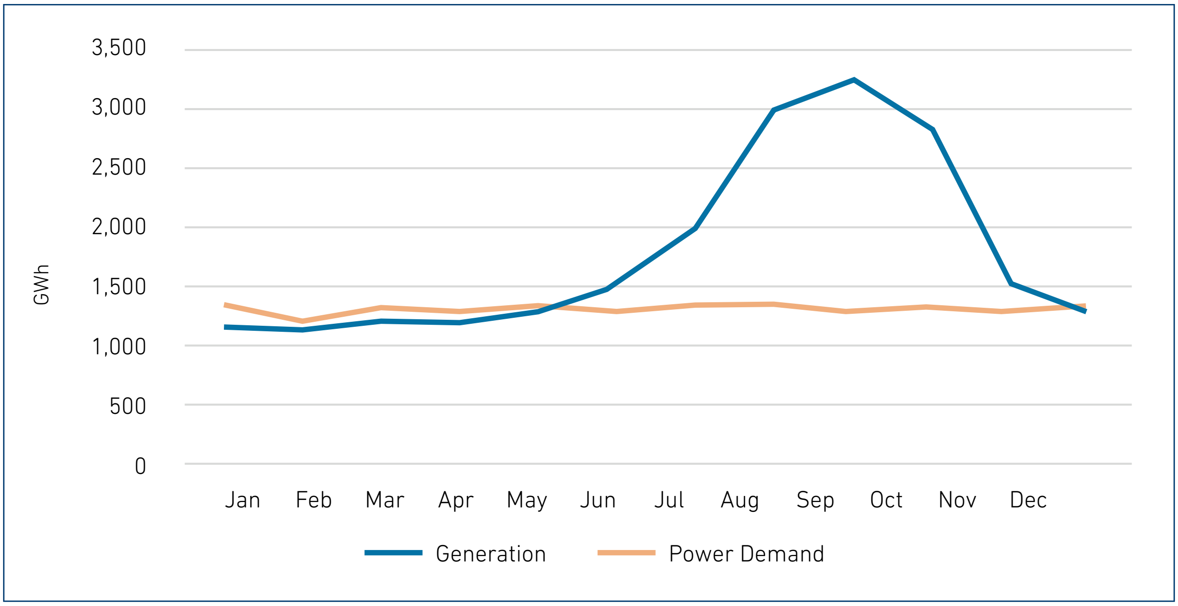
BAU = business as usual, EV = electric vehicle penetration case, IN = industrial demand development case.
Source: MEM (2021b).

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.

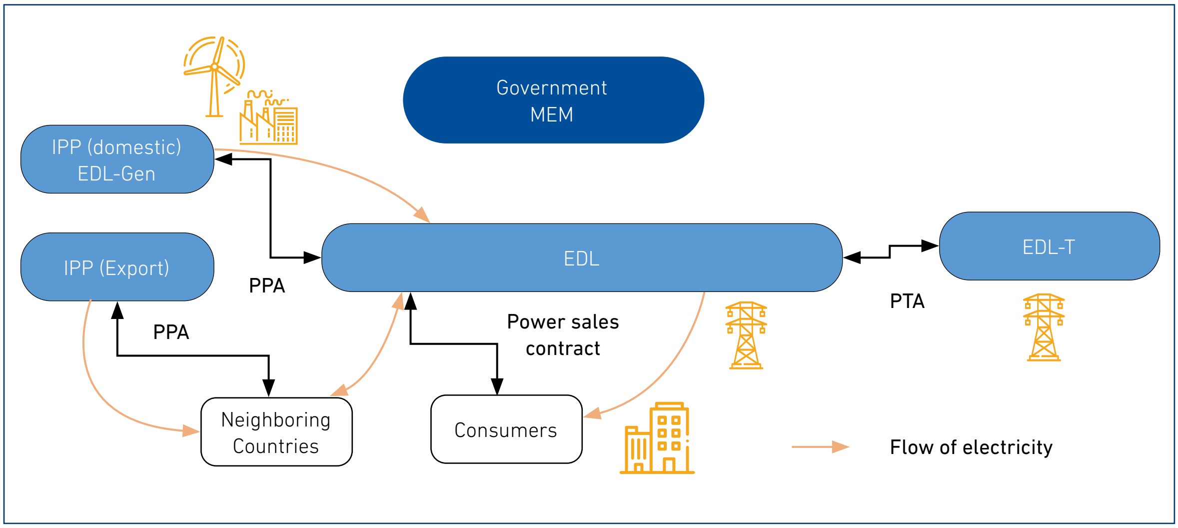
The business of selling electricity in Lao PDR is regulated by the Electricity Law, with one state-owned company – EDL – selling domestic electricity. EDL procures the electricity that it sells from IPPs and EDL-Gen, the domestic power producers.

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.

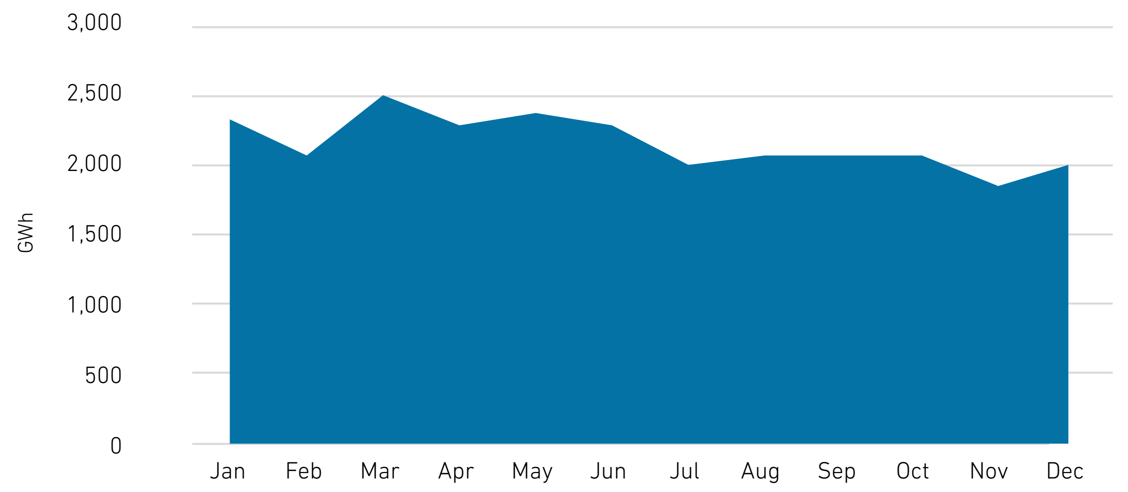
2. Strengths, Weaknesses, Opportunities, and Threats to Energy Security

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.

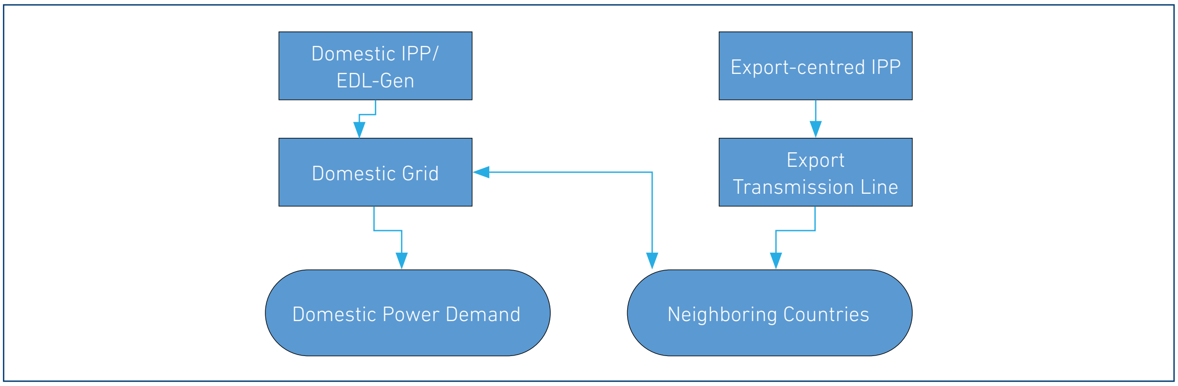
(i) **Develop renewable energy power plants.** In addition to hydropower plants, solar and wind power plants should be developed in sufficient quantities and to ensure power supply capacity to meet domestic demand and needs of neighbouring countries. Investments in solar, wind, and biomass will diversify 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

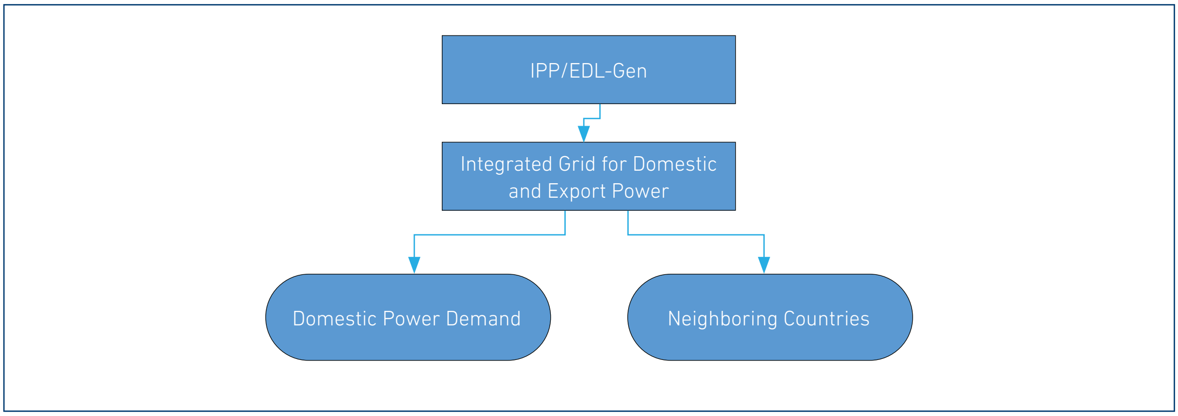


EDL-Gen = Électricité du Laos Generation Public Company, IPP = independent power producer.

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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Chapter 4

Sustainable Transport Systems in Lao PDR and Implications for ASEAN

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1. Introduction

Since 2019, Lao People's Democratic Republic (Lao PDR) has been experiencing an increase in energy consumption for its transport sector. This increase has been driven not only by the completion of the high-speed Laos–China Railway (LCR) but more significantly by the rapid growth in the number of motor vehicles.

In 2016, there were around 365,000 cars and 1.4 million motorcycles in the entire country (ERIA, 2022). Considering the forecasted gross domestic product and population growth, the number of motorcycles is expected to reach more than 4.2 million units in 2040. Cars will number 1.3 million units, and trucks and buses, 162,000 units (ERIA, 2022).

Most of the country's oil demands are met through imports from Thailand and Viet Nam. In 2019, Lao PDR's share of oil consumption was 29% of total energy consumption, with the country importing 0.92 million tonnes of oil equivalent (Mtoe) to supply the demand for the transport sector and others (Phouthonesy, 2023). Demand is projected to increase 3.56 Mtoe in 2050 in a business-as-usual scenario, comprising the third-highest share relative to coal, electricity, and biomass (Phouthonesy, 2023).

This chapter examines the growth of the transport sector in Lao PDR and its increased energy use. First, it analyses the main drivers of the passenger and mobility demand growth in the country. Second, it presents an overview of the main transport corridors and networks in Lao PDR. Third, it discusses some energy-related issues and current policies implemented by the government. Fourth, it conducts in-depth strength, weakness, opportunity, and threat (SWOT) analyses on electric vehicles (EVs), biofuels for transport, public transport, intercity passenger and freight rail, and logistics and distribution centres in Lao PDR. Finally, it provides proposed policy directions for the country's transport system and market.

2. Economic Growth and Mobility Needs

Lao PDR is a landlocked country, bordered by five countries – China to the north, Viet Nam to the east, Cambodia to the south, Thailand to the west, and Myanmar to the north-west. Being a landlocked country makes transport infrastructure key to Lao PDR's economic development. Improved infrastructure can enhance the efficiency of transporting products and people, provide connections between isolated towns and markets, and stimulate investment across several industries. Furthermore, enhanced mobility can facilitate the availability of education and health care, promoting overall socio-economic development and alleviating poverty.

2.1. Development Centres

Lao PDR had a population around 7.5 million in 2022.[1] It is organised into 17 *khoueng* (provinces), and 1 *kampheng nakhon* (prefecture). Vientiane, as the capital and largest city, plays a central role in driving economic growth, social progress, and infrastructure development. Pakse serves as the capital of Champasak Province, located in the southern part of the country, and has relatively advanced infrastructure compared to many other cities in Lao PDR. It has well-maintained roads, bridges, and transport networks, facilitating connectivity within the city and with surrounding areas. Luang Prabang, in the north, is a famous UNESCO World Heritage Site celebrated for its architecture, Buddhist temples, and landscapes. In central Lao PDR along the Mekong River, Savannakhet is the second-largest city in Lao PDR and serves as the capital of Savannakhet Province, which is known as a historical and cultural destination for tourists.

Several cities and areas – including Vientiane, Pakse, and Savannakhet – serve as important trading centres due to their strategic locations, economic activities, and connectivity to neighbouring countries. In addition, the Boten Special Economic Zone (SEZ), in the north, is a prominent trading centre facilitating cross-border trade between Lao PDR and China. The SEZ comprises commercial facilities, duty-free stores, and logistics infrastructure, which serve as a magnet for businesses and traders from both countries. The Golden Triangle SEZ, another important trading centre, is located in Bokeo Province, near the borders with Thailand and Myanmar. This SEZ offers opportunities for cross-border trade, investment, and tourism.

2.2. Crossing Three Economic Corridors

The Greater Mekong Subregion (GMS) initiative was started as a subregional economic cooperation programme, designed to enhance economic relations amongst various countries. The GMS was formed in 1992 and comprises Cambodia, China (including Yunnan Province and Guangxi Zhuang Autonomous Region), Lao PDR, Myanmar, Thailand, and Viet Nam (ADB, 2015a). Only a small portion (14%) of existing GMS lines pass through Lao PDR (Frielink and Bando, 2018). Yet Lao PDR is strategically situated at the intersection of three of its significant economic corridors:

(i) **North–South Economic Corridor.** This corridor is key to facilitating the access of Yunnan Province – and the northern portion of Lao PDR – to seaports. This corridor serves as a transport route linking the cities of Kunming in China and Bangkok in Thailand, while passing through Lao PDR. The portion that traverses Lao PDR spans a distance of 1,434 kilometres (km) (12%).

(ii) **East–West Economic Corridor.** Spanning from Da Nang in Viet Nam to Mawlamyine in Myanmar, with a route that traverses Lao PDR, this corridor serves as a conduit for trade and transport within the GMS.

[1] World Bank, Lao PDR – Population Total, https://data.worldbank.org/indicator/SP.POP.TOTL?locations=LA [accessed 28 April 2024]

(iii) **Southern Economic Corridor.** This corridor connects Cambodia with six provinces in Thailand (including Bangkok), four regions in Viet Nam (including Ho Chi Minh City), and six provinces in Lao PDR. It also extends to Dawei in Myanmar (Figure 4.1).[2]

These corridors are essential for fostering economic growth, regional integration, and connectivity for Lao PDR and its surrounding countries. They enhance the flow of products, services, investment, and people, promoting socio-economic development.

Figure 4.1. Main Economic Corridors in the Greater Mekong Subregion

Source: GMS, Economic Corridors in the Greater Mekong Subregion, https://greatermekong.org/g/economic-corridors-greater-mekong-subregion

2 GMS, Economic Corridors in the Greater Mekong Subregion, https://greatermekong.org/g/economic-corridors-greater-mekong-subregion

The GMS Economic Cooperation Program Strategic Framework 2030 is implementing a strategy consisting of three main components – connectivity, competitiveness, and community – known as the 3Cs (ADB, 2021). First, the programme aims to enhance connectivity by focussing on sustainable development of physical infrastructure and transforming the transport corridors into transnational economic corridors. Second, it seeks to improve competitiveness by efficiently facilitating the movement of people and goods across borders and integrating markets, production processes, and value chains. Lastly, the programme aims to foster a stronger sense of community by implementing projects and programmes that address shared social and environmental issues (Frielink and Bando, 2018).

2.3. Freight Transport Demand

The Ministry of Public Works and Transport (MPWT) in Lao PDR is responsible for the development and upkeep of the transport infrastructure at the national level (ADB, 2010). A study by GIZ (2014) on Lao PDR's transport and logistics industry highlighted that Lao PDR enterprises have a relatively limited range of value-added services available for the agricultural, manufacturing, and trading sectors to import and export freight. Table 4.1 explains the situation of sector-based freight demand in Lao-PDR.

Table 4.1. Sectoral-based Freight Transport Demand in Lao PDR

Sector	Details	Source
Forestry	· International freight transport is limited to Viet Nam and focusses on timber and minerals. · Timber is exported from the southern provinces using trucks.	GIZ (2014)
Agriculture	· Food is distributed and agricultural production is delivered to markets by producers using their own transport or smaller local haulers. · Inter-city trucks deliver beer, coffee, sugar, and candy. · From January to August 2023, Lao PDR–China Railway transported 3,101,400 tonnes of goods, including fruits, cassava flour, barley, rubber, beer, iron ore, rock, and chemical fertilisers.	GIZ (2014), Xinhua (2023)
Mining	· Thai trucks bring copper and gold exports to Thai ports. A Lao PDR forwarder won the Sepon Copper mining contract, but the 25 vehicles in this fleet are the same Thai trucks and drivers that manage shipment. Trucks from Viet Nam or Lao PDR deliver massive amounts of copper ore to Viet Nam ports. The miners are unhappy with Lao PDR trucks available, however, since they do not match requirements, mostly because Lao PDR operators will not invest in the right equipment. · Products primarily carried to Viet Nam from Lao PDR include gypsum, limestone, iron ore, potassium, and lignite. The majority is transported from mines and quarries located in Khammouane Province, as well as from Vientiane Province. · Limestone must go to cement mills in Nakhon Phanom, Thailand. Over the past 8 years, significant Lao PDR operators have emerged to handle the majority of this traffic previously controlled by Vietnamese trucking operators.	GIZ (2014)

Source: Authors.

ADB (2010) reported that overall demand for transport infrastructure is minimal, as the traffic volume on the national network (excluding areas surrounding Vientiane and Savannakhet) is below 1,000 units of average annual daily traffic, and below 500 on most other networks. Nevertheless, there has been a consistent annual increase in demand for commodities at a pace of 5%–8% and for passengers at a rate of 8%–10% (ADB, 2010).

In 2018, 11,894 companies were operating in road freight transport across the entire country, based on company registration data from the Ministry of Industry and Commerce (World Bank, 2018). In the current domestic market, the freight demand is quite low. Buses have limited capacity to meet the demand for transporting goods, although they are often used for delivering time-sensitive cargo weighing 100 kilograms or less (World Bank, 2018). Instead of using semi-trailers to transport containers and cargo on a single vehicle, the trucking industry – along with Lao International Truckers and Freight Forwarders Association (LITFA) – still prefers a transshipment model, involving transferring all cargo at the border onto Lao PDR trucks.

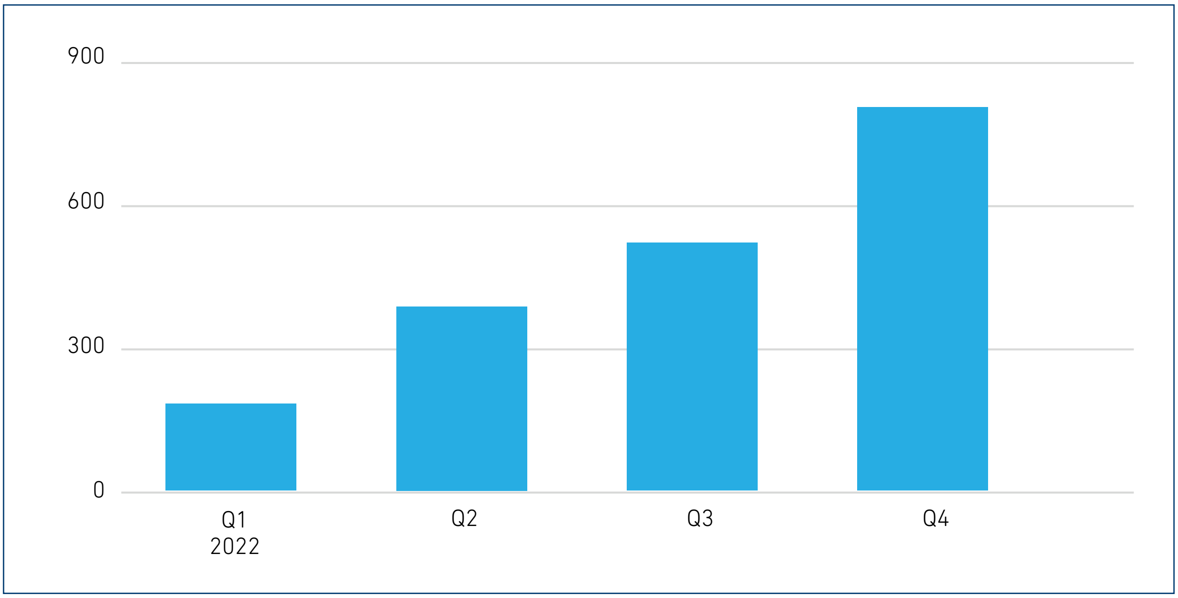
International freight transport routes are predominantly restricted to Viet Nam and are primarily for lumber and minerals. The import and export freight industry heavily relies on foreign trucks, primarily from Thailand, Viet Nam, and China. In contrast, the presence of Lao PDR vehicles in the international freight transit market is minimal (GIZ, 2014).

LITFA serves as the official representation body for express, freight, and logistics firms in Lao PDR. It has been actively involved in the National Transport Committee and National Trade Facilitation Committee, which is working to transform Lao PDR from a landlocked country, which historically has been perceived as disadvantage, to a 'land-linked' one, which focusses on road infrastructure and trade connectivity (UNESCAP, 2011).[3]

The LCR is projected to experience consistent growth in transporting freight, with an estimated 1.9 million tonnes of cargo being transported in 2022, as shown in Figure 4.2 (Allen and Leuangkhamsing, 2023). As of March 2024, the LCR has transported a total of 34.24 million tonnes of freight (*The Nation*, 2024).

[3] LIFTA, https://litfa.org/#/about

Figure 4.2. Cargo Transported through Lao PDR, 2022
('000 tonnes)



Q = quarter.

Sources: Laos-China Railway Company; Asian Development Bank estimates (2023).

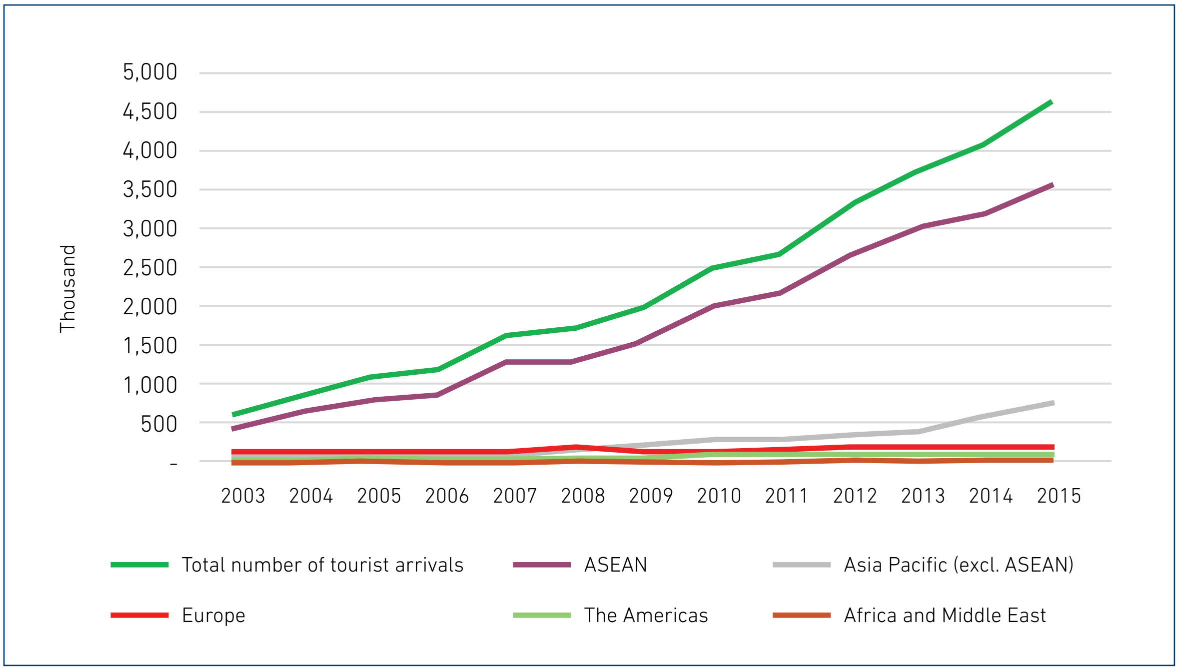
2.4. Passenger Transport Demand

As the population of Lao PDR continues to expand, there is an inherent rise in the need for passenger transport services. Indeed, urban passenger transport demand is projected to double between 2015 and 2050 (ITF, 2021). With the growing urban population and their economic participation, transport is necessary to facilitate access to employment, education, health care, and various other services.

With the growth and increased population density of cities, there is also an escalating demand for public transport services, such as buses, to enhance mobility. The implementation of a bus rapid transit (BRT) plan in Vientiane is expected to result in a 6% increase in the use of public transport. The BRT is expected to accommodate 30,000 passenger rides per day by 2030 (UNESCAP, 2011).

The expansion of the tourism sector also stimulates the need for passenger transport services, including air travel, long-haul buses, and river cruises, to convey both local and global tourists to various destinations. The tourist sector in Lao PDR is experiencing an average yearly growth rate of 19.6% (World Bank, 2023). It has seen a rise in tourist arrivals from all regions in the world (Figure 4.3). In 2019, over 4.8 million tourists travelled from Association of Southeast Asian Nations (ASEAN) countries, as well as Australia, Canada, China, the European Union, Republic of Korea, New Zealand, and United States (World Bank, 2023).

Figure 4.3. Tourist Arrivals in Lao PDR, 2003–2015
('000)



ASEAN = Association of Southeast Asian Nations.
Source: ERIA (2017).

Since its commencement in December 2021, the LCR has facilitated more than 30 million passengers, and its passenger volume is steadily increasing (*Global Times*, 2024). Lao PDR segment significantly increased the number of daily passenger trains from 4 to 12, resulting in a peak daily passenger throughput of 12,808, a significant increase over the previous 720 (*Global Times*, 2024).

3. Supply Side: Transport Corridors and Networks

Although transport demand in Lao PDR has significantly risen – growing annually at approximately 20% to support an overall economic growth rate of around 6% per year – the road network still predominantly handles transport needs, accommodating 90% of freight and 80% of passenger traffic (Nhansana, 2017). River transport serves a smaller portion, around 6% of local freight tonne-km and 15% of passenger-km (Nhansana, 2017). Despite its relatively modest volume, air transport is expanding and serves a vital role in connecting urban centres and remote regions.

3.1. Rail Corridors and Networks

The LCR has the potential to significantly transform the economic geography and logistics environment of Lao PDR. Construction commenced in 2016, and its inauguration took place in 2021 as part of the government's plan to establish itself as a regional logistics hub. It was also a strategic effort to enhance Lao PDR's involvement in China's Belt and Road Initiative (Kuik and Rosli, 2023). The LCR runs 409 km through Lao PDR, stretching from the Chinese border near Boten to Vientiane near the Thai border (Figure 4.4).

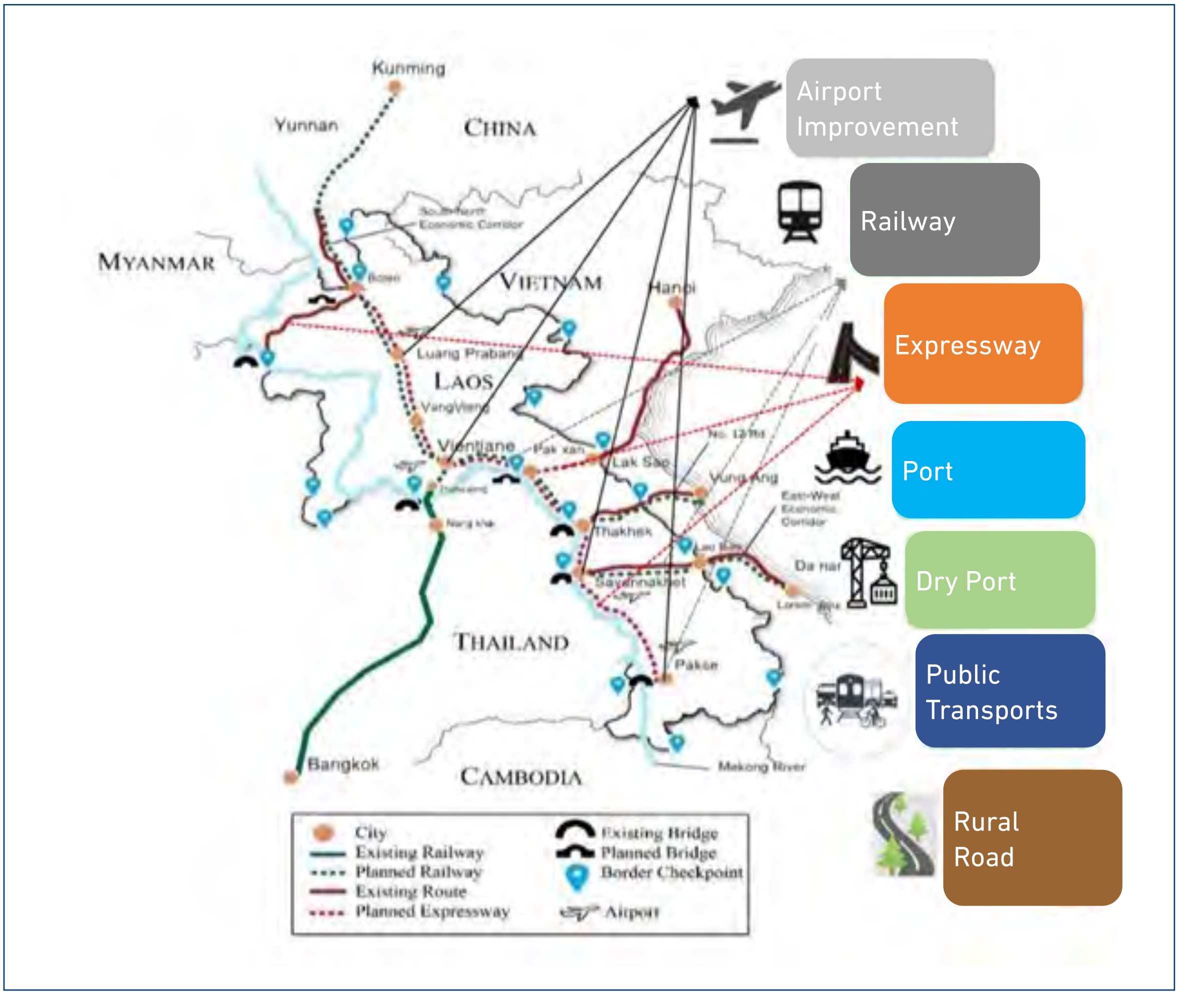
The LCR has a single track with a standard gauge of 1.435 metres. This track uses an electrified mixed-traffic line built according to China's GB Grade 1 standard. The line is suitable for passenger trains travelling at speeds of up to 160 km/hour and freight trains traveling at speeds of up to 120 km/hour. The 554.72-km railway project necessitated a total investment of US$5 billion (*Saigon News*, 2018).

Figure 4.4. Lao PDR–China Railway Route

Source: Vietasia Travel (2022).

According to Sayavong (2018), the sole rail infrastructure in operation between Thailand and Lao PDR is currently a 3.5-km extension originating from Thailand, spanning from Nong Khai and crossing the Friendship Bridge to reach Thanaleng Railway Station, about 20 km east of Vientiane. The project's entire investment amounted to approximately US$6 billion. Thai and Lao PDR officials have been engaged in discussions regarding the enhancement of transport, commercial, and interpersonal connections along the Thailand–Lao PDR border (Kuik and Rosli, 2023). Figure 4.5 shows the railway (and other transport mode infrastructure) planned by the Government of Lao PDR.

Figure 4.5. Lao PDR Railway Planning



Source: Sayavong (2018) and Kattignasack (2022).

Lao PDR and Viet Nam have signed a memorandum of understanding for a rail project connecting Vientiane and Vung Ang (ERIA, 2016). Additionally, the concept encompasses the creation of a highway connecting Ha Noi and Vientiane. Approximately US$1.5 billion would be sourced from the Vietnamese State Budget for this project. The timetable for its construction has not yet been disclosed.

3.2. Airport Infrastructure

Lao PDR now operates seven domestic airports and four international airports. Collectively, they manage approximately 2% of the overall transport volume (Sayavong, 2018). Wattay International Airport in Vientiane and Luang Prabang International Airport manage international air traffic and offer associated customs, immigration, and quarantine services.[4]

Airport capacity and the frequency of international flights have both grown and improved throughout the years. There was a 152% rise in air travel to and from Lao PDR in 2017, with over 2 million people making the trip (Sayavong, 2018). An even more important development is the ongoing expansion of Wattay International Airport in Vientiane, which will allow the airport to process more than 400 passengers per hour and accommodate Boeing 747 aircraft with 350 seats (Sayavong, 2018). Three domestic airports in Lao PDR have also recently undergone upgrades: Luang Prabang in the north, Savannakhet in the centre, and Pakse in the south. The airports in Luang Prabang and Pakse, in particular, are capable of handling planes the size of the Airbus A300, leading to a 21% annual rise in the number of passenger flights between 2010 and 2014.

In 2024, the government stated its intention to transform Nong Khang Airport in Houaphanh Province into an international airport. The facility was formerly financed and constructed by the Government of Viet Nam. The new build–transfer project will be implemented with a total investment of US$82 million, funded by a loan provided by Hoang Anh Gia Lai Agriculture JSC, a company based in Viet Nam. The runway will be extended by 3 km to accommodate larger planes. The airport upgrade is in accordance with the national development goals of the MPWT and the Department of Civil Aviation (Southeast Asia Infrastructure, 2024).

3.3. Inland Waterways

Inland waterway transport in Lao PDR occurs principally on the Mekong River, with 1,865 km that are navigable of the total 4,350 km that cross the country. Most traffic is concentrated between Vientiane and Sainyabuli in the north-west, approximately 400 km apart. The main products transported are sand, building stones, and wood. Barges are also used to transport timber from the northern provinces to sawmills around Luang Prabang and Vientiane (Banomyong and Pholsena, 2004).

[4] After 3 years of construction, a newly built international airport – Bokeo International Airport – was formally opened in February 2024 by Bokeo Province and Golden Triangle Special Economic Zone. It is the third largest airport in Lao PDR, with the capacity to accommodate around 2 million people annually (Lao News Agency, 2024).

There are 29 existing inland waterway ports along the Mekong River (MPWT, 2020). These ports are used to load and unload goods consumed locally as well as to be transported between Thailand and Lao PDR. During the rainy season, the river provides an alternative to road transport along the country's western border and in the northern region. Depending on the stretches, 60–200-tonne ships can navigate the northern section of the Mekong River (i.e. from Savannakhet port to the north) year-round. The southern stretches are, in general, navigable by smaller vessels and for more limited periods of the year. During the dry season, most of the southern stretches are only navigable by light boats, which limits the development of river transport there.

In 2000, an agreement on commercial navigation on the Mekong River was signed amongst China, Myanmar, Lao PDR, and Thailand to facilitate navigation on the upper part of the Mekong River. It provides navigation aids, improvements to river ports, and offers solutions to integrate the river network into the regional road network. However, Lao PDR risks hardly benefiting from it – unlike China and Thailand – as only a small part of the goods transported on the river is intended for Lao PDR market (Banomyong and Pholsena, 2004). It is also difficult to envisage Lao PDR exporting by river, because the industrial centre of the country is in Vientiane, where goods are exported by truck to the port of Bangkok. The only advantage that Lao PDR can derive from this agreement in the medium term lies in the promotion of tourist sites and cruises along the Mekong River.

Indeed, the Mekong River Commission conducted a 2040 forecast study on inland waterway traffic and concluded that relatively strong cargo traffic growth would be achieved in Cambodia, Thailand, and Viet Nam – but not Lao PDR (MRC, 2015). Inland waterway cargo traffic growth in Lao PDR is restricted by boats, poor port infrastructure, and competition from road transport, which has benefitted from improved highway infrastructure. However, investments targeting increasing inland waterway infrastructure and cargo vessel capacity from the current 100 deadweight tonnes (DWT) to 500 DWT will reduce inland waterway transport operating costs and increase competitiveness and the share relative to road transport.

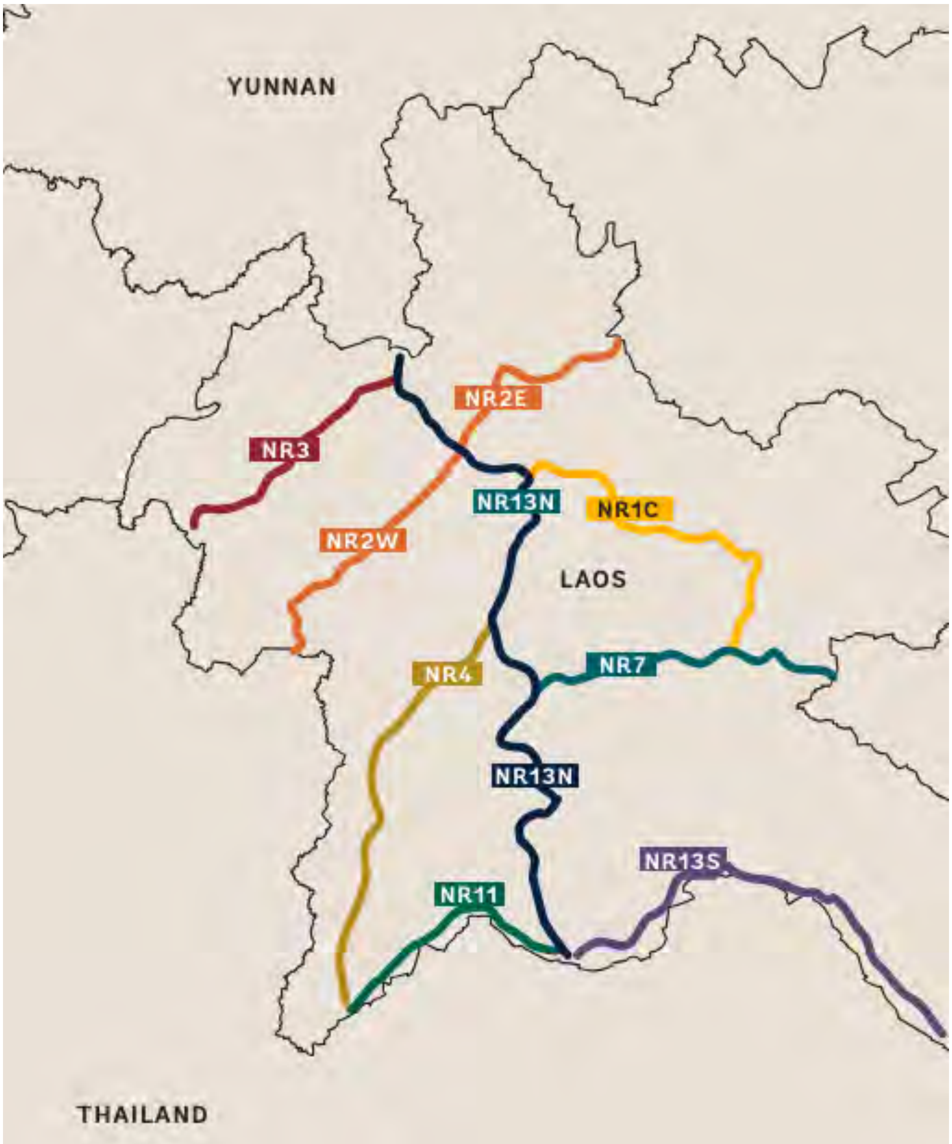
The study also pointed out how the tourist potential of the Mekong River has yet to be fully realised in Lao PDR, owing to a poor safety record and comfort of passenger boats, particularly between Huay Xai and Luang Prabang. Significant improvements to onboard safety and to landing facilities are expected to allow inland waterway tourist traffic to grow at rates approaching the growth in overall tourist arrivals in Lao PDR, around 16% per year (MRC, 2015).

3.4. Road Corridors and Networks

The use of inland waterway transport has decreased since the opening of the First Thai–Lao Friendship Bridge in 1994 that connects Nong Khai, Thailand with Vientiane. In 2006, the Second Thai–Lao Friendship Bridge (Mukdahan–Savannakhet) opened, which is a part of the East–West Economic Corridor route that starts from Myanmar, passes through Thailand and Lao PDR, and ends in Viet Nam.

National Road (NR) 13 is the most important highway in the country, connecting Boten, Luang Prabang, Vang Vieng, Vientiane, Savannakhet, Pakse, and Veun Kham, following the Mekong River. The route consists of two sections: NR13 North, spanning 671 km from Vientiane to Boten, and NR13 South, spanning 829 km from Vientiane to the Cambodian border. The primary segments of the road were constructed in 1997 with an axle load capacity of 8.2 tonnes, which is lower than the regional norm of 11.0 tonnes. It has not undergone any rehabilitation since their completion (World Bank, 2020).

Figure 4.6. Lao PDR Key Road Corridors



Source: World Bank (2020).

As shown in Figure 4.6, the road corridors and network in Lao PDR consist of:

(i) **Chinese–Thai Corridor.** NR3 connects Thailand and China via Bokeo and Luang Namtha in Lao PDR. Due to increased transit traffic and flood frequency, the route requires upgrading.

(ii) **Thailand–Lao PDR–Viet Nam Corridor.** NR2 (NR2W, 187 km; NR2E, 166 km) links Thailand and Viet Nam via Oudomxay. Both NR2W and NR2E, built in 2000, are in bad condition.

(iii) **Luang Prabang.** The main route to Sainyabuli and Nan provinces in Thailand is NR4A. NR1C links Luang Prabang to Nong Khiaw and Houaphanh Province, which are tourism destinations. Luang Prabang is connected to Xiangkhouang and Vang Vieng via NR7 and NR13.

(iv) **Vientiane surrounds.** NR11 links four southern Sainyabuli districts to Vientiane. The first 56 km of road were rebuilt to asphalt concrete in 2012, and the remaining route is being built with support from the Government of Thailand, with completion scheduled by 2023. To encourage tourism and agribusiness in Vientiane Province, officials must repair these provincial roadways.

(v) **Vientiane capital.** The Vientiane Railway Station is the primary passenger station of the LCR, located 9 km from the city centre, and the MPWT must enhance urban mobility near the station to reduce traffic congestion.

(vi) **Beyond Vientiane.** Bolikhamsai and Khammouane provinces are 140 km and 350 km from Vientiane, respectively. NR13S connects this area, with potential for transporting rice and other agricultural products via rail.

3.5. Evolution of Road Transport Modes

In 2016, motorbikes accounted for 76.9% of the vehicle stock in Lao PDR, cars accounted for 20.0%, trucks accounted for 2.8%, and buses accounted for 0.3% (ERIA, 2022). In 2016, the road vehicle fleet consisted of 80% gasoline-fuelled cars and 20% diesel-fuelled vehicles. From 2000 to 2016, the number of road vehicles in Lao PDR increased significantly at an average annual rate of 15%. Amongst the many types of vehicles, diesel vans experienced the highest annual growth rate of 21.4%, followed by diesel pick-up trucks with an average annual growth rate of 18.4% (ERIA, 2022).

Table 4.2. Road Vehicle Stock Data from Lao PDR

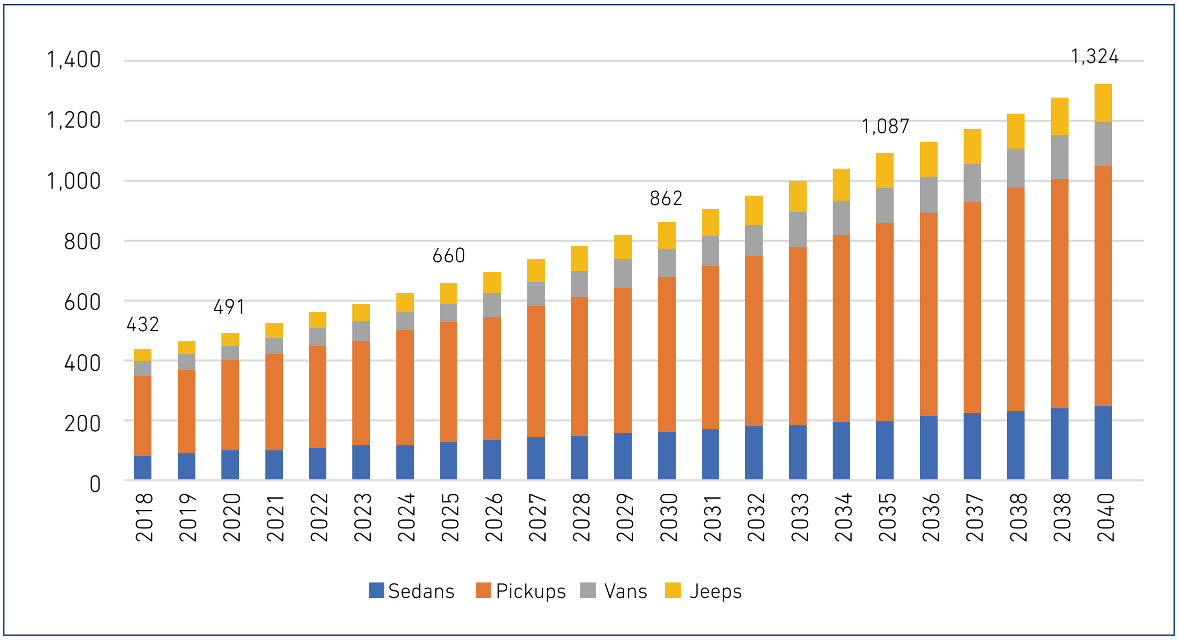
Fuel Type	Gasoline			Diesel				
Vehicle Category	Motorbike		Car				Truck	Bus
Vehicle Type	Two-wheeler	Three-wheeler	Sedan	Pickup	Van	Jeep		
2000	153,781	4,347	8,045	15,074	2,199	3,970	8,424	1,831
2001	168,379	4,405	8,995	17,581	2,603	4,355	10,559	1,899
2002	195,353	4,405	9,428	19,042	2,691	4,584	11,346	2,042
2003	196,963	6,407	9,696	25,490	2,729	5,832	11,841	2,164
2004	285,740	7,871	10,063	38,214	3,777	6,949	13,085	2,179

Fuel Type	Gasoline		Diesel					
Vehicle Category	Motorbike		Car				Truck	Bus
Vehicle Type	Two-wheeler	Three-wheeler	Sedan	Pickup	Van	Jeep		
2005	337,719	8,043	11,204	45,029	4,862	7,909	13,441	2,199
2006	453,158	8,441	12,939	60,352	7,236	8,668	15,296	2,200
2007	509,421	8,518	14,792	68,360	10,355	9,399	17,994	2,242
2008	623,310	8,460	15,203	77,616	12,675	9,752	19,070	2,520
2009	711,800	8,624	17,671	93,080	18,634	10.801	23,031	2,707
2010	804,087	8,542	21,638	109,362	24,727	12,155	25,542	2,852
2011	899,685	8,554	28,096	128,892	32,667	14,169	28,873	3,203
2012	1,005,047	8,588	35,514	147,497	37,831	17,231	33,460	3,532
2013	1,112,072	8,601	43,860	162,633	50,124	19,876	38,454	3,861
2014	1,218,379	8,737	51,284	185,086	42,770	22,515	44,293	4,120
2015	1,318,107	8,761	58,871	204,360	47,553	26,665	48,739	4,448
2016	1,413,990	8,879	65,699	225,060	49,061	30,223	52,443	4,665

Source: ERIA (2022).

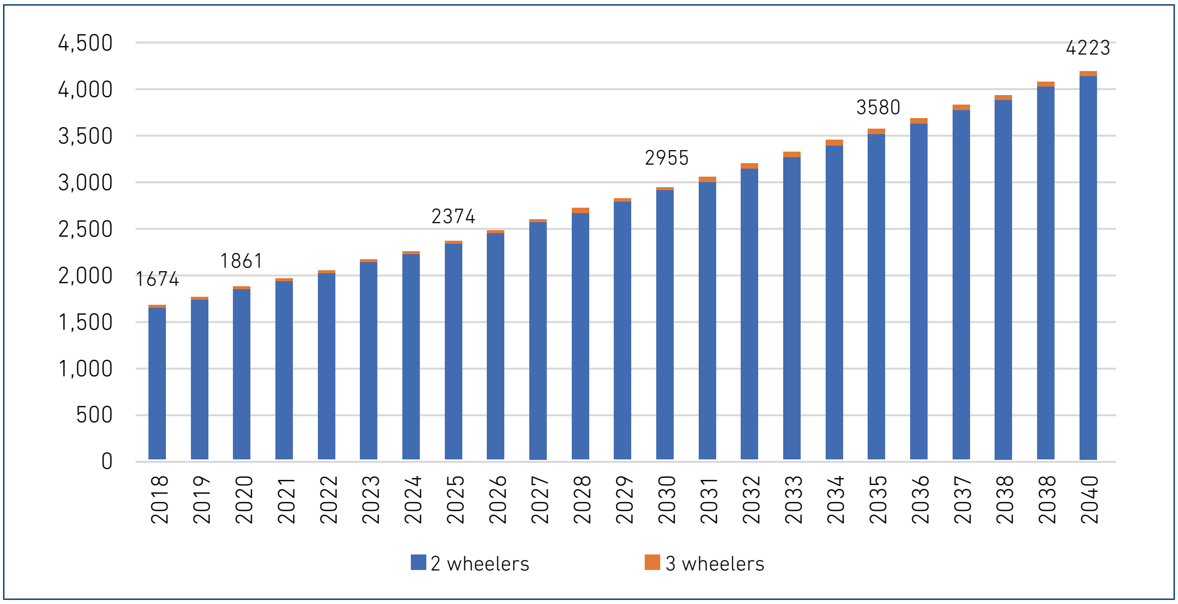
Lao PDR has seen a significant increase in each road transport mode over the few past decades. As a landlocked country, the rapid motorisation in road transport is significantly correlated with growing economic activities. ERIA (2022) projected the number of road transport vehicles for each mode up to 2040 based on 2016 vehicle stock data. The projections were done assuming that the share of each mode would remain constant throughout 2018–2040. The results are shown in Figures 4.7, 4.8, and 4.9.

Figure 4.7. Total Number of Cars in Lao PDR, 2018–2040
('000 units)



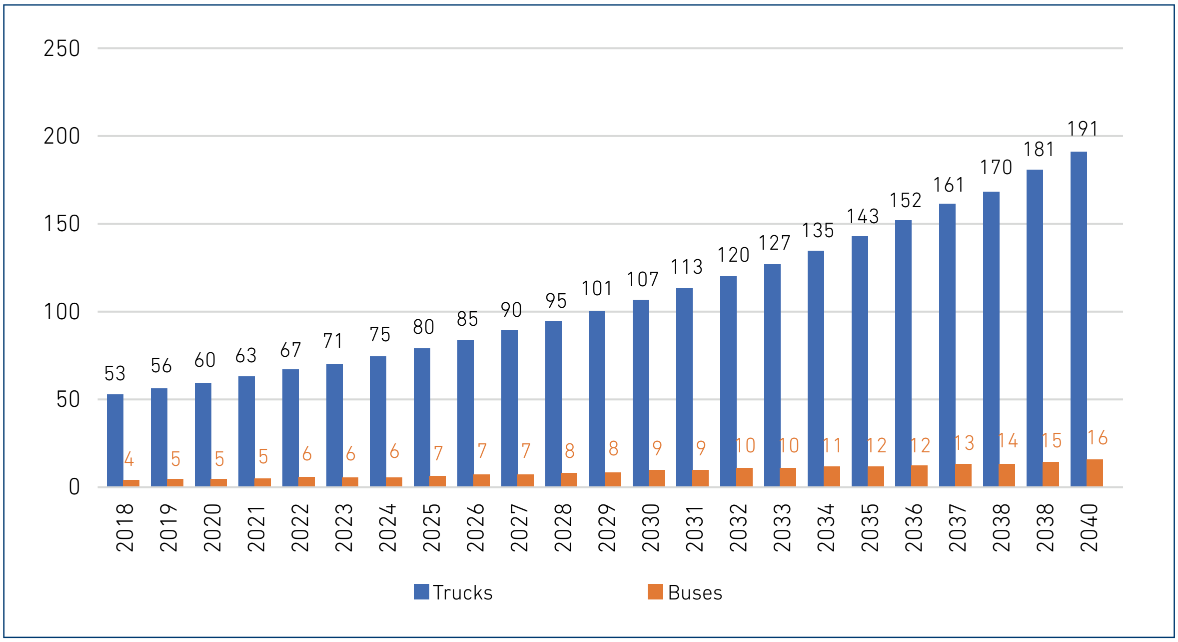
Source: ERIA (2022).

Figure 4.8. Total Number of Motorcycles in Lao PDR, 2018–2040
('000 units)



Source: ERIA (2022).

Figure 4.9. Total Number of Trucks and Buses in Lao PDR, 2018–2040
('000 units)



Source: ERIA (2022).

Based on the projection results, it is expected that cars will grow the fastest, with an annual growth rate of 6.0% up to 2025 then 4.0% until 2040. Motorcycles will still dominate the share of vehicles with 4,223,000 vehicles in 2040. This growth will be slower at 5.0% per year until 2025, and then 3.4% until 2040. Trucks and buses together will have the slowest growth at 4.4% per year up to 2025, and then 3.6% until 2040.

4. Strengths, Weaknesses, Opportunities, and Threats Analyses

4.1. Background

Given Lao PDR's landlocked geography and lack of direct access to seaports, road transport serves as the primary mode of transport for both domestic and international trade. Although road networks are crucial for establishing connections and promoting economic growth, excessive dependence on this form of transport can result in several challenges such as congestion, deterioration of infrastructure, and inefficiencies within the transport system. Moreover, the use of fossil fuels for transport is substantial. The vehicles used in Lao PDR for road transport, including trucks, buses, cars, motorcycles, and tuk-tuks, are predominantly fuelled by gasoline or diesel.

The country's reliance on imported fossil fuels leaves it susceptible to variations in global oil prices and exposes it to dangers related to energy security and disruptions in supply. Therefore, implementing technological innovations and transitioning to alternative fuel sources are essential.

Lao PDR is currently making efforts to decrease emissions in its transport sector. This includes targeting boosting the adoption of two-wheeled and passenger EVs by 30% by 2050; restructuring the country's urban public transport system, particularly in Vientiane; and transitioning 10% of transport fuels to biofuels (SMMR, 2022). These programmes aim to decrease emissions by 29,000–30,000 tonnes of carbon dioxide equivalent (tCO_2e) per year (KNUT and Youngin ITS, 2023). Moreover, the country also has the goal to reduce gasoline and diesel imports by 10% by promoting the production of ethanol and biodiesel (KNUT and Youngin ITS, 2023).

The government has enacted policies to support those targets. The draft national power development plan presents a promising pathway to decrease fuel imports and to reduce emissions by promoting the use of EVs in the transport industry. Moreover, the *9th Five-Year National Socio-Economic Development Plan (2021–2025*) encourages the adoption of vehicles running on clean or locally sourced energy. In December 2022, the Global Green Growth Institute released a document on EVs in Lao PDR (GGGI, 2022).

Furthermore, to decrease its significant reliance on road transport, Lao PDR should encourage a transition to rail transport with the implementation of the LCR. Approximately 40% of maritime freight traffic between ASEAN Member States and China could be redirected to the LCR, while around 54% of land freight traffic between Lao PDR and China could also be shifted to the LCR (World Bank, 2020).

The issue of inequality is also related to the transport sector. Purwanto (2004), for example, synthesised the role of transport as Rawlsian primary goods that allow the free movement of people and goods. Focussing on the movement of people, Wenglenski (2004) described how the inability to move may signify the inability to find a job. Transport in terms of basic mobility can be considered, therefore, as amongst the most important rights that allow people to access basic services such as jobs, health care, and education.

Jouffe et al. (2015) indicated that mobility inequalities are often interpreted in terms of a lack, which is based on the assumption of the lower mobility capacity of the poor and the domination of the rich. The functioning of the housing market often forces the least well-off people to be in the worst position in terms of optimisation between their geographical position for services (i.e. working, education, health care, and social activities) and their affordable and habitable housing space. This spatial configuration of places of residence and employment (and other services) is likely to produce longer potential home-to-work and other home-to-services distances for lower-income social categories.

Moreover, a greater constraint on physical access to employment and other services for lower-income categories can be related to their lower degree of access to the most efficient modes of transport for a given trip (Dupuy, 1995). Travel has an unequal time and monetary cost depending on the mode used. Cars are both the quickest and most expensive and have the ability to reach many destinations quickly. They also represent a monetary cost, which can limit access and use for the less well-off categories. Public transport facilities and networks are, in general, more developed in urban centres and less on the peripheries, which contain more affordable living spaces for the low-income population.

The issue of inequality related to the transport sector – apart from the spatial configuration – must thus be considered as well as the differences in access to modern transport modes that provide affordable and sustainable ways of moving to reach different destinations related to life needs. Transport affects inequality to main public services.

Lao PDR is still one of the least-developed countries in the world – and in ASEAN – due to its low-income level, poor condition of human assets, and high economic vulnerability. According to the ASEAN Secretariat (2022), Lao PDR's gross domestic product per capita is the third lowest in ASEAN, just above Myanmar and Cambodia. Warr, Rasphone, and Menon (2015) revealed how inequality in access to public services in Lao PDR – especially to lower primary and secondary schooling and to primary health care services – decreased between 1997 and 2013. Yet the World Bank (2024) reported that long inflation has increased problems accessing such public services due to several issues including lengthy processes, understaffing, and difficulty in travelling to government offices.

As a South-east Asian country that has experienced fast urbanisation, Lao PDR sees this sort of inequality often in its main urban area, Vientiane (UN, 2018). Vongpraseuth, Song, and Choi (2022) detailed several inequality issues in Vientiane, as there are different levels of access to transport facilities and modes. Low-income commuters are most likely motorbike users; automobile dependency is concentrated in the city centres, with low-income groups bearing the transport cost burdens related to urban sprawl and experiencing poorer urban networks and infrastructure.

JICA and MPWT (2010) stressed three points:

(i) a public transport system, when introduced, should be focussed on low-income people, connecting suburban areas and urban centres;

(ii) as the operating costs of EVs are cheaper than those of internal combustion engine vehicles, EVs should be introduced to the low-income areas to improve their mobility together with a proper government policy; and

(iii) considering the low income of and low motorisation in Lao PDR, subsidising public transport would serve many.

Increasing the equality of the transport system in Lao PDR should aim to equalise the capability of transport users to move in the most energy-efficient and economical ways by using modern transport services and infrastructure to execute their daily activities and to achieve their daily needs. Thus, inequality should be amongst the topics surrounding the country's transport sector, which is closely related to the issue of people's access to modern energy services as well.

Against the background of Lao PDR's economic growth, demand for mobility, and development of the supply side (i.e. transport modes, infrastructure, and systems), the following presents SWOT analyses of various aspects of the transport sector: EVs, biofuels for transport, public transport in urban areas, intercity passenger and freight rail transport, and logistics and distribution centres.

4.2. Electric Vehicles

EV penetration in Lao PDR underwent a SWOT analysis, supported by JICA and MPWT (2010).

Table 4.3. SWOT Analysis of Electric Vehicle Adoption in Lao PDR

	Current	Future	
Strengths	• Vast amount of green electric supply (from hydropower) • Innate capability to adapt imported technology to meet its mobility needs • Strong international support for the development of the road network and connectivity	• Bigger emissions reduction opportunity utilising green electric supply from hydropower • EV development results in reduced reliance on petroleum product importation. • EV costs lower than internal combustion engines • Lessons from neighbouring EV front-runner countries • Close proximity and connectivity with China, an EV manufacturer powerhouse	**Opportunities**
Weaknesses	• Slower economic growth compared to pre-pandemic • Underdeveloped and unpaved road networks and facilities • Limited development budget and technical resources • Lack of EV-charging and other infrastructure • Mountainous terrain, landlocked geography, and poor road network susceptible to disasters	• Electricity export versus supply for powering EVs • Policy gaps in the existing EV regulations • Rapid motorisation without a good public transport system would cause severe and costly traffic congestion in urban areas.	**Threats**

EV = electric vehicle.

Source: JICA and MPWT (2010).

Lao PDR's strength is its abundant supply of green energy, which comes from hydropower. As a landlocked country, Lao PDR relies heavily on road transport, which is mostly dominated by internal combustion engine vehicles. When EVs are introduced, however, reliance on petroleum can be lowered. Further, higher unabated petroleum prices may also increase the shift to EVs due to more economically feasible costs.

Strong international support – combined with the country's high adaptability towards technology – can be beneficial in increasing the EV share. Building connections and collaboration with neighbouring countries can accelerate EV adoption as well as improve the development of the EV industry within the country. Policy gaps, however, need to be addressed from existing regulations to reduce uncertainty and to promote investment. As a neighbour to China – an EV manufacturer powerhouse – Lao PDR can also benefit from its mature technology and industry, which additionally secures the supply chain of EVs to the country. Benchmarking can also be done with other neighbours such as Thailand, which adopted EVs earlier and has a higher rate of EV penetration.

Although Lao PDR has strong potential to develop and adopt EVs, there are several challenges that need to be considered. Its low level of infrastructure development is the first barrier. Many of the road networks are still unpaved and underdeveloped, which inhibits access. Coupled with the lack of EV-charging stations, which are currently only available in Vientiane, it will be hard to push people to switch. Infrastructure development coupled with incentives will be necessary to accelerate the transition to low-carbon transport. However, this leads to the second barrier – limited budget and technical resources.

A limited budget will restrain the development of the infrastructure required to attract new EV markets. Technical expertise in EV and low-carbon transport in the country is also lacking, which may hinder EV implementation strategies. A solution is through international cooperation to help reduce the investment financing burden and conduct knowledge transfer and capacity building for local experts. Strategic financing structure within the cooperation scheme will be required to not burden the state budget in the future.

Another barrier is related to policy and regulation gaps. There are currently limited regulations specific to EVs, although the government has a clear target to reach a 30% EV share by 2030 and to build 500 EV-charging stations on urban and rural roads and national highways. The government has also removed import limits and instituted a 30% road tax reduction for EVs. However, the regulations have not addressed several more specific policy issues, such as standardisation, vehicle registration, charging infrastructure, and aligned policies between related ministries (GGGI, 2022; Dixon et. al., 2023). The absence of specific regulations could impact EV uptake from the consumer side as well as the ease of doing business from the supplier side.

Finally, several future threats may also loom from accelerated EV adoption and development. Developing public transit infrastructure in parallel with EV promotion is crucial to relieve the road network burden from the growing number of vehicles, which may worsen the current congestion in cities. Power supply planning is also necessary to incorporate the growing demand of EVs. Although currently the country has a big surplus, the growing demand of EVs may compete with electricity exports, which may affect the sustainability of Électricité du Laos.

4.3. Biofuels for Transport

As an agricultural country, Lao PDR has a vast amount of biofuel potential from its agricultural byproducts such as rice, soybean, cassava, maize, sugarcane, as well as oil-producing energy crops like Jatropha, coconut, palm oil, and castor oil plants. In 2011, the government targeted a 10% of biofuel share in the transport sector by 2025 (MEM, 2011). It is also aiming to increase the production of biofuels, such as biodiesel and bioethanol, to reduce oil import dependency to fulfil growing energy demand, which mainly comes from the transport sector. In terms of developing biofuel for transport in Lao PDR, a SWOT analysis was conducted (Table 4.4).

Table 4.4. SWOT Analysis of Biofuel Development for the Transport Sector in Lao PDR

	Current	Future	
Strengths	• High potential of biofuel production from agricultural byproducts • Growing interest from various stakeholders; previous research conducted • Strong international support to develop biofuel production	• May help reduce oil import dependency • A new economic sub-sector could create new revenue and job opportunities, especially in rural areas. • International cooperation from neighbouring countries for biofuel	**Opportunities**
Weaknesses	• Lack of coordination amongst stakeholders in biofuel projects • Limited technologies for biofuel production and processing on an industrial scale • Limited budget for research and development • Limited regulations and policy on pricing may hinder biofuel development due to low profitability.	• In a case where a biofuel market is highly developed, competition towards traditional crops may arise. • Biofuel production is target-driven rather than based on overall land available. • Limited development budget on biofuel production • Companies favour exports more than domestic market.	**Threats**

Source: Authors.

The interest in the development of biofuels, especially for the transport sector, has been growing for years, but actual development has been slow. Although fuel crop plantations as well as pilot projects have been conducted by private investors – and the government has created policies to promote biofuel production and use – the sector remains hardly developed (Souliyathai et al., 2018). This is related to the economic feasibility and certainty in conducting business.

Kolao Farm and Bio-energy Company, Lao PDR's biggest biodiesel producer, produced 100,000 litres of oil from 400 tonnes of *Jatropha* seeds in 2009, yet it found that profitability was low and the investment returns were uncertain (ADB, 2010). Although policies and targets had been laid out by the government, more specific policies are still required, aligned with expanding coordination and cooperation in research and studies, especially in the implementation stage (i.e. supply chain, production cycle, and industrial-scale processing technology).

4. Public Transport in Urban Areas

As a growing economy, Lao PDR has experienced rapid motorisation over the past few years, especially in urban areas. This has led to the problem of congestion in busy areas, which causes economic and environmental loss. Public transit is a solution to help reduce the use of private vehicles. Developing public transport in Lao PDR cities has its own pros and cons (Table 4.5).

Table 4.5. SWOT Analysis of Public Transport Development in Lao PDR

	Current	Future	
Strengths	• High rate of urbanisation resulted in increased demand for transport • Strong international support to develop public transit in cities • Several previous studies already mapped a development roadmap for public transit systems in bigger cities like Vientiane	• Lower congestion in highly populated cities could reduce economic losses and lower emissions levels. • Lower emissions and fuel consumption compared to private vehicles • Improved economic attractiveness in cities with economic activities • Affordable and reliable public transit system will bring significant socio-economic impacts.	**Opportunities**
Weaknesses	• Low public transit networks and infrastructure currently available • Several busy areas have narrow and busy roads; retrofitting or adding public transit is limited. • Inconvenient and unreliable existing public transit • Services and infrastructure tend to cover fewer low-income people dwelling in suburban areas and other regional peripheries.	• High preference towards the use of private cars and motorbikes • Lack of integrated strategies with urban development • Decreasing trend of public transport usage post-pandemic • Lack of a transport governance system may decrease overall public transit reliability. • Inequality in accessing public services mainly located in urban areas or growth centres may increase.	**Threats**

Source: Authors.

Despite arising challenges in terms of public transport development, plans are already in place, including one to develop a BRT under the Vientiane Sustainable Urban Transport Project, which will be linked to the existing Vientiane Capital State Bus Enterprise (VCSBE) network (ADB, 2021). This will add another 149.0 km to the transport network in Vientiane, which will total 304.4 km.

However, merely adding to the fleet and expanding the network will not provide a long-term solution. Improving transit system governance will be crucial, especially the existing VCSBE, which is known for its unreliability due to an outdated fleet, non-punctual service, and low speed and frequency (UNESCAP, 2022). International support will be integral to provide financial support and technical expertise.

It is also important to implement public transit systems in other growing cities. Luang Prabang and Luang Namtha should also be considered, as these have an increasing number of tourists. Based on Lao Statistics Bureau (2018), in 2017, Luang Prabang attracted 472,942 tourists, and Luang Namtha attracted 600,369 tourists. The number is expected to grow significantly due to the LCR, which passes through these two cities, and to bring more tourists from China. The growing tourism sector may increase the number of businesses, which will ultimately lead to increased urban transport demand.

4.5. Intercity Rail

Lao PDR public has a strong positive perception of the LCR, which is seen as attracting foreign direct investment and tourism (Khamphengvong et al., 2022). A SWOT analysis was conducted towards the LCR, which is summarised in Table 4.6.

Table 4.6. SWOT Analysis of Lao PDR–China Railway

	Current	Future	
Strengths	• Well connected with other existing rail networks • Interconnected with BRI network • Strong perceived benefits and supports towards the LCR and BRI	• May increase freight and passenger demand once more integrated with other ASEAN rail network or GMS corridor • May attract more FDI • Provision of logistic hubs may increase freight demand significantly. • Expansion of domestic rail network connected to LCR may increase economic impact. • Development of new SEZ along the LCR may attract more investment inflows	**Opportunities**
Weaknesses	• Higher logistics transport costs compared to other countries • Logistic transport operators dominated by local providers, no operator offers integrated multimodal logistic solutions. • Only serves 5 provinces in the north • Poor road networks conditions along the railway corridor • Inefficient trade facilitation and services, especially in border administrations	• Without significant policy and efficiency-enhancing reforms, the LCR may not attract the required traffic to reach economies of scale. • Inefficiencies in transport governance may inhibit project's sustainable economic impact. • Inequality may arise if rail network is not extended to the southern (or other rural) parts of the country. • Security checks need to be fortified to reduce transnational crime risks.	**Threats**

ASEAN = Association of Southeast Asian Nations, BRI = Belt and Road Initiative, FDI = foreign direct investment, GMS = Greater Mekong Subregion, LCR = Laos–China Railway, SEZ = special economic zone.

Source: Authors.

In 2016, only 2 out of 40.4 million tonnes of freight demand from China to Thailand, Malaysia, and Singapore was transported on land through Lao PDR (World Bank, 2020). This number may increase with the LCR, which may attract new freight demand that had been transported through maritime modes. Efficient services need to be developed, however, to compete with maritime transport modes, both regarding time and cost.

To expand the economic impact of the rail system and to encourage further development in the regions along the LCR, more SEZs could be developed. Integration with other transport systems is also crucial to improve seamless networks within the country. Connecting the rail system with road freight hubs and intercity buses will increase demand and economic impact. Expansion of the rail system is important, especially to the southern part of Lao PDR, to reduce future inequality.

4.6. Logistics and Distribution Centres

The World Bank (2018) revealed high freight transport costs in Lao PDR, especially in the less-than-truckload segment, which affects the competitiveness of producers and shippers alike. Several factors characterise this high cost:

(i) 12 large players (i.e. having a fleet size of more than 50 trucks) and many small firms (i.e. companies with less-than-trucks or owner-operators) mainly working in the informal sectors;

(ii) low vehicle utilisation as shown by the very low average annual distance driven per truck (i.e. only 55,000 km);

(iii) large overcapacity (i.e. underutilisation of weight capacity as cargo is more voluminous than heavy in Lao PDR);

(iv) possibly high vehicle idle times, considering the above two findings;

(v) overloading (i.e. small companies downsized their fleet used to carry overweight or voluminous loads), which is unlikely to bring a cost benefit to transporters, given the much higher per tonne-km operating costs of smaller vehicles; and

(vi) low annual mileage, together with the high cost of capital and low profit margins, which prevent companies from investing in more expensive, yet more cost-efficient, vehicles, which in turn increases variable operating costs.

Table 4.7. SWOT Analysis of Logistics and Distribution Centres

	Current	Future	
Strengths	• Recently opened Lao–China Railway that serves northern Lao PDR • Mekong River used for specific types of cargo with limited volumes with undeveloped ports and navigability • Road cargo transport has some capacity (in term of volumes and weight) but the use is not optimised.	• To shift more goods from road to rail, development of distribution centres that allow transshipments connecting road, rail, and inland waterways should be prioritised, mainly in northern Lao PDR. • To shift more goods from road to inland waterways, development of distribution centres that allow transshipments connecting road, rail, and inland waterways should be prioritised, mainly in northern Lao PDR as well as physical work needs to increase the navigability of the Mekong River. • Development of both modes should increase efficiency of cargo movement inside Lao PDR and shift some cargo movement from/to neighbouring countries	**Opportunities**
Weaknesses	• Cargo transported mainly by road • High cargo transport costs compared to those of neighbouring countries • Most transporters are small-scale and in the informal sector. • Low vehicle utilisation and large overcapacity • Low capacity in fleet and logistics management • Minimum role of distribution centres	• Unlikely to bring a cost-benefit to transporters, given the much higher per tonne-kilometre operating costs of smaller vehicles • Increasing variable operating costs as annual mileage and profit margins low • Difficult to renew fleet to invest in more cost-efficient vehicles • May increase cargo transport cost more than decrease the sector's competitiveness	**Threats**

Source: Authors.

The above situation of cargo or freight transport in Lao PDR clearly shows inefficient energy use as well as high externalities (i.e. high emissions and air pollution). Cargo transport in the country is also facing the inability to operate in a more efficient manner where weight- and volume-adequate vehicles can be dispatched to move goods in their optimal capacity ratios while minimising the number of idle vehicles as well as deadheading vehicles where productivity and profit can be maximised, and externalities minimised.

5. Key Policy Directions for Transport System and Market

Transitioning to a sustainable transport system in Lao PDR has the potential to bring down the country's emissions and to improve energy security and economic impact. Lao PDR aims to achieve a 30% EV share by 2030, with supporting factors such as abundant hydropower, technological adaptability, and international collaboration, including proximity to China's EV industry. However, challenges include low infrastructure development, limited financing schemes and technical resources, and policy and regulation gaps. Although developing EVs is crucial, transitioning towards sustainable transport may need to go beyond EVs only. Alternatives include biofuel development, public transport improvement, intercity rail enhancement, and logistics and distribution centre advancements. Based on the SWOT analyses, to achieve a sustainable transport system in Lao PDR, the following implementation programmes and policies are recommended.

5.1. Short-Term Plan (2–5 years)

(i) EV acceleration
- (a) **Develop regulatory frameworks for EVs.** Policies such as incentives, standardisation, charging tariffs, charging infrastructure, and vehicle registration should be addressed to increase attractiveness, both on the demand and supply side.
- (b) **Expand public transport.** Incentives towards private companies willing to invest in public transport should be provided.
- (c) **Prioritise electric motorcycles for private EVs.** Motorcycles constitute a more affordable private vehicle mode.

(ii) Biofuel development
- (a) **Incentivise private actors willing to implement biofuel production on an industrial level.** Fiscal incentives may be provided to increase attractiveness and profitability. Other non-fiscal support may be provided, such as training and capacity building.

(iii) Public transport improvement
- (a) **Renew fleet of buses.** Inefficient high-emitting bus fleets should be replaced with newer fleets to improve the reliability of the entire bus transport system.
- (b) **Improve transit system governance**. The current bus transit system needs to increase efficiency, punctuality, reliability, and convenience.

(iv) Intercity passenger and freight rail
- (a) **Develop new SEZs along the railway.** This will accelerate the economic impact and as well attract new opportunities to the country.

(v) Domestic fuel price adjustment
- (a) **Adjust domestic gasoline/diesel prices to reflect international oil prices.** Strategically reducing subsidies will reduce the dependency on oil consumption and help make the transition to EVs more appealing. However, it will need to be done carefully to not have a bigger impact on the economy.

(vi) Integration and intramodality of transport systems
   (a) **Promote the integration of different modes of transport.** This will establish a smooth and uninterrupted travel experience for tourists. The availability of multimodal hubs will facilitate seamless transfers between trains, buses, and other transport modes.
(vii) Sustainable tourism development
   (a) **Implement regulations and incentives to encourage sustainable practices in the tourism industry.** Eco-friendly transport options, such as bicycles, e-scooters, and walking paths within tourist destinations, should be encouraged.
(viii) Community engagement
   (a) **Engage with local communities in transport planning and decision-making processes.** Community needs must be effectively addressed, and their priorities and preferences incorporated.

5.2. Medium-Term Plan (5–10 years)

(i) EV industry development
   (a) **Prepare an EV industry ecosystem area in an SEZ.** Providing a special area specific for EV industry will attract investments. An SEZ near the LCR will be suitable due to the connectivity with China, which will secure the supply chain of components.
   (b) **Set a transfer of technology policy for foreign investors.** The policy will stimulate the development of the domestic EV industry and accelerate research and development with a relatively smaller state budget.
(ii) Biofuel development
   (a) **Ensure integration with international supply chain of biofuel market.** The international market for biofuel products must be ensured to increase the profitability of local businesses. However, certain policies will be required to ensure that domestic demand is securely provided.
(iii) Intercity passenger and freight
   (a) **Develop new logistic hubs near the LCR and SEZs.** New logistic hubs will improve freight transport coverage as well as increase economic activity in regions close to the LCR, especially in SEZs.
   (b) **Modernise the cargo transport sector.** This must include the growing level of functional integration of supply chains and distribution centres.
(iv) Public transport expansion
   (a) **Expand urban public transport systems in emerging cities.**
(v) Logistics and distribution centre development
   (a) **Open the country to integrate to global supply chain.** Lao PDR should start unlocking its market and distribution potential through more geographical integration, not only at the national level but the broader regional level. Currently, the country is not the main destination or origin of the commodities trade, but it needs to explore its potential. Intermediate locations in the regional distribution will be fundamental to the geography of freight circulation, as they provide connectivity between corridors in the region. With this involvement in the global supply chain, the internal logistics and distribution centres of Lao PDR should be developed, which will start to bring in local production centres.

(b) **Improve integration between transport and inventory control by promoting the emergence of major coordinators and integrators in the logistic industry.** Freight distribution in Lao PDR should start to shift from inventory- to replenishment-based logistics where manufacturers play dominant roles to match the commodity demand by taking advantage of more integrated and efficient suppliers, manufacturers, and distributors.

5.3. Long-Term Plan (10–20 years)

(i) Expansion of the railway line across the country
  (a) **Enhance connectivity between different regions of Lao PDR.** To boost cross-border commerce, promote regional integration, and strengthen Lao PDR's position as transit hub, this expansion should be focussed on connecting the southern part of Lao PDR.

(ii) EV development
  (a) **Expand public transport services.** E-buses, e-minibuses, and e-vans should connect people.
  (b) **Provide fiscal and non-fiscal facilities for private actors.** They will continue to help develop public transport, including EV-charging infrastructure and systems.

(iii) Development of logistics and distribution centres
  (a) **Achieve a more functionally integrated supply chain.** This situation should be marked by the emergence of large logistics operators that control many segments of the supply chain and developed economies of scale in distribution supported by advanced information technology and intermodal transport integration.
  (b) **Develop distribution centres to link production and consumption.** In this phase, distribution centres should provide an interface between the industrial and retail geographies of the supply chain concerned. Distribution centres can perform numerous value-added activities, ranging from warehousing, packaging, and labelling to final assembly and taking returns.

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Chapter 5

Securing Affordable Energy for the Growing Industrial, Commercial, and Residential Sectors in Lao PDR

Phouphet Kyophilavong

1. Introduction

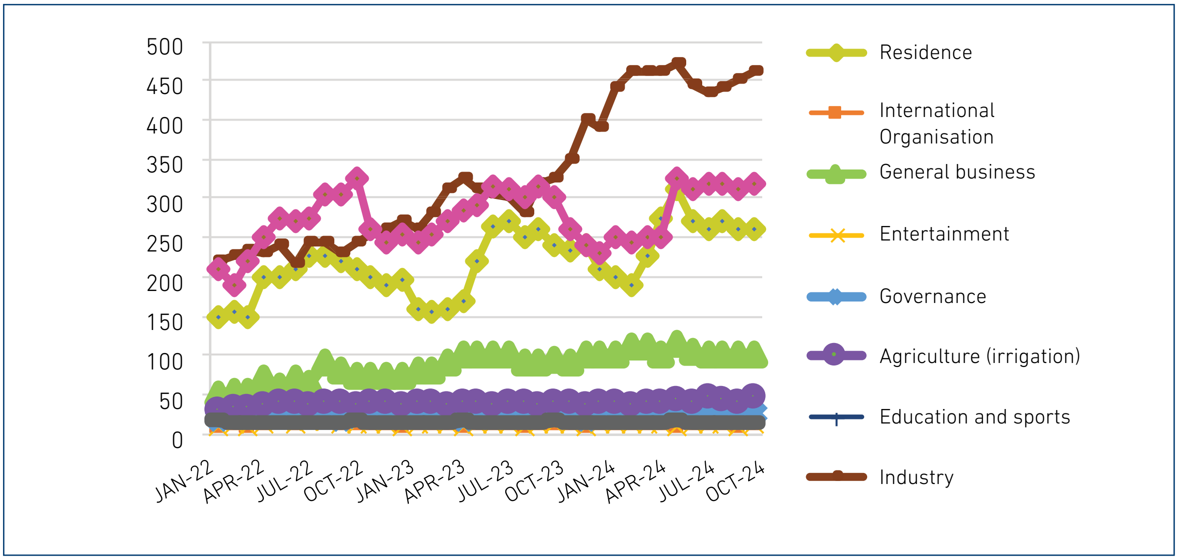
Energy is an engine of economic growth. Yet due to higher demand for energy, lack of a steady supply during the dry season, and high prices, it is also a barrier to economic growth in Lao People's Democratic Republic (Lao PDR). Therefore, securing affordable energy for growing industries there as well as its commercial and residential sectors is crucial.

Some studies exist related to energy development and its impact on Lao PDR, such as Kyophilavong, Phoumin, and Sayvaya (2023); Sousa et al., (2023); Kyophilavong (2023); and Kyophilavong et al. (2017). In addition, Lamphayphan et al. (2015) estimated the impact of the electricity supply from Lao PDR on Thailand. The main objective of this chapter, however, is to identify the key challenges and issues on securing affordable energy for industries and the commercial and residential sectors in Lao PDR. It is important to note that it focusses solely on the electricity sector, which is the main energy source for the industrial, commercial, and residential sectors in Lao PDR.

2. Electricity Demand

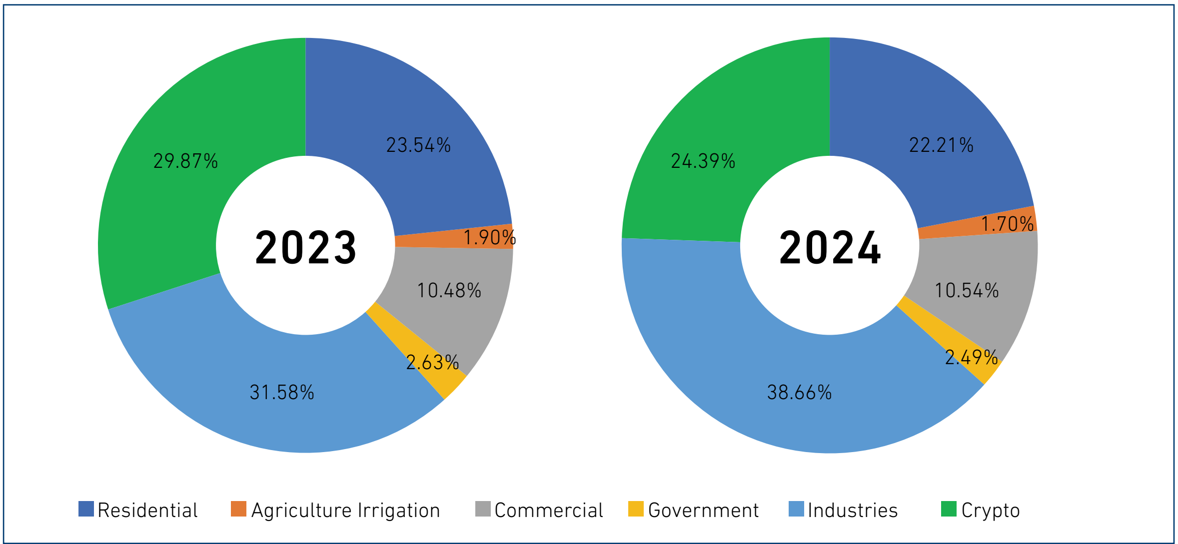
Table 5.1 shows the trends of electricity used by the industrial, commercial, and residential sectors in Lao PDR. Total domestic consumption will increase to 13,762.19 gigawatt-hours (GWh) in 2024, a total increase of 18.81% from 2023. The share of electricity from the industrial sector in the total mix will increase from 31.58% in 2023 to 38.66% in 2024. Those of the commercial and residential sectors will decline during the same period (Figure 5.2).

Figure 5.1. Electricity Use Trends in Lao PDR, 2023–2024
(gigawatt-hours)



Source: EDL (2024).

Figure 5.2. Electricity Demands of the Industrial, Commercial, and Residential Sectors in Lao PDR, 2023–2024



Source: EDL (2024).

There are several new economic activities that could increase the demand for energy in the future. These include Amata Smart and Eco City Natuey Industrial Estate and Amata Smart and Eco City Na Mor Industrial Estate, Saysettha Development Zone, Thanaleng Dry Port, VITA Park in Vientiane, Wangtao-Phonthong Economic Development Zone, and potassium-mining activities in the southern part of the country.

3. Electricity Supply

3.1. Electricity Balance

Table 5.1 shows that Lao PDR is a net electricity exporter. However, it also imports electricity from Thailand, especially during the dry season. Moreover, its electricity losses seem to be high compared to other Association of Southeast Asian Nations (ASEAN) Member States (Table 5.2). The national power grid also faces high distribution losses – an average loss of 13.0% in 2014, 6.8% in 2023, and 8.8% in 2022 (EDL, 2024).

Table 5.1. Electricity Balance in Lao PDR, 2000–2015
(gigawatt-hours)

Year	Production	Export	Import	Consumption	Losses
2000	3,438	2,793	180	640	186
2001	3,654	2,871	184	710	256
2002	3,604	2,798	201	767	240
2003	3,178	2,285	229	884	239
2004	3,348	2,425	278	903	298
2005	3,509,000	2506	330	1,011	323
2006	**3,595,000**	**2,487**	**631**	**1,406**	**333**
2007	3,374,000	1,741	793	1,616	810
2008	3,717	2,315	845	1,916	330
2009	3,366	1,9210	1,175	2.258	362
2010	8,449	6,646	1,210	2,441	571
2011	12,969	10,669	904	2,556	649
2012	**13,057**	**10,363**	**1,329**	**3,075**	**948**
2013	**15,510**	**12,494**	**1,272**	**3,381**	**907**
2014	**15,275**	**11,936**	**1,559**	**3,792**	**1,106**
2015	**16,302**	**11,549**	**2,050**	**4,239**	**2,565**

Source: MEM and ERIA (2018).

3.2. Characteristics of Electricity Production

Private independent power producers (IPPs) own the most electricity generated in Lao PDR – 76% of the total – followed by Électricité du Laos Generation Company (EDL-Gen) at 18% and Électricité du Laos (EDL) at 5%. EDL is also a distributor of electricity in Lao PDR (Table 5.2). Therefore, EDL needs to purchase electricity from EDL-Gen and private IPPs. The sources of electricity production are from hydropower plants, which account for 95% of the total (Table 5.3).

Table 5.2. Characteristics of the Electricity Production by Owner

Owner	Production (kWh)	Share (%)
EDL	834,806,647	5.25
EDL-Gen	2,961,720,290	18.44
Private	12,252,068,246	76.30
Total	**16,057,595,183**	**100.00**

EDL = Électricité du Laos, EDL-Gen = Électricité du Laos Generation Company, kWh = kilowatt-hour.

Source: EDL (2023).

Table 5.3. Characteristics of the Electricity Production by Source

Source	Production (kWh)	Share (%)
Hydropower plant	15,321,289,849	95.41
Coal-fired power plant	604,716,480	3.77
Solar	103,077,814	0.64
Bio	28,511,040	0.18
Total	**16,057,595,183**	**100.00**

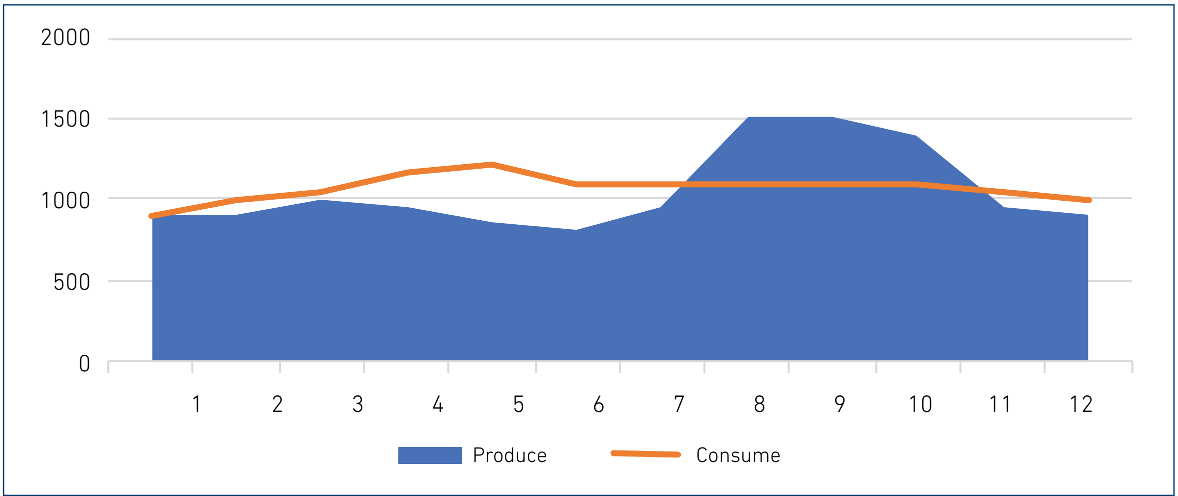
kWh = kilowatt-hour.

Source: EDL (2023).

3.3. Gaps in Electricity Demand and Supply

The source of electricity generation in Lao PDR are hydropower plants; their production surpasses domestic demand during the rainy season and is insufficient during the dry season (i.e. April–July), which is also the hottest time of the year (Figure 5.3). Some hydropower plants do not have resources for storing water during the dry season.

Figure 5.3. Gaps in Electricity Demand and Supply, 2023
(GWh)



Source: EDL (2024).

Lao PDR must purchase electricity from the Electricity Generating Authority of Thailand (EGAT) during the dry season at higher prices but sells it at lower prices to EGAT during the rainy season (EDL, 2022). It is crucial to re-examine the contract and agreement procedure on this matter. Information on selling and purchasing electricity is in the Annex.

To deal with the shortage of electricity during the dry season, EDL and the Ministry of Mines and Energy (MEM) have plans to build several projects as seen in the below table.

Table 5.4. Projects to Enhance Amount of Electricity in Lao PDR

Area	Number	Type	Capacity (megawatts)	Production (gigawatt-hours/year)
Northern	4	Hydropower	305.0	1,198.0
Central	8	Solar	57.0	87.0
Southern	2	Hydropower	20.0	124.0
Unknown	24	Solar	345.5	589.3

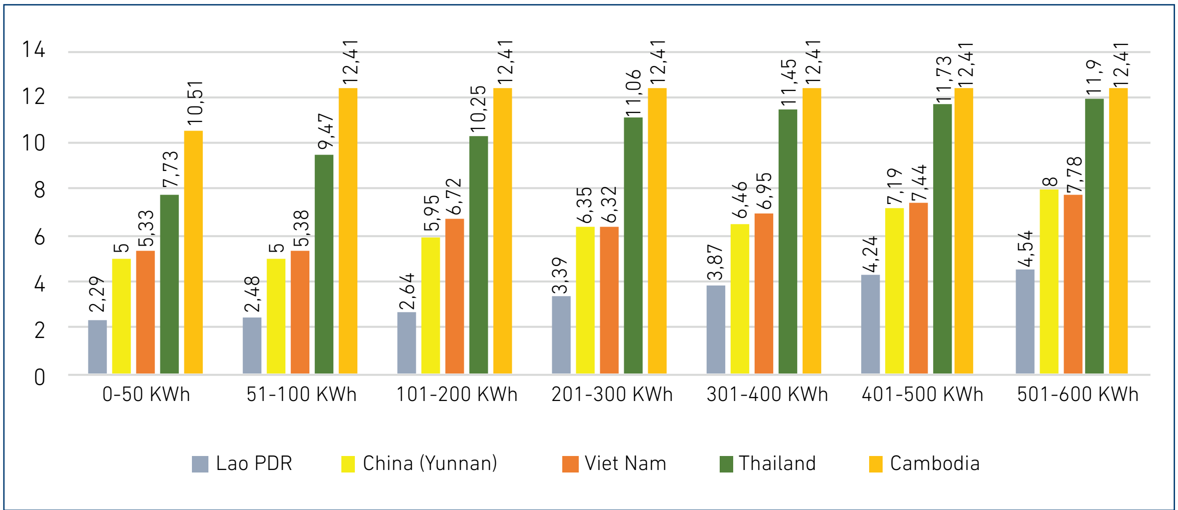
Source: EDL (2023).

Hydropower plants are generally constructed in remote areas, and they need to be connected to the national grid to supply energy to the whole country. The power grid, however, needs large investments and human resources to operate (EDL, 2023). As a result, hydropower plants are not connected to the national grid, and they do not transfer electricity to needed areas, such as the largest city of Vientiane.

3. Electricity Price-Setting

Affordable electricity prices are crucial to sustainable economic development in Lao PDR. Figure 5.4 shows electricity prices in Lao PDR compared to those in other ASEAN Member States; electricity prices in Lao PDR are US$0.023/kilowatt-hour (kWh), the lowest price in the ASEAN.

Figure 5.4. Comparison of Electricity Prices in ASEAN
(US$/kilowatt-hour)



ASEAN = Association of Southeast Asian Nations.

Source: EDL (2024).

In addition, price setting in Lao PDR is based on the amount of electricity used. The price is divided into six levels, depending on the electricity usage of residents. EDL sets low prices for small amounts of electricity use (level 1), which accounts for about 27% of total use. The price increases for 26–150 kWh (level 2), which accounts for the majority, 52% of total use. This price setting needs to be reconsidered, as it should be focussed on reducing prices for the poor and increasing prices as the use of electricity rises (Phoumin et al., 2015). Now, middle- and high-income households seem to pay less compared to their income and total expenditure. Many developing countries have subsidies for electricity prices; EDL should consider these (Han and Kimura, 2015).

Table 5.5. Electricity Prices for the Residential Sector

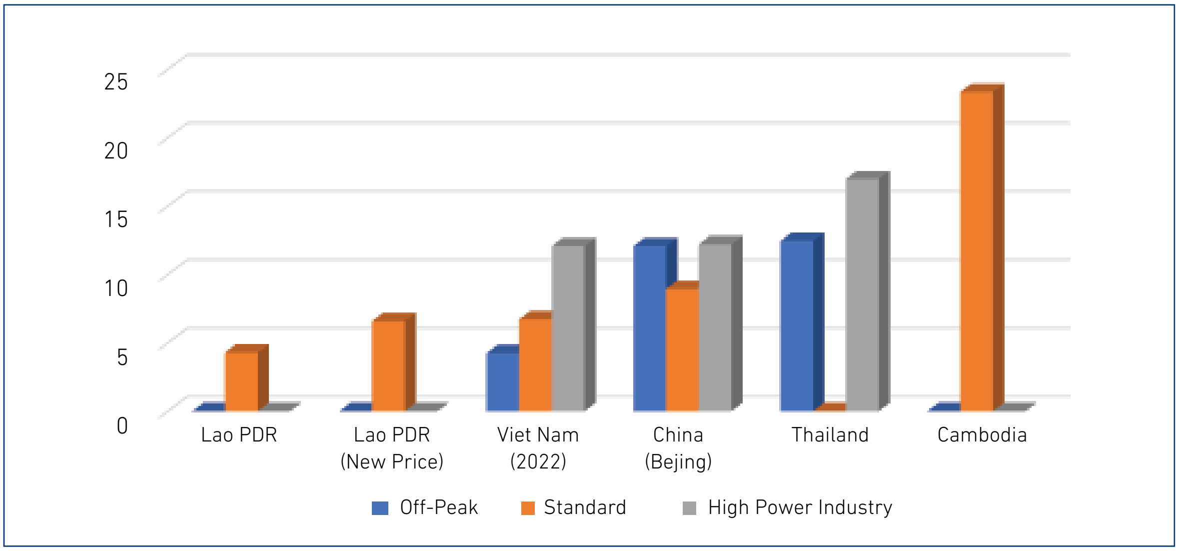
No.	Level of Usage (kWh)	Price (KIP/kWh)	Electricity Usage (Households)	Electric Usage (%)	Payment (KIP/month)
1	0–25	355	401,836	27	355–8,875
2	26–150	422	789,437	52	9,297–61,625
3	151–300	815	206,929	14	62,440–183,175
4	301–400	898	46,970	3	184,773–273,675
5	401–500	948	23,458	2	274,659–372,075
6	> 500	1,019	39,916	3	373,074 KIP and 1,019/kWh
					Excess usage 501 kWh

kWh = kilowatt-hour.

Source: EDL (2023).

Moreover, electricity price setting for the residential sector is not based on demand and supply. The price is fixed all year, which is different from, for example, China, Thailand, and Viet Nam (Figure 5.5).

Figure 5.5. Electricity Prices across ASEAN
(US¢/kilowatt-hour)



ASEAN = Association of Southeast Asian Nations.

Source: EDL (2023).

In addition, electricity price setting for the non-residential sector is shown in the Annex. The recent development of cryptocurrency mining in Lao PDR has increased the high share of domestic electricity use. In September 2021, a new initiative was launched that permits the extraction and commercial exchange of cryptocurrencies. Notification No. 1158, issued by the Prime Minister's Office, establishes an agreement for the sale and purchase of electricity with six cryptocurrency enterprises participating. These companies will be required to pay a set cost for the energy that they consume during data processing or cryptocurrency mining. Moreover, to create new revenue streams, the government authorised 15 additional firms in 2023 to pilot a digital asset business involving cryptocurrency mining and trade in these currencies.

Cryptocurrency mining does not generate employment, but its spillovers affect the economy. Therefore, the electricity price setting for cryptocurrency mining should be evaluated, and some adjustments should be made.

4. Electricity Efficiency and Savings

Electricity efficiency and savings are crucial for Lao PDR; the government has issued a decree on energy saving and conservation (Government of Lao PDR, 2020). This is a small step forwards.

Electricity equipment used in the government and residential sectors is not efficient and must be replaced (Thøgersen and Grønhøj, 2010; Wang et al., 2011). Moreover, public awareness and literacy on energy savings and conservation are still low., so an education campaign should be implemented.

EDL also faces a budget deficit due to various reasons, including subsidies for the residential sector, purchases of electricity at high prices from EGAT during the dry reason, electricity leakage, debts from the government sector, poor grid connections, and inefficient management. Therefore, improving the financial performance of EDL is crucial to a sustainable, affordable energy supply for all sectors in Lao PDR.

5. Conclusion and Recommendations

Energy is crucial to promoting economic growth in Lao PDR. Thus, the securing of affordable energy for all economic sectors is necessary. Current energy pricing – especially electricity tariffs – faces several challenges.

Electricity prices in Lao PDR are lower than those in other ASEAN Member States; this approach is based on government policies to provide cheap energy to residents and the private sector to improve livelihoods and to help develop industries. To sell electricity at the low prices set by the government, EDL must subsidise it, which incurs debt and in turn hurts economic development.

In addition, price setting in Lao PDR is not based on supply and demand. Electricity needs are surpassed during the rainy season, but electricity demand is unmet during the dry season. More than 80% of electricity for domestic use is from hydropower plants, but many plants do not have reservoirs to store water for use in the dry season. Therefore, EDL buys electricity from EGAT and other IPPs at high prices during the dry season. As it sells the electricity at low prices, heavy deficits are thus incurred at EDL.

The following is therefore recommended.

(i) Electricity tariffs should be restructured based on demand and supply. Price setting should be based on a seasonal adjustment – normal season, rainy season, dry season. Price setting should also cover costs. On average, EDL purchased electricity from IPPs at US$0.626/kWh. In 2023, about 11.5 million kWh were purchased, and in 2024, about 14.0 million kWh were purchased. EDL had to subsidise about US$0.04–US$0.05/kWh, which is estimated at US$500 million–US$600 million in 2024.

(ii) The use of solar, wind, and biomass energy should be explored. The development of solar energy in hydropower plant reservoirs could be effective.

(iii) Negotiations with IPPs and EGAT on purchasing electricity price setting should begin. EDL needs to negotiate with IPPs for electricity price adjustment, and IPPs need to lower their prices due to EDL's financial difficulties. The prices then could be raised in the medium and long run.

(iv) Electricity loss must be reduced. The national power grid faced high distribution losses at an average of 13.0% in 2014, 8.8% in 2022, and 6.8% in 2023.

(v) Electricity saving and efficiency should be promoted. Existing electrical equipment is generally of low efficiency, and awareness of electricity saving and efficiency are low.

(vi) Power grids should be improved and connected. The development of a power grid link with southern China is crucial for purchasing electricity during the dry season. In addition, it is a chance to sell electricity to China during the rainy season. It is also important to help develop the ASEAN Power Grid.

(vii) Effective coordination and cooperation between line agencies should be encouraged. The government should improve the coordination mechanism to secure energy to promote industry development and economic growth.

(viii) Reforms to EDL must continue. The Prime Minister appointed a committee to reform EDL, but it has stopped meeting. International donors, experts, and academia should be consulted as well. In addition, the chair should be at a higher position than in the previous committee.

(ix) Electricity from hydropower plants must be secured, as currently, more than 90% is exported to neighbouring countries. Due to the increasing demand for electricity domestically, it is crucial that enough is retained for domestic use.

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Annex

Table 5.A1. Electricity Prices with EGAT
(B/kWh)

Time	EGAT Buying from EDL	EGAT Selling to EDL
Peak: 9:00–22:00, Monday–Friday	2.10	2.20
Off-Peak: 22:00–9:00, Monday–Friday; Saturday and Sunday (all day); off days		

EDL = Électricité du Laos, EGAT = Electricity Generating Authority of Thailand, kWh = kilowatt-hour.

Sources: EDL (2024).

Table 5.A2. Wholesale Rate of Electricity
(B/kWh)

Time	Rate
Peak: 9:00–22:00, Monday–Friday	4.0476
Off-Peak: 22:00–9:00, Monday–Friday; Saturday and Sunday (all day); off days	2.3555

kWh = kilowatt-hour.

Sources: EDL (2024)

Table 5.A3. Energy Price Setting, 2023

No.	User	Price	Monthly Price (Feb–May)	Monthly Price (Jun–Aug)	Monthly price (Sep–Dec)
	Non-Residential				
A	**Low-Voltage Sectors**				
1	International Organisations	1,448	1,945	2,053	2,160
2	General Businesses	1,123	1,509	1,592	1,675
3	Education and Sports Businesses				
3.1	Education	882	1,163	1,223	1,283
3.2	Sports	882	1,390	1,499	1,608
4	Entertainment	1,487	1,012	2,125	1,137
5	Governance	882	1,187	1,253	1,318

No.	User	Price	Monthly Price (Feb–May)	Monthly Price (Jun–Aug)	Monthly price (Sep–Dec)
6	Agriculture and Irrigation				
6.1	Irrigation and Folk Art	537	926	1,009	1,092
6.2	Commercial Agriculture	537	1,110	1,233	1,356
7	Industry				
7.1	Processing	795	1,295	1,402	1,509
7.2	Agriculture-Processing Plants	795	12,272	1,375	1,477
B	**Middle-Voltage Sectors**				
1	International Organisations	1,448	1,764	1,402	1,509
2	General Businesses	795	1,272	1,375	1,477
3	Education and Sports Businesses				
3.1	Education	749	1,015	1,072	1,129
3.2	Sports	749	1,215	1,315	1,415
4	Entertainment	1,413	1,802	1,886	1,969
5	Governance	749	1,037	1,098	1,160
6	Agriculture and Irrigation				
6.1	Irrigation and Folk Arts	457	810	885	961
6.2	Commercial Agriculture	457	1,061	1,191	1,320
7	Industry				
7.1	Processing	728	1,149	1,239	1,329
7.2	Agriculture-Processing Plants	728	1,128	1,213	1,299
7.3	Mining and Ore Processing	728	1,471	1,631	1,790
7.4	Special Economic Zones	728	1,255	1,369	1,482
C	**115-Kilowatt Voltage or More**				
1	General Businesses	954	1,267	1,334	1,401
2	Industry				
2.1	Processing	728	1,121	1,205	1,289
2.2	Agriculture-Processing Plants	728	1,083	1,159	1,235
2.3	Mining and Ore Processing	728	1,434	1,585	1,736
2.4	Special Economic Zones	728	1,206	1,309	1,411
3	High-Speed Railway	728	1,301	1,424	1,547

Source: EDL (2024).


E
F
G

Chapter 6

Energy Efficiency in End-use Sectors – Implications for ASEAN and Lao People's Democratic Republic

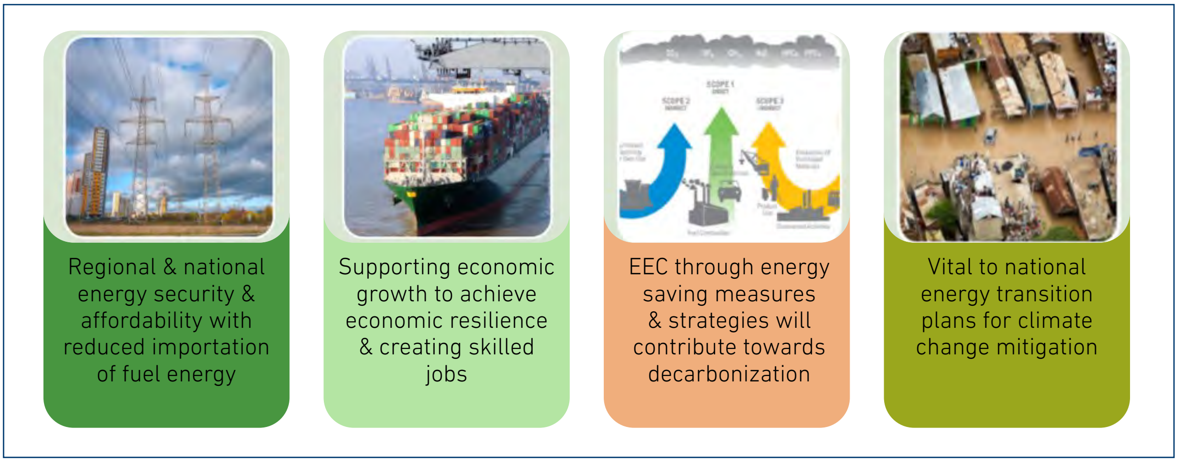
Leong Siew Meng

1. Introduction

The planning for energy security and sustainable development is incomplete without including energy efficiency. Energy efficiency is known as the 'first fuel', as the resulting energy saved becomes an energy source. The International Energy Agency (IEA) reported that energy efficiency plays a critical role in improving living standards around the world; providing reliable, affordable, and universal access; supporting economic growth; and accelerating the clean energy transition towards net-zero emissions by 2050.[1] However, the implementation of energy efficiency and conservation (EEC) initiatives is not straightforward, but energy savings can be achieved through proper and thoughtful planning.

EEC is vital to climate-change mitigation action plans as well as to clean energy transitions for the Association of Southeast Asian Nations (ASEAN) and Lao People's Democratic Republic (Lao PDR). These action plans will contribute significantly to decarbonisation as well as to energy and cost savings while creating skilled jobs. Appropriate and timely government policies on EEC will play an important role in improving energy security, economic resilience, and climate-change mitigation. Figure 6.1 highlights the multiple benefits that can be derived from investments in EEC initiatives.

Figure 6.1. Significance and Impact of Energy Efficiency and Conservation Strategies



EEC = energy efficiency and conservation.

Source: Author.

[1] IEA, Energy Efficiency: The Decade for Action, https://www.iea.org/reports/energy-efficiency-the-decade-for-action

It is essential to map out a holistic plan for all end-use sectors in the country to implement best practices and to undertake a holistic approach in regard to EEC. Efficiency improvements will also help reduce the vulnerability of businesses and consumers to potential disruptions to electricity supplies, especially during peak load demands. This chapter provides policy directions for the planning and implementation of EEC strategies and programmes in Lao PDR.

2. Strengths, Weaknesses, Opportunities, and Threats

Having recognised the investments needed to implement EEC programmes and measures, it is important to evaluate the strengths, weaknesses, opportunities, and threats (SWOT) of Lao PDR's energy scenario before developing policy directions. The SWOT analysis will facilitate the development of a holistic EEC implementation plan.

2.1. Strengths

Lao PDR has a relatively small population of about 7.633 million as of 2023.[2] It is well-endowed with renewable energy resources, especially hydropower and biomass. The strengths of Lao PDR's energy security are as follows:

(i) It possesses abundant hydropower and biomass resources for a small population, resulting in excess capacity to export electricity.
(ii) It has established infrastructure for power exports to neighbouring countries.
(iii) Effective energy policies since the establishment of the Ministry of Energy and Mines in 2006 have evolved, which support the development of a sustainable energy sector. As a result, the ministry is knowledgeable about sustainable energy development following various international collaborative programmes.
(iv) Building on its longstanding history of trading electricity with Thailand, Lao PDR has transformed its landlocked country status into an asset that has facilitated its power integration and electricity exportation to neighbouring countries.
(v) Power integration across the region enhances Lao PDR's energy security.
(vi) Well-planned energy policies have enabled Lao PDR to increase its power supply efficiency and capacity, which can meet domestic demand and export targets, including policies that promote energy savings and conservation by aiming to reduce energy consumption by 10% by 2030.

[2] World Bank, Lao PDR, Data, https://data.worldbank.org/country/lao-pdr [accessed 3 July 2024]

2.2. Weaknesses

For sustainable energy planning, it is also important to examine any shortcomings and/or gaps that may exist in Lao PDR's energy system. The list below summarises these weaknesses.

(i) Its landlocked status limits Lao PDR's access to other energy resources such as oil and gas.
(ii) There is a lack of long-term sustainable energy policies for holistic implementation of EEC to minimise supply interruption.
(iii) The dry season affects hydropower generation capacity, which can cause supply interruptions.
(iv) No EEC legislative framework exists.
(v) There is no funding mechanism for sustainable EEC implementation.
(vi) There is minimal infrastructure and resources to support EEC targets and management of energy demand and supply.

2.3. Opportunities

Despite the challenges to sustainable energy planning, opportunities do arise if Lao PDR is prepared. Potential opportunities are as follows:

(i) Improving efficiency in energy use in end-use sectors will increase Lao PDR's capacity to export electricity, and hence, attract foreign revenue.
(ii) A concerted effort in promoting and adopting EEC measures will improve the energy performance of all end-use sectors; thus, better productivity in domestic production will improve the affordability and competitiveness of domestic goods.
(iii) The drive towards reduction in energy consumption will contribute towards emissions reduction, and achieving decarbonisation will contribute to achieving net-zero emissions in line with global efforts in climate-change mitigation by 2050.
(iv) The drive towards achieving net-zero emissions will attract investments in transitional energy developments and EEC facilities.
(v) Such 'green' or EEC investments will create skilled job opportunities at various skill levels as well as technology transfer to energy management professionals and technical staff in Lao PDR.

2.4. Threats

If no action plans are undertaken for EEC implementation, the threats encountered are summarised as follows:

(i) End-use sectors in Lao PDR will continue to experience power interruptions during the dry season when hydropower generation capacities fall below peak load demand.
(ii) End-use (commercial and industrial) sectors in Lao PDR will not be energy-efficient, resulting in higher domestic production costs, which will affect the affordability of goods and services.
(iii) It will be more difficult to attract foreign investment in transitional energy developments and EEC facilities.

(iv) There will be no significant increase in 'green' skilled jobs. Lao PDR will fall behind in EEC technologies for the commercial and industrial sectors.
(v) Lao PDR will encounter dumping of energy-inefficient appliances and products by acquiring cheap imports, which will result in a wasteful use of energy and higher running costs.
(vi) Lao PDR will experience difficulty in curbing emissions due to the increase in demand for use of fuel energy.

3. Key Directions and Implementation Plan

Strategies for implementing EEC plans vary from country to country. The diversity of ASEAN Member States precludes the use of a 'one-size-fits-all' approach towards implementing such plans. However, the joint ministerial statement of the 41st ASEAN Ministers on Energy Meeting 2023 acknowledged the importance of accelerating EEC measures, not only for the power sector but also for the larger energy-consuming sectors such as transport, industry, and buildings (ASEAN, 2023). The benefits in accelerating EEC measures are also highlighted by IEA, which noted that more efficient and lower energy demand supports faster, universal access to modern, affordable energy in developing countries (IEA, 2014).

A legislative framework is necessary to accelerate the implementation of EEC measures. Table 6.1 shows the legislative frameworks enacted in some ASEAN Member States.

Table 6.1. Legislative Frameworks across ASEAN

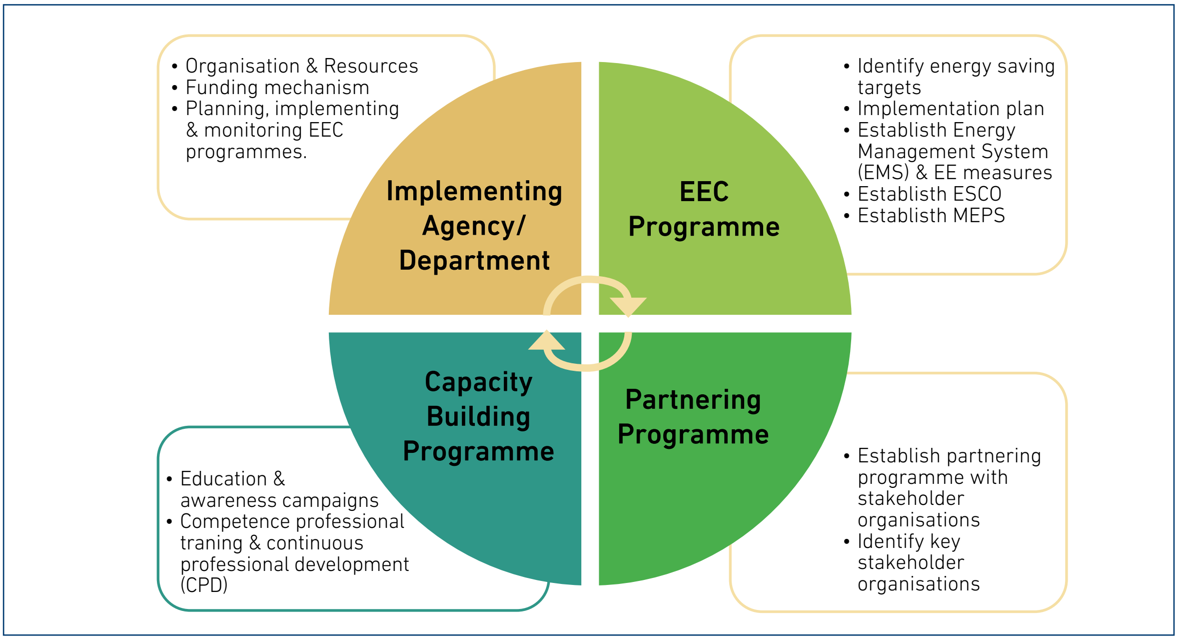
Country	Legislative Framework
Thailand	Energy Conservation Act 1992 Mandatory energy management for companies that consume more than 20,000 GJ/year
Viet Nam	Law on Economical and Efficient Use of Energy, effective 2011 MEPS and labelling for equipment and appliances
Singapore	Energy Conservation Act 2012 Mandatory energy management for companies that have attained the energy use threshold of 54–500 TJ/year in at least 2 out of the 3 preceding calendar years
Philippines	Energy Efficiency and Conservation Act 2019 MEPS for electric motors and similar devices
Malaysia	Efficient Management of Electrical Energy Regulations 2008 Energy Efficiency and Conservation Act, 2023 Mandatory energy management for companies that consume more than 21,600 GJ/year
Indonesia	Law No. 30/2007 on Energy Government Regulation No. 70/2009 on Energy Conservation Mandatory energy management for companies that consume more than 6,000 toe/year (251,200 GJ/year)

GJ = gigajoule, MEPS = minimum energy performance standards, TJ = terajoule, toe = tonnes of oil equivalent.

Source: Kim and Yang (2020) and author.

Developing an EEC act in Lao PDR will take time. It is advisable to take small steps, such as first empowering an existing agency or department to be dedicated to driving the EEC agenda through government directives or statutory regulations (Figure 6.2). The expertise and resources available within ASEAN may also be tapped to help expedite these programmes, which can be implemented simultaneously or under a staggered timeline subject to the availability of financial and human resources.

Figure 6.2. Key Directions to Kickstart EEC Implementation



EE = energy efficiency, EEC = energy efficiency and conservation, ESCO = energy service company, MEPS = minimum energy performance standards.

Source: Author.

The suggested programmes depicted in Figure 6.2 are discussed below.

3.1. Implementing Agency

To kick-off EEC implementation, it is necessary to identify an agency or department that is empowered to implement programmes, collect energy data, monitor and analyse energy performance, disseminate information, and provide guidance to end-use sectors. The implementing agency/department should be staffed with qualified, well-trained, and knowledgeable personnel. For sustainable EEC implementation, a mechanism must be determined to fund the operation of this implementing agency/department as well as an in-depth study and planning. The funding mechanism may be established through government budgets, levies on electricity and/or fuel energy usage, or levies on independent power producer power generation.

3.2. Energy Efficiency and Conservation Programme

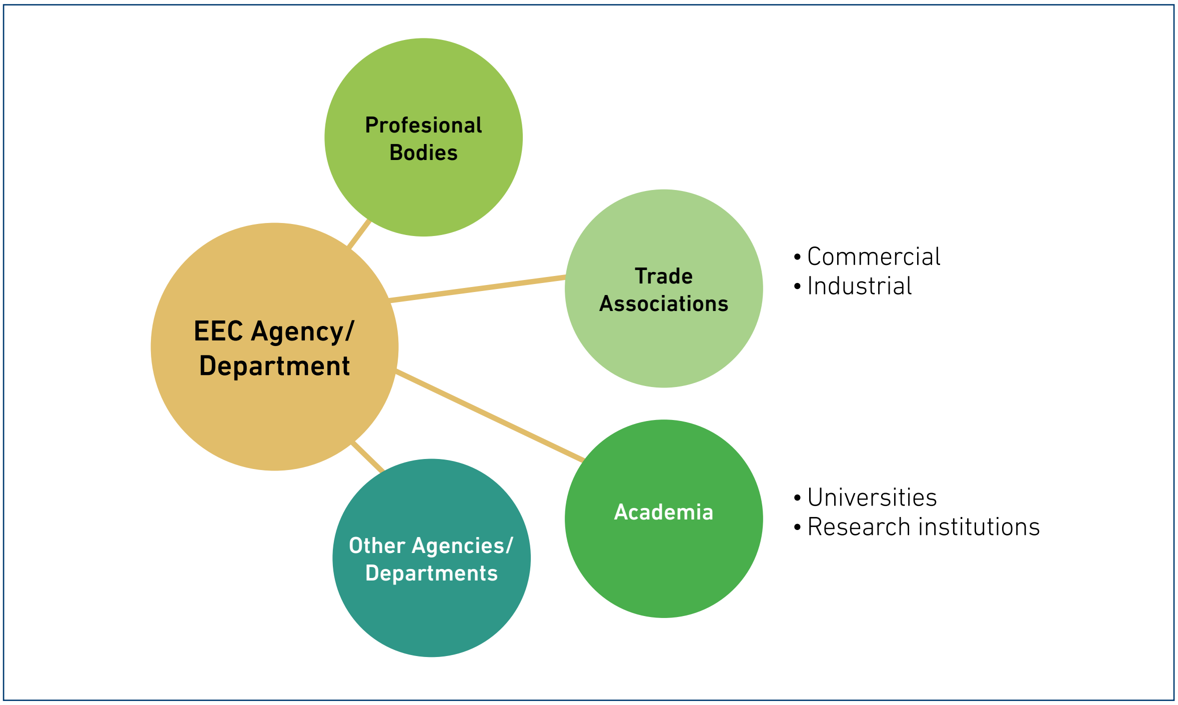
Energy-saving targets should also be set. Subject to the intensity of such targets, the implementing agency/department should develop an EEC programme comprising:

(i) EEC guidelines, composed of best practices for the commercial and industrial sectors;
(ii) an energy management system (EMS) with regimented maintenance practices to achieve energy efficiency;
(iii) energy-efficiency indicators (EEIs), such as building energy intensity for the commercial buildings sector, and energy use intensity for the industrial sector with statistical benchmarking values;
(iv) implementation of energy-saving measures in the industrial and commercial buildings sectors with the establishment and participation of energy service companies (ESCOs); and
(v) minimum energy performance standards (MEPS) for energy-efficient electrical appliances and equipment, which are primarily used in the residential sector.

3.3. Partnering Programme

A partnering programme is a consultative programme designed to involve pre-identified stakeholder organisations, such as industrial and commercial sub-sector associations, professional bodies, academia, and other governmental departments (Figure 6.3). This programme should be led by the implementing agency/department. The objectives of the partnering programme are to (i) obtain stakeholders' input for greater effectiveness and coverage of EEC programmes, (ii) facilitate the dissemination of information pertaining to EEC programmes, and (iii) improve stakeholders' buy-in process and gain immediate nationwide acceptance and participation of EEC programmes.

Figure 6.3. Suggested Stakeholders in Partnering Programme



EEC = energy efficiency and conservation.

Source: Author.

3.4. Capacity-Building Programme

Capacity building is an essential part of EEC implementation. Greater public awareness will improve the uptake of EEC strategies and measures, which will, in turn, result in significant energy savings and improved energy performance in each end-use sector.

As an immediate measure, capacity-building programmes – including continuous professional development – should be developed to target training energy managers and professionals for energy management in the industrial and commercial buildings sectors. Establishment of ESCOs in the longer term will provide much-needed resources for sustainable development. Meanwhile, awareness of EEC in the selection and use of efficient electrical appliances and energy conservation in daily energy use should be promoted to consumers in the residential sector through MEPS with energy performance labelling. Publicity is also required to promote awareness of the benefits of energy-efficient appliances.

4. Energy Efficiency and Conservation Guidelines

After establishing an implementing agency/department, priority should be given to developing and publishing guidelines to advise end-use sectors on EEC strategies and measures. Guidelines for the industrial and commercial sectors should focus on the following topics with case studies, which are subjected to finalisation by a taskforce: (i) procedural guidelines to establish an EMS; (ii) decarbonisation strategies; (iii) computation of EEIs and benchmarking values for respective sub-sectors; (iv) plans for digitalisation; (v) categories of EEC measures (low, medium, and high investment initiatives); (vi) passive and active design measures for the commercial buildings sector; and (viii) significant energy users (with specific energy consumption and guides on best practices in selection, optimisation, design, installation, operation, and maintenance).

For the residential sector, information on MEPS with energy performance or 'energy star' labelling and efficient home energy use guides should be developed, published, and made easily accessible. The EEC guidelines for industrial and commercial buildings sectors may be used as a syllabus and reference book for professional training courses as well.

4.1. Energy Management System

Based on the ISO 50001 Energy Management System standard, the EEC guidelines should provide a framework for establishing energy management best practices to help organisations establish systematic procedures to improve their energy efficiency based on the concept of plan–do–check–act.

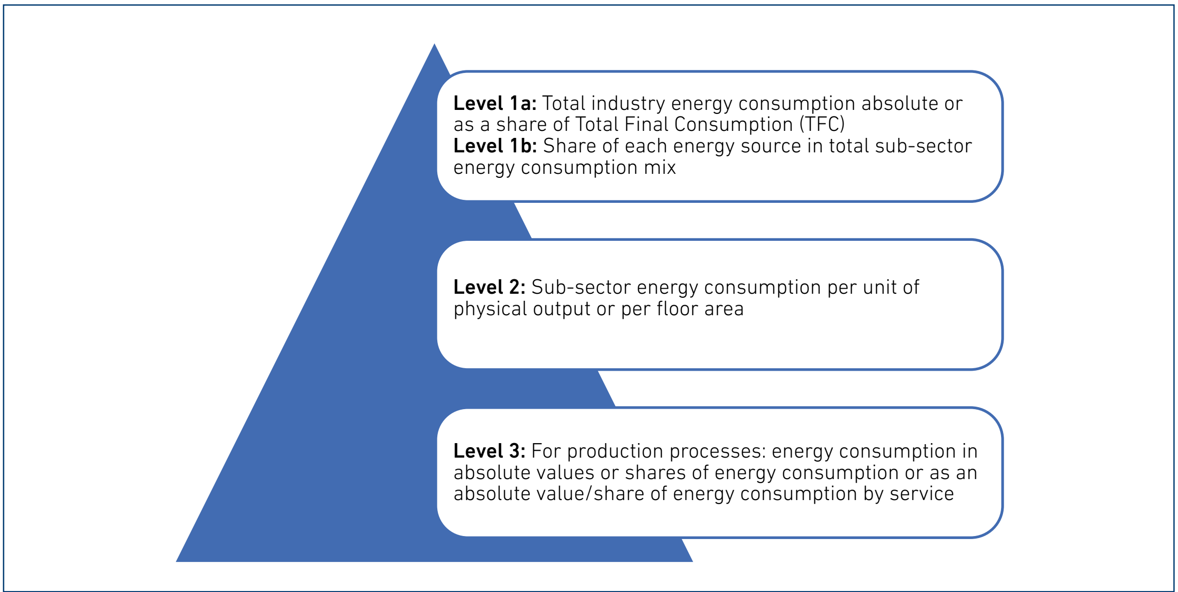
4.2. Decarbonisation

Achieving significant emissions reduction requires a broad range of policy approaches and technologies. EEC measures – together with renewables – are the key pillars of decarbonisation. In general, buildings are responsible for roughly 40% of energy-related emissions in the world. Priority should be given to the efficient design of new buildings; efficient operation of existing buildings will be challenging. Rationalisation of fuel energy use will be an effective measure to achieve decarbonisation as well. EEC guidelines will be a useful guide to achieving decarbonisation.

4.3. Energy-Efficiency Indicator Benchmarking

EEI benchmarking can be established after collecting sufficient data. However, as an interim measure, it may be possible to establish an initial set of EEIs, especially for the commercial buildings sector through surveys and consensus in the consultative partnering programme as well as through resources available within ASEAN. An initial set of EEIs may be referred to from neighbouring countries. Energy-saving targets can then be set for the commercial buildings sector once there are EEIs or building energy intensity benchmarking values under various building categories (Figure 6.4).

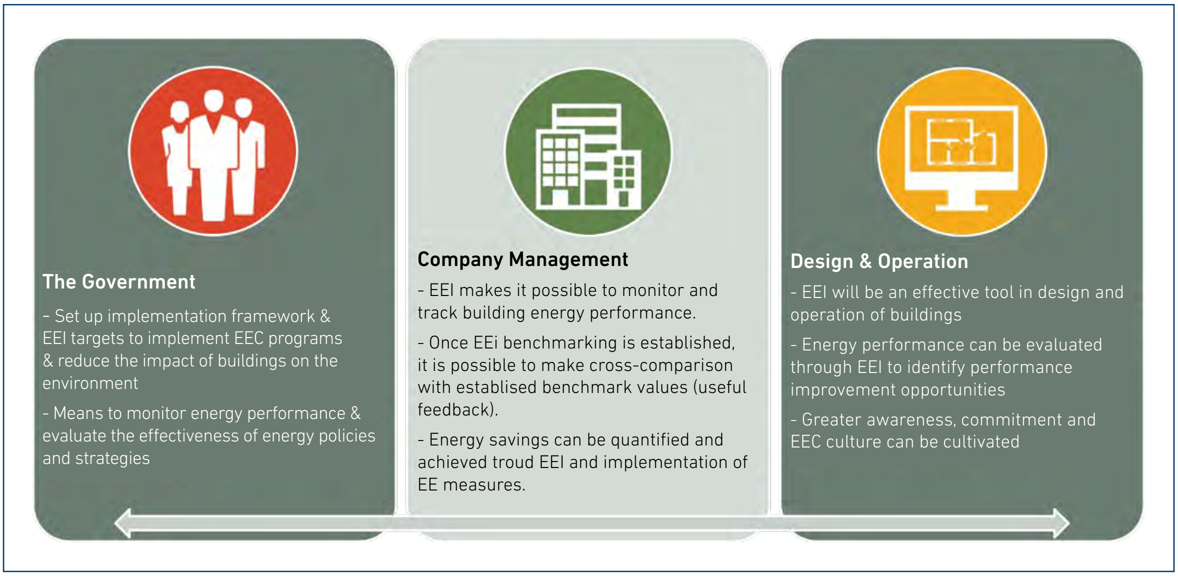
Figure 6.4. Generic Pyramid of Energy-Efficiency Indicators for the Industrial and Commercial Buildings Sectors



Source: IEA (2014).

Level 3 EEIs are useful for comparing absolute values or shares of energy consumption by services (buildings) or processes (industries). EEIs are valuable for policymakers to set energy-efficiency targets, monitor energy performance, and evaluate the effectiveness of energy policies and strategies (Figure 6.5). Company management many find EEI benchmarking useful for evaluating energy performance of their premises or plant operations. Designers can make use of EEIs to help produce energy-efficient designs.

Figure 6.5. Significance and Benefits of Energy-Efficiency Indicator Benchmarking



EEC = energy efficiency and conservation, EEI = energy efficiency indicator.

Source: Author.

4.4. Digitalisation

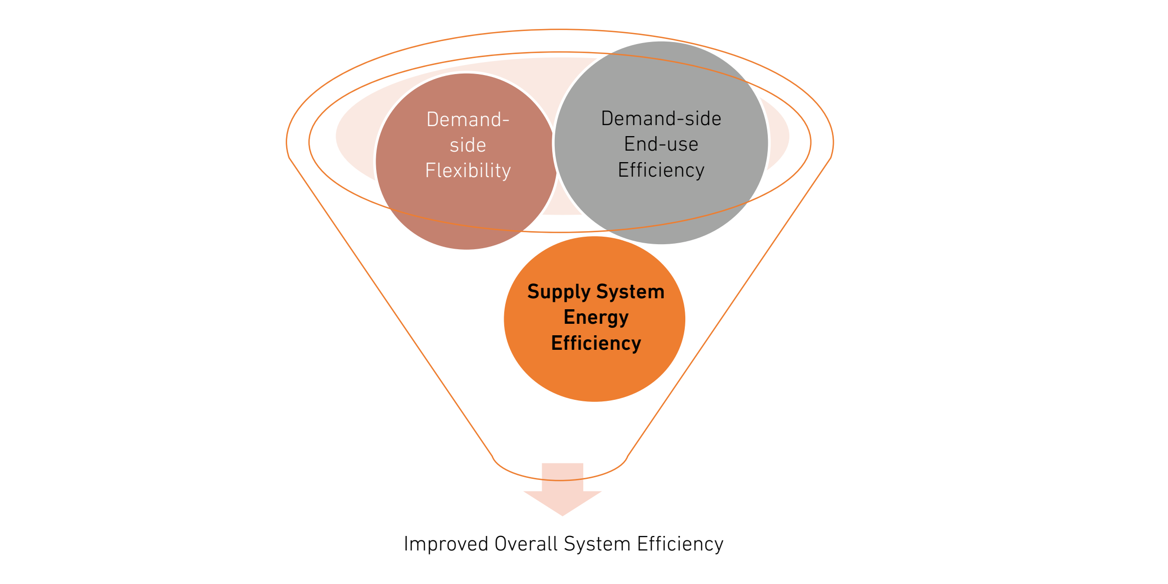
Achievement of EEC is changing with the application of state-of-the-art digital technologies, which enable greater control, flexibility, optimisation, and savings in equipment investments. Digitalisation offers opportunities to increase EEC through technologies for the industrial and commercial buildings sectors, in addition to other well-established EEC initiatives. Digitalisation is useful in the following areas:

(i) **Energy-efficient design**. Optimisation in design – with optimal selection/sizing of equipment through simulation of various usage scenarios – can be achieved and is cost-effective. Such design will also save equipment and ancillary capital costs due to reduced equipment and ancillary infrastructure sizing.

(ii) **Energy-efficient operation**. Through data-gathering technologies via sensors and smart meters, data are processed into useful information through real-time data analysis technologies such as artificial intelligence (AI) algorithms and internet-of-things (IoT). Processed information is sent to devices that can effect physical changes to optimise energy use. Seamless integration and connectivity for an IoT ecosystem consisting of web-enabled smart devices and control instrumentation will enable real-time and AI-assisted optimisation for a higher level of energy-efficient operation.

Digitalisation will also enable smart buildings and industrial facilities to provide flexible load demands to facilitate better management of the supply system (IEA, 2019). The power of digital technologies to both improve end-use efficiency and to supply system efficiency ultimately benefits overall energy system efficiency by managing demand and supply, improving energy resiliency, minimising supply disruption, as well as reducing financial burdens through avoided capital investments in energy infrastructure (e.g. peaking plants and improved integration of renewable energy for greater flexibility and options) (Figure 6.6). However, the challenge is the timing of investing in digital technologies due to continual improvement and rapid advancement in technologies.

Figure 6.6. Overall Demand- and Supply-side System Efficiency Improvement by Digitalisation



Source: IEA (2019).

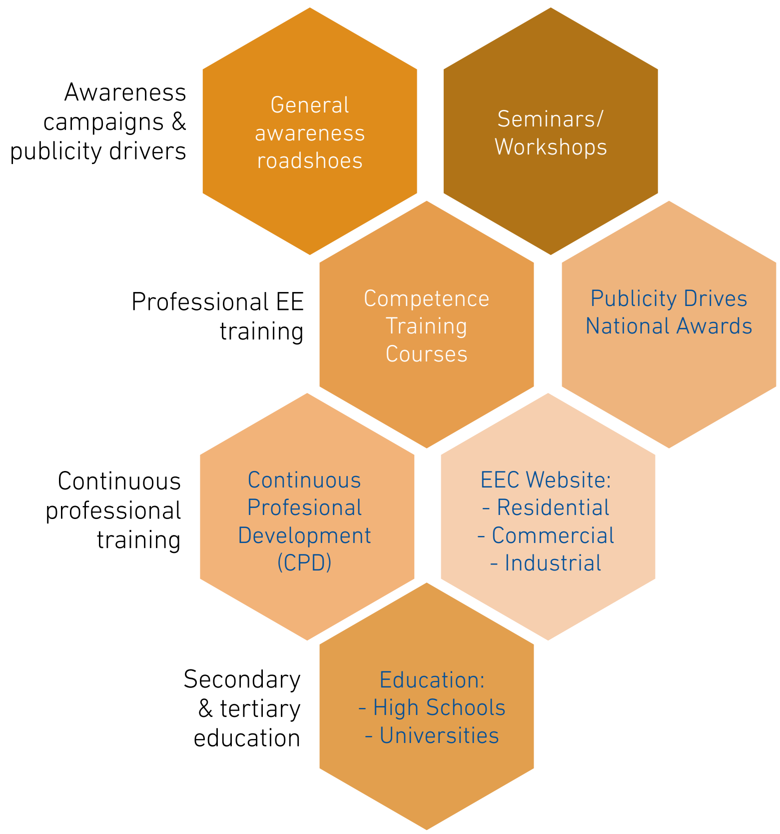
5. Capacity Building through Continuous Education and Awareness Campaigns

As previously noted, capacity building is an important part of EEC implementation. To expedite such programmes, the expertise and resources within ASEAN may be sourced. Capacity building should cover the following areas:

(i) **Immediate measures**. Competency professional training courses for the development of expertise and skills in energy-efficient design, system operation and energy management, and energy audits, which may be classified into elementary, intermediate, and advanced levels; continuous professional development programmes; and awareness campaigns via roadshows, seminars, workshops, social media, and other publicity drives.

(ii) **Long-term measures**. EEC school curriculum for secondary schools and universities (Figure 6.7).

Figure 6.7. Capacity-Building Programmes and Awareness Campaigns



EE = energy efficiency, EEC = energy efficiency and conservation.

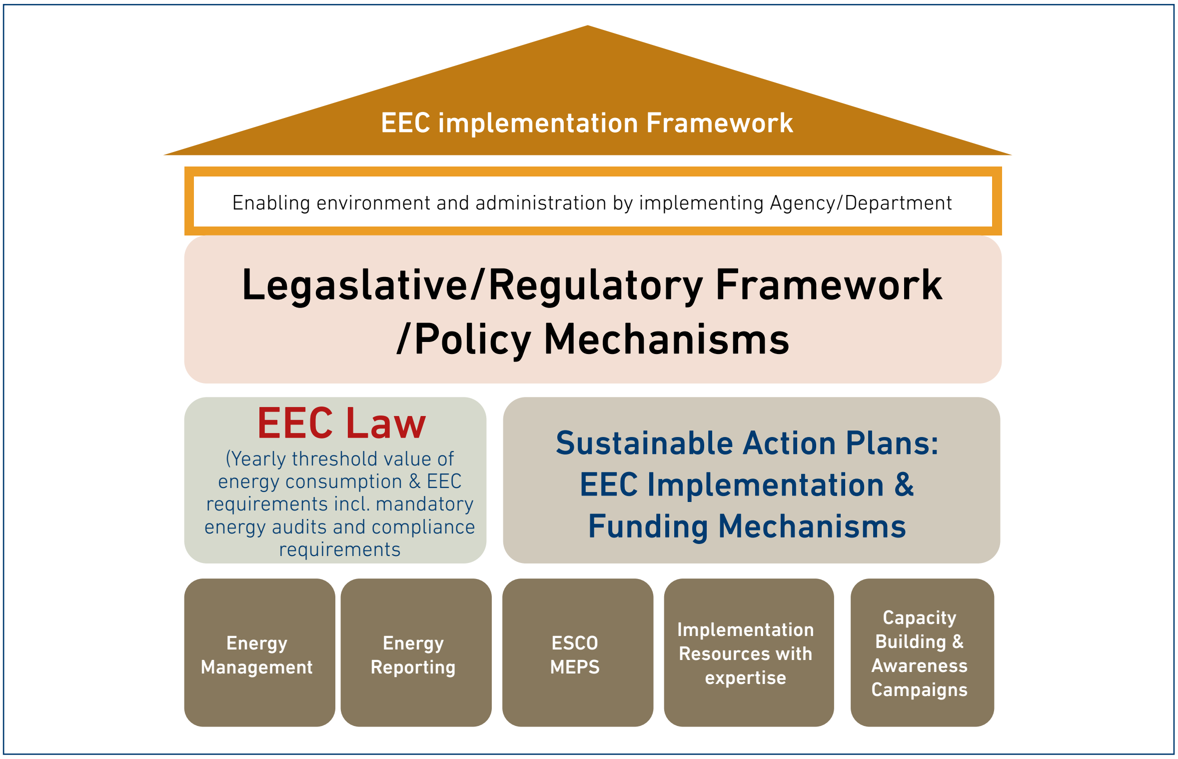
Source: Author.

6. Legislative Framework

Lao PDR's total final energy consumption grew by 2.1% from 2010 to 2019. Electricity consumption grew the fastest at 11.7%, followed by petroleum products at 3.8%. Biomass – although having the highest share of total final energy consumption – decreased at an average rate of 0.7% per year (Kim and Yang, 2020). Comparing the growth rates of final energy consumption by sector during 2000–2019, the industrial sector grew the fastest at 10.0% per year, followed by the transport sector at 6.2% per year, and the 'others' sector (including residential, commercial, services, and agriculture) at 1.9% per year. Industry's high growth rate in energy consumption is expected to continue during 2019–2050 at 5.4% per year (Kim and Yang, 2020).

In view of the expected increase in energy demand – especially in the industrial sector – EEC measures are key to curbing demand growth whilst maintaining economic growth. Adopting the recommended EEC programmes without a legislative framework will make them voluntary; thus, uptake rates are not expected to be strong. The development and enactment of a legislative framework will enable Lao PDR to accelerate the EEC programmes as part of the country's sustainable development policy. An EEC law will provide the necessary enabling environment for EEC implementation (Figure 6.8).

Figure 6.8. Overview of Energy Efficiency and Conservation Implementation and Legislative Framework



EEC = energy efficiency and conservation, ESCO = energy service company, MEPS = minimum energy performance standards.

Source: Author.

The EEC programmes outlined in this chapter should thus be made mandatory for large energy consumers that exceed a pre-determined yearly threshold value of energy consumption in the industrial and commercial buildings sectors. This threshold value of yearly energy consumption will be defined in the EEC law. Compliance requirements and penalties due to repeated non-compliance will also be stipulated in the EEC law.

7. Policy Recommendations

EEC implementation will bring multiple benefits to Lao PDR such as enhancing energy security, improving the affordability and access of energy supply, supporting economic growth, and contributing to decarbonisation and climate-change mitigation measures. EEC implementation must start with a government directive – a top-down approach – while the EEC programmes listed below will constitute a bottom-up approach. In summary, it is recommended that these EEC programmes in Lao PDR be executed in three stages.

Immediately:

(i) **Create competency professional training courses for the development of expertise and skills in energy-efficient design, system operation and energy management, and energy audits.** These may be classified into elementary, intermediate, and advanced levels.

(ii) **Foster continuous professional development**.

(iii) **Begin EEC awareness campaigns through roadshows, seminars, workshops, social media, and other publicity drives.**

For the short term (i.e. within 2–3 years from the start of EEC implementation):

(i) **Establish an implementing agency/department to spearhead the execution of EEC implementation**. This agency/department is empowered with the authority and human and financial resources to implement programmes, collect energy data, monitor and analyse energy performance, disseminate information, promote EEC activities, and provide guidance to end-use sectors.

(ii) **Execute EEC programmes**. Develop and publish EEC guidelines for an EMS, decarbonisation, EEIs and associated benchmarking for respective commercial and industrial sub-sectors, digitalisation, categories of EEC measures, passive and active design measures for the commercial buildings sector as well as significant energy users with specific energy consumption.

(iii) **Establish EEIs**. These should include building energy intensity for the commercial buildings sector, and energy use intensity for the industrial sector with statistical benchmarking values.

(iv) **Implement energy-saving measures for the industrial and commercial buildings sectors with the establishment and participation of ESCOs.**

(v) **Establish MEPS for energy-efficient electrical appliances and equipment**. These are primarily used in the residential sector.

(vi) **Develop and implement an EEC partnering programme**. The objectives are to obtain stakeholders' input for greater effectiveness and coverage of EEC programmes, facilitate the dissemination of information, and improve stakeholders' buy-in process.

(vii) **Develop and implement capacity-building programmes**. The expertise and resources within ASEAN may be sourced.

In the long-term (i.e. within 4-5 years from commencement of EEC implementation):

(i) **Develop an EEC school curricula for secondary schools and universities**.

(ii) **Develop and establish an EEC legislative framework**. Once this is established, human resources for the enforcement of EEC legislative requirements should be increased. A policy direction to implement EEC plans as early as possible will complement the development and establishment of an EEC legislative framework for Lao PDR's long-term sustainable energy plan.

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Chapter 7

Energy Management Systems and Energy Service Companies

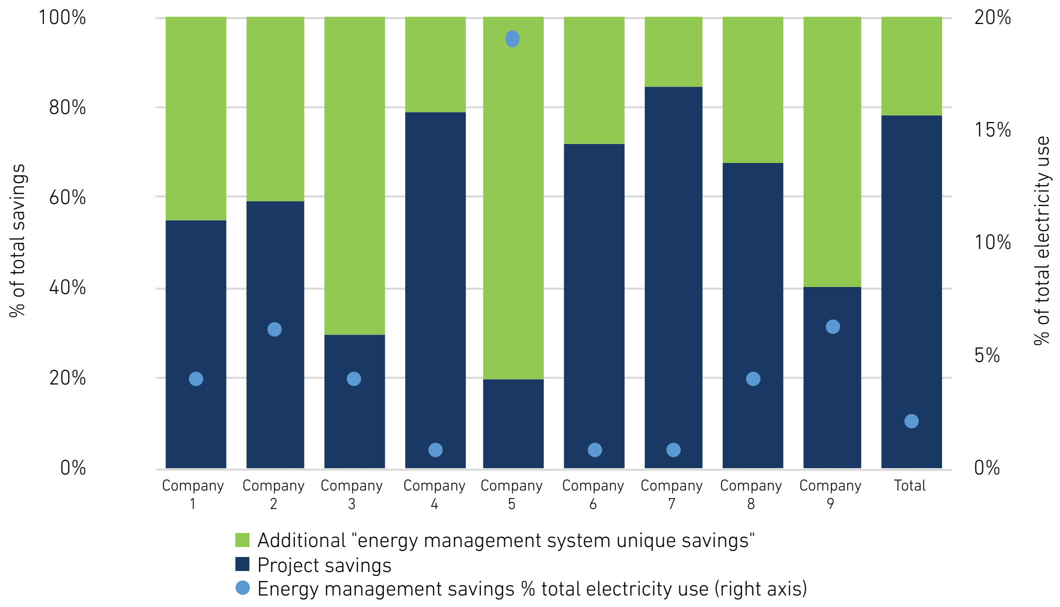
Ong Ching Loon

1. Introduction

The energy-efficiency agenda is not new; it began gaining attention during the energy crises in the 1970s when the West, particularly the United States (US), Canada, Western Europe, Australia, and New Zealand, faced substantial petroleum shortages and increased oil prices. The crises led to the creation of various energy-efficiency programmes, one of which was the US's Energy Star programme initiated by the Environmental Protection Agency and Department of Energy. Energy Star aims to improve the energy efficiency of buildings and products, resulting in cost savings and environmental protection.

The benefits of energy efficiency have proven to be huge. As such, besides an energy management system (EMS) introduced by the International Organization for Standardization (ISO) to aid countries with their energy-efficiency targets, the concept of energy service companies (ESCOs) emerged in 1980s, particularly in the US. The International Energy Agency (IEA) highlighted the results of nine companies in developing economies that implemented EMSs under the guidance of the United Nations Industrial Development Organisation (UNIDO) (Figure 7.1).[1]

Figure 7.1. Implementation of Energy Management Systems – Benefits



Source: IEA, Productivity, Multiple Benefits of Energy Efficiency, https://www.iea.org/reports/multiple-benefits-of-energy-efficiency/productivity

[1] IEA, Productivity, Multiple Benefits of Energy Efficiency, https://www.iea.org/reports/multiple-benefits-of-energy-efficiency/productivity

According to Figure 7.1, energy-efficiency projects implemented through EMSs led to electricity savings of over 26,000 megawatt-hours. An additional 8,000 megawatt-hours were achieved from 'EMS- unique' savings; these were linked to improvements in staff awareness of energy efficiency, energy management capability, daily routine operations, and staff accountability. This resulted in total savings of 12%–80% from the baseline.

While EMSs provide a systematic process to improve energy performance continually from in-house energy management teams, energy-efficiency programmes involving medium and high costs – such as retrofitting projects – are executed by competent energy service providers or ESCOs. An ESCO provides a comprehensive range of energy-efficiency and conservation solutions and accepts some degree of financial risk.

To achieve energy efficiency holistically and sustainably, EMSs and ESCOs cannot be mutually exclusive.

2. Energy Management Systems

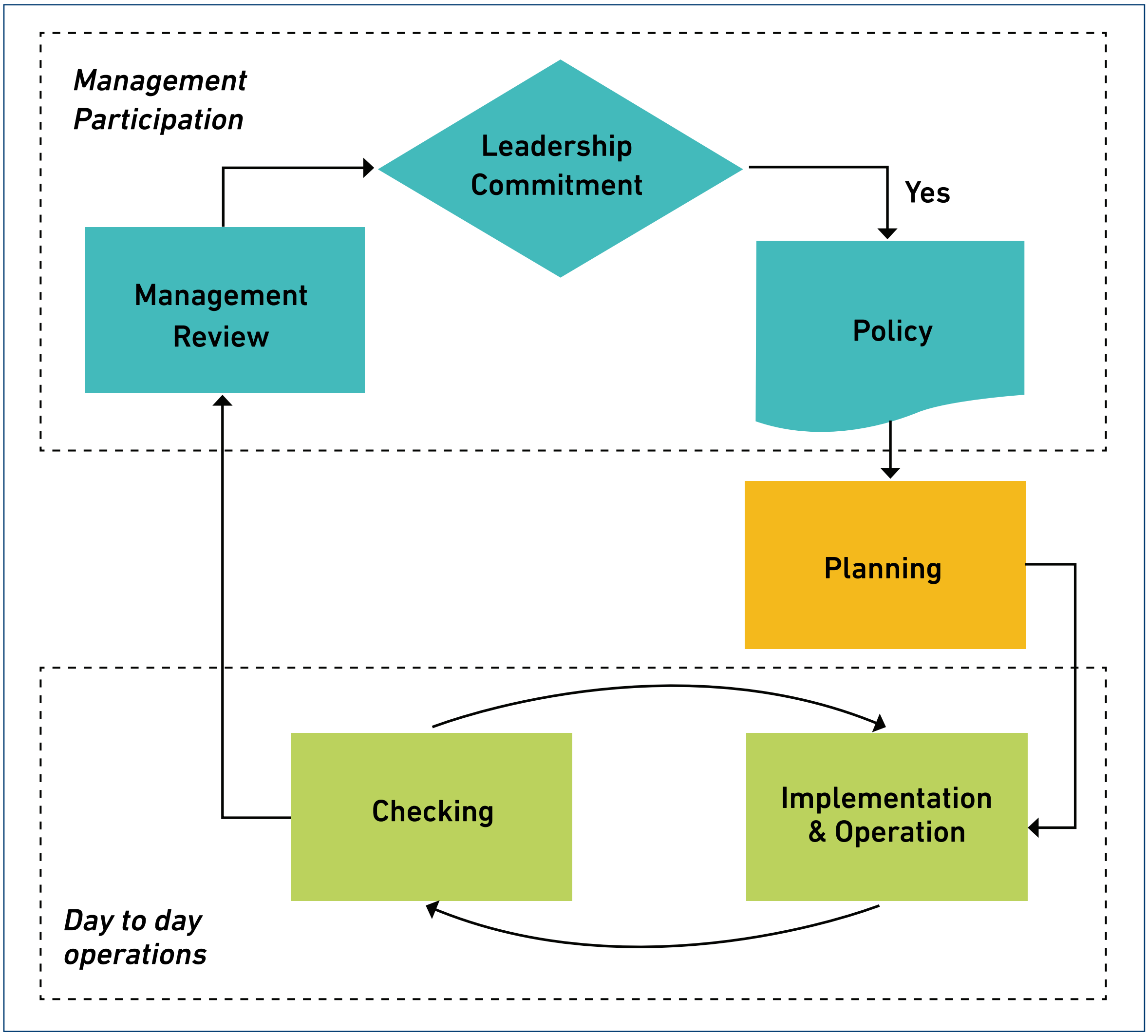
EMSs represent a systematic approach to energy use management. They are not just technical systems composed of computer-aided tools used by operators of electric utility grids to monitor, control, and optimise the performance of the generation or transmission system; an automation system that collects energy consumption data that computes metrics; nor an online monitoring tool that generates graphs and scorecards. EMSs are often misconstrued as building EMSs or building automation systems; these are usually self-generated, in-house practices to energy-saving management processes that are not holistic and integral of all elements to attain sustainable energy performance.

A systematic framework for EMSs is missing. Mostly, standards are used to generate EMSs based on ISO 50001 or the ASEAN Energy Management Scheme (AEMAS) (i.e. an ASEAN system of certification based on excellence in energy management). The fundamental requirement or AEMAS certification rests with ISO 50001, and it was established to support the regional blueprint for the energy sector under *the ASEAN Plan of Action for Energy Cooperation (APAEC)* (ACE, 2023).

ISO 50001 is a framework for developing an effective EMS with the primary objective of improving energy performance for organisations.[2] Energy performance is defined as measurable results related to energy consumption in the context of energy efficiency. An EMS adopts the 'plan–do–check–act' principle for continual improvement, and its broad framework revolves around the following six criteria: (i) leadership commitment, (ii) energy policy, (iii) energy planning, (iv) implementation and operation, (v) checking, and (vi) management review.

[2] ISO, ISO 50001: Energy Management Systems, https://www.iso.org/iso-50001-energy-management.html

Figure 7.2. Main Criteria of an Energy Management System



Source: UNIDO (2015).

2.1. Leadership Commitment

This dictates the core responsibilities of top management of an organisation and that they must be committed to allocate resources (i.e. financial, human, technical, and technological) to an EMS, assign responsibilities and define the roles of those on the energy management team, appoint a management representative, sign and enforce energy policy, give support, and make decisions. While the other five criteria are integral to achieve energy savings, failure of top management to commit to these responsibilities would destroy its implementation.

2.2. Energy Policy

Policy is the beacon of all action plans; the same applies to energy policy. It is essential for an energy policy to define its objectives and commitments. It must mandate complete compliance with national legislation, acts, regulations, and other requirements related to energy-using activities. It must support energy-efficient designs, procurement of energy-efficient products that have minimum energy performance standards (MEPS), and continual improvement. The policy must be communicated to all levels of staff within an organisation. A typical energy policy is depicted in Figure 7.3.

Figure 7.3. Typical Energy Policy

ENERGY POLICY

Cofreth (M) Sdn Bhd, a Facilities Management,Energy Consultancy and Energy Services company is committed to optimise building energy consumption through continual improvement of Energy Management System (EnMS).

The policy governs the following commitments:

1. Comply with all applicable energy related legislation and other requirements;
2. Optimizing building energy performance through procurement of energy-efficient product and services, efficient design and implementation of operational control;
3. Provide necessary resources and information required to achieve objectives and targets;
4. Continually improve energy management system (EnMS) performance through yearly audits and management reviews.

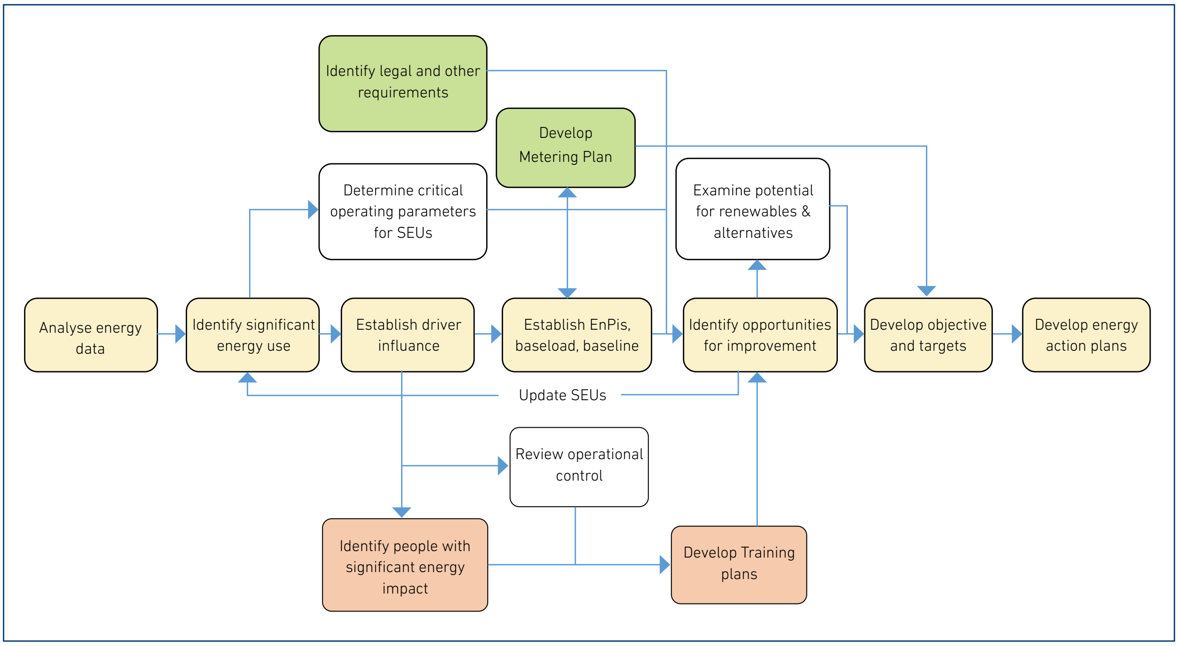
This policy will be reviewed and revised as necessary and communicated to all employees within he organization

Source: Cofreth (M) Sdn Bhd.

2.3. Energy Planning

Energy planning is the most comprehensive requirement, as it reviews the business activities and processes that affect energy use and thus energy performance in a company. It covers the need to develop plans to analyse energy data, identify significant energy users (SEUs), establish drivers of or variables' influence on energy use, energy performance indicators (EPIs), baselines, and baseloads. Opportunities for improvement must be identified, and objectives, targets and energy action plans must be developed. The core workflow is depicted in Figure 7.4.

Figure 7.4. Core Workflow of Energy Planning



SEU = significant energy user.
Source: Author's adaptation of UNIDO's EnMS.

Amongst all of the above work activities, identifying which systems consume the most or least electricity or fuel from past or present energy consumption data is known as identifying SEUs. The purpose is to prioritise energy-saving measures (ESMs) for the highest users to the lowest. Typically, the top five users are in a factory or commercial building. Besides SEUs that are systems-based, people whose involvement in the entire ecosystem of the EMS have an impact on energy use must also be identified as SEUs.

Equally important is establishing energy variables or drivers, as they are the factors that affect energy consumption. Examples of variables are occupancy, operating hours, production volume, external ambient temperature, and cooling degree days.

It is also crucial to have EPIs that provide energy consumption data in simple efficiency ratios or metrics. Energy use intensity covers all types of metrics, and the most commonly used is specific energy consumption or building energy intensity in the format of kilowatt-hours/square metre/year. For data centres, power usage effectiveness is used. There are many parameters to be considered when energy use intensity is computed, and they are generally aligned to the local energy framework or practices.

Energy metrics without baseloads cannot be used as baselines, as metrics or ratios do not necessarily represent total energy consumption. The best method to identify the baseload is linear regression; the energy data value at the intercept of the best fit line against the Y-axis is the baseload. The baseload can also be determined from data logging of an SEU over at least a 24-hour cycle when unwanted energy is consumed during off-production hours or when the business is closed. The baseload is normally ignored, despite the fact that energy is used for nonproductive activities. This is a great opportunity to save energy.

Other important processes are determining opportunities for savings, known as ESMs; developing objectives, targets, and action plans associated with ESMs; and obtaining schedules and resources required to meet the targets. Under ESMs, measures such as no-cost and medium- and high-cost are identified, and with the exception of no-cost measures, the corresponding financial outlay, return on investment, and work schedules are generated. No-cost measures, such as switching off energy-consuming equipment when not being used and setting room temperatures according to the ASHRAE standard of 24oC, can be easily implemented.

2.4. Implementation and Operation

Having completed the energy planning process, action plans – which include operational control of SEUs – should be implemented to achieve energy savings. Often overlooked under operational control are the key areas of operation and maintenance (O&M), competence of service contractors, and methods under which O&M are carried out. Past practices of O&M without operations limits for certain important parameters, absence of service performance indicators, and lack of documentation must be revamped. All stakeholders of O&M must be aware of the need for energy efficiency, and this must be communicated regularly. Maintenance personnel must be technically competent, and associated training and re-training should be scheduled in a structured manner. Implementation in this context includes energy-efficient designs and procurement of energy-efficient equipment, which meet at least MEPS as well as safety requirements.

2.5. Checking

Checking is a daily activity to ensure operating parameters of SEUs do not deviate from set limits and thresholds. Activities include monitoring the energy consumption of SEUs in term of energy use indicator metrics and comparing the data against preceding months (Figure 7.5). This is an effective systematic check to understand any excessive deviation or non-conformity and to identify corrective and preventive actions. Under an EMS, yearly internal audits are required, the frequency of which is recommended to be twice per year. An internal audit process should include developing an audit plan and appointing trained auditors with the objective of checking the performance of the system and compliance with legal and other requirements.

Figure 7.5. Monitoring of Specific Energy Consumption

Yr	Month	m2/mth	Δ(%)	SEC for Utiliteas (kWh/m2mth)										Overall SEC	Δ(%)
		Total Production output		SEC for Chiller	Δ(%)	SEC for Chiller	Δ(%)	SEC for Chiller	Δ(%)	SEC for Chiller	Δ(%)	SEC for Chiller	Δ(%)		
2022	Jan-22	7,631	-8.6%	183.06	4.7%	81.54	9.7%	39.72	14.7%	92.48	4.6%	19.02	15.3%	420.61	7.1%
	Feb-22	7,058	-7.5%	185.21	1.2%	78.49	-3.7%	39.51	-0.5%	89.22	-3.5%	18.32	-3.7%	415.53	-1.2%
	Mar-22	8.036	13.9%	164.8	-11.0%	74.79	-4.7%	39.25	-0.7%	84.97	-4.8%	14.87	-18,9%	382.52	-7.9%
	Apr-22	7,102	-11.6%	208.75	26.7%	80.69	7.9%	43.76	11.5%	95.6	12.5%	15.98	7.5%	450.68	17.8%
	May-22	7,383	4.0%	174.93	-16.2%	78.38	-2.9%	40.04	-8.5%	85.3	-10.8%	15.21	-4.8%	397.79	-11.7%
	Jun-22	8,077	9.4%	138.5	-20.8%	68.56	-12.5%	46.75	16.7%	82.91	-2.8%	14.13	-7.1%	354.71	-10.8%
	Jul-22	7,265	-10.0%	173.93	25.6%	80.36	17.2%	54.25	16.0%	96.46	16.3%	15.74	11.4%	426.81	20.3%
	Aug-22	6,043	-16.8%	200.1	15.0%	98.36	22.4%	55.46	2.2%	117.89	22.2%	19.04	21.0%	496.7	16.4%
	Sep-22	5,202	-13.9%	247.04	23.5%	114.02	15.9%	81.29	46.6%	108.82	-7.7%	21.68	13,9%	580.71	16.9%
	Oct-22	3,158	-39.3%	479.69	94.2%	188.06	64.9%	146.62	80.4%	172.13	58.2%	34.21	57.8%	1,033.38	78.0%
	Nov-22	1,237	-60.8%	1,128.81	135.3%	438.09	133.0%	330.58	125.5%	278.37	61.7%	76.77	124.4%	2,277.43	120.4%
	Dec-22	2,329	88.2%	566.66	-49.8%	233.64	-46.7%	176.93	-46.5%	168.41	-39,5%	44.2	-42.4%	1,196.70	-47.5%
2023	Jan-23	1,554	-33.3%	791.45	39.7%	340.14	45.6%	234.09	32.3%	252.83	50.1%	82.36	86.3%	1,720.82	43.8%
	Feb-23	925	-40.5%	1,421.18	79.6%	639.33	88.0%	423.63	81.0%	392.12	55.1%	129.21	56.9%	3,034.10	76.3%
	Mar-23	3,216	247.7%	448.08	-68.5%	175.86	-72.5%	120.43	-71.6%	121.74	-69.0%	39.49	-69.4%	908.54	-70.1%
	Apr-23	3,401	5.7%	429.08	-4.1%	156.74	-10.9%	107.01	-11.1%	140.06	15.1%	37.11	-6.0%	877.74	-3.4%
	May-23	4,268	25.5%	349.68	-18.6%	132.03	-15.8%	85.31	-20.3%	129.6	-7.5%	31.58	-14.9%	733.48	-16.4%
	Jun-23	5,481	28.4%	289.21	-17.3%	106.67	-19.2%	66.14	-22.5%	103.06	-20.5%	27.41	-13.2%	596.44	-18.7%
	Jul-23	1,173	-78.6%	1,332.59	360.8%	428.5	301.7%	179.75	171.8%	376.19	265.0%	124.05	352.6%	2,483.06	316.3%
	Aug-23	3,169	170.2%	432.44	-67.5%	138.87	-67,6%	39.24	-78.2%	91.45	-75.7%	35.63	-71.3	740.06	-70.2%
	Sep-23	2,194	-30.8%	558.4	29.1%	204.7	47.4%	111.31	183.7%	145.74	59.4%	46.66	31.0%	1,081.00	46.1%
	Oct-23	3,824	74.3%	340.34	-39.1%	119.92	-41.4%	64.62	-41.9%	100.66	-30.9%	28.79	-38.3%	657.3	-39.2%
	Nov-23	3,345	-12.5%	384.25	12.9%	133.31	11.2%	72.06	11.5%	118.77	18.0%	32.63	13.3%	748.63	13.9%
	Dec-23	3,851	15.1%	348.38	-9.3%	122.24	-8.3%	63.81	-11.4%	105.83	-10.9%	29.05	-11.0%	674.7	-9.9%
2024	Jan-24	2,322	-39.7%	546.42	56.8%	202.1	65.3%	104.85	64.3%	166.48	57.3%	45.58	56.90%	1,078.40	59.8%
	Feb-24	3,159	36.1%	372.66	-31.8%	138.24	-31.6%	72.89	-30.5%	114.38	-31.3	34.47	-24.4	736.3	-31.7%
	Mar-24	3,089	-2.2%	424.95	14.0%	153.56	11.1%	80.08	9.9%	134.22	17.3%	39.25	13.8%	838.64	13.9%

CDA = compressed dry air, FCU = fan coil unit, HPCW = hot processed chilled water, kWh = kilowatt-hour, m² = square metre, OAC = outdoor air conditioner, PCW = pump for chilled water, SEC = specific energy consumption.

Source: Author and Cofreth (M) Sdn Bhd.

2.6. Management Review

The cycle of an EMS ends with a management review. Again, the frequency of this review is dependent on the issues to be discussed and remedial actions that require top management decisions and support. Annual management review meetings with defined agendas aim to demonstrate to the top management the results of implementing energy-saving action plans and the overall energy performance achieved from an EMS (Figures 7.6–7.8). The meeting sets the plans and targets of energy performance and resources required for the following year. All energy management team members should be mandated to attend the review meeting, which is chaired by top management.

Table 7.1. Example Agenda of a Management Review Meeting

No.	Agenda Item
1	Confirmation of Minutes and Status of Action from Previous Meeting
2	Review of Energy Performance, Action Plans, SEUs, and EPI for last Financial Year (2022/2023) and Plan for 2023/2024 Overall Energy Performance and Improvement Energy Consumption, EPIs, Baselines, Variables, SEUs Energy Objective and Target Achievement Status of Action Plan Implementation with Savings Made
3	Planning for 2023/2024 Energy Objective and Targets New Baseline, SEU, EPI, Variables Action Plan (Opportunity List)
4	Information on EMS Performance, including trends in: Non-Conformities and Corrective Actions Audit Results Analysis of Legal and Other Requirements Evaluation Monitoring and Measurement of Other EMS Performance
5	Review Organisational Context Internal and External Issues Relevant to EMS Needs and Expectations of Interested Parties
6	Review Risks and Opportunities
7	Corrective Actions, Improvement Plans, and Management Decisions Opportunities to Improve Energy Performance Energy Policy EPI and Energy Baseline Energy Objectives and Targets, Action Plans, and Other Elements of the EMS, and Actions to Be Taken if They Are not Achieved Opportunities to Improve Integration with Business Processes Allocation of Resources Improvement of Competence, Awareness, and Communication

EMS = energy management system, EPI = energy performance indicator, SEU = significant energy user.

Source: Cofreth (M) Sdn Bhd.

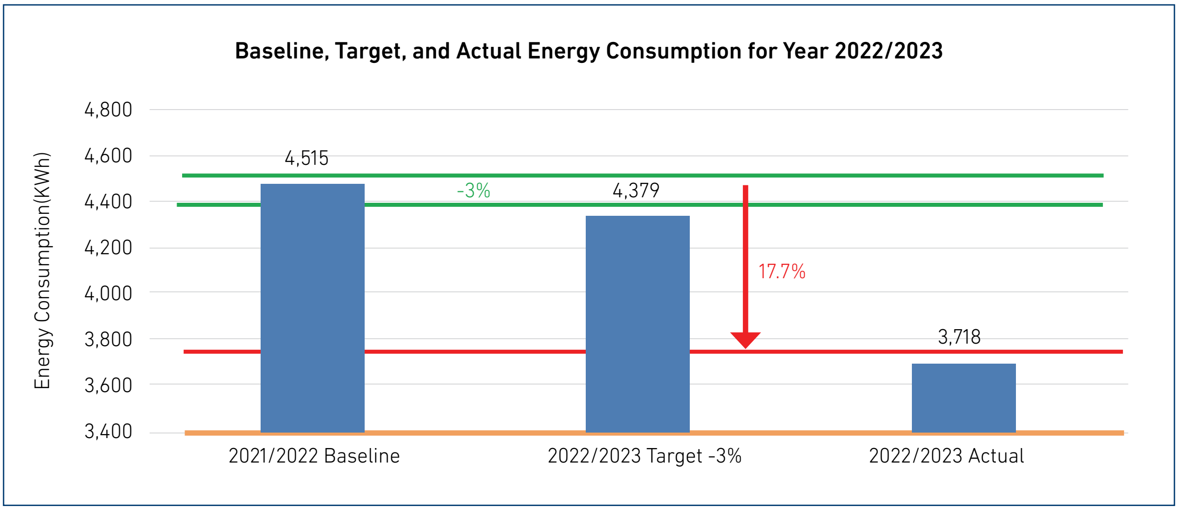
Figure 7.6. Example of Results of Implementing Energy-Saving Action Plans

		Estimate									Actual						
No	Overall Description of Opportunity	Saving		CAPEX	Simple Pay-back	CO_2 Reduction	% of savings (total building)	PIC	Status	Date	Saving		CAPEX	Simple Pay-back	CO_2 Reduction	% of savings (total building)	Status
		kWh/yr	RM/yr	RM/yr	years	ton-CO_2					kWh/yr	RM/yr	RM/yr	years	ton-CO_2		
Short Term																	
ST #1	Condensate spray for air-conditioning using Syabas water (for 2 nos ACSU for Server Room & 2 nos for F&A office)	312	147	300	2,0	0,24	0,58%	CT	Completed	17.5.22	1344	634,368	300	0,5	1,05	2,48%	Completed
ST #2	Condensate spray for air-conditioning (For 4nos ACSU at Level 4)	240	113	300	2,6	0,19	0,44%	CT	Completed	15.6.22	240	113,28	300	2,6	0,19	0,44%	Completed
ST #3	Condensate spray for air-conditioning (For 5nos ACSU at Level 3)	120	57	300	5,3	0,09	0,22%	CT	Completed	25.9.22	936	441,792	300	0,7	0,73	1,73%	Completed
ST #4	Replace downlights at Level 2 Meeting Rooms (Venus, Mars & Board Rooms) by LED lights (Qty: 26). Before = 52 units	-	-	-	-	-	-	CT	Completed	30.6.22	5.267	2.225	208	0,09	4,11	9,72%	Completed
ST #5	Replace T8 lighting at staircase to T5 (Qty: 5)	-	-	-	-	-	-	CT	Completed	15.7.22	198	138	36	0,3	0,15	0,36%	Completed
ST #6	Implementation of shading device at Level 4 area	-	-	-	-	-	-	CT	KIV	-	-	-	-	-	-	-	Pending
Total Short Term Action Plans		**672**	**317**	**900**	**10**	**1**	**1%**				**7.984**	**3.552**	**1.144**	**4**	**6**	**15%**	
Long Term																	
LT #1	Installation of tinted glass window	-	-	-	-	-	-	CT	To discuss in EMT Year 2023/2024	-	-	-	-	-	-	-	To discuss in EMT Year 2022/2023
LT #2	Replace faulty/old units of ACSU in the building	-	-	-	-	-	-	"OPC /CT"	To discuss in EMT Year 2023/2024	-	-	-	-	-	-	-	To discuss in EMT Year 2022/2023
Total Long Term Action Plans		**0**	**0**	**0**	**0**	**0**	**0**				**0**	**0**	**0**	**0%**	**0%**	**0,00%**	
Total		**672**	**317**	**900**	**2,84**	**0,52**	**1,24%**				**7.984,48**	**3551,94**	**1144,00**	**4,16**	**6,23**	**14,74%**	

ACSU = air-cooled split units, CAPEX = capital expenditure, CO_2 = carbon dioxide, CT = central team, kWh = kilowatt-hour, PIC = person in charge.

Source: Cofreth (M) Sdn Bhd.

Figure 7.7. Example of the Energy Performance of a Company with an Energy Management System



Source: Cofreth (M) Sdn Bhd.

The key success of an EMS is the reiterative process of top management commitment, energy planning, implementation and operation, checking, and management reviews based on the overarching principle of continual improvement. Implementation leads to lower energy demand and supply and decarbonisation of the environment. Recognising the benefits of an EMS, the Government of Malaysia stipulated EMSs as a provision in the recently passed Energy Efficiency and Conservation Act.

3. Energy Service Companies

ESCO is a generic name; typically, it is a company with personnel specialised in energy solutions to improve energy efficiency with or without financing for an energy-efficiency project. There are various definitions of ESCOs internationally:

(i) **European Union**. An 'ESCO is a natural or legal person that delivers energy services and/or other energy-efficiency improvement measures in a user's facility or premises and accepts some degree of financial risk in so doing. The payment for the services delivered is based (either wholly or in part) on the achievement of energy-efficiency improvements and on the meeting of the other agreed performance criteria', (EU, 2006).

(ii) **US**. Per the Department of Energy, 'ESCOs develop, design, build, and arrange financing for projects that save energy, reduce energy costs, and decrease O&M costs at their customers' facilities. In general, ESCOs act as project developers for a comprehensive range of energy conservation measures and assume the technical and performance risks associated with a project'.[3]

(iii) **Malaysia**. Per the Association of Energy Service Companies (MAESCO), an 'ESCO is a company that provides a comprehensive range of energy-efficiency and conservation solutions and services with or without the ability to undertake energy performance contracting'.[4]

Fundamentally, ESCOs provide energy solutions and can finance and/or implement them. ESCOs in the European Union and US generally finance them and take on the financial or credit risk, while ESCOs in other nations – predominantly in Asia – are generally reluctant to arrange financing due to lower risk appetites. Some of the ESCOs simply do not have the capacity to arrange for finances as well.

3.1. Scope of Work

To implement the medium- and high-cost ESMs identified under EMSs, some works must be contracted to ESCOs, as in-house technical personnel may not have the expertise, capability, and/or resources to carry out ESMs. Typically, the scope of work includes supplying energy-efficient devices and equipment, consultancy services, contract works (e.g. retrofitting and/or new installation) and project management; energy audits; design engineering; project financing; management of energy performance contracts (EPCs); commissioning and services; O&M of equipment and energy-efficient installation; and inspection of energy-efficiency improvement projects.

3.2. Energy Audits

Energy audits are a process to determine the level of energy efficiency of a building, factory, or installation against its energy-consuming equipment and systems. Without them, the owner of these systems does not know if the facilities or systems are energy efficient. It is a process of mining and analysing data, identifying energy-saving opportunities, recommending ESMs with costs and without costs, and computing the return on investment. In most energy audits, there are three levels (Figure 7.9).

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[3] Government of the US, Department of Energy, Energy Service Companies, https://www.energy.gov/femp/energy-service-companies

[4] MAESCO, internal, unpublished document.

Table 7.2. Levels of an Energy Audit

Level 1: Walk-through Audit	Level 2: Standard Audit	Level 3: Investment Grade Audit
Walk-through familiarisation	Follow-up from Level 1 audit where available; a comprehensive audit	Inclusive of all scope of works of Levels 1 and 2 with the exception of when only an energy audit of specific systems is requested
Desktop analysis	A minimum of 7 days logging and metering on major energy-consuming equipment of building services or industrial equipment/systems	A minimum of 14 days of logging and metering on major energy-consuming equipment of building services or industrial equipment/systems
Generate energy intensity	Review system design, installation, O&M	Detailed review of processes
Recommend no-cost ESMs	Detail system energy inputs and use	IEQ audit, if required
Written report with broad conclusion	Identify sources of inefficiency	Comfort study, if relevant
	Compute BEI or specific energy consumption index	Include indoor air quality report (if chiller audit)
	Generate load apportioning	Recommend no-cost, medium-cost, and high-cost ESMs
	Provide energy performance indicators	Detailed recommendations on comprehensive ESMs
	Recommend no-cost, medium-cost, and high-cost ESMs	Detailed investment plan using NPV methodology against lifecycle
	Written report and presentation	Written report and presentation

BEI = building energy intensity, ESM = energy-saving measure, IEQ = indoor environmental quality, NPV = net present value, O&M = operation and maintenance.

Source: Author.

A Level 1 audit is a walk-through audit, sometimes known as a preliminary audit. As the title implies, it does not require data logging, and the energy auditor of the ESCO conducts the analysis of energy data from past records. Energy metrics are produced, and the metrics are compared against the EPIs of known sources and/or from industry benchmark data. The desktop analysis, in general, identifies ESMs.

A Level 2 audit is the standard audit process where data mining with energy loggers and portable flowmeters are extensively employed. Unlike a spot measurement audit, which provides a value for each spot measurement, logging for a 24/7 cycle provides the energy-consuming trends or profile of any SEU that was being logged. It depicts the data consumption trend every 5–10 minutes and questions how energy is being consumed. Gaps of operations or wasteful practices are unearthed, and ESMs to close the gaps and to improve energy efficiency can be accurately produced. Through intensive data analysis and where necessary, a more complex mathematical approach by linear and/or multi-variate linear regression is used to generate EPIs or metrics and to ascertain the variables that impact energy consumption. For the standard audit, besides no-cost measures being recommended, medium- and high-cost measures are proposed.

The most comprehensive energy audit is the Level 3 audit, also known as an investment-grade audit. All processes of a Level 2 energy audit are carried out, but the difference is the number of days of logging. Under a Level 3 audit, logging days are increased to 14. Sometimes, indoor environmental quality, covering indoor air quality and comfort surveys, are included in the scope. The key requirement is to recommend ESMs complete with a high level of financial return on investment for decision making.

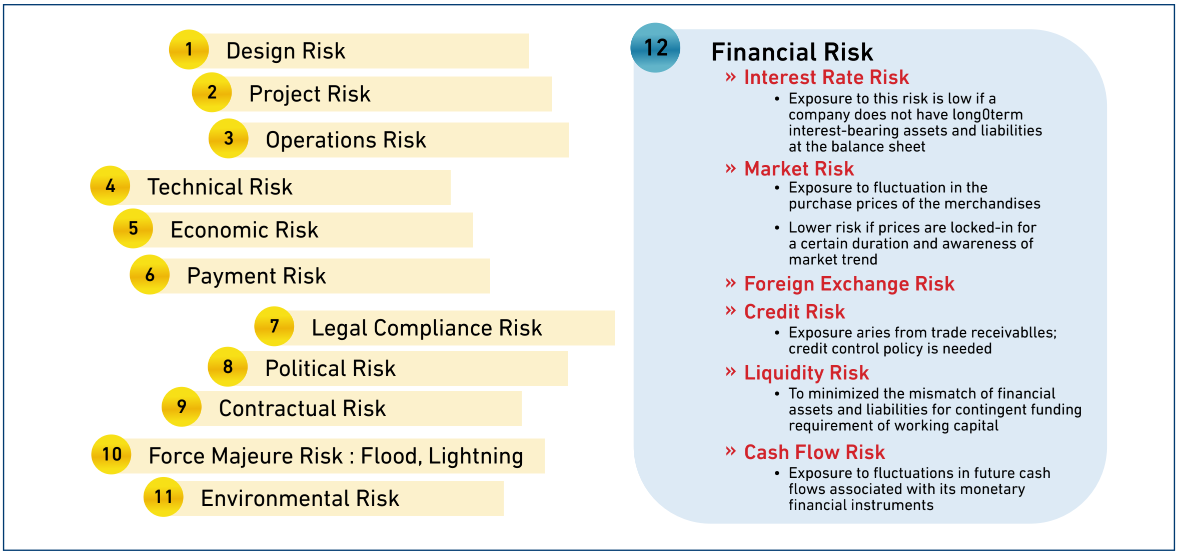
The simple payback method is not conducive to investment consideration; a detailed and comprehensive financial or investment model complete with various sensitivity analysis of cash inflow and outflow and other parameters is required. The analysis must include basic information on the internal rate of return and return on equity, after taking into account the entire lifecycle of a project. A Level 3 audit is the pre-requisite for an EPC.

3.3. Energy Performance Contract

An EPC is a contractual arrangement between a client/building owner and an ESCO of an energy-efficiency improvement project, where investment in that project is funded by the ESCO and repayment of the capital outlay is periodically made through cost savings from reduced energy consumption under a contractually agreed upon level of energy-efficiency improvement. It is also known as off-balance sheet financing. This mechanism relieves the client from the constraint of cashflow, which deters the energy-saving project from being implemented.

Under an EPC where investment comes from an ESCO, it must confront the various risks and plan to mitigate these risks (Figure 7.10). Therefore, it is not unreasonable for an ESCO to incur higher costs for insurance to offset any risks that it can anticipate. Depending on the type of EPC model, under the guaranteed saving model, project financing is undertaken by the client, and the ESCO implements the project and guarantees energy savings.

Figure 7.8. Risks Assessment of Energy Performance Contracts

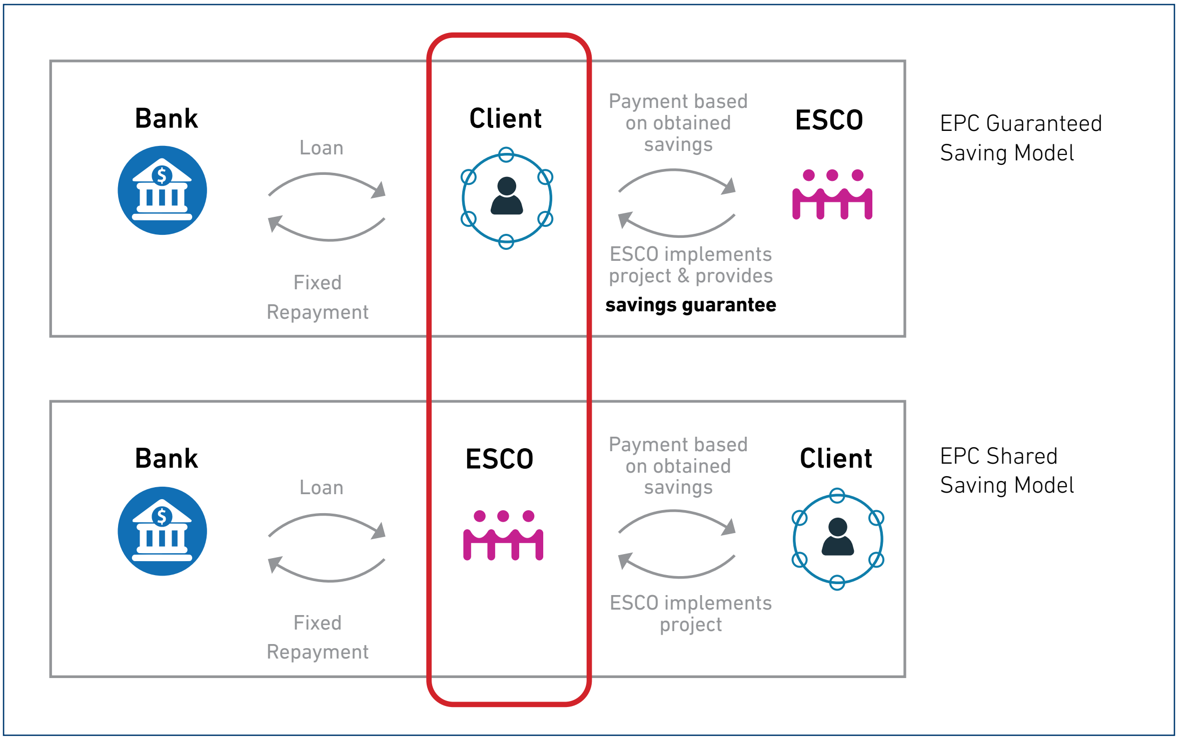


Source: Author.

The energy services industry generally adopts two types of EPC models – the guaranteed saving model and shared saving model (Figure 7.11). The former does not require the ESCO to obtain bank loans or to use its internal funds to finance the capital investment and other costs of the project. The ESCO must, however, guarantee reduction on energy consumption and its corresponding monetary savings and assume all technical and operational risks associated with the project.

Under the shared saving model, the ESCO provides financing for capital expenditures and other expenses, such as project development and implementation costs, and unlocks the asset from the balance sheet of the client. This model is attractive to most companies. Further, the ESCO assumes an additional risk on a loan, which is absent from guaranteed saving model. Payment to the ESCO comes from the energy saved from the project. The net saving after deducting the debt service of principal and interest and cost of O&M is shared between the ESCO and client at a predetermined ratio over the duration of the contract period. ESCOs without strong balance sheets often resist this financing model or are unable to obtain funding from financial institutions.

Figure 7.9. Core Differences between Energy Performance Contracts

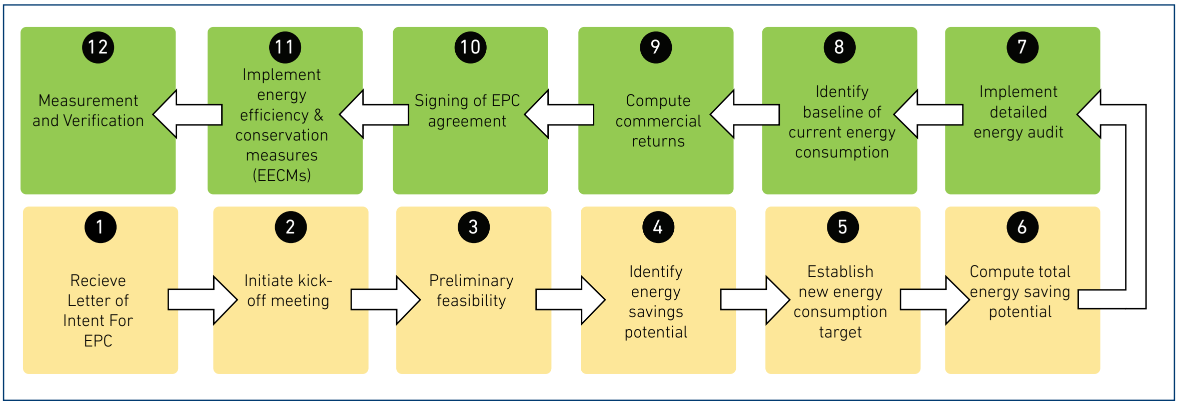


EPC = energy performance contract, ESCO = energy service company.

Source: IEA.

EPCs, however, have been unsuccessful in some countries. The process of EPCs is lengthy (Figure 7.12). There is also no generic EPC template that is acceptable to both the client and ESCO regarding the commercial terms on interest, costs, quantity of guaranteed energy savings, ratio of shared savings, and duration of contracts.

Figure 7.10. Process of Energy Performance Contracts



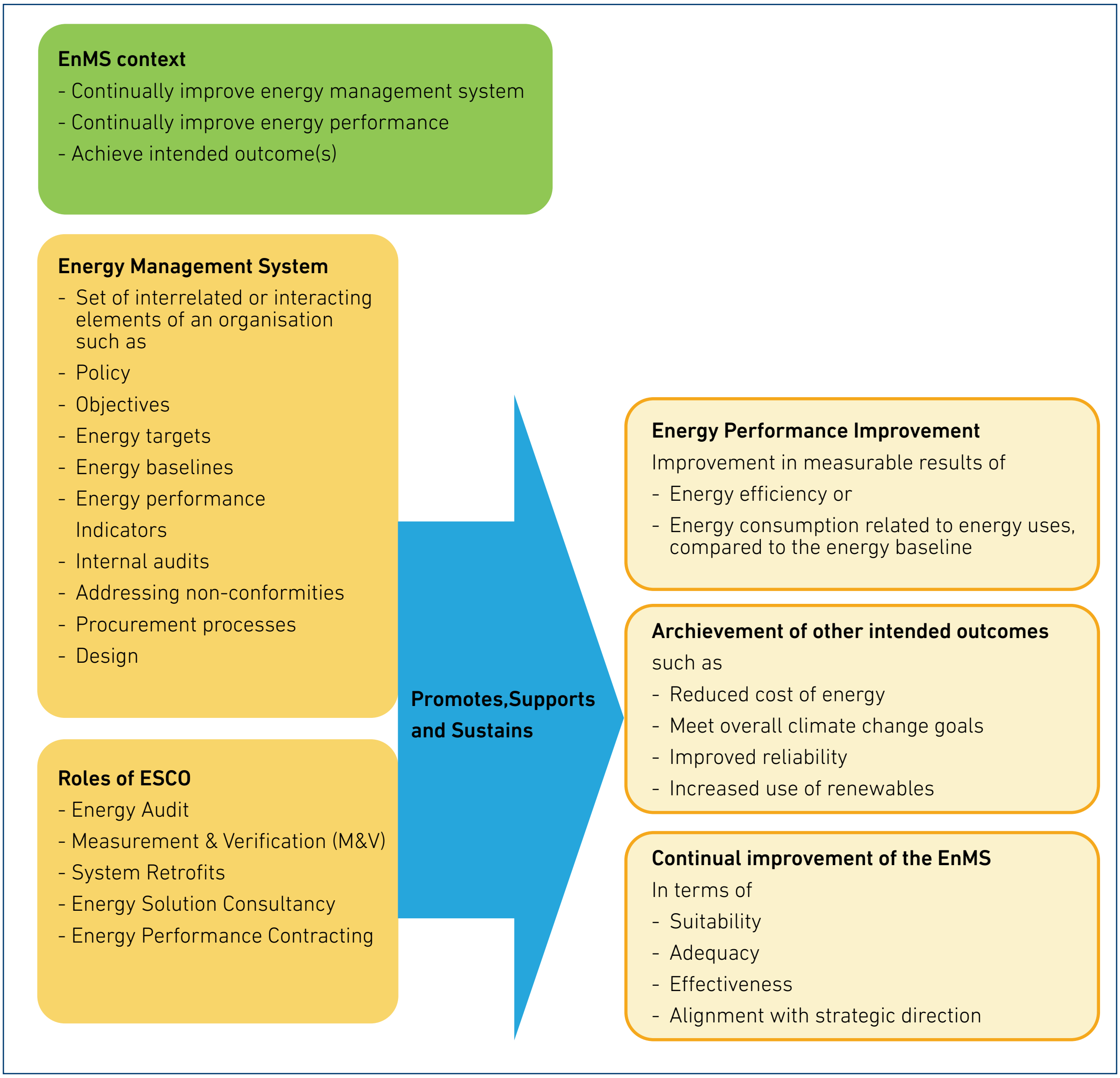
EPC = energy performance contract.

Source: Author.

Yet the numerous benefits of EPCs cannot be understated. In the quest to meet net-zero emissions by 2050 against tight fiscal budgets, a few countries have instituted policies to adopt EPCs for the retrofitting of government buildings. It is believed that EPCs managed with EMSs will expand within the next decade.

The relationship between EMSs and ESCOs for improving energy performance is depicted in Figure 7.13.

Figure 7.11. Relationship between Energy Management Systems and Energy Service Companies



EnMS = energy management system, ESCO = energy service company.

Source: Author's adaption from ISO 50001.

4. Strengths, Weaknesses, Opportunities, and Threats

The strengths, weaknesses, opportunities, and threats for EMSs and ESCOs in Lao PDR are listed in Figure 7.14.

Figure 7.12. Strengths, Weaknesses, Opportunities, and Threats for Energy Management Systems and Energy Service Companies

Strengths

Political	: Has the desire to achieve environmental sustainability
Economic	: Implementation of EnMS improves balance of payment
Societal	: People aware of the need to combat climate crisis
Technology	: Readily available and will be supported by ASEAN and other advanced nations on EE technologies
Environmental	: Adopts SDG and practice ESG
Legal	: Keen to implement policies which are beneficial to the nation

Weaknesses

People	: low awareness on benefits of EE
Industry ESCO	: Absence of accreditation of ESCOs and association
Competency	: Inadequate qualified and competent energy managers, energy auditors and M&V professionals
Tariff	: Low electricity tariff
Financial Support	: Financial institutions may not be ready to offer EPC funds
Financial Capacity	: Nedds Financial aids

Opportunities

Markets	: Vast potential to reap savings from EE
People	: Positive and hardworking people to take new challenge and accept new technologies
Industry	: Build capacity of ESCOs and establish an ESCO association
Government Support	: Commitment of government to implement EE initiatives products on EE
Technology	: Best available technologies (BAT) on EE are available

Threats

Government Policy	: Low priority on EE; faltering commitment; vague EE framework; absence of sustainable funding and implementation strategies
Electricity Tariff	: Barriers to implementation of energy saving measures by consumers
Finances	: EE loans requirement from financial institutions are too rigid and process is overly bureaucratic. Interest rate is not attractive for ROI
People	: Low capacity of competent professionals to support the industry; staff from financial institutions (FIs) do not have technical knowledge to assess loan application
Competency	: Inconsistent competency of EE professionals and ESCOs caused resistance towards adoption of EE initiatives

ASEAN = Association of Southeast Asian Nations; EE = energy efficiency; EnMS = energy management system; ESCO = energy service company; ESG = environmental, social, and governance; M&V = measurement and verification; ROI = return on investment; SDG = Sustainable Development Goal.

Source: Author.

The fact that the Government of Lao PDR requested this chapter speaks to the strengths of the nation and its political maturity. The country's energy supply is admirably dominated by hydropower, demonstrating long-term energy supply planning and execution of these plans. These national attributes provide further impetus to attain energy neutrality by 2050.

However, the low electricity price of US$0.024–US$0.045/kilowatt-hour does not bode well for energy efficiency. The low awareness of energy efficiency and lack of competent energy professionals and ESCOs are inherent weaknesses of Lao PDR. Moreover, the absence of a policy framework, legislation, and regulations on energy savings enhance the country's weaknesses. Funding from financial institutions pivots on governmental policies to accelerate energy savings and the number of ESCOs capable of offering shared EPC savings models. The low capacity of competent professionals to support the industry is a huge challenge towards energy efficiency as well. The major threat to these weaknesses is that energy efficiency will not be realised soon enough due to lack of a national energy-efficiency legislative framework.

Against this backdrop of weaknesses and threats lie opportunities for Lao PDR. The opportunities for lower energy consumption are enormous as the efforts to save energy by ESCOs and implementation of EMSs are relatively untapped. As tabulated in Chapter 1, the final energy demand is forecasted to grow from 6.11 million tonnes of oil equivalent (Mtoe) in 2030 to 9.46 Mtoe by 2060, an increase of 1.5 times from 2030. The scenario offers many opportunities to lower energy consumption substantially with the services of ESCOs and implementation of EMSs.

5. Proposed Policy Directions

To take advantage of the vast potential of energy savings through implementation of EMSs and ESCOs, the following short-term (i.e. 1–3 years) and medium- to long-term (i.e. from year 4) policies are recommended.

5.1. Short-Term Policies

(i) **Issue a special order or ministerial directive to implement EMSs**. The directive is to compel all government buildings, government-owned manufacturing plants, and installations consuming more than 500,000 kilowatt-hours/month of electricity to implement EMSs. Private sector buildings consuming energy at a similar threshold may be requested to comply with this directive as well.

(ii) **Fast-track registration of ESCOs**. Local engineering consultancy companies, practicing engineers, and architects who have experience in providing energy services locally and/or working with registered foreign professional engineers or registered ESCOs from any of the ASEAN Member States on transfer of energy-efficiency knowledge can apply for this fast-track registration scheme. This policy would allow Lao PDR to register an initial pool of ESCOs and corresponding professionals to carry out energy audits, energy-efficiency consultancy services, building or facility retrofitting, and EPC services.

(iii) **Implement a national demonstration project**. Amongst the high energy-consuming government buildings or factories, one should be chosen for an energy-efficiency demonstration project to be implemented by a registered ESCO and maintenance staff. The scope of work would be to conduct a Level 3 energy audit, implement energy savings starting from no-cost measures to high-cost measures, implement medium- and high-cost measures with an EPC, and implement an EMS. This project should be completed within 2–3 years, and the energy performance must be reported monthly to the Ministry of Energy and Mines.

(iv) **Build the capacity of energy-efficiency professionals through structured training**. One of the weaknesses is the low capacity of energy-efficiency professionals including energy auditors, energy managers, and measurement and verification professionals. These group of professionals support effective implementation of EMS and the long-term national plans on energy efficiency and conservation.

(v) **Promote energy efficiency and conservation nationally through a communication plan**. Awareness of energy efficiency and conservation is crucial towards lowering final energy use and maximum demand, resulting in a lower increase of energy supply and installed capacity. Promotion of energy efficiency and conservation should cut across all sectors. Stakeholder engagement seminars and workshops are necessary to impart knowledge, and focus should also be on educating families and students through fundamental practices of conserving energy (e.g. any appliance set on standby mode is a waste of energy).

5.2. Medium- and Long-Term Policies

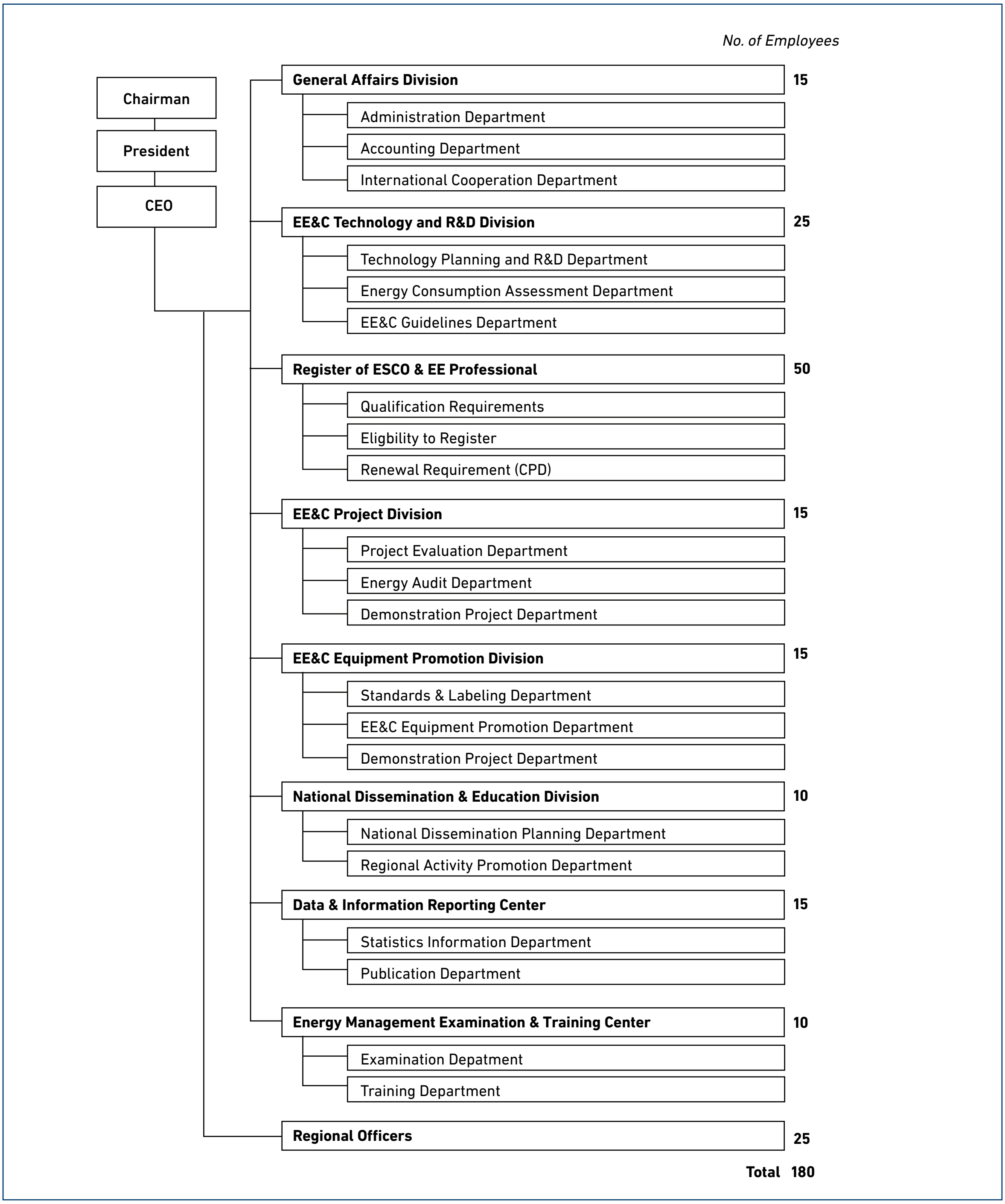
One of the key policies for Lao PDR on energy efficiency and conversation is the eventual enactment of a holistic national decree or legislation. Understandably, the process of developing the act will take considerable time. The following are the recommended medium- and long-term policy directions.

(i) **Legislate a national energy-efficiency and conservation act**. The act should have prescribed premises relating energy efficiency to the industrial, commercial, and residential sectors; prescribed energy-using products; operational requirements to implement EMSs and to carry out energy audits; establish a national implementation agency under the Ministry of Energy and Mines; enable registration of ESCOs, energy managers, energy auditors, and training providers; create a sustainable funding mechanism for energy efficiency including expenditures and conservation of the fund through investment; detail information-gathering power and enforcement provisions; and define general provisions such as publication of information, power of the minister to make regulations, and power of authority to make rules and issue guidelines.

(ii) **Legislate energy-efficiency and conservation regulations**. While an energy-efficiency and conservation act would stipulate the broad provisions of laws, regulations are required for lowering the threshold of prescribed premises to capture more consumers. The regulations should have key provisions such as an obligation to submit information on EMSs; qualification requirements and application process of energy-efficiency professionals; certificates of registration, and detailed functions and duties of ESCOs and energy-efficiency professionals; fee structures for ESCOs and energy-efficiency professionals; required reports from EMSs; and declarations of registered energy-efficiency professionals.

(iii) **Operationalise the implementation agency**. The main functions of the implementation agency as empowered by the proposed act should be to coordinate with prescribed premises, collaborate with government agencies and other bodies, recognise and utilise existing resources and infrastructure, and perform such functions and exercise such powers as assigned. These may include developing guidelines for factories, developing guidelines for buildings, registering ESCOs and energy-efficiency professionals, prescribing guidelines for energy-using equipment, promoting measures for consumers, implementing common measures including distributing financial assistance and incentives, creating a data and information repository centre, and establishing regional offices. The existing energy-efficiency department of the Ministry of Energy and Mines can be expanded into a national implementation agency with adequate human, technical, technological, and financial resources to manage all provisions of the energy-efficiency act and regulations. The typical organisation structure of an implementation agency is in Figure 7.15.

Figure 7.13. Organisational Structure of Implementation Agency



CEO = chief executive officer, EE = energy efficiency, EE&C = energy efficiency and conservation, ESCO =energy service company, R&D = research and development.

Source: Author.

(iv) **Operationalise a sustainable funding mechanism**. The success of any project depends on the timeliness and adequacy of financial resources to meet the budget requirements yearly. It should be independent from the fiscal budget and sustainable to meet the operational budget of the implementation agency, expenditures of energy-efficiency campaigns, and incentives for implementation of high-cost ESMs and others.

(v) **Enhance capacity building through structured trainings**. With growth of the gross domestic product and population in the foreseeable future, final energy demand will increase in Lao PDR. It is hoped that with effective implementation of an energy-efficiency legislative framework, EMSs, and ESCOs, the final energy demand will decouple from the scenario of business-as-usual. The needs for energy-efficiency professionals to support implementation of the act and regulations will grow even faster. The following are subjects of some courses to be conducted for capacity building: ISO 50001 EMSs; energy audits; measurement, reporting, and verification; EPCs; registration, functions, and roles of ESCOs; project management; and ESMs from electrical and thermal systems.

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Chapter 8

Minimum Energy Performance Standards

Lam Kim Seong

1. Introduction

Minimum energy performance standards (MEPS) for appliances and equipment are a widely used, cost-effective tool to improve the efficiency of products available or sold. They are used to define the minimum performance criteria that regulated thermal as well as electrical energy-using products have to meet before they can be manufactured or imported and placed in the market. They are designed to restrict the availability of low-efficiency products in the market by banning the sale of products that do not meet specified minimum energy-efficiency levels.

MEPS can be used as a regulatory tool to improve energy efficiency and to curb the impacts of climate change. MEPS aligned with international targets and best practices can be adopted to save energy and costs for consumers in Lao People's Democratic Republic (Lao PDR).

At the launch of the Super-Efficient Appliance Deployment Call to Action at the United Nations Climate Change Conference in Glasgow in 2021 (COP26), 14 economies pledged to double the efficiency of lighting, air conditioners, refrigerators, and industrial motors by 2030 (Mavandad and Malinowski, 2022). Model regulation guidelines were also developed for lighting, air conditioners, refrigerators, and industrial motors by United for Efficiency (U4E), a public–private partnership comprising the International Copper Association, National Resources Defense Council, and the United Nations Environment Programme.

Several economies in the Association of Southeast Asian Nations (ASEAN) region have adopted MEPS and energy labelling with mandatory enforcement (Table 8.1).

Table 8.1. Countries Adopting MEPS and Energy Labelling

Country	Implementation Agency	Participation Mode
Viet Nam	Ministry of Industry and Trade	Mandatory/Voluntary
Thailand	Electricity Generating Authority of Thailand	Voluntary
Malaysia	Energy Commission of Malaysia	Mandatory
Singapore	National Environment Agency	Mandatory
Indonesia	Ministry of Energy and Mineral Resources	Mandatory/Voluntary
Philippines	Department of Energy	Mandatory

MEPS = minimum energy performance standards.

Source: Author.

A list of equipment and appliances with MEPS in some regional economies is shown in Table 8.2.

Table 8.2. Equipment/Appliances with MEPS Implemented for Regional Economies

Equipment/ Appliances	Viet Nam	Thailand	Malaysia	Singapore	Indonesia	Philippines
Air Conditioners	√	√	√	√	√	√
Lamps	√	√	√	√	√	√
Refrigerators	√	√	√	√	√	√
Domestic Fans	√	√	√		√	√
Televisions	√	√	√	√		
Washing Machines	√	√	√			√
Microwave Ovens		√	√			
Electric Rice Cookers		√	√		√	
Freezers			√			
Clothes Dryers				√		
Water Heaters	√	√				
Electric Kettles		√				
Electric Irons		√				
Water Pumps		√				

MEPS = minimum energy performance standards.

Source: Author.

2. Energy-Efficiency Indicators

Various types of energy-efficiency indicators are used to define the energy-efficiency levels for equipment and appliances due to their unique functions and performance, such as air conditioners (consumption based on cooling load), water heaters (consumption based on volumetric heating/standby), and washing machines (consumption based on washing load/weight). Commonly used indicators include the Energy Star Index (%), energy-efficiency ratio, efficiency (%), cooling seasonal performance factor (CSPF), and lumens per watt (lm/W). These indicators reflect the product's energy efficiency and serve as a guide for consumers to select a product based on its energy performance.

3. MEPS Adoption

In the adoption and implementation of MEPS, the following social, economic, and environmental factors must be considered:

(i) **Energy reduction potential.** The impact of energy savings that can be realised based on usage distribution and reduction potential must be considered in the selection of appliances.

(ii) **Industry readiness**. The level of energy performance to be specified needs to consider the readiness of manufacturers.

(iii) **High-energy performance**. These products have inherent higher costs, which could affect consumers' acceptance.

On the enforcement side, standards for product performance levels as well as regulations must be developed for MEPS implementation. Investment in human resources for effective management and enforcement is inevitable.

3.1. Product Selection

Due to the wide range of electrical appliances available in the market, selected appliances should be targeted for MEPS and labelling implementation. Targeted appliances to be regulated should be assessed based on their overall energy reduction potential. High-energy appliances have higher energy savings potential. The market penetration of a product also has a direct impact on energy savings as more widespread use of a product will result in greater energy consumption reduction.

3.2. Product Standards

For any appliance to be regulated, product standards must be in place so that the energy performance level of the product can be determined. Existing standards mandated by other economies could be referred to in the standards development process. Standards in use by other countries could be adopted (without any changes) or adapted with minor changes to suit the local environment and conditions. Product performance standards to be developed must outline the capacity range to be included or excluded, energy performance levels to be achieved, and testing method to be used.

3.3. Testing Standards

To verify the compliance of a product with energy-efficiency standards, tests based on accepted testing methods as stipulated in the product standards must be carried out. Testing standards set out specific testing methods and procedures required for the product so that the energy efficiency of the product can be verified. These standards provide independent assurance and enhance customers' confidence of the quality, reliability, and safety of products.

3.4. Product Registration

Appliances that fall under MEPS, known as 'regulated goods', should be registered with the relevant registration bodies. The registration of products, by manufacturers or importers, serves the purpose of monitoring and enforcing MEPS compliance.

4. MEPS Implementation

A systematic approach should be employed for MEPS implementation in Lao PDR. Table 8.3 depicts the roadmap, and Figure 8.1 summarises the implementation of MEPS and energy labelling.

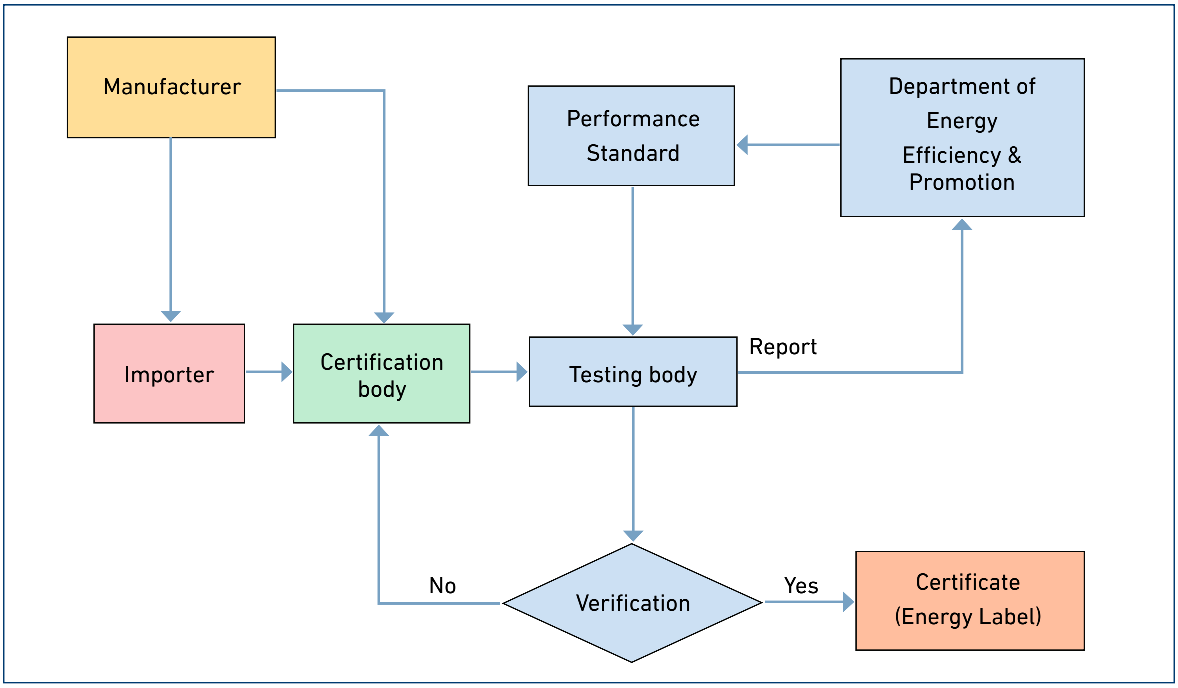
Table 8.3. Roadmap and Implementation Programme for MEPS in Lao PDR

Phase	Milestones Activities	Target Groups	Organisations Involved	Time Schedule
Phase 1	Stakeholders engagement	DEEP	Engineering instituions and associations Regulatory bodies Standard-writing organisations Consumer associations	1 year
Phase 2A	Setting up of registration requirements	DEEP	DEEP	3 years
Phase 2B	Setting up of certification and assessment bodies/standard-working group/testing bodies for MEPS	DEEP and IS	DEEP and IS	1 year
Phase 3A	Certification and assessment bodies	DEEP and IS	DEEP and IS	1 year
Phase 3B	Standards working group	DEEP and IS	All stakeholders	2 years
Phase 3C	Testing lab	DEEP and IS	Appointed lab	5 years

DEEP = Department of Energy Efficiency and Promotion, IS = Institute of Standards, MEPS = minimum energy performance standards.

Source: Yau (2020).

Figure 8.1. Flow Diagram of MEPS and Energy Labelling Programme



MEPS = minimum energy performance standards.

Source: Author.

Involvement of government agencies and stakeholders are crucial. Relevant stakeholders, such as regulatory bodies, engineering institutions, manufacturers, importers, and consumer bodies, must be identified and incorporated for successful implementation.

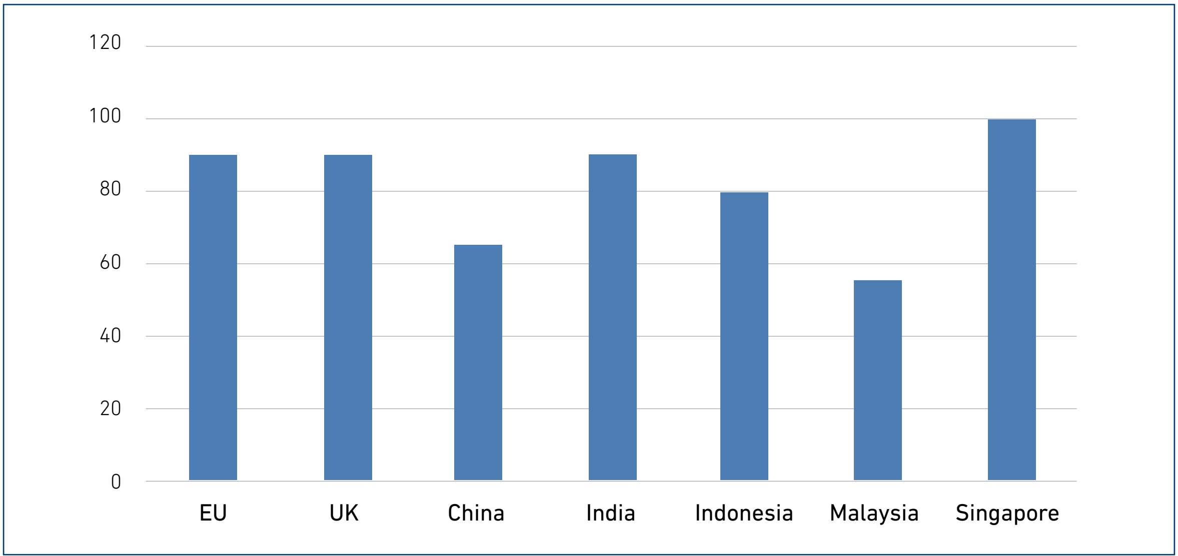
5. Specific MEPS Methodology

The methodology used for setting MEPS for commonly used equipment and appliances should be aligned with U4E's Model Regulation Guidelines.[1]

5.1. Lighting

The metric used for lighting efficiency is lamp luminous efficacy or lm/W. The advent of LED has brought about tremendous improvement in lamp luminous efficacies from below 20 lm/W (incandescent lamps) to greater than 80 lm/W. Figure 8.2 shows a comparison of LED MEPS for some countries that have implemented lighting MEPS.

Figure 8.2. LED Lighting – MEPS Comparison
(lumens per watt)



EU = European Union, LED = light-emitting diode, MEPS = minimum energy performance standards, UK = United Kingdom.
Source: Mavandad and Malinowski (2022).

[1] U4E, Model Regulation Guidelines, https://united4efficiency.org/resources/model-regulation-guidelines/

With the exception of the European Union and the United Kingdom, most countries have not adopted technology-neutral standards. Separate technology-specific standards have been set for other non-LED fittings, such as conventional fluorescent tubes utilising magnetic or electronic ballasts, compact fluorescent lamps (CFLs), and incandescent lamps. Adopting technology-specific MEPS has not led to a significant reduction of lighting energy consumption, as it allows inefficient fittings to still be assessable in the market. Implementing technology-neutral MEPS for lamps will help phase out less-efficient lamps such as CFLs and incandescent lamps, however.

5.2. Air Conditioners

The CSPF is used to define efficiencies of air conditioners. Implementation of MEPS by some regional economies is shown in Table 8.4.

Table 8.4. Air Conditioner MEPS of Regional Economies

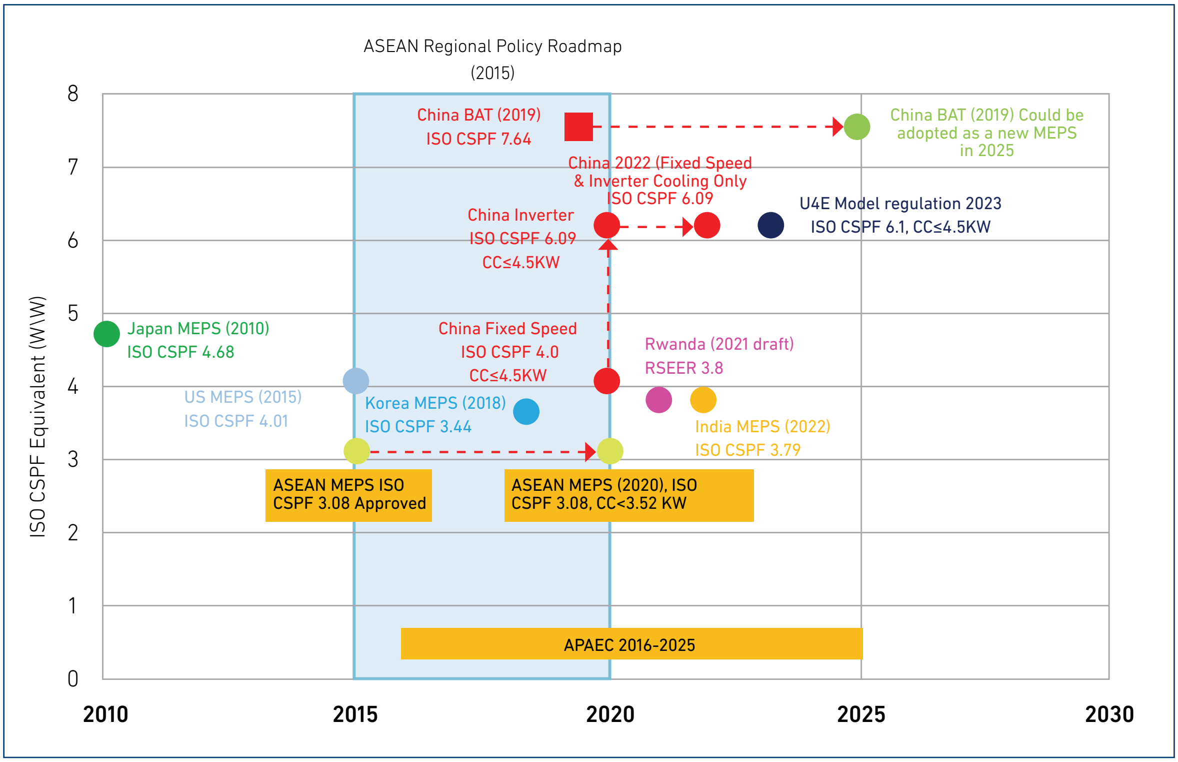
Regional Economies	CSPF as MEPS	Adoption Year	Remarks
Japan	4.68	2010	
China	4.00	2020	
	6.09	2023	
	7.64	2025	Proposed
Singapore	4.60	2023	
	6.09	2025	
Thailand	3.90	2023	Sold mostly with 4.00–4.30 CSPF
Indonesia	3.40	2023	Target 4.00–4.20 by 2025
	4.00–4.20	2025	Target
Malaysia	3.10	2014	For cap. < 4.5 kW
	2.90	2014	For cap. ≥ 4.5 kW, < 7.1 kW
ASEAN	3.70	2023	
	6.09	2024	

ASEAN = Association of Southeast Asian Nations, CSPF = cooling seasonal performance factor, MEPS = minimum energy performance standards.

Source: Author.

China is the global leader for split air conditioner efficiency, with its MEPS ahead of those of other countries and regions, including the European Union, Japan, United Kingdom, and United States. Its current MEPS is set at a CSPF of 6.09 W/W with an ambitious target of 7.64 W/W for 2025.[2] As the cooling demand is high for most economies and air conditioners are used often, China's air conditioner MEPS should be the standard to be targeted. Most manufacturers already have the technology and know-how, so this is achievable. Figure 8.3 shows the regional roadmap for air conditioner MEPS.

Figure 8.3. Regional Roadmap for Air Conditioner MEPS



ASEAN = Association of Southeast Asian Nations, BAT = best-available technology, CSPF = cooling seasonal performance factor, ISO = International Organization for Standardization, MEPS = minimum energy performance standards, US = United States.

Source: ASEAN-SHINE (2021).

[2] CSPF, a ratio of cooling seasonal total load (W) over cooling seasonal energy consumption (W).

5.3. Refrigerators

Refrigerator energy efficiencies are measured based on annual energy consumption (kilowatt-hours [kWh] per year). The methodology used to determine their MEPS varies depending on size (capacities in litres [L]) and configuration (number of doors). Due to the wide range of refrigerators available in the market, most countries have adopted ratings for single- and double-door configurations.

Some countries specify refrigerator MEPS based on Energy Star ratings, which are converted from the annual energy consumption based on the refrigerator's capacity and configuration. The calculation methodology used to determine the star ratings varies. In Singapore, the MEPS specified is 'two-tick' for capacities up to 900 L, with and without freezers. The maximum annual energy consumption for 400-L refrigerators without freezers is 334 kWh/year and with freezers, 434 kWh/year. In Malaysia, the minimum mandatory rating is two-star, and for a typical double-door refrigerator with a 400-L capacity, the maximum allowable consumption is 630 kWh/year. Higher efficiency or lower maximum allowable consumption has been proposed.

Table 8.5 is the MEPS for refrigerators in Malaysia; two-star is the required rating that must be met. The star rating is determined from the Star Index Value, which is calculated using tested energy-efficiency factor derived from measured electrical power consumption of the appliance.

Table 8.5. Star Ratings of Refrigerators in Malaysia

Star Rating	Star Index Value
5	Star Index ≥ +25%
4	(+10%) ≤ Star Index < (+25%)
3	(-10%) ≤ Star Index < (+10%)
2	(-25%) ≤ Star Index < (-10%)
1	(-35%) ≤ Star Index < (-25%)

Source: Suruhanjaya Tenaga (Energy Commission of Malaysia).

Table 8.6 demonstrates the MEPS for refrigerators in Singapore. The annual energy consumption determined corresponds to Singapore's minimum required rating of 'two-tick'. Of the two MEPS, it is easier to determine a refrigerator's performance under Singapore's MEPS.

Table 8.6. MEPS for Refrigerators in Singapore

Type of Refrigerators	Adjusted Volume, $V_{adj\ tot}$	Maximum Annual Energy Consumption (AEC) in kWh
Refrigerator without freezer	≤ 900 liters	$(368 + (0.0892 \times V_{adj\ tot})) \times 0.461$
Refrigerator with freezer	≤ 900 liters	$(465 + (1.378 \times V_{adj\ tot})) \times 0.427$
Refrigerator with freezer and through-the-dorr ice dispenser	≤ 900 liters	$(585 + (1.378 \times V_{adj\ tot})) \times 0.409$

kWh = kilowatt-hour, MEPS = minimum energy performance standards.

Source: National Environment Agency of Singapore.

6. Strengths, Weaknesses, Opportunities, and Threats

Figure 8.4 summarises some attributes that are unique for establishing MEPS in Lao PDR.

Figure 8.4. Strengths, Weaknesses, Opportunities, and Threats for MEPS in Lao PDR

Strengths		**Weaknesses**	
Political	Has The right ministry to lead MEPS implementation	People	Low awareness on benefits of MEPS
Economic	Implementation of MEPS leads to reduced energy consumption in the residential and end-user sector	Legal	Lack of EE&C legislative framework & enabling infrastructure
Societal	Has support from stakeholders and professional bodies	Resources	Lack of responsible agency/resources to develop MEPS
Technology	Readily available and will be supported by ASEAN and other advanced nations on EE technologies	Financial Support	Needs funding mechanism to support MEPS development
Legal	Keen to implement Policies which are beneficial to nation	Technical Capacity	Lack of standard on MEPS & Energy Efficiency guidelines
		Infrastructure	Lack of testing facilities
Opportunities		**Threats**	
Markets	Great potential to reduce energy consumption	Dumping Ground	Becomes dumping ground of inefficient & energy-guzzling appliances/equipment by manufacturers
People	Potential to create awareness through public promotions and education	Cheap Appliances	Barriers to implementation of energy-saving measures
Industry	Build capacity of ESCOs and establish an ESCO association	Affordability	People end up paying more in using inefficient appliances/equipment due to higher consumption of electricity
Government Support	Commitment to implement MEPS		
Technology	Utilization of best available technologies from manufacturers		

ASEAN = Association of Southeast Asian Nations, EE = energy efficiency, EE&C = energy efficiency and conservation, MEPS = minimum energy performance standards.

Source: Author.

The low electricity tariff of US$0.024–US$0.045/kWh – coupled with low public awareness of energy efficiency – is a barrier towards energy consumption reduction efforts in Lao PDR. Moreover, the current absence of MEPS allows for the manufacturing and importing of low energy-efficiency equipment and appliances. The adoption of MEPS would present an opportunity for Lao PDR to lower energy consumption in the residential and end-use sectors.

7. Policy Recommendations

The implementation of MEPS is expected to take time in Lao PDR due to the availability of a wide range of equipment and appliances, lack of sufficient testing facilities, lack of sufficient performance standards, and needed capacity building. However, implementation of MEPS would help Lao PDR reduce energy consumption.

The implementation of MEPS should be carried out in stages.
Short-term plan (within 2–3 years from the commencement of MEPS implementation):

(i) **Create energy-efficiency awareness**. The lack of energy-efficiency awareness is hindering consumers from buying into the concept of energy savings. An energy-efficiency awareness programme should be set up regarding the importance of energy consumption reduction. It could be carried out through school curricula, public road shows, and seminars and workshops.

(ii) **Establish an implementing agency to lead and to execute the MEPS implementation plan**. This agency/department should be tasked to develop the necessary product specifications and testing procedures, manage certification bodies, and set up the registration bodies.

(iii) **Develop performance and testing standards**. This should be carried out through a consultative programme. Stakeholders, such as professional bodies, industrial and commercial associations, academia, and research institutions, whose involvement are crucial to the implementation of MEPS should be identified and incorporated into the programme. These stakeholders should assist in assessing the effectiveness of targeted product impact on the energy reduction objective and establishing the energy-efficiency levels achievable depending on manufacturers' readiness and best available technologies.

Long-term plan (within 4–5 years from the commencement of MEPS implementation):

(i) **Establish testing facilities**. Testing facilities, an important element of MEPS, are required to carry out product compliance tests. In the absence of accredited testing facilities, an interim measure would be to accept independent third-party testing for energy-efficiency verification. International and regional facilities will be available to assist with the testing conforming to the standards set.

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Chapter 9

Renewable Electricity and Energy Transition in Lao PDR: Opportunities for Green Hydrogen and Ammonia

Anousak Phongsavath

1. Introduction

The global impetus towards a low-carbon economy has led to the emergence of decarbonised or renewable hydrogen and ammonia as crucial energy carriers that can support the transition of Lao People's Democratic Republic (Lao PDR) towards a net-zero emissions status and sustainable energy system. Redirecting surplus renewable hydropower electricity to decarbonised hydrogen and ammonia production represents a significant but under-evaluated opportunity to diversify Lao PDR's economy across multiple sectors, contribute to sustainable development objectives, and reduce emissions.

Ultimately, the existing and planned hydropower fleet places Lao PDR in a unique position to rapidly adopt renewable hydrogen and ammonia as a new and dynamic industry geared to emerging global trends in decarbonised energy systems and transitions. Redirecting surplus hydroelectricity presents Lao PDR with an opportunity to position itself as an early adopter and regional leader in the hydrogen-ammonia energy system.

The internationally accepted principle to differentiate decarbonised hydrogen and ammonia from fossil fuel derivatives – and the definition used throughout – is the singular reliance on renewable electricity for the entire production, storage, and distribution processes of hydrogen and ammonia. Decarbonised hydrogen and ammonia produce less than 1 kilogram (kg) of carbon dioxide equivalent (CO_2e) per kg of hydrogen. Fossil fuel-based processes produce approximately 10 kg CO_2e/kg of hydrogen.

To capitalise on this opportunities, in 2023, the Government of Lao PDR prioritised developing an integrated and comprehensive national roadmap, strategy, and action plan as a critical first step towards developing a green hydrogen and ammonia industry. Indeed, establishing a robust and integrated planning process is critical to allow policymakers to ensure that sustainable economic and social benefits are shared, while improving community livelihoods and maintaining the integrity of the environment. The strategy will set out the vision and actions to develop a decarbonised hydrogen and ammonia industry in Lao PDR, making important contributions to the renewable energy transition goals set out in the *9th Five-Year National Socio-Economic Development Plan, 2021–2025* (MPI, 2020).

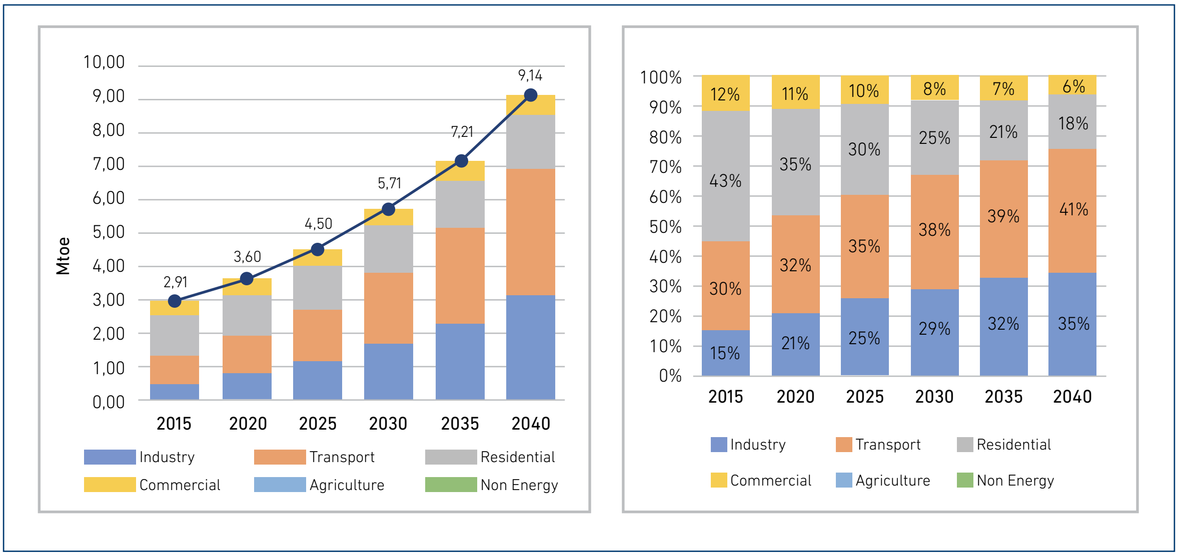
Hydrogen and ammonia are strategically important for countries like Lao PDR that are heavily dependent on the importation of liquid fossil fuels and fossil fuel derivatives, including fertilizers and chemical feedstocks. In transitioning from an emerging technology to viable commercial assets, the policy imperatives woven into hydrogen and ammonia development must focus on integrated decision-making; flexible governance; skills and capabilities; market activation; concession agreements; safety and risk management; and the importance of research, development, and innovation investment.

2. Energy Sources in Lao PDR

Consistent with Lao PDR's riparian neighbours, the majority of energy evaluations, modelling, and analysis – expressed as statutory policy and planning architecture – are concerned with electricity generation, demand, and consumption. A review of the *9th Five-Year National Socio-Economic Development Plan, 2021–2025* and the energy and renewable energy plans reveals a nearly singular focus on electricity (Government of Lao PDR, 2011; MEM, 2021). Other energy sources have received limited attention in energy planning, despite biomass, oil, gas, and petroleum derivatives making up the majority of total energy consumption in Lao PDR (MEM and ERIA, 2020; Kimura, Phoumin, Purwanto, 2023).

Comprehensive and integrated energy planning and policy demand more than a singular focus on electricity. Global energy outlook assessments have addressed this oversight. Electricity represents 20% of the 2021 global total final energy consumption compared to liquid and gaseous fossil fuels, as oil comprises 40% of total final energy consumption and natural gas, 16% (IEA, 2021, 2022).[1] Petroleum imports and derivatives represented 30% of Lao PDR's total energy consumption in 2015 and are estimated to become 37% in 2025, more than twice the proportion of electricity at 13% in 2015 and 20% in 2025 (Figure 9.1). Imported oil, used primarily for road transport and due to the increased demand for passenger vehicles, is estimated to increase to 44% in 2040.

Figure 9.1. Total Lao PDR Final Energy Consumption by Sector, 2015–2040



Mtoe = million tonnes of oil equivalent.

Source: MEM and ERIA, 2020.

[1] IEA, Share of World Final Energy Consumption by Source 2019, https://www.iea.org/data-and-statistics/charts/share-of-world-total-final-consumption-by-source-2019 [accessed March 2023]

2.1. Electricity Generation in Lao PDR

Lao PDR has an estimated 24,000 megawatts (MW)–26,000 MW[2] of potential hydropower capacity of which 18,000 MW are technically exploitable (MEM, 2021; IHA, 2021). In 2023, Lao PDR had an overall installed power generation capacity of 11,652 MW with actual production estimated to be approximately 57,000 gigawatt-hours (GWh) (Bounpha, 2023). About 83% (9,658 MW and 45,050 GWh) was from hydropower, 16% (1,878 MW and 12,200 GWh) from the Hongsa coal-fired power plant, with the remaining from solar (56 MW and 95 GWh) and biomass (43 MW and 228 GWh).

The government continues to rely on the electricity sector as a major driver of growth and development and a source of increased revenue through exports to neighbouring countries. The electricity sector nearly tripled its share of the economy over the past decade, accounting for 21% of exports in 2021 and 25% in 2022,[3] substantial increases compared to 5% in 2010 (BOL, 2021). Electricity led the export sector and power generation in 2021 with 9.7% of real gross domestic product as well (BOL, 2021). Electricity exports are expected to more than triple by 2030 (Bounpha, 2023).

Based on recent memoranda of understanding with neighbouring countries, Lao PDR aims to dedicate 18,000 MW of installed capacity to export by 2030, an increase of about 300% from present export levels. Exports comprise commitments of 10,500 MW of electricity to Thailand[4] and 5,000 MW to Viet Nam (of which less than 1,000 MW has been utilised so far) (MEM, 2021). New agreements with Cambodia will see 6,000 MW exported mostly from the Don Sahong Dam on the Mekong River and two proposed coal-fired plants in southern Lao PDR.[5] Generation from the Monsoon Wind Power Project of 600 MW is destined for Viet Nam. Malaysia has also expanded its agreement to purchase 300 MW of electricity from 100 MW via the Thailand grid, and there are also plans to sell up to 600 MW to Myanmar and 100 MW to Singapore.

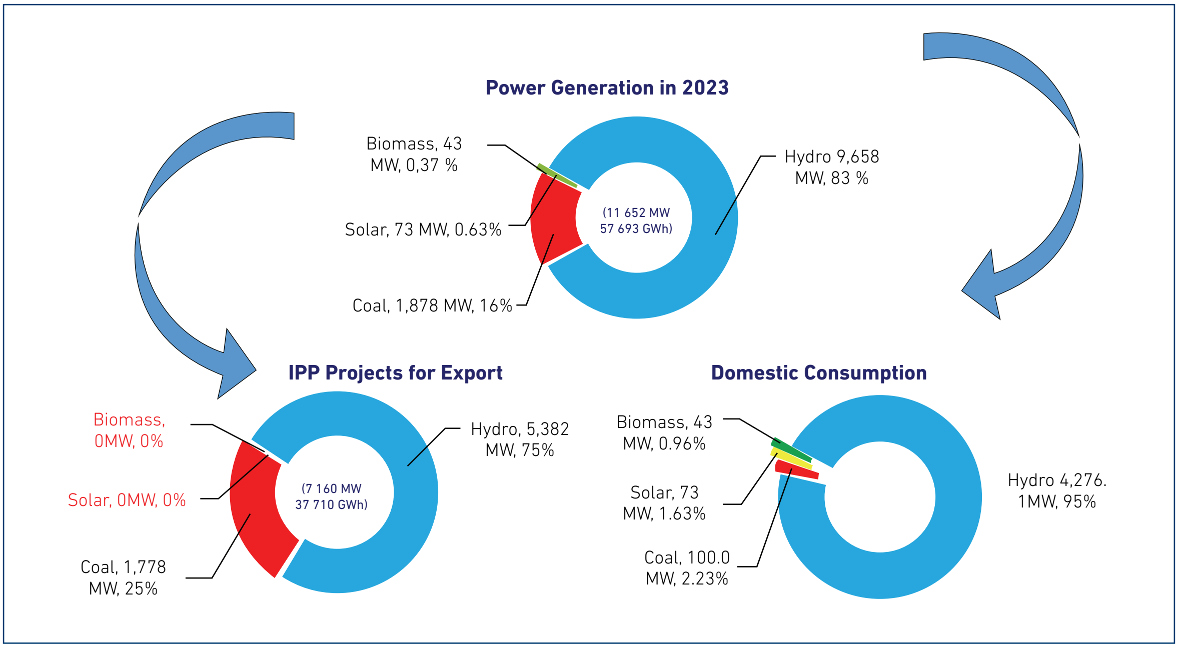
[2] The International Hydropower Association assumes that the more exploitable and profitable projects are usually developed first, with subsequent projects costing more and having less projected production efficiencies (IHA, 2021).

[3] Electricity contributed 21.2% to export revenues in 2021 and 25.0% in 2022. See OEC, Laos, https://oec.world/en/profile/country/lao [accessed 1 June 2024]

[4] About 6,000 MW was exported to Thailand in 2020.

[5] At the time of this writing, discussions with Ministry of Energy and Mines officials indicate that the two coal-fired plants may not proceed due to uncertainties around the kilocalorie content of local lignite and the rising costs of Indonesian imports.

Figure 9.2. Lao PDR Electricity Generation by Source, 2023



GWh = gigawatt-hour, IPP = independent power producer, MW = megawatt.

Source: Bounpha (2023).

In Lao PDR, total domestic electricity demand in 2023 was 11,583 GWh, which is expected to increase to 13,700 GWh in 2024 (Kyophilavong, 2024). Industry consumption was the largest user (39%), followed by cryptocurrency production (24%), and the residential (22%) and commercial/government (13%) sectors.

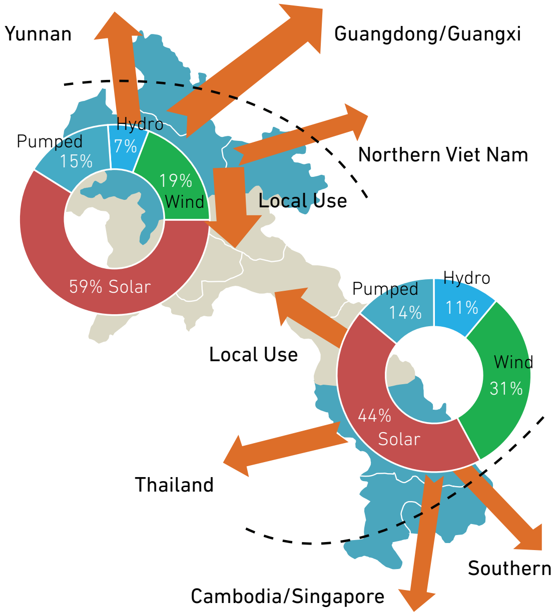
The proposed development of future renewable electricity in Lao PDR is illustrated in Figure 9.3. Hydropower generation is planned to rise from 9.6 gigawatts (GW) to 28.0 GW – a 290% increase – assuming all planned, under construction, and memoranda of understanding developments are realised. Solar will increase by 15.6 GW and wind by 13.7 GW. Currently, only projects under development can proceed, and over 300 projects are categorised as 'to be developed after 2030' (The Asia Foundation, 2021). The total renewable energy generation planned by 2030 is 5.7 GW, excluding the 1.0 GW of planned coal generation (Phongsavath, 2024).

Figure 9.3. Renewable Electricity Development Plan

Hydropower	No	MW
Existing	81	9615.14
Under-Construction	21	1259.3
CA	18	2466.2
PDA	109	6431.95
MOU	245	8143.43
Total	**474**	**27916.02**

Solar	No	MW
Existing	8	56
Under-Construction	0	0
CA	4	2688
PDA	13	873
MOU	25	12147
Total	**50**	**15672**

Wind	No	MW
Existing	0	0
Under-Construction	0	0
CA	1	600
PDA	1	187.2
MOU	17	13.000
Total	**19**	**13.787**



CA = concession agreement, MW = megawatt, MOU = memorandum of understanding, PDA = project development agreement.

Source: Bounpha (2023).

Estimates of domestic electricity demand across scenarios –which include industry expansion and more electric vehicles – range from 2.1 GW to 2.6 GW in 2024 and 2.9 GW to 3.8 GW in 2030 (MEM, 2021). An estimated surplus of approximately 2.0 GW to 2.5 GW is therefore available from the 4.5 GW assigned to meet domestic demand.

Redeploying seasonal renewable electricity that is surplus to domestic demand to decarbonised hydrogen and ammonia production is a central pillar of the rapid development of the industry in Lao PDR. Seasonal generation refers to total generation during the wet season months of typically May through October and dry season generation during the remainder of the calendar year. Surplus generation refers to additional supply in excess of domestic electricity demand and export obligations. Redeployment of existing surplus renewable electricity helps Lao PDR avoid the capital expenditures of renewable electricity infrastructure and confers a significant advantage in developing a national hydrogen-ammonia industry. This advantage translates as reduced construction times and up to a 60% reduction in capital expenditure and investment (IRENA, 2022; Hosseini et al., 2023).

3. Hydrogen and Ammonia Production Chain

Flagship reports by The Royal Society, International Energy Agency, Commonwealth Scientific and Industrial Research Organization (CSIRO), and International Renewable Energy Agency identify hydrogen and ammonia (and their derivatives) as having a significant role in meeting global climate change objectives and national net-zero emissions goals.[6]

Hydrogen, as a component of ammonia, can be produced by the gasification of coal or biomass, steam reforming of methane, water electrolysis, or methane pyrolysis, with each pathway characterised by high levels of energy intensity and a process dependent on levels of technical and commercial maturity. Over 95% of global hydrogen is produced by steam methane reforming, associated with 9.3 kg of CO_2e for every 1 kg of hydrogen produced.[7] In 2022, hydrogen production resulted in more than 900 million tonnes of emissions – only 2% of total global emissions.

General convention designates hydrogen produced via methane reforming without carbon capture and storage (CCS) as grey hydrogen, as blue hydrogen when CCS is included in the production process, and as green hydrogen when only renewable electricity is deployed to produce electrolytic hydrogen. These qualitative classifications are also applied to ammonia (Figure 9.4). Grey hydrogen accounts for 96% of global production, responsible for 10 kg of CO_2e for every 1 kg of hydrogen, CCS reduces this to 1–3 kg of CO_2e/kg of hydrogen in blue hydrogen production, and less than 1 kg of CO_2e/kg of hydrogen for green hydrogen.

[6] See reviews by IEA (2021), The Royal Society (2018), IRENA (2021), and CSIRO, HyResource, https://research.csiro.au/hyresource/

[7] Not including the carbon footprint of compression and transport.

Figure 9.4. Classification of Hydrogen Production According to Carbon Intensity

Color	Primary Feedstock	Primary energy Source	Primary Production Process	Carbon Intensity $kgCO_{2}e/kgH_{2}$
Brown	Coal or Lignite	Chemical Energy in Feedstock	Gasification & Reformation	
Gray	Natural Gas	Chemical Energy in Feedstock	Gasification & Reformation	
Blue	Coal, Lignite, or Natural Gas	Chemical Energy in Feedstock	Gasification with Carbon Capture and Sequestration	
Pink	Water	Nuclear Power	Electrolysis	
Green	Water	Renewable Electricity	Electrolysis	
	Biomass or Biogas	Chemical Energy in Feedstock	Gasification, Reformation, & Thermal Conversion	

kg = kilogramme.

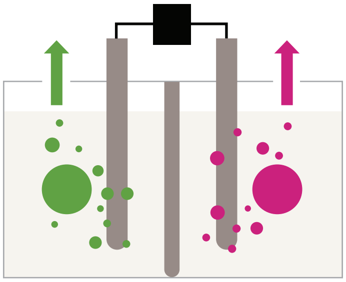
Source: Connell et al. (2022).

3.1. Hydrogen Production

Electrolytic hydrogen production, also known as electrolysis, splits water into hydrogen and oxygen using electricity in an electrolysis cell (Figure 9.5). The electrolysis produces pure hydrogen, which is ideal for low-temperature fuel cells (e.g. in electric vehicles currently in production by BMW, Hyundai, and Toyota).

There are four main electrolyser technologies: alkaline, proton exchange membrane (PEM), anion exchange membrane (AEM), and solid oxide electrolyser cell (SOEC). The most mature electrolysis technology is the alkaline electrolyser, which has been in commercial use since the mid-20th century. An alkaline electrolyser uses a cell with a cathode, anode, and electrolyte based on a solution of caustic salts (e.g. sodium hydroxide). Alkaline technology has a relatively low capital cost compared to other types of electrolysers. Other advantages include virtually instant operation and resistance to humidity and salt air. Alkaline fuel cells are mostly used in backup generators or long-duration uninterruptible power supplies as well as for powering telecommunications towers.

Figure 9.5. Production of Hydrogen and Oxygen via Alkaline Electrolysis



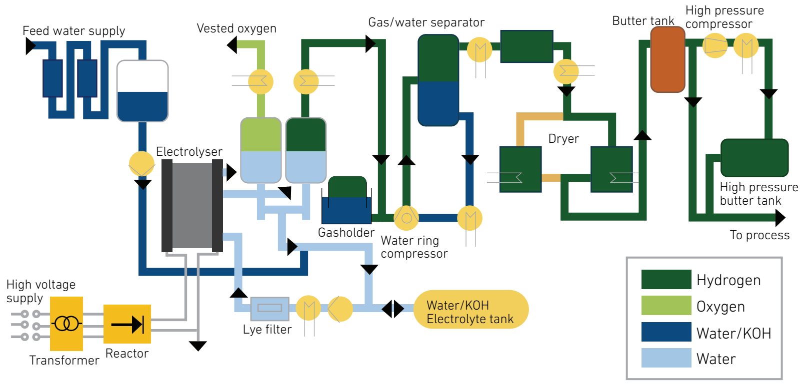
Source: The Royal Society (2018)

Alkaline electrolysis

- A DC electrical power source is connected to two electrodes which are placed in the water
- An electrolyte or a membrane allows the charge exchange and is the namesake of the various technologies
- Hydrogen will appear at the cathode. Oxygen at the anode
- The production rate is proportional to the total electrical charge

Electrolysis

- 1 kg of hydrogen needs 9 liters of waterr
- The energy content of 1 kg = 39,4 kwh(or enough to drive a medium size car for 100 km).

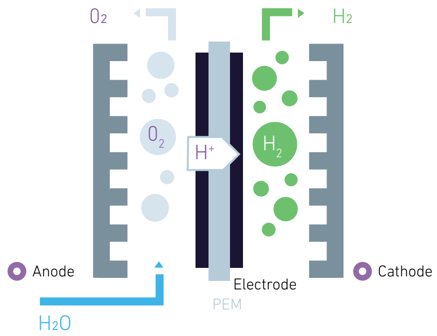


kg = kilogram, km = kilometre, kWh = kilowatt-hour.

Source: The Royal Society (2018) and IRENA (2021a).

PEM electrolysers utilise an ionically conductive solid polymer rather than a liquid to drive hydrogen production (Figure 9.6). PEM electrolysers can react quickly to the fluctuations in power generation typical of renewable power and produce higher-purity hydrogen gas. PEM electrolysers can be used for renewable power-to-gas applications.

Figure 9.6. PEM Electrolyser for Green Hydrogen Production



- Electrodes are attached on both sides of the proton exchange membrane
- The proton exchange membrane is the electrolyte
- The proton exchange membrane acts as separator to prevent mixing of hydrogen and oxygen gases

- High power density
- Well suited to intermittent renewable electricity supply
- Extended dynamic range and direct connection to PV and wind renewables as well as hydropower
- High efficiency
- High purity of gases
- Relatively low maintenance

PEM = proton exchange membrane.

Source: Connell et al. (2022).

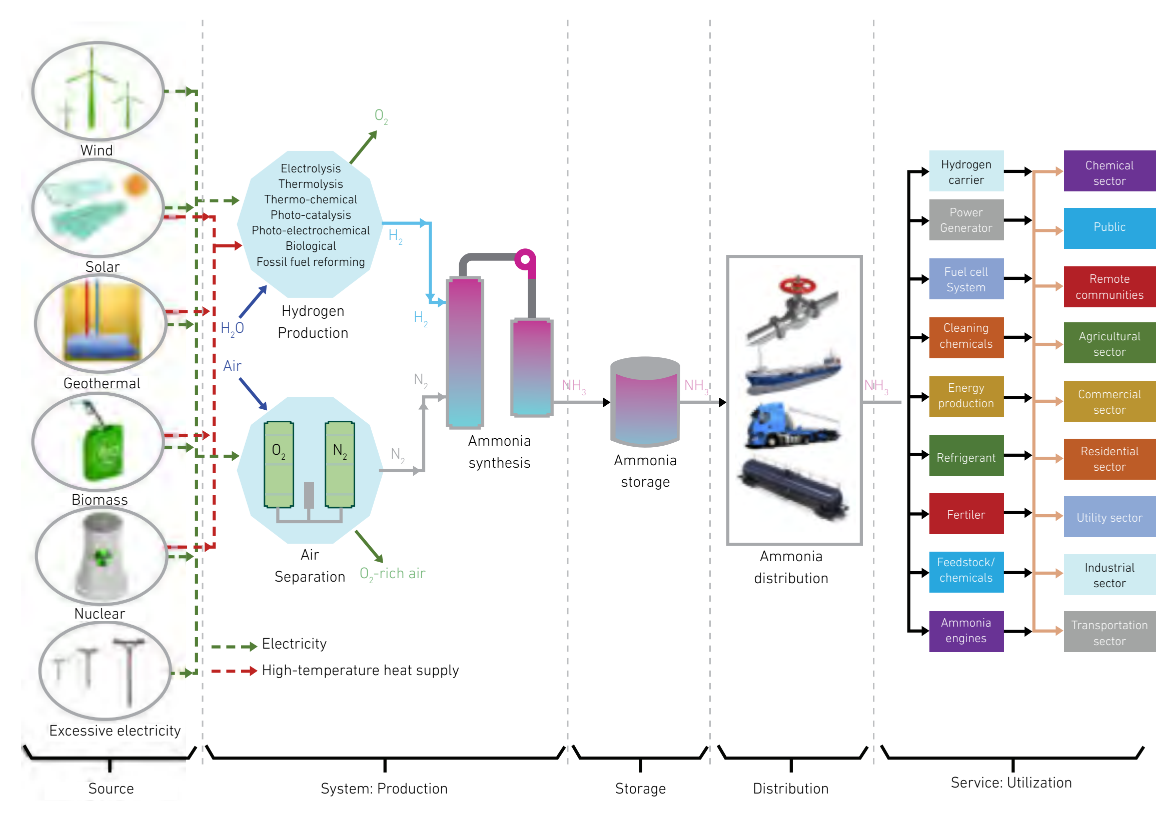
High-temperature SOEC utilises ceramic membranes that conduct ions at very high temperatures and pressures to separate superheated steam into oxygen and hydrogen. The efficiency offered by a SOEC electrolyser is much higher than other technologies, but this technology is in an early commercialisation stage.

Increasing the size of an alkaline electrolyser facility has the largest cost reduction effect; however, facility size is also a function of the intended application. Smaller units are best aligned to residential, agricultural, or transport use where higher investment costs can be offset by onsite reductions in transport costs. Alkaline electrolyser investment costs vary according to plant size – US$1,000 per kilowatt (kW) as a median estimate for a 1-MW unit, US$620/kW for a 10-MW unit, and US$450/kW for a 100-MW unit (Böhm et al., 2020; IRENA, 2021). PEM electrolysers range from US$700 to US$1,400/kW.

3.2. Ammonia Production

Ammonia is an essential global commodity. Around 85% of all ammonia is used to produce synthetic nitrogen fertilizer, and the balance is deployed in a wide range of other applications such as refrigeration, mining, pharmaceuticals, water treatment, plastics and fibres, and abatement of nitrogen oxides (Figure 9.7). The relatively inefficient application of nitrogen-based fertilizers (i.e. approximately 14% reaches plant roots) has a substantial impact on global nitrogen, potential eutrophication of waterways, and biodiversity (IRENA, 2022). Ammonia is also a highly efficient and relatively safe hydrogen carrier (Giddey et al., 2017; The Royal Society, 2020).

Figure 9.7. Economic Cycle of Ammonia from Production to Utilisation



Source: Erdemir and Dincer (2021).

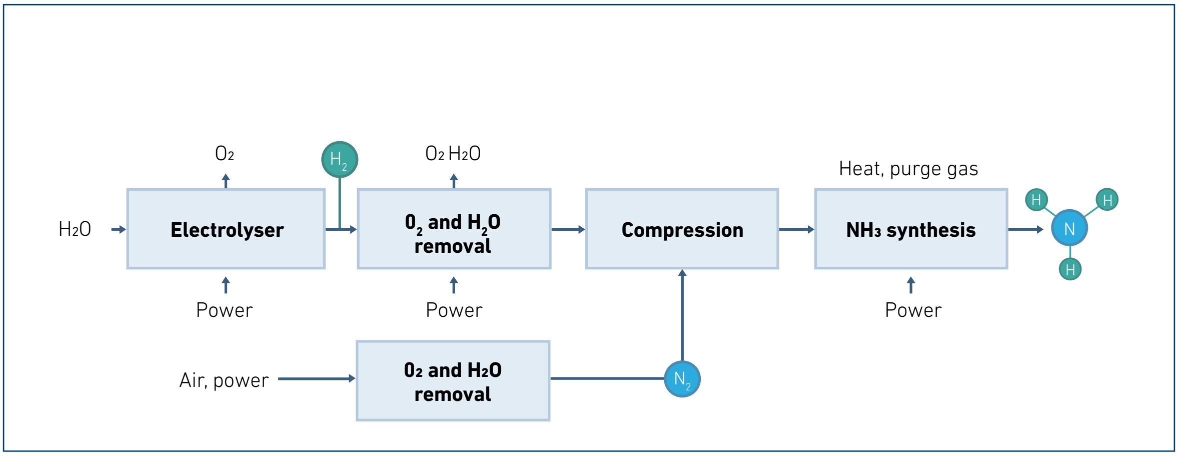
Global production of up to 176 million tonnes of ammonia per year only accounts for around 2% of overall global emissions (The Royal Society, 2020). However, to meet net-zero emissions targets, an urgent plan to decarbonise ammonia production needs to be developed and implemented, which in turn would open opportunities for ammonia to replace fossil fuels in other applications.

The electrolysis of water to produce hydrogen offers a pathway to zero-carbon ammonia production but relies on low-cost renewable electricity and continuing reductions in electrolyser costs. Renewable energy electricity costs are already close to a tipping point for the cost-competitive production of zero-carbon ammonia (IRENA, 2022). An ammonia market would strengthen the economic opportunities to extend renewable energy penetration into Lao PDR.[8]

[8] Developing and enforcing a safety regulatory framework to include the production, storage, and distribution of ammonia is key as identified by decision-makers (Ward and Smajgl, 2023). International standards have been developed over the 100 years of ammonia production and can be readily adapted for Lao PDR ammonia production.

To produce renewable ammonia, water is split into hydrogen and oxygen via electrolysis using a renewable electricity source. Various electrolysis technologies can be used, which vary in temperature and energy consumption (The Royal Society, 2020; IRENA, 2021, 2022).[9] Nitrogen is purified from the air using an air separation unit. Hydrogen plus nitrogen are converted to ammonia in a Haber-Bosch synthesis loop (Figure 9.8).

Figure 9.8. Ammonia Synthesis Using Water, Air, and Renewable Electricity



Source: Rouwenhorst, Travis, Lefferts (2022).

The Haber-Bosch process requires high temperatures (400°C–500°C), high pressure (100 bar–200 bar), and purified nitrogen and hydrogen. The high plant costs associated with these high temperatures and pressures and reliance on fossil fuels (i.e. natural gas) translate as industrial-scale operations producing thousands of tonnes per day and generally accepted production boundaries of ammonia.

Developing new small-scale plant designs that couple electrolysis with ammonia production are also under development, including smaller-scale Haber-Bosch units (The Royal Society, 2020; Suryanto et al., 2021). The opportunity to combine smaller-scale ammonia production with remote renewable generation is attractive if lower capital costs can be realised. To enable ammonia to be produced at this scale, adaptation must operate at a sub-MW scale. The downscaling of the Haber-Bosch process (i.e. 30 kW–500 kW) presents intermittency challenges for solar and wind sources, but not for hydropower.

For small renewable ammonia plants, capital expenditure is critical. The operational cost is not as important as for larger plants, as reflected in the process design that minimises equipment and applies standardised plant components and design modules where possible to decrease construction work, time on site, and cost-effective expansion.

[9] See CSIRO, HyResource, https://research.csiro.au/hyresource/ for more information.

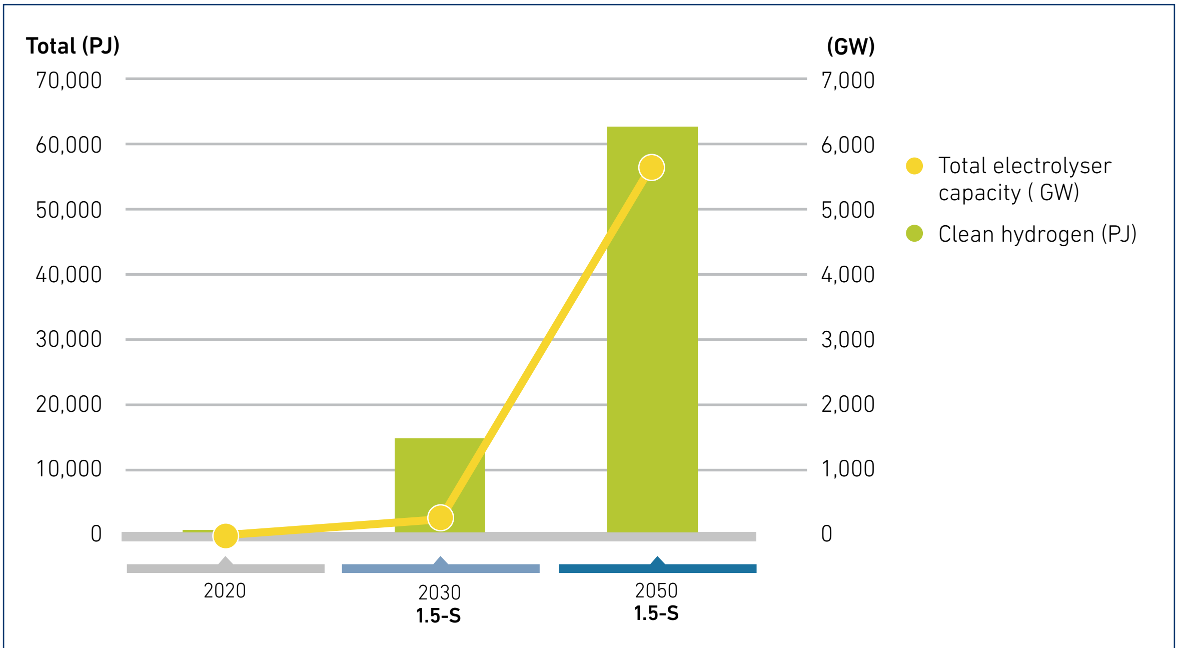
Hydrogen produced from renewable electricity-based water electrolysis is the basis of both large- and small-scale ammonia production. Alternative ammonia catalytic reactors to the Haber-Bosch process are being rapidly developed and tested and may play a substantial role in future ammonia production in Lao PDR (MacFarlane et al., 2020; The Royal Society, 2020; Chehade and Dincer, 2021; Suryanto et al., 2021).

4. Hydrogen Outlook

In 2022, approximately 95 million tonnes of predominately natural gas-based grey hydrogen were produced globally. Grey hydrogen is produced through steam reforming during the methane production process. It is primarily used in industrial applications such as crude oil refining, ammonia production, and methanol synthesis, which collectively account for nearly 93% of total hydrogen consumption (IEA, 2023).

Green hydrogen is expected to play a significant role in the energy transition towards the 1.5°C climate goal by 2050 (IRENA, 2023; UNIDO, IRENA, IDOS, 2024). Indeed, a substantial increase in global green hydrogen production is predicted, reaching approximately 492.0 million tonnes by 2050. Residual blue hydrogen production will total around 31.5 million tonnes (IRENA, 2023).

Figure 9.9. Global Green Hydrogen Supply in 2020, 202.3 and 2050 under a 1.5 °C Scenario



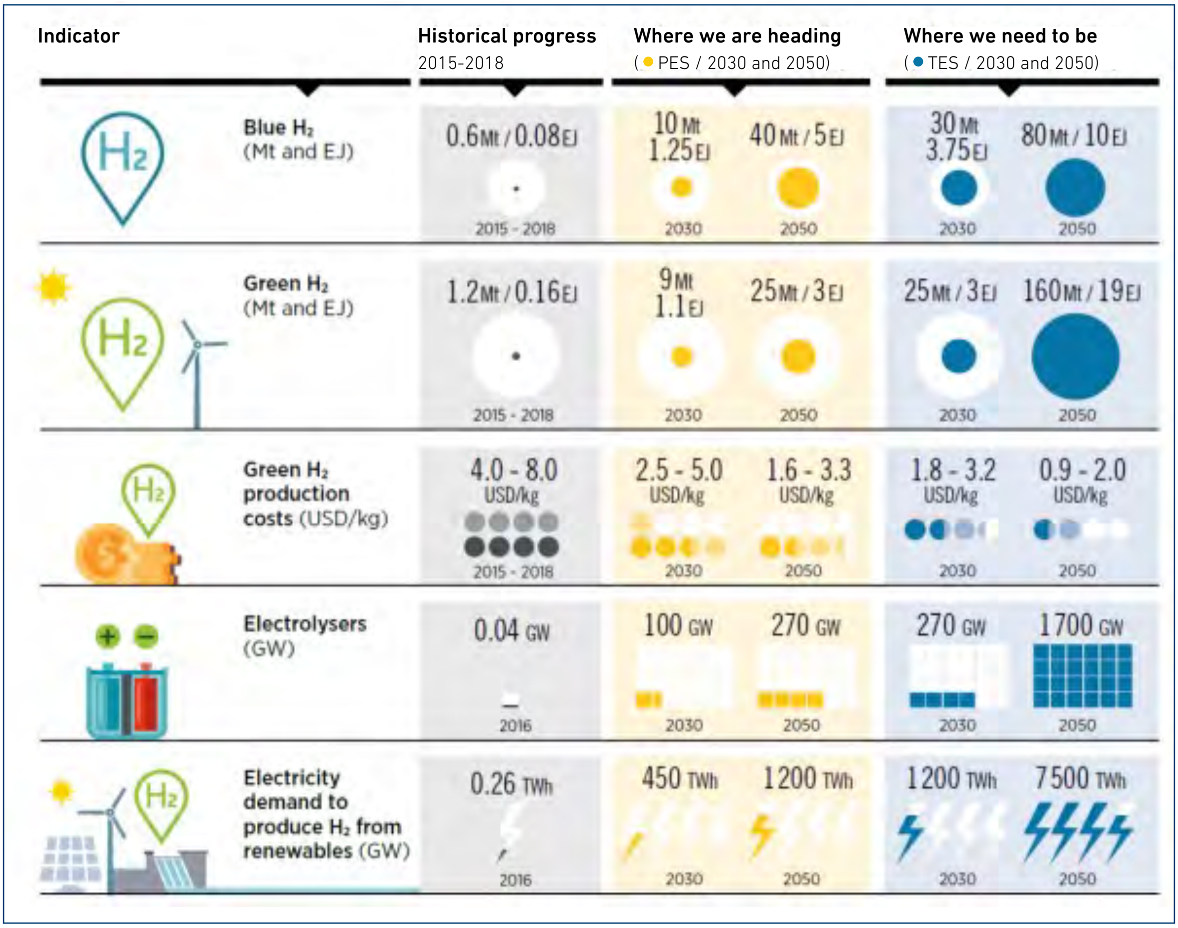
GW = gigawatt, PJ = petajoule.

Source: Ruf and Weichenhain (2024).

Figure 9.9 estimates that the capacity of green hydrogen projects will grow to 119 GW by 2030, less than half of the 260 GW that governments have committed to globally and only around one-fifth of the 590 GW required to achieve the 1.5°C target (Ruf and Weichenhain, 2023). For this reason, experts consider the 2030s a critical decade for the hydrogen industry, including that of Lao PDR. About 2,400 GW of installed electrolyser capacity is also forecasted by 2040 (Ruf and Weichenhain, 2023).

The relative capacities for green hydrogen production (especially for hard-to-electrify solutions) across three emissions scenarios were also estimated – a baseline of 43.0 gigatonnes (Gt) in 2025, a planned energy scenario (PES) with an emissions target of 33.0 Gt in 2050, and a targeted energy scenario (TES) with an emissions target of 9.5 Gt in 2050 (IRENA, 2023). In the TES, green hydrogen production costs would decrease to US$0.90–US$2.00/kg of hydrogen, and electrolyser capacity would increase to 1,700 GW requiring 7.5 petawatt-hours of renewable electricity (Figure 9.10). Total emissions abatement from green hydrogen production is estimated at 80 Gt by 2050 (Hydrogen Council and McKinsey & Co., 2022).

Figure 9.10. Historical Progress and Targets for Hydrogen Production



EJ = exajoule, GW = gigawatt, kg = kilogram, Mt = million tonnes, PES = planned energy scenario, TES = targeted energy scenario, TWh = terawatt-hour.

Source: IRENA (2023).

Green hydrogen can be produced at competitive costs with blue hydrogen in the best-case scenario, where low-cost renewable electricity is around US$20/megawatt-hour (MWh) coupled with trading in high-value carbon offsets (IRENA, 2021). Indeed, trading in carbon offsets from green hydrogen and ammonia will be a crucial source of revenue for Lao PDR. Capital expenditure reductions of up to 60% can be achieved, depending on a combination of electrolyser costs, manufacturing scale, technological improvements, and increased stack module size and deployment levels.

The costs for alternate production pathways for hydrogen were compared against a benchmark target of US$2.00/kg of hydrogen. Depending on electricity costs, capital expenditures, and the capacity factor (i.e. approximately 60%–70% in the case of Lao PDR seasonal hydropower surpluses), Lao PDR can potentially produce hydrogen at an estimated median price of US$1.86/kg (Baldwin et al., 2021).

4.1. Outlook for Developing Countries

The hydrogen and ammonia economy is a major opportunity for sustainable development and shared prosperity amongst low-income and developing countries (Gielen, Lathwal, Lopez Rocha, 2024; UNIDO, IRENA, IDOS, 2024). To date, there are five green hydrogen projects outside of China of more than 10 MW and three in the final investment decision phase that will be operational by 2030 (i.e. Neom in Saudi Arabia and proposed green ammonia plants in Ba Tri, Viet Nam and India).

The world's energy transition requires a global roll-out of green hydrogen production to obtain the necessary volumes by 2030. Organisation for Economic Co-operation and Development (OECD) countries alone do not have the renewable resources necessary to sustain a global renewable hydrogen industry. About 25%–30% of all clean hydrogen will be traded internationally, mainly in the form of hydrogen derivatives; by 2050, developing countries will account for 35% of that trade (Hydrogen Council and McKinsey & Co., 2022). Therefore, active support in developing countries is crucial to accelerate hydrogen production.

For Lao PDR, it is important to remember the following.

(i) **Green hydrogen projects are capital-intensive**. They are comparable to hydropower and large mining projects, where typically large private sector institutions have been able to assume risk.

(ii) **Utilising the existing surplus from Lao PDR hydropower fleet avoids capital expenditure of new renewable energy**. Renewable energy represents up to 66% of total project capital expenditures, and the remaining investment is related to domestic manufacturing and installation. Electrolyser investments follow a similar pattern; stacks, gas-processing equipment, and inverters are likely to be purchased overseas, and local value-added to the economy may be limited.

(iii) **Demand certainty in terms of volume and price remains as important as perceived risk**. Government mechanisms to mitigate risks related to users are being developed by OECD countries but not in developing countries, compromising reliable social and economic impact analysis from hydrogen and ammonia production.

(iv) **Green hydrogen projects create many jobs during the initial construction phases of the project but are limited in the later stages**. Initial assessments suggest that job creation during the operation stage is less than one-tenth of the early years during project construction.

Lao PDR is well placed to address the first two points, as it has a long history of successful large-scale hydropower plants characterised by multi-billion-dollar capital expenditures. Lao PDR can avoid the infrastructure costs and demands of new renewable electricity at least in the formative years of green hydrogen and ammonia production development. Initial Lao PDR demand for green hydrogen and ammonia is focussed on domestic use, primarily green ammonia fertilizer to replace imports, stabilise supply, add value to renewable electricity, and minimise global price volatility. Predictable domestic demand enables reliable social and economic analysis, addressing the last two points. Export opportunities are more likely to be realised during 2030–2040.

4.2. Green Ammonia Outlook

Ammonia production accounted for around 45%–50% of global hydrogen consumption or around 33 million tonnes of hydrogen in 2020. Replacing conventional ammonia with renewable ammonia produced from renewable hydrogen presents an early opportunity for action in decarbonising the chemical, energy, transport, maritime, and refining sectors. Ammonia is also proposed as one of the most cost-effective hydrogen carriers for long-range transport (MacFarlane et al., 2020; Erdemir and Dincer, 2021).

By 2050, in a scenario aligned with the Paris Agreement goal of keeping global temperature rise within 1.5°C, this transition would lead to a 688-million-tonne green ammonia market, nearly four times larger than in 2022 when 566 million tonnes of ammonia were estimated to have been decarbonised, produced from renewable hydrogen and renewable electricity (IRENA, 2022).

A global manufacturing and distribution system is in place, with over 100 years of infrastructure development and operation. While the safe transport and use of ammonia are well-established, new applications will require careful risk assessment. Additional control measures are required to reduce risks to health and the environment (The Royal Society, 2018, 2020; IRENA and ACE, 2022). Moreover, the rate at which renewable ammonia plants are being announced is correlated with the speed at which the cost of renewable electricity is decreasing. As of 2022, renewable ammonia production costs for new plants are estimated to be US$720–US$1,400/tonne, falling to US$310–US$610/tonne by 2050 (IRENA, 2022).

There are five major issues to be considered when evaluating the route towards ammonia production: capital expenditures, availability and cost of renewably sourced electric power, restrictions and cost of ammonia transport, restrictions of emissions to meet national and global targets, and carbon-related taxes and offsets (Chehade and Dincer, 2021).

Green ammonia production will cost US$450–US$500/tonne in Lao PDR by 2030 and can be competitive with non-renewable ammonia relatively quickly. Applying a carbon-trading price of US$50/tonnes (t) of CO_2e, offsetting the 2.6 tCO_2e/tonne of ammonia associated with grey ammonia would bridge the price gap between renewable and grey ammonia (IRENA, 2022). Significant funding and financial resources, directed at developing countries, are required to meet the 10%–15% green hydrogen targets set for 2050 (Lopez Rocha, Gielen, de Calonje, 2024).

Six sub-categories of risks, that if mitigated, would enable developing countries (including Lao PDR) access to finance are: (i) existing buyers, (ii) political and regulatory, (iii) infrastructure, (iv) technology, (v) permitting and compliance, and (vi) macroeconomic (ESMAP et al., 2023). De-risking instruments such as concessional credit lines and carbon offset pricing can be supplemented by well-established Multilateral Investment Guarantee Agency (MIGA) mechanisms focussed on tackling macroeconomic and political risks as well as equity and debt financing from the International Finance Corporation (IFC) and risk mitigation instruments issued by MIGA.

5. South-East Asia Hydrogen and Ammonia Initiatives

In 2020, hydrogen had not formally entered the policy agenda as an alternative fuel (ERIA, 2019). By 2024, Malaysia and Viet Nam had developed hydrogen roadmaps, indicating the rapid change and importance of hydrogen production and use in the region. In addition, in February 2024, Viet Nam approved *Vietnam's Hydrogen Energy Development Strategy to 2030 and Vision to 2050* (MOIT, 2024), which sets out a range of development targets for the hydrogen industry. The strategy details production of hydrogen from renewable energy utilisation and other processes with carbon capture to reach around 100,000–500,000 tonnes/year by 2030 and around 10 million–20 million tonnes/year by 2050. Similarly, Malaysia's Ministry of Science, Technology and Innovation published the Hydrogen Economy and Technology Roadmap, setting out the country's strategies and action plan for hydrogen production, including green hydrogen (MOSTI, 2023).

The *Association of Southeast Asian Nations (ASEAN) Plan of Action for Energy Cooperation Phase II (2021–2025)* (ACE, 2020), which was endorsed at the 38th ASEAN Ministers on Energy Meeting in November 2020, provides policy measures to address emerging and alternative technologies, such as hydrogen storage and entry, into the national energy mix to accelerate the region's energy transition and to strengthen energy resilience through innovation and cooperation.

In a 1.5°C-targeted energy scenario for green hydrogen, demand is expected to grow significantly to 1.5 exajoules or 11 million tonnes by 2050 (IRENA and ACE, 2021). The majority of demand would come from Indonesia, Malaysia, Thailand, and Viet Nam, where there will be a stronger base for hydrogen production. The expectation is that two-thirds of the hydrogen demand will be for green hydrogen from 2030 onwards. The ASEAN region has the technical potential to become a hydrogen hub. A proportion of low-cost green hydrogen (i.e. less than US$2/kg) can be produced in the region (IRENA, 2022).

In Phase III of the ASEAN Centre for Energy green hydrogen trajectory, the expected decreases in capital expenditures for hydrogen production and transport, levelised cost of renewables over the coming decade, and formation of overseas hydrogen energy markets would make green hydrogen competitive compared to fossil fuels (ACE, 2021). Surplus hydropower electricity redeployed to green hydrogen and ammonia production would allow Lao PDR to meet Phase III ACE criteria and have the potential to be at the vanguard of the ASEAN hydrogen and ammonia economy.

5.1. Potential of Green Hydrogen and Ammonia in Lao PDR

Participatory system mapping (PSM) is a practice-oriented network/system analysis tool developed to investigate cross-sectoral energy planning and natural resources governance (Barbook-Johnson and Penn, 2022; Smajgl and Ward, 2013). PSM is a structured tool that can assist key decision-makers in understanding, discussing, and improving complex multi-faceted energy transitions in which multiple, diverse actors either influence green hydrogen and ammonia energy transition outcomes or are affected by those energy decisions (Ward and Smajgl, 2023).

Through a series of interacting casual relationships amongst impacts, representatives from 15 Lao PDR ministries, institutes, and the private sector identified 8 opportunities and 4 risks associated with the development of green hydrogen and ammonia in Lao PDR. The participants prioritised the domestic production of fertilizer from green ammonia, potential for cement kiln co-firing, and applications in mining processing as immediate applications, with export, fuel cells, and substitute fuels for transport as future applications (Ward and Smajgl, 2023).

Risk 1 notes the potential trade-offs between green hydrogen and ammonia production and the environment, affecting the quantity and quality of water and indirectly agricultural production and food security. Risk 2 references the lack of market demand, which connects to the mandates of the Ministry of Industry and Commerce, Ministry of Public Works and Transport, and Ministry of Agriculture and Forestry. Co-development of a strategy with these ministries was recommended to raise community awareness and to prepare for a likely increase in market demand and the associated increased uptake of green hydrogen and ammonia production industry. Risk 3 refers to the required investment for setting up a green hydrogen and ammonia production industry, or Dutch disease, which means that the rapid development of one sector can cause the decline of other sectors, particularly access to capital, labour, and natural resources. The negative consequences of Dutch disease can be avoided by macroeconomic planning and involving sustainable foreign aid strategies.

The eight opportunities noted were as follows.

(i) **Improved policy and governance**. Develop a comprehensive policy framework for hydrogen and ammonia production, establish a dedicated government agency to oversee the development and implementation of these policies, and mobilise international financing institutions to provide financial support.

(ii) **Improved macroeconomy and public debt**. Create new export revenue streams, and reduce dependence on imported fossil fuels, supporting macroeconomic growth and debt reduction.

(iii) **Improved energy security**. Reduce dependence on imported fossil fuels, enhance the reliability and resilience of the energy system, and promote the development of renewable energy sources.

(iv) **Improved economic growth and household incomes**. Generate new skilled employment opportunities, and increase incomes for households and businesses through developing the hydrogen and ammonia production sectors.

(v) **Improved human resources**. Develop a capacity-building and training programme for hydrogen and ammonia production, including technical vocational skills, safety procedures, and environmental regulations; promote innovation through collaboration between the private sector and research and development institutions; implement pilot demonstrations; and encourage regional technology transfers and raise public awareness.

(vi) **A more sustainable and resilient energy market**. Increase the share of renewable energy sources in the energy mix, reduce emissions, and promote sustainable development of the energy market.

(vii) **Improved food and nutritional security**. Increase domestic ammonia production for use as a fertilizer, promoting food security and reducing dependence on imported fertilizers.

(viii) **Emissions mitigation**. Promote climate-change mitigation by reducing emissions through the displacement of fossil fuels with hydrogen and ammonia.

5.2. Techno-economics of Green Hydrogen and Ammonia Production in Lao PDR

Techno-economic evaluation estimates the flow sheet, mass and energy balance, equipment sizing and list, capital and operating costs, cash-flow analysis, net present value, internal rate of return, pay-back period, and risk and sensitivity analysis of green hydrogen and ammonia production and distribution technologies (Hosseini et al., 2023).

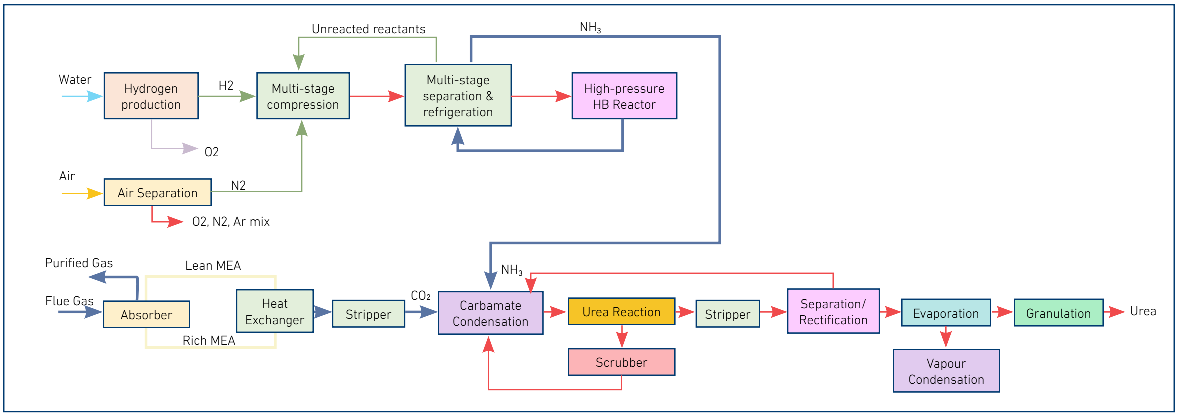
CSIRO modelling was informed by the main findings from the PSM process – domestic production and use of 200,000 tonnes of green urea per year. The capital cost estimation for green hydrogen and ammonia production was based on correlations from publicly available references and proprietary CSIRO databases. Estimated and calculated raw material inputs, labour, utilities, consumables, maintenance, insurance, and the cost of capital were imputed for operating cost estimates. A sensitivity analysis was undertaken by varying the key inputs of the operating cost, including electricity tariffs, taxes, and labour. Lao PDR modelling relied on a package of background tools and research on hydrogen and ammonia production technologies based on previous and current CSIRO research studies (Hosseini et al., 2023).

Evaluating production comprised a comparative analysis of alternative hydrogen and ammonia production and distribution technologies identified during participatory processes. The intended outcome is improved capacity of the Ministry of Energy and Mines and the Research Institute for Energy and Mines to negotiate for such production and distribution technologies as an alternative to fossil fuel generation and independently undertake robust social, ecological, and economic assessments of private sector and government proposals.

Urea is a compound of ammonia and carbon; bioethanol is the main carbon source. Urea importation prices in Thailand in 2022–2023 fluctuated between US$357/tonne and US$1,050/tonne (with an average of US$722/tonne). The average exportation price was US$670 (IndexBox, 2024). Lao PDR imports from Thailand commanded a 40% price increase. The May 2023 retail price of urea in Lao PDR was US$700/tonne.

The primary raw materials to produce urea are ammonia and carbon dioxide. For urea to be designated as green, carbon via carbon dioxide needs to be produced from bio-ethanol production (e.g. sugar cane or cassava). The urea production sequence is illustrated in Figure 9.11.

Figure 9.11. Urea Production



HB = Haber-Bosch, MEA = monoethanolamide.

Source: Musa et al. (2023)..

CSIRO modelled production variables to produce green hydrogen (20 kilotonnes per year [ktpa]), ammonia (113 ktpa) and urea (200 ktpa), which are depicted in Table 9.1. The total estimated investment cost is US$258 million, and the levelised costs over 30 years are US$488/tonne of urea, US$710/tonne of ammonia, and US$2,963/tonne of hydrogen. Levelised costs represent the unit cost a green urea plant would need to break even over a 30-year plant life at an electricity price of US$50/MWh. Sensitivity analysis of variable tax rates, electricity prices, and capital expenditure indicated the critical role that electricity tariffs would play in the annual operating costs and potential to produce price-competitive ammonia and urea.

Table 9.1. Production Variables for the Green Urea Base Case, 2022

Parameter	Urea Production	Ammonia Production	Hydrogen Production
Plant capacity (tpa)	200,000	113,000	20,000
Plant life (years)	30	30	30
Total Investment Cost (US$ million)	258	184	104
Variable OPEX	69	62	50
Fixed OPEX	12	9	5
Total OPEX	81	71	55
Operator labour cost (US$/hour)			3.5
Supervisor labour cost (US$/hour)			8.0
Electricity cost (US$/MWh)			50
Discount rate (%)			8.5
Levelised cost (US$/tonne)	488	710	2,963

MWh = megawatt-hour, OPEX = operating expenses, tpa = tonnes per year.

Source: Musa et al. (2023).

The levelised production costs of US$488/tonne of urea compete with 2023 importation prices. The inclusion of a carbon offset value of US$60/$tCO_2e$ would mean that Lao PDR-produced green urea competes with the costs of Thai imports of brown urea from the Middle East.[10] A reduction in the electricity tariff to US$10/MWh translates to a levelised cost of urea at US$296/tonne or a 40% reduction. The levelised cost of ammonia at US$10/MWh is US$376/tonne, and hydrogen US$1.20/tonne.

Lao PDR green urea production thus translates to an annual importation replacement value of approximately US$120 million/year at 2023 market prices – coupled with the development of new industries, new vocational skills, and a less volatile urea price. The critical role of electricity tariffs introduces three important discussion themes for Lao PDR:

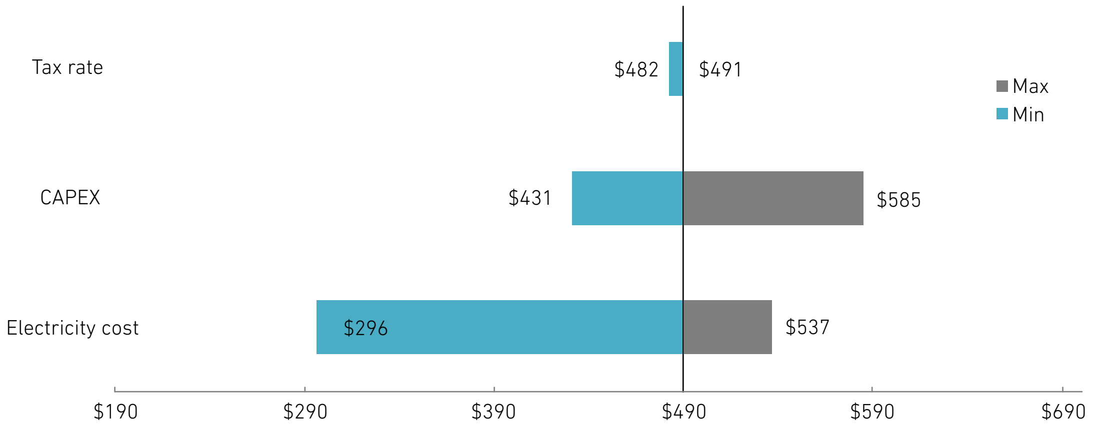
(i) **Alternate public–private partnership business model for the Government of Lao PDR and Électricité du Laos (EDL)**. EDL would be compensated for supplying a reduced electricity tariff due to shareholding in the green ammonia-urea plant, carbon offset revenues, and attendant profit sharing.

(ii) **Short-term power purchase agreements**. These would focus on EDL agreements on the above. Medium-term contracts would focus on a power purchase agreement with individual hydropower plants and operators and be located close to sites suited to urea production and markets. Long-term electricity purchases could involve direct contracts and shareholding with the government as build–operate–transfer hydropower dams reverting to full government ownership.

[10] 1.0 tonne of brown ammonia produces 2.6 tCO_2e or a US$156 offset (2.6 x US$60).

(iii) **Trading of carbon offsets**. These would have direct and indirect impacts on the financial viability and performance of the urea plant operator, government, and potentially communities. Establishing international carbon trading arrangements, especially in high-value markets, such as the European Union Emissions Trading Scheme, would directly affect the profitability and marketing potential of Lao PDR green urea.

Figure 9.12. Sensitivity Analyses of the Levelised Costs of Green Urea Production in Lao PDR (US$)



Parameter	Minimum	Base	Maximum
Tax rate (%)	0	0 for 10 years	10
CAPEX (%)	–30	100	+50
Electricity cost	Hydropower	20.0	124.0
($/MWh)	10	50	60

CAPEX = capital expenditure, MWh = megawatt-hour.

Source: Musa et al. (2023).

6. Applications of Green Hydrogen and Ammonia

6.1. Mining Sector

There are substantial opportunities for green hydrogen and ammonia in the mining sector as a replacement for grey ammonium leachates and fossil fuel in co-firing and heavy machinery. Mining concessions (i.e. combined exploration and extraction) in Lao PDR have been approved for 11.12 million hectares (ha) (Ingalls et al., 2019). In 2018, the area of active mining concessions in Lao PDR was estimated at 0.42 million ha, whilst the area of exploration concessions was 10.70 million ha. The number of artisanal miners is increasing, especially those focussed on rare earth and critical minerals, and are estimated to number more than 10,000 in Lao PDR (Hatcher, 2020).

Up to 10 tonnes of ammonium sulphate per tonne of rare earth mineral is used as a leachate the initial processing phase, all based on grey ammonia production (Zapp et al., 2022; Andrews-Speed and Hove, 2023). That equates to 26 tCO_2e per tonne of rare earth production. There are an estimated 600,000 tonnes of rare earth deposits in Lao PDR, mainly in Xiangkhouang and Houaphanh provinces, with exploration contracts signed with 18 companies (Liang et al., 2022). The processing of rare earth minerals is currently under a Prime Minister's decree to explore a pilot project and represents an important potential market for green ammonia production in Lao PDR.

The production of silicon metal in Lao PDR uses energy-intensive heating, primarily from coal and biomass. Co-firing with green ammonia is an additional potential market. The substitution of liquid fuels in heavy trucks and mining equipment with hydrogen fuel cells or ammonia has been recommended and is another potential application of green ammonia (The Royal Society, 2020; IRENA, 2022). All substitutions of decarbonised ammonia in mining operations represent substantial carbon offset trading opportunities and revenues.

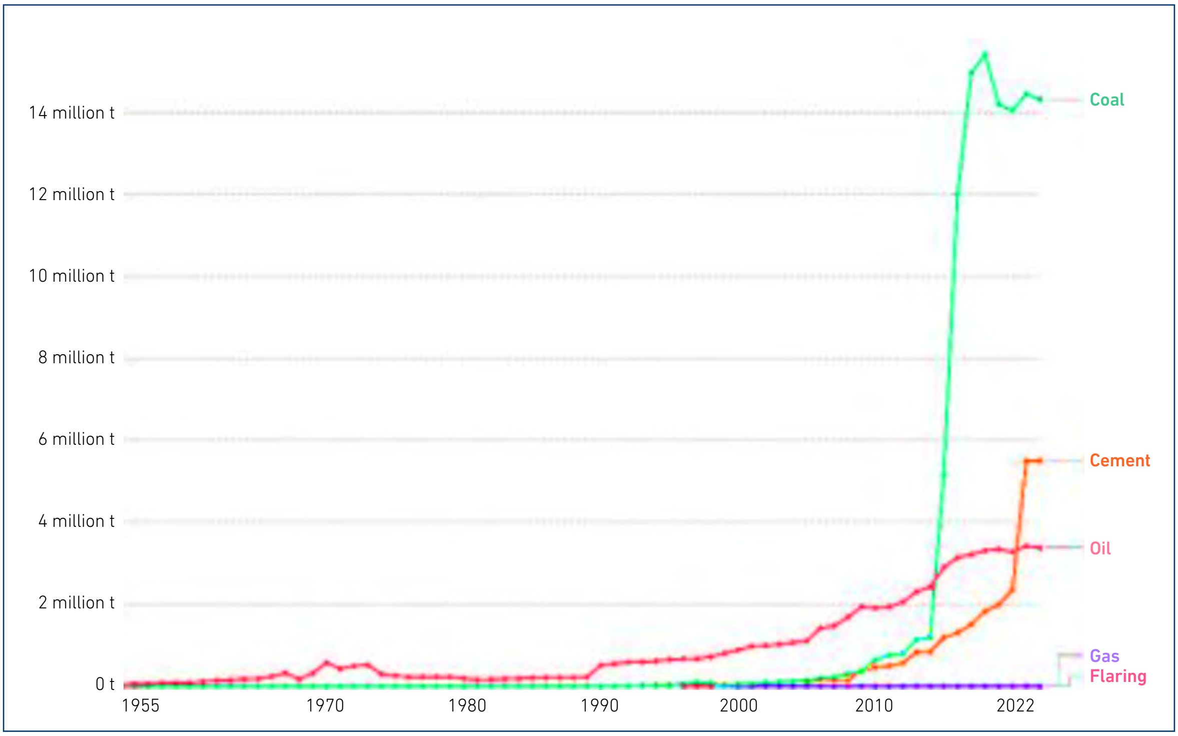
6.2. Cement Production and Co-firing

Lao PDR has 15 integrated cement plants. Because most are fairly small, they only have a total combined capacity of 10.7 million tonnes/year (Edwards, 2020). The largest producer by installed capacity is Lao Cement Public Company, which produces 3.4 million tonnes/year of capacity across four plants – three in Vientiane and one in Khammouane Province. The company is jointly operated by and obtains funding from China. The company's major products are Kating Thong Portland cement clinker and Kating Thong high-grade Portland cement. This cement is supplied mainly to Vientiane, as well as the provinces of Vientiane, Xiangkhouang, and Luang Prabang.

The second-largest cement producer by installed capacity is Khammouane Cement, a 100% subsidiary of Thailand's Siam Cement Group. Its 1.8 million tonnes/year plant at Khammouane was built in 2017. The third-largest producer is Luang Prabang Cement, a joint venture by Anhui Conch Cement and local investors. It operates three cement plants, all in Luang Prabang, with capacities of 0.1, 0.2, and 1.0 million tonnes/year. The third and largest plant is the most recent, first firing its kiln in December 2019.

Lao PDR cement kilns used 744,000 tonnes of anthracite in 2022.[11] Green ammonia, via an autothermal process to release the hydrogen fuel, can substitute for lignite and immediately fire site furnaces to manufacture cement (Cranfield University, 2024). This could offset the 2022 total emissions from Lao PDR cement production, estimated at 5.5 million tCO_2e (Figure 9.13).

Figure 9.13. Emissions by Fuel Type or Industry, 1955–2022
(million tonnes)



t = tonne.
Source: Ritchie et al., 2024

[11] According to the Government of Lao PDR, Ministry of Mines and Energy, Department of Mines Management.

6.3. Transport and Imported Liquid Fossil Fuels

Lao PDR is entirely dependent on imported liquid fossil fuels, primarily from Thailand. Petroleum imports and derivatives represented 30% of 2015 Lao PDR total energy consumption and are estimated to rise to 37% in 2025, more than twice the proportion of electricity at 13% in 2015 and 20% in 2025, respectively. Imported oil, primarily for road transport and passenger vehicles, is estimated to increase to 44% of total energy consumption by 2040 in the business-as-usual scenario (MEM and ERIA, 2020).

The number of pick-up trucks, sedans, minivans, jeeps, and trucks in Lao PDR in 2021 (764,612) increased by 26% compared to 2020 (567,373).[12] Assuming five motorcycles represent one pick-up truck (i.e. 2.2 million motorcycles in 2021), the total number of vehicles in 2021 equals 1,135,244. Total liquid fossil fuels were estimated to be 1.6 billion litres in 2023.[13] Emissions in 2022 from vehicles were estimated at 3.4 million tCO_2e (Figure 9.13). Fuel imports cost Lao PDR US$1.25 billion in 2022 or 16% of total imports.

Applications of both hydrogen and ammonia as a complement to electric vehicles and as a replacement/transitional fuel for liquid fossil fuels is a key focus of global research and applications, particularly for heavy trucks, mining machinery, and river transport (Giddey et al., 2017; The Royal Society, 2020; Chehade and Dincer, 2021; IRENA, 2022). Ammonia as a transport fuel has been used since the 1940s; although Toyota, Hyundai, Cummins, and MAN Truck & Bus are developing both ammonia and hydrogen internal combustion engines, this technology is still in an immature phase. Yet hydrogen fuel cells are rapidly being developed and deployed for long-distance trucking applications, passenger vehicles, and public train and bus transport (MacFarlane et al., 2020; The Royal Society, 2020; Erdemir and Dincer, 2021; IRENA, 2022; IRENA and ACE, 2022; Kimura, Phoumin, Purwanto, 2022). The *Renewable Energy Development Strategy for Lao PDR* forecasted approximately 50% of new vehicles will be electric vehicles by 2031 based on a medium scenario of uptake (i.e. 3%–6% increase per year) (Castalia Advisory Group, 2020).

[12] Lao Statistics Bureau, Type of Car for the Whole Country, Statistics Database, https://laosis.lsb.gov.la/statHtml/statHtml.do?orgId=856&tblId=DT_YEARBOOK_Q003&language=en&conn_path=I3 [accessed 1 June 2024]

[13] Personal communication from the Department of Customs, Ministry of Industry and Commerce, 2024, and World Bank, World Development Indicators, https://databank.worldbank.org/source/world-development-indicators [accessed 1 June 2024]

7. Conclusion and Policy Implications

The PSM described the opportunities and risks identified as a consequence of green hydrogen and ammonia in Lao PDR. Its third-order system map illustrated the direct and indirect downstream causality or impacts of green hydrogen and ammonia production, storage distribution, and utilisation.

Upstream enabling factors and constraints represent the precursors and conditions necessary for green hydrogen and ammonia production to commence in Lao PDR. There are two critical enabling factors. The first is the allocation of an agreed, secure, and reliable proportion of hydropower generation deployed to hydrogen and ammonia production, including likely infrastructure locations and based on generation surplus (MEM, 2021). The second critical enabling factor is the drafting and ratification of a national hydrogen and ammonia roadmap and strategy. The Ministry of Energy and Mines is coordinating a cross-sectoral drafting of the roadmap with multiple ministries aligned with the Prime Minister's Hydrogen Decree.[14] A collaborative process to draft and to agree on a national hydrogen and ammonia production roadmap, strategy, and action plan is the foundation of effective energy system planning and policy that meets the needs of all sectors.

In transitioning from an emerging technology to a commercial asset, the policy imperatives woven into the national hydrogen and ammonia roadmap and strategy must focus on market activation and the importance of investment in research and innovation while reducing costs and other barriers to technology deployment. CSIRO noted that the hydrogen transition parallels the recent experience in the solar photovoltaic industry, especially in developing clean hydrogen technology solutions across the value chain capable of large-scale deployment by 2030.[15]

There is no one one-size-fits-all solution; hydrogen-ammonia roadmaps require extensive consultation and collaboration with all affected stakeholders across all sectors. Each will always base its policies and actions on its social and political priorities and constraints, as well as resource availability and existing infrastructure. An adaptive management approach to policy design and implementation is recommended, with established review periods to evaluate agreed on performance indicators and metrics. If Lao PDR acts as an early adopter, there may be opportunities to draw upon energy resources that are underutilised or used in lower-value applications. A summary of recommended approaches to drafting a national hydrogen and ammonia roadmap and strategy as well as examples from ASEAN Member States can be found in Ward and Smajgl (2023).

To identify additional enabling factors, a group of experts familiar with Lao PDR energy systems were invited to review the hydrogen and ammonia production maps developed by Lao PDR officials during a series of participatory systems mapping workshops (Ward and Smajgl, 2023). The process employs the Delphi method[16] to further enrich the PSM and to identify additional consequences and potential intervention points, likely to be important in the design of the National Hydrogen and Ammonia Roadmap and Strategy.

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[14] The Prime Minister's hydrogen decree is currently in draft format and expected to be ratified in late 2023.

[15] CSIRO, HyResource, https://research.csiro.au/hyresource/

[16] Delphi techniques help structure a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem. The Delphi technique relies on the collectivisation of individual opinions and evaluations, because discovering solutions can benefit from subjective judgments on a collective basis (Linstone and Turoff, 2002).

Expert opinions and discussions held during the 2023 participatory systems mapping workshops identified additional enabling factors that warrant consideration by the government:

(i) **Form a national task force responsible for coordinating the development of the green hydrogen and ammonia production industry**. The task force should include government agencies, industry associations, and experts to monitor and help implement the national strategy and action plan for green hydrogen and ammonia production. The task force would facilitate policy and regulatory discussions, evaluate infrastructure development, and promote public–private partnerships.

(ii) **Establish a centre of excellence as a trusted source of data and analysis**. Research institutes and the National University of Laos should be integrated into this, with a focus on hydrogen and ammonia production research and development and selection of a site for a pilot plant.

(iii) **Establish a green hydrogen and ammonia industry association**. This will represent the interests of industry stakeholders, enabling collaboration between the public and private sectors and development partners.

(iv) **Negotiate and formalise participation in international carbon credit trading networks**. A legal property rights framework for hydrogen and ammonia carbon offsets and tradable renewable energy certificates based on green hydrogen and ammonia production should be created in Lao PDR. The distribution of revenue from carbon trading will need to be specified in contractual arrangements with foreign entities investing in hydrogen and ammonia production and distribution. The proposed hydrogen and ammonia industry association could also play an active role in negotiations.

(v) **Create incentives for developing a green hydrogen and ammonia industry.** These should include adapting existing special economic zone tax breaks, subsidies, and import duty exemptions for hydrogen and ammonia capital goods.

(vi) **Foster strong collaborative frameworks**. These will help accelerate the uptake of emerging hydrogen and ammonia technologies by fostering knowledge transfer, promoting economies of scale, and identifying failures. Weak cooperation mechanisms can slow down the deployment of technologies in the demonstration phase by up to 10 years or more (IRENA, 2020).

(vii) **Access Australian and other international expertise and training programmes to support sound energy and financial analysis of hydrogen and ammonia investments and trends**.

(viii) **Actively collaborate with regional neighbours to expand information sharing and to build relationships on hydrogen and ammonia production safety, transport, and utilisation**.

Additional constraints were identified during the second and third 2023 participatory system mapping workshops: (i) absence of university curricula and vocational training programmes geared towards green hydrogen and ammonia production, creating a lack of skilled engineering and tradespeople; (ii) limited access to low-interest funding and investment, exacerbated by the current national and EDL debt and downgrading of Lao PDR's credit rating by Moody's and Fitch Ratings; (iii) inertia of EDL to expand the electricity exportation strategy; (iv) uncertainty that ammonia and hydrogen infrastructure will not become stranded assets; (v) green hydrogen and hydrogen production not specified in the power development plan; (vi) volatility in global demand and price premiums for green hydrogen and ammonia; and (vii) poorly specified incentives to decarbonise through green hydrogen and ammonia.

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Chapter 10

Optimising Sustainable Hydropower Development on the Mekong: What Direction Should Lao PDR Take?

Anoulak Kittikhoun
Sophearin Chea
Sopheak Meas
Ly Thim
Peeti Ngamprapasom

1. Introduction

The Mekong River is intricately woven into the fabric of life across the countries it traverses. Its significance extends far beyond its physical presence, touching upon diverse aspects of food security, energy generation, economic prosperity, fisheries, and navigation. For millions of people residing in Cambodia, China, Lao People's Democratic Republic (Lao PDR), Myanmar, Thailand, and Viet Nam, this mighty river serves as a lifeline, or, as many describe, a hydrologic backbone or current of life that sustains livelihoods and shapes the socio-economic landscape of the region (Hudson-Rodd and Shaw, 2009; Jacobs, 2002).

Hydropower development is at the forefront of global renewable energy initiatives. It presents both promises and challenges in meeting the world's growing energy demands while striving for sustainability. Since its modest inception in 1878, hydropower has blossomed into a significant player in the global energy landscape. Today, it accounts for approximately 16% of the world's total electricity generation and is the third-largest source of energy, following coal and natural gas (IHA, 2023).

Within the Mekong region, this trend is particularly pronounced. As the most upstream country, China has erected 11 mainstream dams along the upper reaches of the Mekong River within its territory. In the Lower Mekong River Basin, plans for a cascade of another 11 mainstream dams are in various stages of development, with 2 operating and 3 under construction in Lao PDR. The tributaries of the Mekong River are contributing to this surge in hydropower projects, hosting another 122. Of these, 88 projects are operational, 20 are under construction, and 14 are in the planning phase. The installed capacity of operational dams stands at over 13,257 megawatts (MW), with the potential to double to 27,302 MW if all planned dams are completed.[1]

Amidst the fervour for hydropower development, a host of challenges and concerns have emerged, however. Environmental degradation, alteration of river flows and ecosystems, and socio-economic impacts have cast a shadow over the perceived benefits of hydropower. Efforts have been introduced to address these challenges; at the same time, the global community has turned towards embracing alternative energy sources. This shift reflects the growing recognition of the necessity for a diversified and sustainable energy portfolio, ensuring a more resilient and environmentally friendly future for generations to come.

In this chapter, the complex terrain of sustainable hydropower development on the Mekong River is examined, with a focus on guiding the direction that Lao PDR – a member of the Mekong River Commission (MRC) and the host to its headquarters – may consider taking. By examining the current energy landscape and hydropower initiatives in the Mekong River Basin and in Lao PDR, this chapter seeks to provide practical policy recommendations, ensuring the sustainability of hydropower development, optimising energy resources, and bolstering water–energy security.

[1] MRC (2021b), MRC Hydropower Database, https://archive.iwlearn.net/mrcmekong.org/programmes/Hydropower/hydropower-database.htm

2. Evolution of Hydropower

2.1. Origins

Hydropower emerged from humble origins to rapidly proliferating around the globe, with technological advancements that made it a cornerstone of today's renewable energy landscape. In 1878, the world saw its first hydropower project lighting up a single lamp at Cragside country house in England – known at the time as the 'palace of the modern magician' (BBC, 2013). Just 4 years later, Wisconsin launched the first hydropower plant to serve both private and commercial customers, sparking a proliferation of hundreds of hydropower plants worldwide within a decade.[2] Germany pioneered its first three-phase hydroelectric system in 1891, while Australia unveiled the first publicly owned hydropower plant in the Southern Hemisphere in 1895. In Asia, China joined the movement in 1905 with a hydropower station on the Xindian River near Taipei, which boasted an installed capacity of 500 kilowatts (kW).

As the 20th century unfolded, hydropower facilities underwent rapid innovation and transformation. In the 1930s, United States (US) President Franklin Roosevelt's New Deal spurred the construction of multi-purpose projects like the Hoover and Grand Coulee dams, which boosted hydropower to 40% of the country's electricity generation by 1940. From the 1940s to the 1970s, driven by post-war economic growth, state-owned utilities in Japan, North America, the Soviet Union, and Western Europe embarked on significant hydropower projects. This period saw low-cost hydropower supporting the rise of energy-intensive industries like aluminium smelters and steelworks. In the latter half of the century, Brazil and China emerged as hydropower leaders. The Itaipu Dam, inaugurated in 1984, stood as a testament to Brazil's hydropower expertise (jointly with Paraguay) with a capacity of 12,600 MW, later expanded to 14,000 MW. China's Three Gorges Dam, boasting 22,500 MW, became the world's largest.[3]

However, the late 1980s witnessed a slowdown in hydropower capacity growth, followed by a decline in the 1990s. Financial constraints and mounting concerns over environmental and social impacts halted many projects globally. International financial institutions, notably the World Bank, curtailed lending and support in the late 1990s, impacting hydropower construction in the developing world (IUCN, IBRD, World Bank, 1997).

Towards the end of the 20th century, increased global awareness of environmental and social impacts prompted a re-evaluation of hydropower's role in national development. In 2000, the World Commission on Dams published a major report (WCD, 2000), and the World Bank also implemented environmental and social safeguards for hydropower projects to ensure responsible development and to minimise negative impacts on ecosystems and local communities. The International Hydropower Association, established in 1995 under the United Nations Educational, Scientific, and Cultural Organization (UNESCO), began crafting the Hydropower Sustainability Guidelines in 2004, which later laid the groundwork for the Hydropower Sustainability Assessment Protocol.

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2 IHA, A Brief History of Hydropower, https://www.hydropower.org/iha/discover-history-of-hydropower

3 *Ibid.*

Shortly after the dawn of the 21st century, hydropower development surged, especially across Asia and South America. Between 2000 and 2017, the global installed capacity for hydropower grew by nearly 500 gigawatts (GW), a remarkable 65% increase. In terms of energy contribution, hydropower surpassed nuclear by 55% and exceeded the combined output of all other renewables, including wind, solar, bioenergy, and geothermal (IEA, 2021).

Currently, hydropower fulfils the majority of electricity demand in 28 developing nations, with a total population of 800 million, by offering an economical means to enhance electricity accessibility (IEA, 2021). On a global scale, approximately half of the economically feasible capacity of hydropower remains untapped, with emerging and developing economies exhibiting particularly high potential for it. Significant untapped hydropower potential indicates that a substantial portion of the sector's expansion will likely occur in Africa and Asia.

Because of its numerous advantages and contributions, hydropower is projected to continue as the leading renewable energy source globally for the foreseeable future. To 2020, the global installed capacity of hydropower reached 1,308 GW, accounting for 16% of the world's total electricity generation and making it a crucial component of the global energy mix (IHA, 2020). This positions it as the third-largest source of energy, following coal and natural gas. The International Energy Agency suggested that to achieve the primary energy-related objectives of the Sustainable Development Goals, such as fulfilling the Paris Agreement's target of limiting global warming to below 2°C, approximately 800 GW of extra hydropower capacity must be added in the next 20 years (IEA, 2021). Nevertheless, the increase of hydropower capacity cannot solely rely on market forces; governments must devise mechanisms that incentivise flexibility to maintain system balance (IHA, 2023).

2.2. In the Mekong Region

With its basin hosting approximately 70 million inhabitants, the Mekong River serves as an economic artery. It sustains the livelihoods of millions across the region by providing vital resources including energy, food, water, and income (Hudson-Rodd and Shaw, 2009; Jacobs, 2002; MRC, 2019c). As the population continues to grow and various factors such as rising incomes, urbanisation, industrialisation, and increased electrification take hold, the demand for electricity in the region is poised to experience significant expansion in the future (Han, Meas, An, 2021).

Further, with demands for energy in the Lower Mekong River Basin continuing to escalate at a rate of 6%–7% annually, these riparian countries are increasingly turning to hydropower as a solution. With its extensive and intricate network of tributaries, the Mekong River system has been recognised as an important source of hydroelectric power generation since the 1960s (Soukhaphon, Baird, Hogan, 2021). Today, the basin is a key site for large-scale hydropower development that has helped shape the energy landscape and economic development of these nations over the years.

Hydropower development on the Mekong River began in the early 20th century and started to intensify in the 1990s to 2000s (MRC, 2019a). The Mekong Committee (the predecessor of the MRC), with the support of the United Nations, US, and others, promoted hydropower development from a basin-wide perspective in the 1960s–1980s with the objectives of meeting the needs of all Mekong countries (Kittikhoun and Kittikhoun, 2022; Mekong Secretariat, 1989). Yet the ambitions for multiple dams in the basin, especially on the mainstream, were impeded by Cold War conflicts, resulting in many projects remaining unrealised (Sneddon, 2015). When peace returned to the region in the 1990s, hydropower development re-emerged due to rising energy needs driven by economic growth, population expansion, and migration from rural to urban areas, as well as a transition from public financing to collaborative ventures between governments and private enterprises, resulting in the infusion of capital for dam initiatives (Grumbine, Dore, Xu, 2012; Kondolf, Rubin, Minear, 2014; Pearse-Smith, 2012).

An initiative to harness hydropower began in north-eastern Thailand with the construction of the Nam Pung Dam in Sakon Nakhon Province in November 1965 (Hirsch, 2010). The Nam Pong Dam emerged in the Upper Chi River Sub-basin in Khon Kaen Province and was operational in March 1966. The Ubol Ratana Dam was then completed, followed by the Lam Pao Dam by 1968. Subsequent developments included the Sirindhorn Dam in the Mun River Basin in Ubon Ratchathani Province in 1971 and Chulabhorn Dam in 1972. The Nam Ngum Dam, the first significant dam in Lao PDR, was completed in 1971; it was one of the few hydropower projects completed from the Indicative Basin Plan of the Mekong Committee (Mekong Secretariat, 1989).

Primarily due to Cold War tensions, significant progress in hydropower dam development was then stalled until the Pak Mun Dam was constructed on the Mun River, a key tributary of the Mekong River, in Ubon Ratchathani Province in 1990 (Foran and Molle, 2009). Throughout the 1990s, the Government of Thailand embarked on the construction of several medium and large irrigation dams under the Khong–Chi–Mun Interbasin Transfer Project (Sneddon, 2003). Concurrently, Lao PDR resumed dam construction in the mid-1990s with foreign investment, which led to the Houay Ho Dam in southern Lao PDR and the Theun-Hinboun Dam in central Lao PDR (Whitington, 2019). In China, the inaugural dam on the Upper Mekong Basin, which the Chinese call the Lancang River, was erected during the 1990s, culminating in the completion of the Manwan Dam in 1993 (Baird, 2013; Whitington, 2019). Meanwhile, in Viet Nam's Central Highlands, the construction of the Yali Falls Dam commenced in 1993 and concluded in 2001 (Ang et al., 2024; Wyatt and Baird, 2007).

However, the 1997/98 Asian financial crisis led to the cancellation of several planned hydropower projects, with others either delayed or reduced in scale (Soukhaphon, Baird, Hogan, 2021). As a result of decreased market demand for hydropower and ongoing financial challenges, limited progress was made in hydropower development within the Lower Mekong River Basin during the early 2000s. Furthermore, the World Commission on Dams findings from 2000 dissuaded major institutions from financing new large-scale dam projects during this period. Nevertheless, hydropower projects persisted in the Upper Mekong River Basin in China (Wouters, Daza-Clark, Devlaeminck, 2024). Then, in 2005, the World Bank approved the Nam Theun 2 Hydropower Project, with 1,075 MW installed capacity, in central Lao PDR. At the time, this was the largest dam ever constructed in the entire Mekong River Basin. This project became operational in 2010. In the 2010s, hydropower dam development then increased dramatically, particularly in China and Lao PDR.

Today, China has 11 operational dams – 2 of which are large storage dams (i.e. Nuozhadu and Xiaowan) – in the Upper Mekong River Basin that make up the cascade along the mainstream (MRC, 2021b). The country has more than 23,000 large hydropower dams and approximately 50,000 smaller ones (Sun et al., 2019). By the end of 2019, China's total hydropower installed capacity reached approximately 356 GW, which includes 30 GW of pumped storage capacity with an annual generation capacity of around 1,300 terawatt-hours, the highest in the world (Bin, 2021). In comparison, Brazil is ranked second with 109 GW, while the US is ranked third with 102 GW (IHA, 2020). China added 4,170 MW of new hydropower capacity in 2019, slowing down its rate of installation. This placed China in the second position globally, with Brazil taking the lead by installing 4,919 MW of new capacity in the same year (IHA, 2020).

A large portion of China's hydropower comes from rivers within its borders, but some dams are connected to rivers that cross into other countries. These include rivers like the Amur, Brahmaputra, Mekong, and Salween, many of which hold a lot of untapped potential for hydropower (Xiao et al., 2023).

In Myanmar, the first dam on its Mekong River tributaries was commissioned in 2017, and there are plans for at least six more small storage dams (MRC, 2024b).

In the Lower Mekong River Basin, a cascade of another 11 mainstream dams has been planned or in operation (Table 10.1). Two of the dams are in Cambodia, while nine dams are in Lao PDR, with two already operational (i.e. Xayaburi and Don Sahong). In Cambodia, construction of the tributary Lower Sesan 2 Dam commenced in 2014, marking it as the largest dam project undertaken in the country up to that point. The project reached completion in 2018. Additionally, studies have been undertaken regarding the potential development of the Sambor Dam on the mainstream Mekong River. However, recent reports indicated that the Sambo and Stung Treng mainstream projects are postponed for at least a decade (Kijewski, 2020; Prak, 2020).

Table 10.1. Hydropower Projects in the Lower Mekong Basin by Country

Country	Mekong			Tributaries			Total
	In Operation	Under Construction	Planned	In Operation	Under Construction	Planned	
Cambodia			2	2		9	13
Lao PDR	2	1	5	65	20	5	98
Thailand			1	7			8
Viet Nam				14			14
Total	**2**	**1**	**8**	**88**	**20**	**14**	**133**

Lao PDR = Lao People's Democratic Republic.

Source: MRC, MRC Hydropower Database, https://archive.iwlearn.net/mrcmekong.org/programmes/Hydropower/hydropower-database.htm

On the tributaries of the Mekong River, there are another 122 hydropower projects, of which 88 are operational, 20 are under construction, and 14 are planned (Table 10.1). The installed capacity of operational dams stands at just over 13,257 MW (Table 10.2). However, this number could possibly double to 27,302 MW if all planned dams are built and all ongoing dam construction is finished. This includes 14,403 MW from tributary dams and 12,899 MW from the 11 dams on the mainstream.[4]

Table 10.2. Total Installed Capacity of Hydropower Projects in the Lower Mekong Basin by Country
(megawatts)

Country	Mekong				Tributaries				Grand Total
	In Operation	Planned	Under Construction	Total	In Operation	Planned	Under Construction	Total	
Cambodia		4,000.00		4,000.00	401.00	1,110.00		1,511.00	5,511.00
Lao PDR	1,545.00	4,865.00	1,410.00	7,820.00	7,959.39	265.00	1,315.70	9,540.09	17,360.09
Thailand		1,079.00		1,079.00	744.68			744.68	1,823.68
Viet Nam					2,607.00			2,607.00	2,607.00
Grand Total	**1,545.00**	**9,944.00**	**1,410.00**	**12,899.00**	**11,712.07**	**1,375.00**	**1,315.70**	**14,402.77**	**27,301.77**

Source: MRC, MRC Hydropower Database, https://archive.iwlearn.net/mrcmekong.org/programmes/Hydropower/hydropower-database.htm

Today, hydropower remains a crucial component of the energy mix in the region. China has continued to be a global leader in hydropower development, with projects along the Upper Mekong River Basin contributing significantly to the country's renewable energy capacity. While Thailand and Viet Nam have already developed most of their tributary sites, three other countries – Cambodia, Lao PDR, and Myanmar – currently possess the greatest potential for hydropower development. In addition, the four MRC Member Countries – Cambodia, Lao PDR, Thailand, and Viet Nam – have been exploring other alternative energy sources to meet energy demands and to help decarbonise their countries and the region (MRC, 2024a, 2024b).

3. Hydropower Development in Lao PDR

Lao PDR boasts significant geographical advantages for hydropower development, with abundant water resources and topographical features conducive to dam construction. Despite the promise of hydropower, however, several challenges must be addressed to ensure sustainable development. Uncertainties in hydrological flow and climate change pose significant risks to hydropower projects, necessitating adaptive strategies to manage seasonal variability in water availability. The need to balance energy demand with water resources management priorities underscores the complexity of hydropower development.

According to the *Lao National Power Development Strategy, 2021–2023*, and its data on electricity generation capacity, as of 2020, the nation's power infrastructure comprises a total capacity of 10,091 MW and an annual output of 53,196.94 gigawatt-hours (GWh) (MEM, 2021). The same source noted that the majority of electricity generation stems from hydropower, constituting 80.41% of the total capacity, followed by coal-fired plants at 18.61%, with renewable energy sources such as biomass and solar accounting for a modest 0.98%. Furthermore, the distribution of electricity usage reflects significant reliance on hydropower for both domestic and exportation purposes. Specifically, 72.00% of electricity generated from hydropower plants is directed towards exportation, while domestically, hydropower remains the primary source, contributing to 91.49% of the total energy consumed. Coal-fired plants and renewable energy sources, including biomass and solar, collectively contribute 3.17% and 5.34%, respectively, to the domestic energy supply.

The country's energy strategy emphasises the need to balance the security of supply, affordability, and sustainability (Keokhoungning, 2024). This strategy entails leveraging hydropower resources while exploring opportunities for investment and collaboration in solar, wind, energy storage, and electric vehicle infrastructure. Outlined within the energy strategy are several key objectives:

(i) develop potential power sources in the country with mixed power generation for domestic use and export;
(ii) target mixed power generation for domestic use from hydropower at 75%, coal-based power plants at 14%, and renewable energy at 11%;
(iii) reach electrification rate targets of 95% for 2020, 98% for 2025, and 100% for 2030;
(iv) promote power generation for export and power exchange amongst neighbouring countries;
(v) promote electricity exportation for the ASEAN Power Grid; and
(vi) promote the use of electric vehicles, targeting these comprising 15% of total vehicles in country by 2025 and 30% by 2030 (MEM, 2021).

The importance of regional cooperation and synchronisation amongst neighbouring countries is crucial to achieving clean energy goals and to promoting renewable energy adoption. This entails fostering joint projects, sharing resources, and developing common policies to facilitate energy trading between Lao PDR and Thailand, China, Cambodia, Malaysia, Myanmar, Singapore, and Viet Nam. Currently, cross-border power trading between Lao PDR and its neighbours stands at 6,000 MW with Cambodia, 600 MW with China, 300 MW with Malaysia, 600 MW with Myanmar, 4,000 MW with Singapore, 10,500 MW with Thailand, and 5,000 MW with Viet Nam (Keokhoungning, 2024).

3.1. Context and Challenges

Approximately 90% of Lao PDR is located in the Mekong River Basin, giving it abundant water resources and hydropower development potential. In the Lower Mekong River Basin, 133 projects with a total installed capacity of 27,302 MW were identified at different stages of development. Of these, 98 projects with an installed capacity of 17,360 MW are in Lao PDR, representing 64% of the total installed capacity in all stages (MRC, 2021b; 2024b).

Positioned downstream of China and Myanmar, Lao PDR contributes about 41% of the annual flow to the Mekong (MRC, 2016). This suggests that any water resources development in the territory – including water infrastructure projects like hydropower – may impact the Mekong River's environment and, in turn, society. Furthermore, the development of water infrastructure projects upstream – particularly in China – impacts the river system, including changing the flow regime and sedimentation, thereby potentially affecting hydropower operation and production in Lao PDR.

The basin's climate is projected to be changing. Future scenarios show higher temperatures and the potential for more extreme floods and droughts (MRC, 2018). It was reported that the overall basin water yield could either increase or decrease, with the range of annual river flow varying between –59% and +27%, and the dry season minimum 1-day flow changing between –65% and +35% at Chiang Saen in Thailand by 2060 (MRC, 2018).

Climate change, coupled with the uncoordinated operation of water infrastructure on the river, is expected to have serious impacts on the hydrology of the Mekong River, its environment, associated economies, and vulnerable communities. As highlighted in the *Sustainable Hydropower Development Strategy*, hydropower development has a number of risks including the loss of livelihoods, reduced yields of capture fisheries, declining sediment flows, disrupted ecosystems, and loss of wetlands and forests (MRC, 2022b). To mitigate these potential impacts and to address sustainable hydropower development, the MRC aims to achieve a balance between the benefits of hydropower development and the preservation of the Mekong River's ecological integrity.

3.2. Sustainable Hydropower Development in Lao PDR

Lao PDR is one of the signatory members of the MRC and is, therefore, bound by the 1995 Mekong Agreement and associated procedures and guidelines. In supporting sustainable hydropower development and water resources management, the MRC plays a crucial role as an instrument for regional cooperation and collective action to address challenges and to realise the shared vision of sustainable development in the Mekong River Basin. This intergovernmental organisation has indeed been a force for peace, forum for dialogue, repository of knowledge, and platform for conflict resolution and water diplomacy (An, Kittikhoun, Meas, 2020; Sok, Meas, Pheakdey, 2023).

By adopting a balanced approach to energy development, leveraging geographical advantages, and addressing key challenges, Lao PDR can unlock the full potential of its hydropower potential while promoting regional energy security and sustainability. Some considerations for making hydropower development sustainable in Lao PDR are as follows.

Look for joint investment with other Mekong countries. Joint investment projects between two or more countries offer a strategic approach to harnessing the collective strengths and resources of multiple countries for mutual benefit. They are the ultimate realisation of the aspirations of 'One Mekong, One Spirit' as well as 'shared river, shared future'. By pooling financial resources, technical expertise, and infrastructure, these projects enable economies of scale and optimise the utilisation of shared water resources. Moreover, joint projects facilitate the coordination and management of transboundary water systems, fostering greater participation of relevant stakeholders and meeting multiple objectives for a more sustainable Mekong (MRC, 2024a; 2024b).

The Pak Chom and Ban Khoum projects are transborder hydropower projects between Lao PDR and Thailand. Pak Chom is expected to generate 1,079 MW, while Ban Koum is expected to generate 1,872 MW (ICEM, 2010). Both projects, which are in the early stages of planning and study, hold significant potential to benefit the region. However, these projects are currently under study by private companies. If these projects could become a joint project between the governments of Lao PDR and Thailand, they could enable the sharing of resources and expertise, leading to more efficient project planning, implementation, and operation. Both countries can leverage their respective strengths and capabilities to optimise the feasibility study, design, construction, and management of the hydropower facilities, thereby maximising the benefits while minimising risks and costs. The MRC Secretariat can offer facilitation and early technical support to improve project quality as well. This proactive involvement is preferable to later participation during the Prior Consultation process, a formal 6-month procedure under the Procedures for Notification, Prior Consultation, and Agreement (PNPCA). Overall, if Pak Chom and Ban Khoum can become bi-national joint hydropower projects, they will serve as models of regional cooperation and integration that can demonstrate how joint initiatives can yield mutual benefits.

Moreover, the MRC is currently working with Member Countries to carry out Proactive Regional Planning, expecting that an initial adaptive basin plan be available by the end of 2024, in which several joint investment projects will be recommended. It is expected that many joint investment projects will be identified as those in 'grey' or 'green' infrastructure and be undertaken jointly, with cost- and benefit-sharing agreements by two or more of the six basin countries. Investment projects may include river regulation structures, dams, multi-purpose storage, flood-warning systems, and systems for monitoring of water flow.

Joint investment projects, such as multi-purpose dams and hydropower ventures, are exemplified globally. Notable instances include the Columbia River projects between the US and Canada (Muluye, 2021); the Sambangalou project involving Mali, Senegal, and Mauritania (Choplin and Lombard, 2014; Gakusi, Delponte, Houetohossou, 2015); and the Itaipu venture shared amongst Brazil, Paraguay, and Argentina (Gwynn, 2023). These initiatives stand as remarkable transformations of conflict into cooperation.

Implement alternative and complementary cost-effective energy/water system integration options. Modification of the flow on the mainstream is expected to continue with further development of mainstream and tributary hydropower projects. Through an ongoing study under Proactive Regional Planning, there is potential for more inter-seasonal storage for optimisation of hydropower generation and improvement of water security as well as for supplementing energy with the development of alternative energy options for water-related infrastructure, including pumped storage hydropower (MRC, 2024a; 2024b).

Implementing complementary cost-effective energy/water system integration options involves a multi-faceted approach aimed at enhancing the resilience and sustainability of energy and water systems in the context of hydropower development. One of the options is integrating various renewable energy sources into power development plans, which presents opportunities for synergies between water resources management and energy production.

The Government of Lao PDR recognises that there are emerging issues related to the use of run-of-river conventional hydropower plants, with excess electricity being generated in the wet season, while generation is potentially only just meeting current demand during the dry season. Various strategies are being considered to address these challenges, including (i) installing solar, and taking advantage of the complementary nature of solar and existing conventional hydropower (e.g. supplying daytime needs, thus allowing conventional hydropower plants to 'reserve' their limited dry season capacity for evening peaks); (ii) installing pumped storage hydropower facilities and/or large-scale batteries; as well as (iii) instituting demand management approaches, and increasing electricity exports during the wet season (DEPP, EDL, LNMCS, 2023).

Pumped storage hydropower is a unique form of hydropower technology that utilises the principles of energy storage and regeneration. During off-peak hours, when electricity demand is low, these systems pump water from a lower reservoir to an upper reservoir, effectively storing potential energy. During peak demand periods, the stored water is released through turbines, generating electricity as it flows back to the lower reservoir. This cycle can be repeated continuously, making pumped storage hydropower a flexible and efficient means of managing fluctuations in energy demand. Blakers et al. (2020) showed that Lao PDR has over 5,500 potential sites that may be suitable for pumped storage hydropower development, with a total potential storage capacity of 188,156 GWh.

Floating solar photovoltaic systems also offer an innovative approach to harnessing solar energy. These systems consist of solar panels mounted on buoyant structures that float on the surface of water bodies, such as reservoirs, lakes, or human-made ponds. These systems offer several advantages, including reduced land requirements, improved energy efficiency due to the cooling effect of water and the potential for co-location with existing hydropower facilities (Majumder et al., 2023).

Over the last decade, the cost of producing electricity with renewables, including wind and solar, has decreased rapidly (Gilfillan and Pittock, 2022). The decreasing cost of renewably generated electricity is a key driver of the growing use of renewables-based generators as is the need to reduce electricity sector emissions. Investing in new and diverse renewable energy could create a more secure and affordable energy supply in both domestic and regional markets.

Apply MRC strategies, procedures, tools, and guidelines. The *Integrated Water Resources Management-based Basin Development Strategy* and *Sustainable Hydropower Development Strategy*, approved by the MRC, recognise the opportunity to develop hydropower to meet the clean energy and development needs of riparian countries while contributing to flood and drought management and a low-carbon economy (MRC, 2021; 2021a). Both provide guidance on procedures, guidelines, tools and mechanisms necessary to make hydropower development responsible, optimal, and sustainable, without significant adverse impacts, especially transboundary impacts.

In terms of procedures – especially PNPCA – there are specific requirements for hydropower development. Projects on tributaries must be notified, while those planned on the mainstream require a more detailed process known as Prior Consultation. During Prior Consultation, the project's studies, data, and design must be shared with MRC Member Countries and the public, and they are subject to independent review. The process then continues with dialogue, exchange, monitoring with the MRC, and adaptive management (MRC, 2003). Five mainstream hydropower projects in Lao PDR have undergone the PNPCA Prior Consultation, including the Don Sahong, Luang Prabang, Pak Beng, Pak Lay, and Xayaburi. A sixth project, Sanakham, is in Prior Consultation, while a seventh, Phou Ngoy, has been notified for Prior Consultation.

After Prior Consultation, based on the recommendations of the MRC, the Xayaburi hydropower project undertook design adaptation or change for fish passage, navigation, and sediment transport facilities as well as investigation of seismic risk (MRC, 2019b). Best practices from Xayaburi were used in the development of the Luang Prabang hydropower project, particularly regarding fish passage and sediment management based on its monitoring programme.

The post-Prior Consultation process for Don Sahong yielded the development of MRC Joint Environmental Monitoring, which focusses on hydrology and hydraulics, sediment, water quality, ecological health, and fisheries (MRC, 2022a). To date, Joint Environmental Monitoring methods and protocol have been integrated into the MRC Core River Monitoring Network, an arrangement of monitoring stations and associated infrastructure designed to collect scientific data on various aspects of the Mekong River Basin.

Furthermore, the Prior Consultation processes for Pak Beng, Pak Lay, and Luang Prabang were concluded with agreed on statements by the four MRC Member Countries, outlining measures to optimise project benefits, and to avoid, minimise, and mitigate potential transboundary adverse impacts. To implement these statements, the MRC Joint Committee agreed on a Joint Action Plan (JAP) for each project to be executed as part of the post-Prior Consultation process and to involve the continuous exchange of data regarding the project's design, construction, and operation. The JAP provides opportunities for the government to engage with experts from the MRC with a view to enhancing existing measures to avoid, minimise, and mitigate the potential for transboundary impacts, and to enhance the benefits of the project via adaptive management.

Besides the above procedures, several guidelines also exist to make hydropower development more sustainable. Preliminary Design Guidance for Mainstream Dams (PDG), established by the MRC, serves as the standard for developers and participating countries. This framework encompasses criteria essential for effective dam design and operation, including parameters related to flow management, water quality, dam safety, and the provision of passage systems for both fish and sediment as well as for navigation and the preservation of river-based livelihoods (MRC, 2023b). Mainstream hydropower developers in Lao PDR, including those involved in projects such as Pak Beng, Pak Lay, Luang Prabang, and Sanakham, have used the PDG during their feasibility studies.

Other MRC guidelines related to the development of hydropower dams include the Rapid Basin-wide Hydropower Sustainability Assessment Tool (RSAT), and the Transboundary Environmental Impact Assessment (TbEIA) guidelines. These provide a basis for a hydropower project that is profitable, environmentally friendly, and socially responsible. The RSAT is a multi-stakeholder dialogue and assessment tool designed to assess hydropower development and management issues at a sub-basin level (MRC, ADE, and WWF, 2014). It helps identify gaps, risks, and key institutional responses and management strategies that can be adopted for sustainable hydropower development in the tributary.

The TbEIA guidelines, approved in 2022 as a voluntary application, were designed as a supporting tool applicable in compliance with different national environmental impact assessment legislation systems in MRC Member Countries (MRC, 2023a). The TbEIA actively supports national systems by facilitating environmental impact assessments for projects with potential significant transboundary impacts. Collaboration with neighbouring countries enhances the efficacy of this process, fostering regional cooperation and ensuring better environmental assessments. It is a useful tool in the early design phase of projects to avoid any significant environmental impacts. Lao PDR used these guidelines for the Sekong A hydropower project with the technical support of the MRC and in dialogue with Cambodia and Viet Nam. As a result, Cambodia and Viet Nam expressed appreciation to Lao PDR for sharing data, listening to their concerns, and committing to improvement of the project.

In summary, through the utilisation of various MRC procedures and guidelines, as well as active engagement with other MRC Member Countries and stakeholders during the PNPCA process, Lao PDR is optimising project benefits while also avoiding, minimising, and mitigating potential adverse transboundary effects. This approach consequently fosters basin-wide cooperation amongst riparian countries.

Work toward coordination of basin management operations. Realising that the basin is becoming more developed and regulated by dams, coupled with heightened vulnerability to extreme weather events induced by climate change, a pressing need is arising for more data and information sharing and transboundary coordination of operations regarding flow management, sediment management, management of emergencies, and design and management of hydropower cascades (MRC, 2023c). Coordination of dam operations is crucial, considering the number of dams operated by various operators to ensure energy optimisation and good management of other issues such as sediment transport, water flow, and emergencies.

The increasing number of tightly linked cascades of dams within the Mekong system presents both opportunities and challenges for integrating water resources and energy resource/demand planning. Coordinated operation allows for the management of seasonal flows, enabling downstream projects to benefit from regulated water releases and increased energy production. For instance, for dams in northern Lao PDR, such as those from Pak Beng to Sanakham along the mainstream, storage operation in both the Upper Mekong River Basin and the Nam Ou tributary can enhance the efficiency of energy production. Different developers/operators of the mainstream hydropower projects in Lao PDR have indicated that they would benefit from MRC's coordination with both these individual projects and the Chinese dams.

Achieving effective coordination requires a high degree of cooperation amongst stakeholders, including dam developers and operators, as well as amongst governments. Challenges arise when projects are owned by different entities with varying interests and priorities. These differences may complicate the timing and quantity of water release, particularly if developers aim to cater to diverse markets and customers with different demand patterns. Therefore, integrating water resources and energy resource/demand planning is essential for optimising the benefits of hydropower development while mitigating potential conflicts and ensuring sustainable management of the Mekong River Basin. By aligning water release schedules with energy demand patterns and considering the broader implications for water availability and ecosystem health, countries can achieve a more balanced and coordinated approach to hydropower development that maximises benefits.

As a consequence, national regulations, procedures, and platforms to establish a dam coordination and management centre to facilitate data and information sharing amongst different dam operators need to be in place, especially in Lao context. The Compagnie Nationale du Rhône, a French electricity generation company, has a coordination and monitoring centre concept, which should be revived and enhanced. Such a centre could help support coordinated operation and management for energy and water as well as related issues like sediment, floods, and droughts, bringing together the Ministry of Energy and Mines and Ministry of Natural Resources and Environment.

Also, as one of the MRC Member Countries, not only is it crucial but also beneficial that Lao PDR continues to work with the MRC as it has the mandate to work with other riparian countries, including China, to exchange dam operational data to improve information sharing and transboundary coordination in the basin regarding management of flow, sediment, and emergencies.

4. Conclusion and Policy Recommendations

To navigate the challenges and to fortify Lao PDR's journey towards sustainable hydropower development, four strategic actions and policy directions are proposed.

4.1. Identify and Implement Planned and New Options for Joint Investment Projects

The development of proposed mainstream hydropower dams planned along the border between Lao PDR and Thailand (i.e. Ban Khoum and Pak Chom) should be elevated as national joint projects with the Government of Thailand, so that both countries can work together, with the technical support of the MRC, at the pre-feasibility and feasibility stages to ensure quality reports and studies that illustrate clear impact assessments and mitigation measures. This pre-Prior Consultation engagement with the MRC Secretariat will be helpful regarding the submission and application of the Prior Consultation process within the MRC framework.

Moreover, the work with the MRC and other Mekong countries should be reinforced to identify potential new joint investment projects in the MRC Adaptive Basin Plan, which the MRC is working with Member Countries to formulate under the Proactive Regional Planning to be fully completed in 2027. These projects can be jointly invested, operated, or managed by two or more riparian countries to cope with floods and droughts, optimise energy production, and secure food production for the Mekong River Basin and region.

4.2. Identify and Implement Alternative and Complementary Cost-effective Energy/water System Integration Options

More opportunities in alternative renewable energy sources, like solar and wind, should be identified and implemented. Aligning with Lao PDR energy development plans and leveraging advancements in technology, these alternative energy sources offer the potential for reduced investment and greater energy resilience as well as preserving the river environment for future generations. Embracing such diversification also addresses the pressing challenges posed by climate change to water security for Lao PDR's arsenal of hydropower dams.

Alternative energy options for water-related infrastructure, such as floating solar, and pumped storage hydropower development to supplement energy supply available from existing hydropower projects should also be explored.

4.3. Strengthen and Apply MRC Procedures, Tools, and Guidelines

The early and effective application and utilisation of the MRC procedures, tools, and guidelines – as well as data and studies, such as PNPCA – should be incorporated into national process of hydropower project development with targeted capacity building to relevant line agencies and companies. This will support Lao PDR in conducting quality feasibility studies and reliable environmental and social impact assessments as well as proposed mitigation measures to avoid, minimise, and mitigate potential adverse impacts at both national and transboundary levels.

The implementation of the post-PNPCA process should be further strengthened, including JAPs agreed on at the completion of the PNPCA Prior Consultation process of the hydropower projects. These plans are considered a mechanism for dialogue amongst the MRC Member Counties and other stakeholders, as they keep them informed of the development of hydropower projects. Improvement of plan implementation will demonstrate Lao PDR's commitment towards openness and transparency; in return, Lao PDR will gain more trust and support for its future hydropower development.

4.4. Work towards Coordinated Water Infrastructure Operation and Communication in the Mekong River Basin

National regulations and platforms to establish a dam coordination and management centre to facilitate data and information sharing amongst different dam operators should be developed, building on the current momentum. Good data and information sharing is crucial, due especially to various dams that are operated by different operators. A coordination and monitoring centre could support coordinated operation and management for energy (and water) optimisation as well as back up the disaster mitigation and management efforts. The centre can be hosted by the Ministry of Mines and Energy with active participation of the Ministry of Natural Resources and Environment and connection to the MRC.

The Government of Lao PDR should continue and even advance its efforts in sharing the operational data of hydropower dams amongst MRC Member Countries and other basin countries to improve data and information sharing and transboundary coordination regarding the management of flow, sediment, and emergencies. This can be done under the MRC cooperation platform to enhance regional collaboration, ensure sustainable water resource management, and mitigate the impacts of hydrological events.

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Chapter 11

Voluntary Carbon Markets and Mechanisms in Lao PDR's Energy Sector

Hoyyen Chan

1. Introduction

Lao People's Democratic Republic (Lao PDR) has established its unconditional nationally determined contribution (NDC) target, aiming for a 60% reduction in emissions compared to the 2000 baseline scenario, equivalent to approximately 62 million tonnes of carbon dioxide equivalent (tCO_2e) (Government of Lao PDR, 2021). In addition to the unconditional mitigation targets, Lao PDR also set forth more ambitious conditional targets, which will be achieved with voluntary international cooperation or external financial support, with a total financing need estimated at US$2,980 million. With support from the international community, Lao PDR aims to achieve net-zero emissions by 2050.

One of the criteria of Article 6 under the Paris Agreement is the provision of additionality, whereby a project leads to emissions reductions that would not otherwise occur. Therefore, all conditional mitigation measures of the NDC are eligible to utilise Article 6 in achieving the targets. As shown in Table 11.1, these measures include the deployment of non-hydro renewable energy, electric vehicles (EVs), biofuels in the transport sector, and reduction of final energy consumption. Thus, Lao PDR may consider the potential of international cooperation through Article 6. For instance, potential projects could involve increasing installed capacity from renewable energy to replace thermal power plants, which currently account for 14% of the generation mix by 2030; establishing low-carbon EV-charging stations to accelerate the share of EVs in the national vehicle mix; and implementing carbon capture, utilisation, and storage in coal-fired power plants and cement production.

Table 11.1. Lao PDR's Nationally Determined Contribution Mitigation Targets for Energy-related Measures

	Unconditional Mitigation Targets	Average Abatement, 2020–2030 (tCO_2e/year)
Hydropower	13 GW total hydropower capacity (domestic and export use)	2.5 million
Energy efficiency	Introduction of 50,000 energy-efficient cookstoves	50,000
Transport	New bus rapid transit system in Vientiane and associated non-motorised transport	25,000
	Laos–China Railway	300,000

Conditional Mitigation Targets		Average Abatement, 2020–2030 (tCO_2e/year)	Financing Needs (US$ million)
RE other than hydropower	Solar and wind: 1 GW total installed capacity	100,000	1,500
	Biomass: 300 MW total installed capacity	84,000	720
Transport	30% EV penetration in national vehicle mix	30,000	500
	Biofuels to meet 10% of transport fuels	29,000	230
Energy efficiency	10% reduction of final energy consumption compared to business-as-usual scenario	280,000	30

EV = electric vehicle, GW = gigawatt, Lao PDR = Lao People's Democratic Republic, MW = megawatt, tCO_2e = tonne of carbon dioxide equivalent.

Source: Government of Lao PDR (2021).

Lao PDR has expressed its interest in the internationally transferred mitigation outcomes (ITMOs) approach for achieving its mitigation objectives in its NDC (Government of Lao PDR, 2021). Consequently, the Ministry of Natural Resources and Environment (MNRE) is developing carbon markets in the country, which focus on the forest sector. This chapter discusses the development of voluntary carbon markets (VCMs) in Lao PDR, particularly regarding Article 6, with a focus on the energy sector. It addresses the challenges, policy directions, and implications for the next NDC.

VCMs are platforms or marketplaces where entities – typically corporations, governments, or individuals – voluntarily engage in the purchase and trade of carbon offsets. A carbon-crediting mechanism is an initiative that issues tradable credits to entities voluntarily undertaking emissions reduction activities. The relationship between VCMs and carbon-crediting mechanisms rests on the fact that VCMs provide the marketplace for trading carbon credits generated through emissions reduction or removal projects. Entities that voluntarily undertake such projects can earn carbon credits, which they can then sell on VCMs to buyers looking to offset their own emissions or to demonstrate their commitment to sustainability. In this way, carbon-crediting mechanisms provide the framework for generating tradable assets (i.e. carbon credits), while VCMs facilitate the exchange of these credits amongst participants in the market. There are three approaches to managing this crediting mechanism:

(i) **Domestic (or regional) crediting mechanisms**. Credits are issued through mechanisms established by the government(s), which set regulations and criteria for credit generation.
(ii) **International crediting mechanisms**. Governed by international institutions, examples include the Clean Development Mechanism (CDM) and Joint Implementation under the Kyoto Protocol, or Article 6 under the Paris Agreement.
(iii) **Independent crediting mechanisms**. These are administered by private and independent third-party organisations, such as the Gold Standard and Verified Carbon Standard (World Bank, 2021a).

In some instances, a carbon tax or cap-and-trade programme allows regulated entities to utilise 'carbon credits' from voluntary market programmes to meet a share of – or offset – their compliance requirements. However, it is essential to ensure that the crediting mechanism's scope excludes entities, gases, or activities covered by carbon-pricing instruments – or other mandatory emissions reduction regulations – to prevent overlaps and potential double-counting of emissions reductions (World Bank, 2021a).

The World Bank views mandatory carbon-pricing instruments (i.e. carbon taxes or cap-and-trade programmes) as more effective tools for driving reductions across the entire economy compared to voluntary carbon crediting (World Bank, 2021a). An earlier investigation by Down to Earth and the Centre for Science and Environment found that VCM projects may not actually benefit people nor the climate (Crook, 2023). Nevertheless, carbon crediting does offer its own set of benefits. For instance, credits can be used by regulated entities to fulfil compliance requirements within a carbon tax or emissions trading scheme (ETS), thereby adding flexibility in compliance. Additionally, a crediting mechanism can serve as an alternative to carbon-pricing instruments in cases of legal barriers or political resistance.

2. Voluntary Cooperation under Article 6 of the Paris Agreement

Article 6 of the Paris Agreement permits countries to engage in voluntary collaboration to achieve emissions reduction targets specified in their NDCs. In essence, this provision allows a country or a group of countries to transfer carbon credits earned through emissions reductions to assist other countries in meeting their climate goals. Sub-sections of Article 6 that outline the cooperation through emissions trading are Article 6.2: ITMOs and Article 6.4: International Carbon-Crediting Mechanism. These provisions aim to foster international cooperation and innovative solutions to combat climate change while addressing the diverse needs and preferences of participating countries. Joint research carried out by the International Emissions Trading Association and the University of Maryland suggested that governments – by working together to implement NDCs through Article 6 as opposed to isolated efforts – could lead to governments saving more than US$300 billion per year by 2030 (Edmonds, Yu, Steponaviciute, 2022).

2.1. Cooperative Approach through Article 6.2

Article 6.2 suggests that countries work together to establish 'cooperative approaches' for trading ITMOs between different jurisdictions. This can be achieved by reducing emissions in a host country and generating ITMOs that can then be transferred to a partnering country to help it meet its NDC or to other stakeholders for international mitigation purposes. However, ITMO implementation is subject to revisions and updates over time based on new international guidance by the Conference of the Parties, updated

NDCs of the host and buying governments, and potential future bilateral and multilateral agreements with other countries or development partners.[1] The following is the ITMO implementation framework as of this writing.

(i) **Definition of ITMOs.** ITMOs must be real, verified, and additional; generated from emissions reductions and removal activities undertaken from 2021 onward (Table 11.2); measured in tCO_2e or in other non-greenhouse gas metrics determined by parties that are consistent with their NDCs; authorised for utilisation within an NDC or authorised for use in other international mitigation objectives beyond NDCs (e.g. Carbon Offsetting and Reduction Scheme for International Aviation [CORSIA]); and encompass emissions reductions issued under Article 6.4 arrangements[2] (Moosman et al., 2022; CMI, 2021; UNFCCC, 2022).

Table 11.2. Examples of Emissions Reduction and Removal Activities

Activity	Technology-based	Nature-based
Emissions reduction	Energy-efficiency projects Renewable energy production Low-carbon transport Clean aviation fuels Waste management	Agroforestry practices Land-use optimisation
Emissions removal	Direct air capture with carbon storage (DACCS)[a] Bioenergy with carbon capture and storage (BECCS)[b] Carbon capture, utilisation, and storage (CCUS)[c]	Reforestation and afforestation Tree planting Restoring mangroves Algae-based carbon sequestration Enhanced mineralisation/carbon dioxide mineralisation[d]

[a] DACCS is a technology that uses chemical processes to capture and separate carbon dioxide (CO_2) directly from ambient air. The CO_2 is then separated from the chemicals and captured so that it can be injected into geological reservoirs or used to make long-lasting products. The chemicals are then reused to capture more CO_2.

[b] BECCS involves capturing and permanently storing CO_2 from processes where biomass is converted into fuels or directly burned to generate energy. Because plants absorb CO_2 as they grow, this is a way of removing CO_2 from the atmosphere.

[c] CCUS involves the capture of CO_2, generally from large point sources like power generation or industrial facilities that use either fossil fuels or biomass as fuel. If not being used onsite, the captured CO_2 is compressed and transported by pipelines, ships, rail, or trucks to be used in a range of applications or injected into deep geological formations such as depleted oil and gas reservoirs or saline aquifers.

[d] Enhanced mineralisation accelerates the natural processes by which various minerals absorb CO_2 from the atmosphere. This natural weathering process converts about 1 billion tonnes/year of atmospheric CO_2. One proposal for implementation would involve grinding rocks (olivine or basalt) into powder and spreading the powder over soil, where it reacts with the air to form carbonate minerals that provide reliable, long-term carbon storage.

Sources: Institute for Carbon Removal Law and Policy (2018a; 2018b), IEA, Bioenergy with Carbon Capture and Storage, https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage/bioenergy-with-carbon-capture-and-storage; IEA, Carbon Capture, Utilisation and Storage, https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage; author.

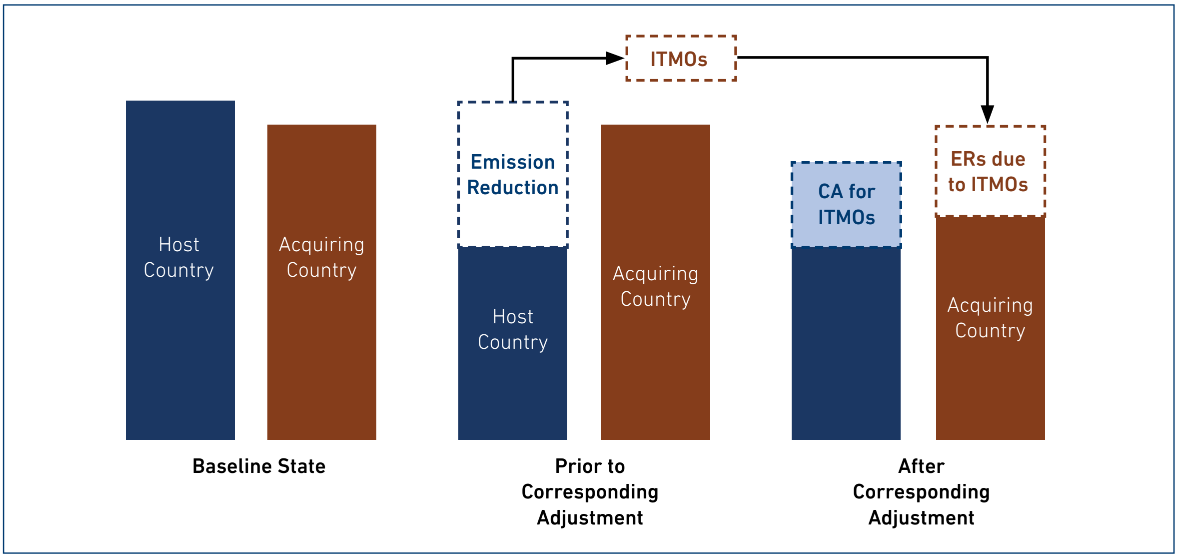
[1] UNDP, Platform for Voluntary Bilateral Cooperation, https://carboncooperation.undp.org/

[2] While Article 6.4 emissions reductions can serve as ITMOs, it is important to note that not all ITMOs comply with Article 6.4 requirements.

(ii) **Participation**. Each participating country must ensure that it is a party to the Paris Agreement; has prepared, communicated, and is maintaining an NDC; has arrangements in place for authorising the use of ITMOs towards achievement of NDCs; has provided the most recent national inventory report; and ensures that its participation contributes to the implementation of its NDC, long-term low-emissions development strategy, and long-term goals of the Paris Agreement (Moosman et al., 2022; CMI, 2021; UNFCCC, 2022).

(iii) **Application of corresponding adjustments**. In the accounting framework established under Article 6.2, when two countries engage in the transfer of carbon market units, they must apply 'corresponding adjustments' for ITMOs. Specifically, the country selling ITMOs – representing emissions reductions or removals achieved within its borders – adds this amount to its recorded emissions level. Conversely, the country acquiring the ITMOs deducts this amount from its emissions inventory (Figure 11.1). Subsequently, both countries compare this adjusted balance with their respective target levels to determine if they have successfully met their emissions reduction goals. This approach ensures that only the purchasing country can apply the transferred emissions reductions, effectively preventing any instances of double-counting (Moosman et al., 2022; CMI, 2021; UNFCCC, 2022). The framework further specifies that only units supported by corresponding adjustments are eligible for fulfilling NDCs or for international compliance, as exemplified by the CORSIA overseen by the International Civil Aviation Organization (ICAO). Carbon credits without corresponding adjustments may find application in other contexts, such as within domestic emissions trading systems. Additionally, Article 6.2 mandates the application of corresponding adjustments, irrespective of whether the emissions reductions fall under the NDC of the selling country (e.g. in the case of methane emissions reductions in a country whose NDC exclusively addresses carbon dioxide emissions).

Figure 11.1. Illustration of Corresponding Adjustment



CA = corresponding adjustment, ER = emissions reduction, ITMO = internationally transferred mitigation outcome.

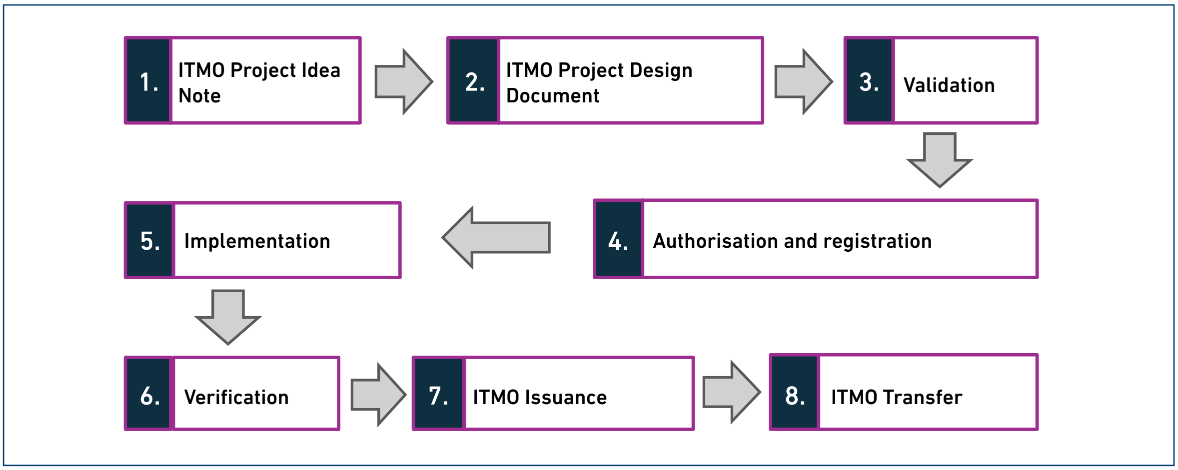
Source: ADB (2021).

(iv) **Time periods and units**. One significant challenge in implementing carbon market approaches stems from the fact that many countries establish their emissions targets for a single year, such as 2030, rather than for multi-year periods, which is the typical framework for carbon market compliance. To address this issue, regulations offer two distinct methods for accounting for single-year targets. Countries have the option to adopt multi-year trajectories for accounting purposes, allowing them to spread the emissions reductions or ITMOs transactions over several years to align with their single-year targets. Alternatively, countries can employ an averaging approach, wherein they account for the average amount of ITMOs bought or sold over a multi-year period in the target year. Additionally, the rules established during the 2021 United Nations Climate Change Conference (COP26) mandate that all accounting must be conducted in greenhouse gas emission metrics, expressed in tCO_2e. While there is some flexibility to consider other metrics, such as hectares of land afforested, countries must still quantify the impact within the context of a greenhouse gas emissions balance. Furthermore, the accounting rules explicitly disallow the carry-over of carbon market units from one NDC period to the subsequent period. This measure is in place to prevent situations in which countries accumulate substantial quantities of carbon market units that lack genuine emissions reductions behind them, and then employ these units to meet forthcoming climate targets, a practice that was observed during the implementation of the Kyoto Protocol (Moosmann, et al. 2022).

(v) **Safeguards and limits**. Article 6.2 cooperative approaches must contribute to global mitigation, ensure accountability and transparency, and promote sustainable development. These approaches must result in an overall reduction in global emissions, ensuring that there is no net increase in emissions amongst participating countries. This necessitates the incorporation of appropriate safeguards and limits. The approaches must guarantee transparency, accuracy, consistency, completeness, and comparability in monitoring the implementation of these approaches and tracking progress towards achieving NDCs. Finally, activities undertaken within these approaches must elucidate how they will support the sustainable development goals of the participating parties. It is imperative that countries respect, promote, and consider their respective obligations concerning human rights; the right to health; rights of indigenous peoples, local communities, migrants, children, persons with disabilities, and individuals in vulnerable situations; as well as the right to development. Additionally, they should be attentive to principles of gender equality, the empowerment of women, and intergenerational equity (CMI, 2021; UNFCCC, 2022).

(vi) **Project development process**. Project development consists of eight steps, from the ITMO project idea note (i.e. proposal) to the ITMO transfer (Figure 11.2 and Table 11.3).

Figure 11.2. ITMO Project Development Process



ITMO = internationally transferred mitigation outcome.

Source: UNDP, Platform for Voluntary Bilateral Cooperation, https://carboncooperation.undp.org/

Table 11.3. Steps of ITMO Project Development Process

No.	Step	Details
1	ITMO Project Idea Note	The developer outlines the mitigation strategy, underlying rationale for generating the ITMOs, monitoring approach, governance framework, contribution to sustainable development, and financial needs.
2	ITMO Project Design Document	The developer drafts the document by employing the recommended emissions baseline and monitoring methodology.
3	Validation	Validation of the developer's mitigation project is carried out by independent auditors, followed by assessments by ministries, national entities, and agencies, and the approval of the validation report by the Article 6 Secretariat.
4	Authorisation and Registration	The host and buying country governments grant authorisation for the ITMO project, and the Article 6 Secretariat registers and publishes it.
5	Implementation	The developer carries out implementation and commences monitoring in accordance with the approved monitoring plan.
6	Verification	The Article 6 Secretariat publishes the results of an independent auditor's verification, confirming that the emissions reductions, as asserted, align with the approved monitoring plan.
7	ITMO Issuance	Following the signing of the certificate by the Article 6 Secretariat, administrative checks are conducted, and serialised ITMOs are generated in the holding account of the buying entity.
8	ITMO Transfer	A portion of the proceeds are deducted for administrative purposes, and the ITMOs are transferred and recorded in the national registry of the transferring country.

ITMO = internationally transferred mitigation outcome.

Source: UNDP, Platform for Voluntary Bilateral Cooperation, https://carboncooperation.undp.org/

(vii) **Existing international cooperation**. As of this writing, there are nine countries actively seeking cooperation with developing countries to acquire ITMOs: Australia, Japan, Republic of Korea, Monaco, Norway, Singapore, Sweden, Switzerland, and the United Arab Emirates (Table 11.3). As of 25 March 2024, the United Nations Environment Programme (UNEP) Copenhagen Centre recorded a total of 141 pilot projects under these cooperation frameworks, with 119 belonging to the Joint Crediting Mechanism (JCM).[3] (UNEP, 2024). These projects are predominantly related to energy efficiency and solar industries. However, only five projects have authorisation statements, which are all under Switzerland's cooperation framework (Table 11.4).

Table 11.4. Existing International Cooperation Frameworks Similar to the ITMO Mechanism

International Cooperation Framework	Acquiring Countries	Since	Number of Partner Countries	Host Countries from ASEAN
Joint Crediting Mechanism	Japan	2013	29	Cambodia, Indonesia, Lao PDR, Myanmar, Philippines, Thailand, Viet Nam
Procurement Programme for International Carbon Offsets	Switzerland (Foundation for Climate Protection and Carbon Offset, KliK)	2018	16	Thailand
Norwegian Carbon Credit Procurement Programme through the Global Green Growth Institute	Norway	2023	3	Indonesia
Indo-Pacific Carbon Offsets Scheme	Australia	2021	2	None
Bilateral cooperation under the Paris Agreement	Monaco	2024	1	None
	United Arab Emirates	2023	1	None
	Singapore	2022	20	Cambodia, Indonesia, Thailand, Viet Nam
	Sweden (Swedish Energy Agency)	2021	3	None
	Republic of Korea	2020	6	Lao PDR, Viet Nam

ITMO = internationally transferred mitigation outcome, Lao PDR = Lao People's Democratic Republic.

Note: As of 25 March 2024.

Source: UNEP, Copenhagen Climate Centre, Article 6 Pipeline, https://unepccc.org/article-6-pipeline/ [accessed 30 March 2024]

[3] UNEP Copenhagen Climate Centre, Article 6 Pipeline, https://unepccc.org/article-6-pipeline/ [accessed 30 March 2024]

Table 11.5. Projects with Authorisation Statements under the Cooperation Framework of Article 6.2

Project	ITMO-acquiring Country	Host Country	Authorised Reductions (tCO_2e)
Promotion of climate-smart agriculture practices for sustainable rice cultivation	Switzerland	Ghana	1,126,000
E-bus programme	Switzerland	Thailand	500,000
Electrification of inhabited islands through Solar Power ITMO Programme	Switzerland	Vanuatu	97,000
Integrated waste recycling and composting for methane reduction	Switzerland	Ghana	1,589,000
Transformative cookstove activity in rural areas	Switzerland	Ghana	3,231,000

ITMO = internationally transferred mitigation outcome, tCO_2e = tonne of carbon dioxide equivalent.

Note: As of 24 March 2024.

Source: UNEP Copenhagen Climate Centre, Article 6 Pipeline, https://unepccc.org/article-6-pipeline/ [accessed 30 March 2024]

2.2. New International Carbon Crediting Mechanism under Article 6.4

Article 6.4 introduces a global trading platform, overseen by the United Nations Framework Convention on Climate Change (UNFCCC), which facilitates the trading of emissions reductions amongst all countries. Often referred to as the Sustainable Development Mechanism, this new market is set to replace the CDM, which was previously in operation under the Kyoto Protocol (and succeeded by the Paris Agreement as of 2020). Compared to the CDM, this new mechanism imposes more rigorous regulations. Notably, it introduces new principles for demonstrating the additional nature of mitigation activities, mandates the application of robust environmental and social safeguards, and establishes a grievance mechanism that allows for appeals against decisions (Moosman, et al., 2022). The Article 6.4 mechanism will be administered by the A6.4 Secretariat (housed in the UNFCCC Secretariat) and overseen by the A6.4 Supervisory Body made up of 12 representatives from parties to the UNFCCC, including two from each of the five United Nations regional groups, one from a least-developed country, and one from a small island developing state. The elected members will serve 2-year terms. The A6.4 Supervisory Body is responsible for establishing the requirements and processes for operation of the mechanism (CMI, 2021; UNFCCC, 2022). The Article 6.4 mechanism is not expected to be operational until the end of 2024 at the earliest (GGGI, 2023).

Activities implemented under Article 6.4 mechanism must (i) ensure overall reduction in global emissions, preventing any net increase; (ii) achieve mitigation of emissions that is additional, including reducing emissions and increasing removals and mitigation co-benefits of adaptation actions and/or economic diversification plans; (iii) apply Article 6.4-approved methodologies that ensure real, transparent, conservative, credible, and below business-as-usual emissions reductions; (iv) minimise risk of non-permanence and leakage while avoiding adverse social and environmental consequences; (v) have been approved by the A6.4 Supervisory Body, including updated methods transitioned from the CDM or those developed by countries or other non-party stakeholders; (vi) engage in consultation with local and sub-national stakeholders, as appropriate, including local communities and indigenous peoples; and (vii) obtain approval from a host country that is a party to the Paris Agreement, has an NDC in place, and possess a designated national authority responsible for overseeing Article 6.4 activities (CMI, 2021; UNFCCC, 2022).

Emissions reduction units (A6.4ERs) are generated from emissions reductions and removal activities and exclude activities occurring before 2021. Crediting periods vary; for reductions, they are 5 years, renewable twice, or for a single non-renewable period of 10 years. For removals, they are 15 years, renewable twice if deemed appropriate and subject to approval by the A6.4 Supervisory Body. A6.4ERs are housed in an Article 6.4 registry, which will be developed and operated in accordance with the guidance provided by the A6.4 Supervisory Body. The A6.4 Secretariat will serve as the registry administrator and operator. A6.4ERs are authorised and undertake corresponding adjustments for utilisation within an NDC or for other international mitigation purposes beyond NDCs (e.g. CORSIA) (CMI, 2021; UNFCCC, 2022)

To prevent any instances of double-counting, parties must implement corresponding adjustments for both A6.4ERs authorised for NDCs and those authorised for international mitigation purposes. Moreover, Article 6.4 mandates a minimum of 2% of the issued A6.4ERs to the account for cancellation for delivering overall mitigation in global emissions. Additionally, 5% of the A6.4ERs must be allocated to the Adaptation Fund as a share of a proceeds levy (UNFCCC, 2022). Consequently, the corresponding adjustment process must encompass these units that are earmarked for the fund (CMI, 2021; UNFCCC, 2022). This specific requirement applies exclusively to Article 6.4 and not to Article 6.2.
The COP27 extended A6.4ERs into two distinct categories:

(i) **Authorised emissions reductions**. A6.4ERs that are authorised for use towards achievement of NDCs and/or for other international mitigation purposes pursuant to paragraph 42[4] of the rules, modalities, and procedures for the mechanism established by Article 6, paragraph 4, of the Paris Agreement (UNFCCC, 2022).

[4] 'The host Party shall provide a statement to the Supervisory Body specifying whether it authorises A6.4ERs issued for the activity for use towards achievement of NDCs and/or for other international mitigation purposes as defined in decision 2/CMA.3. If the host Party authorises any such uses, the Party may provide relevant information on the authorization, such as any applicable terms and provisions. If the host Party authorises A6.4ERs for use for other international mitigation purposes, it shall specify how it defines "first transfer" consistently with paragraph 2(b) of the annex to decision 2/CMA.3'.

(ii) **Mitigation contribution units**. A6.4ERs that are not specified as authorised for use towards achievement of NDCs and/or for other international mitigation purposes may be used for results-based climate finance, domestic mitigation pricing schemes, or domestic price-based measures to contribute to the reduction of emissions levels in the host party (UNFCCC, 2023a). Mitigation contribution units are not required for a corresponding adjustment. Although their use emphasises domestic application, their eligibility for the international voluntary offset market remains uncertain, which raises concerns about the potential for private companies to engage in 'greenwashing' by making offset claims using non-authorised units.[5] To prevent misuse, it is imperative that mitigation contribution units serve as a legitimate measure for companies to provide climate finance, supporting mitigation efforts in developing countries, rather than solely as a means for claiming voluntary credits to meet net-zero emissions targets.

Carbon Emission Reductions (CERs) issued under the CDM may be utilised to meet a NDC requirement, but with certain conditions. Specifically, these CERs can only be used if the associated project was registered after 2012 during the Kyoto Protocol's second commitment period. In such cases, these CERs will be transferred from the CDM registry to the Article 6.4 mechanism registry and classified as pre-2021 emissions reductions. These pre-2021 CERs can only contribute to the achievement of a first NDC, and no corresponding adjustment or share of proceeds levy is required for their transfer or use. The CDM no longer registered, extended crediting periods, or issued CERs for emissions reduction activities after 2020. However, existing CDM-registered activities have the opportunity to transition to and register under the Article 6.4 mechanism.

To transition existing CDM activities, project participants had to submit their requests to the Article 6.4 Secretariat and the CDM host country no later than 31 December 2023. The approval of these requests must be conveyed to the Article 6.4 Supervisory Body by the CDM host country by 31 December 2025. During this transition period, CDM activities may continue to use the currently approved CDM methodology until either their current crediting period expires or until 31 December 2025, whichever comes first. Afterward, they must adopt an approved Article 6.4 methodology (CMI, 2021; UNFCCC, 2022).

In addition to the transition of CDM activities, financial resources from the CDM Trust Fund will be allocated for various purposes, including (i) US$30 million to support the expedited establishment of the Article 6.4 mechanism, (ii) US$10 million to aid capacity building for the Article 6.4 mechanism in developing countries and to facilitate the transition of eligible CDM activities to Article 6.4, and (iii) US$20 million to contribute to the Adaptation Fund.[6]

[5] For instance, consider a company in Country A that claims to offset its emissions through voluntary credits from Country B. Such claims would not count towards Country A's national emissions commitment.

[6] IEA, Bioenergy with Carbon Capture and Storage, https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage/bioenergy-with-carbon-capture-and-storage; IEA, Carbon Capture, Utilisation and Storage, https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage

2.3. Pending Matters of Article 6

The regulations outlined in Article 6 represented the concluding element of the Paris Agreement upon their approval at the COP26. However, further deliberations are still necessary to establish the requisite guidance for their implementation. Although there was a tendency amongst parties to converge on various operational matters during the COP28, the final draft did not garner adequate consensus (UNFCCC, 2024). Consequently, these unresolved issues will be revisited during the 60th session of the UNFCCC Subsidiary Body for Scientific and Technological Advice in June 2024 and the COP29 in November 2024. The following are summaries of pending matters pertaining to Articles 6.2 and 6.4.

Regarding Article 6.2, guidance concerning the authorisation of ITMOs remains unsettled, with ongoing discussions on the potential for revocation of authorisation in cases such as human rights violations, a point contested by some parties due to concerns about double-counting (Krishnamurthy and Dev, 2024; Marcos, 2023; Crook, 2023). Additionally, there is an absence of concrete measures within Article 6.2 to protect the rights of indigenous peoples and local communities (Johnstone and Reséndiz, 2024, Pairojmahakij and Ganz, 2023). Deliberations will also extend to the establishment of an international registry, particularly in terms of its interface with the registry specified in Article 6.4 (Marcos, 2023). Furthermore, discussions will involve the reporting of transactions, including the scope of information and format for annual carbon-trading reports, with particular attention to issues of confidentiality.

Regarding Article 6.4, the centralised nature of the mechanism in Article 6 has led to slower development and uptake compared to cooperative approaches, with expected operationalisation not occurring before 2025 (Johnstone and Reséndiz, 2024). Ongoing discussions amongst parties focus on negotiating guidance and standards for calculating emissions reductions and removals from projects, with consideration of the definition of removals (Marcos, 2023; Johnstone and Reséndiz, 2024; Latham & Watkins, 2023; UNFCCC, 2023b). While the A6.4 Supervisory Body defines removals as outcomes of processes that remove greenhouse gases from the atmosphere through anthropogenic activities and then destroy or store them, concerns have been raised about the lack of specificity, particularly regarding the duration and permanence of carbon storage. This ambiguity could lead to projects that only temporarily store carbon being classified as removals, without ensuring long-term mitigation of emissions (Krishnamurthy and Dev, 2024).

Furthermore, debates persist regarding the treatment of REDD+[7] activities under Article 6.4. Some argue that REDD+ activities should be considered as emissions reduction, removal, or possibly a distinct category under Article 6.4. The lack of clarity on this issue has prompted a request for the A6.4 Supervisory Body to consider whether REDD+ activities should be included under Article 6.4 until 2028 (Latham & Watkins, 2023). Additionally, emissions avoidance is not currently permitted as a method for issuing carbon credits under Article 6, although negotiators have been tasked with reassessing this at the COP28. Stakeholders are growing impatient with the centralised United Nations mechanism, with delays potentially driving more projects towards the more advanced Article 6.2 (Krishnamurthy and Dev, 2024; Latham & Watkins, 2023). This delay has spurred interest in regional initiatives like an Association of Southeast Asian Nations (ASEAN) regional carbon market (Pairojmahakij and Ganz, 2023).

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7 REDD stands for reducing emissions from deforestation and forest degradation in developing countries, while the '+' indicates additional forest-related activities that protect the climate, such as sustainable management of forests and the conservation and enhancement of forest carbon stocks.

3. Development of Voluntary Carbon Markets in ASEAN

All ASEAN Member States (AMS), with the exception of Brunei Darussalam, have experience with market-based mechanisms through CDM projects under the Kyoto Mechanism and JCM projects through bilateral collaborations with Japan. This experience has played a crucial role in familiarising these countries with carbon-crediting mechanisms, facilitating the development of some VCMs in the region.

AMS are actively exploring opportunities, considering benefits, and evaluating how participation in carbon markets could assist in achieving their NDCs. Except for Malaysia, all other AMS either welcome or maintain a neutral stance towards international cooperation through VCMs under Article 6. As of March 2024, five countries – Japan, Republic of Korea, Norway, Singapore, and Switzerland – have signed bilateral agreements with some AMS regarding carbon markets. For Japan, collaborations involve almost all AMS except Brunei Darussalam, Malaysia, and Singapore. Norway recently signed a bilateral agreement with Indonesia (GGGI, 2023). After signing a bilateral agreement with Viet Nam, the Republic of Korea also began approaching other potential partners such as Cambodia, Lao PDR, Myanmar, Philippines, and Thailand. Although Thailand is the only AMS with which Switzerland currently collaborates, the partnership on the E-Bus Programme is the first authorised Article 6 programme in Asia (South Pole, 2023; World Bank, 2023).

Key developments of VCMs in AMS are summarised in Table 11.5. Detailed information on VCMs in ASEAN is included in the Annex.

Table 11.6. Voluntary Carbon Markets in ASEAN

	Brunei	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam
Experience with CDM (number of registered projects)	0	10	156	24	157	3	77	5	155	260
Experience with JCM projects (number of active projects)	0	5	36	4	0	8	6	0	42	30
Trading platform for voluntary carbon market	0	0	IDXCarbon	0	BCX	0	0	CIX	FTIX	By 2025

	Brunei	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam
MOU partners for cooperation under Article 6 (or equivalent)	0	Japan, Singapore, Korea	Japan, Singapore, Norway	Japan, Korea	0	Japan, Korea	Japan, Korea	As a buyer	Japan, Singapore, Switzerland, Korea	Japan, Singapore, Korea

BCX = Bursa Carbon Exchange, CDM = Clean Development Mechanism, CIX = Climate Impact X, FTIX = Federation of Thai Industries Exchange, IDXCarbon = Indonesia Carbon Exchange, JCM = Joint Crediting Mechanism, Lao PDR = Lao People's Democratic Republic, MOU = memorandum of understanding.

Notes:

1. As of 31 March 2024.
2. Although the review found no records of official MOUs between these countries and the Republic of Korea, the cited references revealed that the cooperation is either in the process of negotiation or has been implemented.

Source: Author.

4. Challenges for Carbon Market Initiatives in the Lao PDR Energy Sector

Lao PDR has gained familiarity with carbon markets through its involvement in projects such as the CDM and JCM (Latham & Watkins, 2023; UNFCCC, 2023). Yet participation has primarily been by the private sector, with limited direct engagement from the government, specifically the Ministry of Agriculture and Forestry. This ministry, however, has been involved in the REDD+ project supported by the World Bank under the Forest Carbon Partnership Facility (Saysanavong, 2023b; World Bank, 2021b). The government is cautious about establishing a new mechanism, whether for compliance or VCMs, due to perceived complexities (Saysanavong, 2023a). This section explores the potential challenges that Lao PDR may face in developing a carbon market and carbon-crediting mechanism for energy-related projects.

4.1. Regulatory Framework

MNRE is currently drafting a decree on the National Climate Change Committee and a decree on carbon credit-trading management (Vientiane Times, 2024; Saysanavong, 2023b). However, the latter decree only applies to carbon credits generated by Lao PDR forests for sale on international markets. As of this writing, these decrees have yet to be launched, so it remains unclear to what extent mitigation efforts from the energy sector will be covered. For instance, it is uncertain whether energy-related projects will be subject to the same regulatory framework for participation in carbon trading under the Paris Agreement or if there will be a separate management system for registration, database maintenance, monitoring, verification, and reporting (MRV). The lack of robust policies or regulations pertaining to energy-related carbon crediting may hinder the energy sector's ability to participate in VCMs.

4.2. Technical Expertise and Institutional Capacity

A challenge for Lao PDR lies in its limited capacity to access carbon markets, which is accentuated by its reliance on foreign experts for project documentation. Another issue is the limited institutional capacities and cross-sectoral coordination for mainstreaming climate-change mitigation into development plans (Saysanavong, 2023b).

4.3. Effective Measurement, Reporting, and Verification System

While Lao PDR has a basic greenhouse gas inventory system in place, it is not sufficient for tracking project implementation for carbon trading or crediting. Establishing reliable baselines for emissions reduction projects, along with an effective MRV system for emissions, is foundational for participating in carbon markets and crediting mechanisms.

5. Policy Direction and Recommendations

The following outline policy directions and recommendations for the development of carbon market initiatives in Lao PDR's energy sector.

5.1. Align Policy Objectives of Carbon Market Initiatives

Policymakers must establish objectives and prioritise the roles of carbon markets and crediting in the context of Lao PDR. This step is crucial in shaping the ecosystem of the carbon market as well as the country's participation in international VCMs. Policy objectives for Lao PDR should include:

(i) **Reduce emissions and contribute to meeting NDC targets**. A domestic crediting mechanism would assist in emissions abatement as well as contribute to achieving Lao PDR's NDC targets. However, international cooperation under Article 6 approaches may not provide substantial benefits in meeting a Lao PDR's NDC targets, as mitigation outcomes from the project will need corresponding adjustments. Under the Article 6.2 approach, the sharing ratio of mitigation outcomes will depend on the agreement between Lao PDR (the host country) and the acquiring countries (e.g. Japan shared at least 80% of issued credits for most JCM projects). Similarly, with international carbon trading through Article 6.4 or independent crediting mechanisms, participating countries must adjust their national emissions inventories accordingly based on the traded credits. For instance, if Lao PDR, as the host country, sells credits to a buying country, the emissions that are equivalent to the traded credits are accounted for in Lao PDR's emissions inventory.

(ii) **Generate government revenue and capitalise debt swaps with creditors**. *The 9th National Socio-Economic Development Plan Financing Strategy (2023–2025)* acknowledges that ETSs could generate a significant amount of revenue for Lao PDR (Government of Lao PDR, 2023). Implementing such schemes will require the development of guidelines, procedures, systems, and capacity building to be cost-effective. Mandating carbon or emissions trading projects to register and to trade under the administration of a national registry will generate revenue for the government, irrespective of whether it is a mandatory ETS or a VCM. Additionally, the strategy considers debt-for-nature swaps as an innovative fiscal policy. This concept can be applied to the Article 6.2 approach by cooperating with creditor countries. For instance, using generated credits for interest repayments can be integrated into negotiation strategies to alleviate the debt burden. This may be more suitable for nature-based activities due to lower costs compared to energy-related activities.

(iii) **Mobilise green investment and measure the benefits**. VCMs and crediting mechanisms can channel private or foreign investments into climate-change mitigation activities in Lao PDR. Foreign investors can invest in specific projects to obtain carbon credits through Article 6 approaches or independent crediting mechanisms. Additionally, the methodologies used in crediting mechanisms can be utilised by the government and private investors to estimate the emissions reduction value of a particular measure or to understand the emissions reduction impact of a financial investment. This approach is used in results-based climate finance, which relies on the ability to measure, in a cost-effective way, the actual emissions reduction performance of a specific investment. Consequently, it provides a tangible investment opportunity that can attract investments from a broad range of financial players. As issued carbon credits are used as a metric of performance for results-based climate finance – but not for meeting the financial providers' NDCs – these credits are defined as mitigation contribution units under Article 6.4 and are not obliged to corresponding adjustments.

(iv) **Promote low-carbon development and local environmental benefits**. In many developing countries like Lao PDR, prioritising the development of emerging economic sectors or addressing local environmental issues often takes precedence over emissions mitigation. Carbon-crediting mechanisms, however, offer the potential to generate additional benefits beyond simply reducing emissions. They can serve as a financial incentive for businesses to adopt cleaner technologies, thereby facilitating climate-change mitigation alongside other objectives such as enhancing air quality, safeguarding water resources, and promoting soil health and biodiversity. Additionally, there are social and economic advantages, including improved energy access, job creation through the implementation of new technologies, enhanced livelihoods, and support for the early commercialisation of emissions reduction technologies or products. Furthermore, while Article 6 may not be the primary approach for meeting a host country's NDCs, activities undertaken within its framework must ensure environmental integrity and promote sustainable development, thus yielding environmental benefits.

(v) **Gauge the market response toward carbon-pricing signals.** According to the *9th National Socio-Economic Development Plan Financing Strategy (2023-2025)*, Lao PDR is undertaking the study of the feasibility of environmental fiscal reform, including introducing a carbon tax (Government of Lao PDR, 2023). In this context, a crediting mechanism could be an option if there are barriers, such as legal hurdles or political resistance, to implementing a mandatory ETS or carbon tax. Thus, a crediting mechanism may serve as a good starting point to send a carbon-pricing signal and build familiarity with market mechanisms. Furthermore, by assessing the market sensitivity to carbon-pricing signals, Lao PDR can evaluate whether there will be sufficient supply and demand for credits before embarking on a mandatory or voluntary domestic ETS.

(vi) **Provide offset options for corporate climate objectives and compliance obligations**. VCMs and crediting mechanisms can facilitate stronger voluntary commitments to emissions abatement, particularly where mandatory carbon pricing is absent or for entities not subject to mandatory policies or emissions constraints. These approaches provide a source of credible emissions reductions that businesses and other organisations can use to voluntarily offset their emissions. As Lao PDR is considering a carbon tax for financing environmental and climate priorities, VCMs and crediting mechanisms can offer additional flexibility to compliance options by allowing offsets in addition to tax payments. Yet to ensure that there is sufficient supply for the domestic carbon market, jurisdictions may limit the domestic carbon credits to trade in international markets. Most jurisdictions that allow the use of offsets limit them to either credits from domestic carbon markets or carbon trading that apply corresponding adjustments to ensure that the outcomes contribute to achieving their NDCs.[8] In contrast, internationally transferred carbon credits that do not undergo corresponding adjustments should not be used to meet NDCs.

[8] For example, Singapore is the first country to implement a carbon tax with an offsetting mechanism that aligns with the requirements of Article 6 under the Paris Agreement (NCCS, 2023). By setting offsetting criteria compliant with Article 6, all emissions offset through international platforms contribute to national emissions reduction. These carbon credits are compulsory for corresponding adjustments, making them eligible for claiming emissions reductions towards meeting NDCs.

5.2. Enhance the Regulatory Framework and Market Infrastructure

As the national focal point for climate change, MNRE is working towards Lao PDR's participation in VCMs, including the introduction of regulatory frameworks and market infrastructure for carbon trading and the development of governance frameworks for Article 6 (Saysanavong, 2023a). These efforts are focussed on nature-based activities. If Lao PDR plans to explore the potential of carbon trading beyond forest contributions, however, the regulatory framework must be expanded. Establishing clear guidelines for project approval and MRV is crucial to ensure effective governance of carbon trading. Additionally, Lao PDR should consider setting a threshold to limit international carbon trading from domestic mitigation activities to ensure that mitigation actions contribute to achieving NDC targets by 2030 and net-zero emissions by 2050.

5.3. Strengthen the Measurement, Reporting, and Verification System

Establishing a comprehensive MRV structure to generate accurate and reliable data is fundamental for any carbon-pricing instrument. Reliable baselines for emissions reduction projects under VCMs and crediting mechanisms are essential for determining additionality and accurately quantifying emissions reductions. Defining baselines for these projects can be complex and may require extensive data collection and analysis.

Most importantly, regardless of whether the energy sector is included in the carbon trading framework, an MRV system is helpful for policymakers in shaping climate-change mitigation policy and measures. Establishing standard guidelines for MRV should be a priority for Lao PDR. Doing so will bring advantages such as developing databases for carbon-crediting mechanisms, accounting for national emissions inventory for UNFCCC reporting, tracking progress towards NDC and net-zero emissions targets, evaluating the effectiveness of climate-change mitigation policies and measures, and assessing the potential for carbon-pricing compliance.

5.4. Enhance International Cooperation

Collaborating with international partners, including neighbouring countries and international organisations, to align Lao PDR's carbon market initiatives with global standards and best practices will enhance its credibility and facilitate access to international markets. Indeed, the Government of Lao PDR, Government of Australia, and Global Green Growth Institute are partnering to support the development of a carbon market in Lao PDR, aligning with the principles outlined in Article 6 of the Paris Agreement (GGGI, 2023b). Moreover, in an effort to bolster knowledge and capacity, the Government of

Lao PDR and Government of the Republic of Korea conducted a knowledge-sharing workshop focussed on creating a master plan to implement a carbon-trading system in Lao PDR; it marked a starting point for emissions trading between Korea and Lao PDR in the future (Vientiane Times, 2023). Lao PDR should also encourage public and private sectors to explore potential collaborations with Japan through the JCM by disseminating information on JCM's crediting mechanism and benefits gained from previous JCM projects (Saysanavong, 2023b).

In addition to bilateral cooperation, Lao PDR could capitalise on opportunities for capacity building and regional policy frameworks under ASEAN, such as participating in the development of guidelines and standards that benefit both Lao PDR and the region. These guidelines and standards can be adopted according to the local context, which is not only more cost-effective but also crucial in ensuring that Lao PDR remains competitive in the ASEAN energy market.

For example, harmonised regional standards of minimum energy performance standards for air conditioners are relevant to Lao PDR (ACE, 2020). These standards help lower the cost of energy systems, improve the uptake of more efficient equipment, reduce energy consumption and emissions, increase efficiency, and facilitate ease in trading. Another example pertains to the taxonomy for green investment. One of the identified issues under the *9th National Socio-Economic Development Plan Financing Strategy (2023–2025)* is to have a clearer taxonomy for green investment (Government of Lao PDR, 2023; 2024). Lao PDR may refer to the ASEAN Taxonomy for Sustainable Finance while developing and adopting its own taxonomy. All this information can be transformed into capacity knowledge and integrated into negotiation strategies when establishing cooperation with international partners (ASEAN Taxonomy Board, 2024).

Lao PDR can also leverage its ASEAN chairpersonship by expressing interest in seeking regional collaboration in specific areas to address capacity or policy gaps, such as advocating for the development of regional harmonised standards or guidelines on energy-related emissions MRV, as well as methodologies for quantifying the impacts of mitigation actions in terms of tCO_2e.

5.5. Mainstream Climate Change and Strengthen Cross-Sectoral Coordination

Lao PDR has set a long-term goal to achieve net-zero emissions by 2050. Mainstreaming the idea of climate change will reinforce the integration of climate-change considerations across different sectors. Policy coordination across sectors is crucial to ensure policy effectiveness, a just transition, and inclusivity. This coordination is particularly important for policies shaping carbon market initiatives and crediting mechanisms.

As mentioned previously, carbon market initiatives in Lao PDR focus on nature-based activities and are governed by MNRE. *The 9th National Socio-Economic Development Plan Financing Strategy (2023–2025)* does not mention carbon trading and crediting beyond nature-based activities. While the common objective is to incentivise climate-change mitigation activities, the role of a carbon-crediting policy in the forest sector may differ from that in the energy sector. Under the Article 6 approach, carbon credits generated from forests may raise revenue for the government; in the energy sector, projects could facilitate low-carbon development through knowledge or technology transfer.

The UNEP Copenhagen Centre has recorded projects under Article 6.2 that dominate the energy-efficiency industry and solar sectors. In Lao PDR, there were five JCM projects in the energy sector between 2017 and 2022, with total expected emissions reduction of 19,751 tCO_2e per year. This indicates the potential for energy-related projects and trading mitigation outcomes under the Article 6.2 approach; this potential should be acknowledged when shaping policies.

The decree on the National Climate Change Committee will be crucial in ensuring effective cross-sectoral coordination. Additionally, engaging stakeholders – including local communities, indigenous groups, and civil society organisations – in the design and implementation of carbon market initiatives is vital for ensuring social and environmental integrity and maximising co-benefits.

5.6. Enhance Capacity-Building Programmes

Building technical expertise and institutional capacity within government agencies, private sector entities, and civil society organisations to understand, implement, and monitor carbon market initiatives is key. Capacity-building programmes can be conducted with international cooperation. For example, Lao PDR may seek support from organisations like the Global Green Growth Institute or Asian Development Bank in developing carbon markets aligned with Article 6. Potential areas requiring capacity building in Lao PDR include identification of appropriate mitigation activities for trading under Article 6, governance of ITMO authorisation and corresponding adjustments, and development of climate-change mitigation activity design documents.

In addition to technical aspects, strengthening institutional capacity in negotiation strategies will maximise benefits from a carbon market, such as integrating debt swaps, human rights, health, and environmental safeguards into negotiations. These capacity-building programmes should involve all relevant stakeholders across sectors, particularly for mitigation measures that potentially generate carbon credits.

Furthermore, conducting MRV capacity building for corresponding agencies and reporting entities, as well as capacity building for competent accredited bodies and verifiers (e.g. ISO 14065), is crucial. This will streamline the carbon-trading process and prepare Lao PDR for reporting biennial transparency reports under the Paris Agreement. Moreover, active participation in reviewing other country reports submitted to the UNFCCC can enhance capacity in MRV and policy development. Lao PDR, through its roster of experts,[9] can learn from other countries' best practices and lessons.

[9] Experts who are nominated by their respective governments through the national focal points of the Parties under the UNFCCC.

6. Policy Implication for the Next Nationally Determined Contribution

Under the Paris Agreement, parties are required to submit their NDCs every 5 years; 2025 is the next year, including for Lao PDR, that second NDCs must be submitted. It is crucial to plan now and to implement innovative and efficient approaches to align country priorities with targeted expertise, finance, and technical assistance.

Lao PDR intends to use the Article 6 approach to meet its NDC targets, although there is no explicit direction from the government regarding the inclusion of energy-related measures in this approach. Drawing from the discussions on carbon market development in this chapter, the following are key recommendations for Lao PDR to consider when formulating its next NDC, particularly concerning conditional targets:

(i) **Consider utilising the Article 6 approach for implementing energy-related measures**. Despite the absence of carbon market initiatives in the energy sector in the *9th National Socio-Economic Development Plan Financing Strategy (2023–2025),* there is significant potential, especially through cooperation such as the JCM, on energy efficiency and renewable energy projects.

(ii) **Define the roles of carbon market initiatives in the energy sector**. Prioritise the objectives of carbon market initiatives, considering financing needs and long-term benefits for low-carbon development.

(iii) **Revise energy-related NDC targets to incorporate carbon market and crediting approaches**. Despite the absence of carbon market initiatives in the energy sector in the current national socio-economic development plan, there is significant potential, especially through cooperation such as the JCM, on energy efficiency and renewable energy projects.

(iv) **Formulate conditional NDC targets with estimated contributions to global emissions reduction**. Formulate conditional targets in plans and strategies, explicitly describing quantifiable mitigation impacts as global emissions reductions instead of domestic emissions reductions, due to the consequence of corresponding adjustments if conditional targets are achieved through Article 6 approaches.

MNRE and the Ministry of Energy and Mines must coordinate when preparing the next NDC. It is anticipated that the National Climate Change Committee will facilitate cross-sectoral coordination. By including carbon market initiatives in the next NDC, the development of regulatory and governance frameworks for carbon trading in energy-related activities will follow. Additionally, this will open doors for international investors to collaborate with Lao PDR's energy sector through Article 6 approaches.

Annex:
Carbon Markets across ASEAN

Brunei Darussalam. Brunei Darussalam lacks prior experience in carbon markets, including the Clean Development Mechanism (CDM) or Joint Credit Mechanism (JCM) (UNFCCC, 2022). Despite this, the nation is actively working towards establishing a carbon-trading mechanism under the Brunei Darussalam National Climate Change Policy. Currently, the Brunei Climate Change Secretariat is exploring opportunities to meet nationally determined contributions (NDCs) through voluntary carbon markets (VCMs) (ACE, 2022).

Cambodia. The implementation of Cambodia's NDC is projected to require US$7.8 billion by 2030. To achieve the 2050 target, there is a need for both public and private investments to increase from US$500 million annually to US$2.5 billion. This financial commitment encompasses the execution of *Cambodia's Action and Investment Plan for the National REDD+* Strategy, aimed at achieving ambitious emissions reductions in the forest sector at an estimated cost of US$185.7 million by 2031 (UNDP, 2022). During 2016–2020, the country generated US$12 million from trading in VCMs with international companies (UNDP, 2022). Furthermore, at the 2022 United Nations Climate Change Conference (COP27), Cambodia committed to entering contracts with international corporate buyers for around 15 million tonnes of carbon credits from REDD+ projects (Chandara, 2022). Drawing from past experiences, including CDM projects, Cambodia is actively exploring engagement in Article 6 and a VCM (UNFCCC, 2022). This exploration is conducted with support from the United Nations Development Programme and the Global Green Growth Institute (GGGI), with a focus on identifying fast-track and high-integrity actions to finance its NDC implementation (UNDP, 2022; GGGI, 2023). Prior to the Paris Agreement, Cambodia collaborated with the Korea Forest Service through the REDD+ project, resembling the mechanisms outlined in Article 6. Under this collaboration, a portion of generated forest carbon credits was shared between the Republic of Korea and Cambodia, while the remaining credits were traded in VCMs to support forest-dependent communities in enhancing their livelihoods through incentives from the sale (Clarke, 2023). Additionally, Singapore has entered into a bilateral agreement with Cambodia to cooperate on the implementation of Article 6, adding to existing partnerships with the Republic of Korea and Japan's JCM projects (MOTI, 2023).

Indonesia. Indonesia draws on extensive experience in carbon markets, notably through initiatives such as the CDM and JCM (UNFCCC, 2022).[10] Leveraging these past endeavours positions Indonesia well in the establishment of its national crediting mechanism. The regulatory framework for carbon crediting was articulated within the scope of a 2021 presidential regulation on carbon pricing (World Bank, 2021a). In line with these guidelines, the Indonesian Carbon Exchange (IDXCarbon) was officially inaugurated in September 2023, operating under the regulatory framework outlined in the Financial Services Authority (OJK) Regulation No. 14 of 2023 (OJK, 2023). IDXCarbon provides a transparent, orderly, fair, and efficient trading system, functioning as a platform for various trading mechanisms, including auctions, regular

[10] GEC, Projects/Studies, The Joint Crediting Mechanism (JCM), https://gec.jp/jcm/projects/ [accessed 20 November 2023]

trading, negotiated trading, and marketplace activities (IDXCarbon, 2023). Beyond its collaboration with Japan through the JCM, Indonesia has a bilateral agreement with Singapore. This agreement aims to explore opportunities within the framework of Article 6 of the Paris Agreement, showcasing Indonesia's commitment to international cooperation and engagement in the evolving landscape of carbon markets (NCCS, 2022).

Lao People's Democratic Republic (Lao PDR). Lao PDR has gained familiarity with carbon markets through its involvement in projects like the CDM and JCM (UNFCCC, 2022). However, the private sector has primarily constituted the participants, with the government's (specifically, the Ministry of Agriculture and Forestry) direct engagement limited to the REDD+ project, supported by the World Bank under the Forest Carbon Partnership Facility (Saysanavong, 2023; World Bank, 2021). A challenge lies in the country's limited capacity to access carbon markets, accentuated by a reliance on foreign experts for project documentation. Consequently, the government is cautious about establishing a new mechanism, whether for compliance or VCMs, due to perceived complexities (Saysanavong, 2023). Complicating matters further, there is a notable absence of existing policies or regulations pertaining to carbon credits within Lao PDR. Recognising these challenges, a collaborative effort has been initiated by the Government of Lao PDR, Government of Australia, and GGGI (GGGI, 2023b). This partnership aims to provide support for the development of a carbon market in Lao PDR, aligning with the principles outlined in Article 6 of the Paris Agreement. Moreover, in an effort to bolster knowledge and capacity, the Government of Lao PDR and Government of the Republic of Korea conducted a knowledge-sharing workshop that signifies a starting point for the potential revitalisation of carbon trading between the Republic of Korea and Lao PDR (*Vientiane Times*, 2023).

Malaysia. Malaysia has engaged in the CDM without establishing any bilateral agreements with other nations (UNFCCC, 2022). However, a significant development occurred when the Malaysian stock exchange introduced the Bursa Carbon Exchange (BCX) in December 2022, marking the world's first shariah-compliant VCM (Bursa Malaysia, 2023a). On 16 March 2023, the BCX successfully conducted Malaysia's inaugural carbon credit auction, drawing interest from 15 local buyers, particularly prominent in the financial sector. This resulted in the purchase of 150,000 Verra-registered carbon credits. The Government of Malaysia has also allocated a seed fund of around US$2.2 million to bolster carbon credits generated within the country (Bursa Malaysia, 2023a). The BCX commenced trading and facilitation of off-market transactions of carbon credits in September 2023. By the close of its second day of trading, 10 companies from various industries transacted a total of 16,500 Verra-registered carbon credits (Bursa Malaysia, 2023d). Entities, both foreign and local, meeting eligibility criteria, can register and participate in trading activities on the BCX (Bursa Malaysia, 2023b). Additionally, the launch of the VCM handbook in October 2023 signifies a pivotal step (Bursa Malaysia, 2023c). This comprehensive project development toolkit outlines the VCM concept, VCM mechanism specific to Malaysia, eligible project types, guidance on formulating a VCM project along with its methodologies, and case studies. The creation of this VCM ecosystem underscores Bursa Malaysia's objective of attracting international project developers and investors. The goal is to foster the development of high-quality carbon projects in Malaysia, thereby facilitating the exchange of knowledge, skills, and capital crucial for the rapid scaling up of carbon initiatives in the country. Apart from the federal initiatives, the state of Sarawak recently passed the Environment (Reduction of Greenhouse Gases Emission) Bill, which covers forests and land within Sarawak's boundaries, governing activities such as afforestation and reforestation, the utilisation of land for carbon sink and storage, and related matters concerning financial benefits derived from these initiatives (Jee, 2023). The bill aims to establish a robust system for project verification and validation, overseen by appointed carbon standards administrators, ensuring the integrity and credibility of carbon credits issued in Sarawak (Lee, 2023). This measure positions Sarawak to actively participate and benefit from carbon markets.

Myanmar. Myanmar has gained experience in carbon-market mechanisms through projects like the CDM and JCM, but the number of initiatives remains limited. Additionally, there is a scarcity of public information concerning carbon market development in the country. The absence of transparent rules for allocating forest carbon rights to local communities and project developers poses a significant obstacle to implementing forest carbon projects for both voluntary and regulatory markets. For instance, a key challenge faced by the Myanmar REDD+ Programme is the design of a fair and equitable system for allocating results-based payments (R.P. Myanmar, 2017). In response to these challenges, GGGI has collaborated with the government to develop an investment case for coastal landscape mangrove restoration, initially focussing on the Ayeyarwady Region. This collaboration involves creating a supportive policy environment, analysing potential natural capital value chain returns, assessing benefit-sharing considerations, and identifying financing needs (R.P. Myanmar, 2017). Concurrently, Vlinder, a climate tech company, has partnered with the Worldview International Foundation for the Vlinder Myanmar Blue Carbon project, which aims to restore degraded mangrove areas in the Ayeyarwady Region, benefiting vulnerable communities.[11] Yet despite capacity building through GGGI's support programme, carbon credits from the project are still operated by a reseller in an opaque and unregulated market (Hodgson, 2022). The credits were reportedly controlled by a reseller and sold at nearly three times the price initially agreed upon with Worldview International Foundation. This highlights the need for a robust domestic VCM framework and a solid regulatory foundation to attract investors for collaboration under Article 6 of the Paris Agreement. In a positive development, Myanmar is one of the countries that the Republic of Korea is considering for bilateral collaboration under Article 6 (Korea Energy Agency, 2023). The Republic of Korea has further pledged financial and technical support for the Korea–Myanmar REDD+ Joint Project (*Global New Light of Myanmar,* 2023). Consequently, the Republic of Korea could emerge as a potential partner for international cooperation with Myanmar in participating in VCMs.

Philippines. The Philippines has garnered experience in carbon-market mechanisms through CDM and JCM projects. Apart from the ongoing collaboration with the Government of Japan for the JCM, a Japanese startup specialising in rice cultivation projects has entered into an agreement with the Government of the Philippines for a 45-million-tonne carbon reduction initiative (KLiK, 2023). This project aims to generate carbon credits by sequestering carbon in forests, reducing methane through paddy field management, and implementing changes in agricultural practices. The company is contemplating registering this project under the JCM. Except with Japan under the JCM, the Philippines has not yet entered into bilateral agreements with other countries to cooperate in a VCM under Article 6 of the Paris Agreement. Nevertheless, the Republic of Korea may soon approach the Philippines for such cooperation (Desk and Laos, 2022; Korea Energy Agency, 2023).

Singapore. Due to physical space limitations, high cloud cover, and urban shading, the scalability of renewable energy in Singapore is restricted. This constraint on domestic carbon abatement options has led Singapore to engage in international cooperation through carbon credits. This approach has become an integral part of the country's measures to achieve its decarbonisation goals, complementing its domestic mitigation efforts. It also positions Singapore as a carbon services and trading hub, aligned with Singapore's Green Plan (NEA, 2022). This vision involves creating a space where businesses can acquire high-quality carbon credits from Asia and beyond to offset their emissions. In May 2021, Climate Impact X (CIX) was established by DBS Bank, Singapore Exchange, Standard Chartered, and Temasek

[11] Vlinder Austria, Vlinder Myanmar Blue Carbon, https://vlinderclimate.com/vlinder-myanmar-blue-carbon

(Climate Impact X, 2021a). CIX operates as a marketplace, auction house, and exchange for trusted carbon credits, with the goal of scaling the VCM. The CIX Marketplace offers a curated selection of nature- and technology-based projects aligned with corporate sustainability objectives. CIX Auctions provides a specialised platform for determining the value of unique and desirable projects, newly issued credits, and customised project portfolios. Meanwhile, the CIX Exchange facilitates two-way spot trading, enabling the sale of large-scale, high-quality carbon credits through standardised contracts and individually listed carbon credit projects, primarily catering to multi-national corporations and institutional investors. The CIX's pilot auction, CIX Marketplace, and the CIX Exchange were launched on 21 November 2022, 16 March 2022, and 8 June 2023, respectively (Climate Impact X, 2021b; 2022; 2023). In addition to the CIX Exchange, ACX emerged as another regulated carbon trading platform in Singapore in 2022. The firm expanded its initial focus beyond the CORSIA market, now offering voluntary carbon credits generated from renewable energy projects, clean stoves, and nature-based solutions.[12] Other key players shaping Singapore's carbon landscape include the International Emissions Trading Association and Asia Carbon Institute. The former provides a regional foundation to support its carbon market initiatives, while the latter serves as a registry that certifies and issues carbon credits generated from technology-based and urban-related carbon removal solutions. Moreover, Singapore has entered into bilateral agreements with four neighbouring countries – Cambodia, Indonesia, Thailand, and Viet Nam – to collaborate on emissions reduction under Article 6 of the Paris Agreement (MOTI, 2022a; 2022b; 2023; NCCS, 2022).

Thailand. Thailand stands out as one of the most active participants in the CDM in the Association of Southeast Asian Nations (ASEAN), particularly in its collaboration with Japan through the JCM. Drawing from these experiences, Thailand explored carbon markets as early as 2014, introducing the Thailand Voluntary Emissions Reduction (T-VER) programme (TGO, 2022). To amplify the impact of the T-VER, the Thailand Greenhouse Gas Management Organisation (TGO) joined forces with Verra in August 2022. During fiscal year 2023, the trade volume of the T-VER reached 857,102 tonnes of carbon dioxide equivalent (tCO_2e), a total value of nearly US$2,000, and an average price per tonne of US$2.30. These figures experienced a decline of 28%, 64%, and 26%, respectively, compared to 2022.[13] In a partnership between the Federation of Thai Industries (FTI) and TGO, the Federation of Thai Industries Exchange (FTIX) was inaugurated on 22 September 2022 (Thadaphrom, 2022). FTIX serves as a carbon credit trading platform connected to the T-VER. It empowers private companies and government agencies to engage in carbon credit trading and to monitor their emissions through an online dashboard. Further, regarding Article 6 of the Paris Agreement, Thailand has bilateral agreements with Singapore, Switzerland, and potentially the Republic of Korea, in addition to its existing collaboration with the Japan through the JCM (Korea Energy Agency, 2023; MOTI, 2022; KLiK, 2023). Notably, the partnership with the Government of Switzerland via the KLiK programme represents a milestone, as it is the first authorised Article 6 programme in Asia and the second globally (South Pole, 2023; World Bank, 2023). The KLiK programme since 2023 has facilitated the flow of climate finance from Switzerland to the Bangkok E-Bus Initiative, which works at integrating electric vehicles into privately-operated public transport. This exemplifies Thailand's remarkable climate leadership, particularly in adopting the ITMOs approach under Article 6.2.

[12] ACX, https://acx.net/about-us/

[13] TGO, Carbon Market, https://carbonmarket.tgo.or.th/index.php?lang=EN&mod=Y2hhcnQ=&action=bGlzdA==

Viet Nam. Viet Nam boasts extensive experience in carbon market mechanisms, with its registered projects under the CDM and JCM ranking as the largest and second largest, respectively, amongst ASEAN Member Staes. The pilot National Crediting Mechanism is scheduled to commence in 2024, with full operational status anticipated by 2026, aligning with the crediting mechanisms under Article 6 of the Paris Agreement.[14] Viet Nam actively seeks international collaboration, evident in its bilateral agreements with Singapore and the Republic of Korea, complementing the existing partnership with Japan through the JCM (MOTI, 2022b; Investment and Trade Promotion Centre, 2023). Notably, CT Group, a prominent multi-industry economic group in Viet Nam, inaugurated the ASEAN Carbon Credit Exchange Joint Stock Company in September 2023 (Investment and Trade Promotional Centre, 2023). It offers comprehensive consultancy for enterprises, organisations, and individuals in developing carbon credit projects, understanding carbon offset and credit mechanisms, and navigating the application of carbon taxes at both the regional and global levels. Viet Nam is set to initiate a carbon credit exchange in 2025, coupled with capacity-building initiatives and public awareness campaigns to propel carbon market development.

[14] ICAP, Vietnam, https://icapcarbonaction.com/en/ets/vietnam

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Chapter 12

Regional and International Cooperation to Advance Innovative Technology Transfer for Lao PDR and ASEAN

Weerawat Chantanakome

1. Introduction

The interconnectedness of climate change, energy security, and economic stability is undeniable (IPCC, 2007). The ambitious objectives established to address any of these challenges cannot be fully achieved without recognising and addressing this reality. During this century, the world is confronting the formidable task of sustaining and providing an affordable energy supply to fuel economic growth without causing disruptions to the climate through emissions (Holdren, 2006). The challenge encompasses three primary dimensions: (i) environmental sustainability, which involves ensuring that energy production and consumption do not harm the environment by minimising greenhouse gas emissions and other pollutants that contribute to climate change; (ii) energy security, which entails guaranteeing a reliable and uninterrupted supply of energy to meet the demands of society and the economy, even in the face of geopolitical tensions, disasters, or other disruptions; and (iii) economic stability, which focusses on maintaining stable and affordable energy prices to support economic growth and development while ensuring that the transition to sustainable energy does not negatively impact the economy (IEA, 2011; Lee, Iliev, Preston, n.d.; Carver, 2011; Tomlinson et al., 2008; UNDP, 2015).

In the forthcoming decades, fossil fuels are anticipated to maintain their dominance in global energy, particularly due to the growth of energy demand in developing nations. According to the New Policies Scenario of the International Energy Agency, which assumed cautious implementation of recent government commitments, global primary energy demand is projected to increase by one-third from 2010 to 2035, with 90% of this growth occurring in non-Organisation for Economic Co-operation and Development (OECD) countries. The current share of fossil fuels in global primary energy consumption – approximately 81% – is expected to decline to 75% by 2035. Meanwhile, the contribution of renewables is anticipated to rise from the current 13% to 18% in 2035 (IEA, 2011).

Existing approaches will not expedite the introduction of clean energy technologies into international markets at a pace sufficient to meet demand. The rapid and widespread utilisation of fossil fuels has underscored the need to promptly deploy a comprehensive array of clean energy technologies. These technologies range from those designed to mitigate conventional pollutants such as sulphur dioxide and nitrogen oxides to more advanced options characterised by enhanced energy efficiency and the potential for significant reductions in emissions.

Effectively addressing the dual challenges of climate change and energy security will depend on innovations in clean energy. However, global clean energy innovation is proving to be slow. Analytical assessments reveal a disconcerting misalignment between the urgency of addressing the climate challenge and the historical timeframe required for technology systems to yield returns on investment. Furthermore, the current landscape of clean energy innovations is disproportionately dominated by OECD countries, a factor that will influence the pace and breadth of the diffusion of the most advanced clean energy technologies in the coming decades.

Energy poverty is a situation in which households are unable to access essential energy services and products, which remains a persistent global challenge in developing nations for the foreseeable future. Despite the rapid economic growth experienced by some developing countries, statistics are still alarming. Presently, more than 20% of the global population (1.4 billion individuals) lacks access to electricity, and approximately 40% of the global population (2.7 billion) relies on traditional biomass for cooking. Projections indicate that this issue will endure and potentially intensify in the long term, with an estimated 1.2 billion people still lacking access to electricity in 2030. Concurrently, the number of individuals relying on traditional biomass for cooking is expected to rise to 2.8 billion by 2030. The widespread use of biomass contributes to deforestation and exacerbates the significant climate impact of black carbon, a key contributor to global warming. Furthermore, household air pollution, resulting from the inefficient use of biomass in stoves, is projected to cause over 1.5 million premature deaths annually in 2030 – an alarming toll surpassing premature deaths from malaria, tuberculosis, or HIV/AIDS.

It is a disconcerting reality that, in the absence of an expedited transformation in worldwide clean energy innovation and technology, the world – especially developing nations – risks entrenching itself in an insecure, inefficient, and carbon-intensive energy infrastructure. Addressing this challenge underscores the growing significance of nations possessing the capability to employ effective tools in formulating robust national clean energy innovation strategies and programmes. However, a deficiency exists in comprehending the optimal tools and methodologies for planning, designing, and successfully implementing a national clean energy strategy (IEA, 2021). Specifically, developing nations face a deficit in fundamental technological capabilities or knowledge foundations. For these countries, insights gained and optimal approaches to policy and programme implementation in nations with comparable circumstances can serve as a valuable reference. Notably, China – with clean energy investment approaching US$50 billion in 2010 – stands as the foremost global source and recipient of clean energy investments (Bloomberg New Energy Finance and UNEP, 2011).

The advancement of economic integration in East and South-east Asia is fostering the development of infrastructure and streamlining trade processes. This integration has the potential to reduce the expenses associated with the movement of experts, thereby increasing the likelihood of South–South technology transfer or technology exchange amongst developing nations. Japan, China, Thailand, and other industrialised countries in the region possess transferable technical and managerial capabilities that can benefit less-developed nations. The recent rise in wages in these industrialised countries additionally motivates firms to shift labour-intensive operations and transfer-associated technologies to less-developed countries, including Lao People's Democratic Republic (Lao PDR).

During 2013–2014, two prominent Japanese companies, Nikon and Toyota Boshoku, established new facilities in Savannakhet Province, where the Government of Lao PDR is actively developing a special economic zone. A shared objective amongst companies establishing operations in Lao PDR is to capitalise on the widely recognised 'Thailand-Plus-One' strategy, which allows companies to leverage advanced capabilities from their existing facilities in Thailand and to tap into the abundant labour resources in Lao PDR by operating multiple facilities in both countries at various stages of development. As these companies commence operations in Lao PDR, labour-intensive processes are shifting from Thailand to Lao PDR; simultaneously, the facilities in Thailand are concentrating on higher value-added production. The newly established facilities in Lao PDR complement their counterparts in Thailand, thereby optimising the overall efficiency of the supply chains.

Nonetheless, there is a dearth of case studies focussing on domestic firms and quantitative research addressing the transfer of technology from Thailand and other neighbouring countries to Lao PDR. To address this gap, this chapter refers to a survey conducted in Vientiane and surrounding areas from late 2012 to early 2013, which investigated the dynamics of technology transfer to Lao PDR from China, Thailand, and Viet Nam – the key foreign investors in the country.

2. Current Policy Landscape in Lao PDR

Geographically, Lao PDR is surrounded by five countries – China to the north, Viet Nam to the east, Cambodia to the south, and Thailand and Myanmar to the west. Lao PDR possesses abundant natural resources, notably water resources sourced from significant waterways, including the Mekong River and its basin. Water resources – exploited for electricity generation through hydropower plants – constitute a pivotal element in the nation's economic development strategy spanning several decades.

In terms of demographics, as of 2019, the population of Lao PDR reached 7.12 million, distributed across an average household size of 5.5 persons, equating to an estimated 1,276,867 households. The population exhibited growth from 5.3 million in 2000, representing an annual growth rate of 1.8% between 2000 and 2019. The urbanisation rate, recorded at 36.50% in 2019, is anticipated to rise to 44.55% by 2030 (UNESCAP, 2022).

Classified as a lower-middle-income economy by the World Bank in fiscal year 2021, Lao PDR has emerged as one of the world's fastest-growing economies over the past 2 decades (UNESCAP, 2022). It has witnessed notable economic growth, with the gross domestic product (GDP) growth rate averaging approximately 7.0% since 2000. The COVID-19 pandemic did impact the economy negatively, resulting in a contraction of –0.5% in 2020. Projections indicate a gradual recovery, with expected GDP growth rates of 4.0% in 2021, 4.5% in 2022, and 5.0% in 2025, ultimately ascending to 6.5% by 2030, reverting to pre-COVID levels.

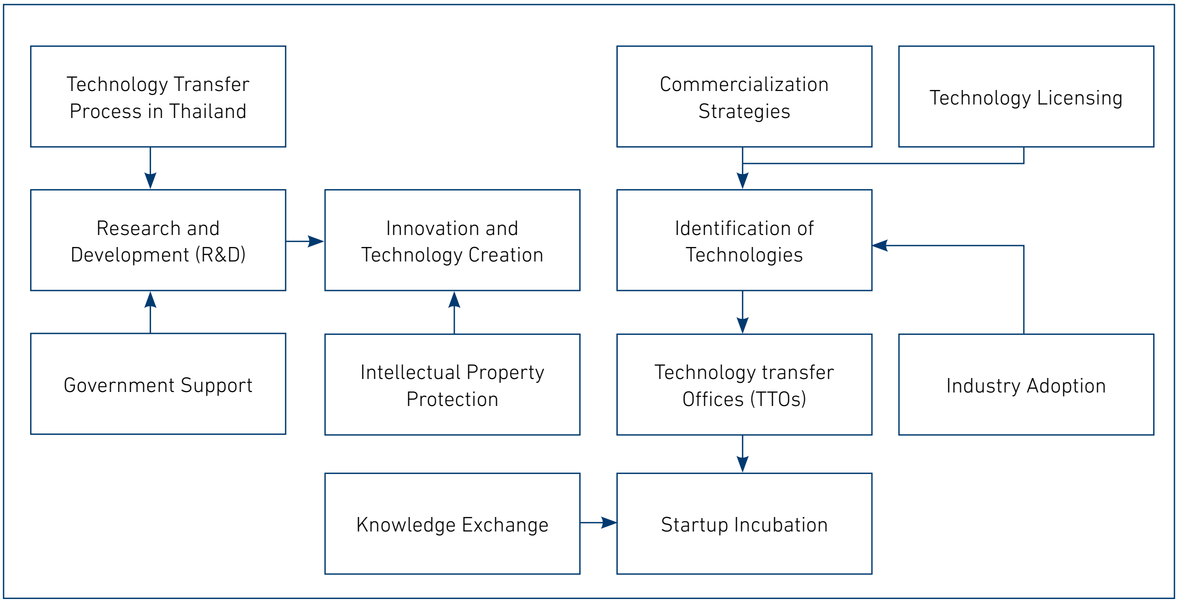
In terms of climate-change risks, Lao PDR is vulnerable to extreme events such as droughts and floods, which have been escalating in frequency and severity. These events have wide-ranging repercussions regarding food security, the water supply, public health, environmental management, and overall lifestyle. Climate change is anticipated to impact key industrial sectors, including mining, hydropower, and wood processing, as these rely on natural resources. Additionally, sectors such as agriculture, animal husbandry, forestry, and fisheries – dependent on specific climatic conditions – may experience reduced productivity due to water shortages and groundwater depletion. This would exacerbate food insecurity and poverty, given the predominant reliance of the population on agriculture for livelihoods (UNESCAP, 2022).

However, Lao PDR has demonstrated notable progress in innovative technology transfer, a strategic initiative aimed at fortifying economic development and addressing societal challenges. Collaborative efforts between the government and diverse stakeholders have actively fostered an environment conducive to synergies amongst research institutions, industry players, and the public sector. This collaborative milieu has facilitated the seamless diffusion of cutting-edge technologies. Significant endeavours include the establishment of innovation hubs, incubators, and technology parks in Lao PDR, which serve as pivotal conduits for knowledge exchange and cultivation of inventive solutions. In parallel, concerted efforts have been deployed to cultivate partnerships with international organisations, leveraging external expertise to enhance the effectiveness of technology transfer initiatives. The sustained advancement in this sphere is key for Lao PDR, as it endeavours to unlock the transformative potential of innovation, stimulate economic growth, and enhance societal well-being.

3. Technology Transfer Process in Thailand

Thailand possesses a noteworthy background in technology transfer, exemplified by the process in Figure 12.1. The purpose of presenting this illustrative model is to provide a representative framework for understanding the analogous technology transfer dynamics applicable to Lao PDR. By sequentially depicting the stages involved, Figure 12.1 serves as a visual guide to facilitate comprehension of the intricacies associated with the transfer of technology, thereby offering insights into potential adaptation for Lao PDR context.

Figure 12.1. Technology Transfer Process in Thailand



Source: Panmaung (2020).

Research and development. Research and development initiate the technology transfer process in Thailand, marked by the commencement of investigative and developmental endeavours undertaken by academia, research institutions, and private enterprises. These entities play pivotal roles in advancing knowledge, fostering innovation, and laying the foundation for subsequent phases in the technology transfer continuum.

Innovation and technology creation. This represents the subsequent phase wherein inventive technologies emerge as outcomes of research initiatives. These advancements span diverse sectors, encompassing information technology, biotechnology, and manufacturing. The transformative nature of this phase underscores the pivotal role played by research efforts in catalysing advancements that contribute to technological innovation across multiple domains.

Intellectual property protection. Such protection assumes a critical role within the technology transfer process. Researchers and innovators strategically safeguard their inventions by leveraging intellectual property rights, which may encompass patents, copyrights, or other pertinent mechanisms. This proactive measure not only preserves the exclusivity of their creations but also establishes a legal framework that facilitates the subsequent transfer and utilisation of the developed technologies.

Technology transfer offices (TTOs). The integral component in orchestrating the technology transfer process is the presence of TTOs within numerous academic and research institutions. These specialised entities are entrusted with the pivotal role of overseeing and expediting the seamless transition of technologies from academia to the commercial sector. Many TTOs in Thailand are equipped with dedicated physical offices, underscoring their commitment to managing the complexities inherent in the technology transfer landscape.

Identification of technologies. The subsequent step involves identification of technologies, wherein potential technologies with prospects for commercialisation are discerned. This process entails a comprehensive assessment of the feasibility of the technologies, coupled with an analysis of market demand. The meticulous evaluation of these factors is imperative to ascertain the viability and potential success of the identified technologies in the commercial domain.

Commercialisation strategies. Following the identification of technologies, TTOs engage in collaborative efforts with businesses, entrepreneurs, and/or investors to formulate effective commercialisation strategies. These strategies encompass a spectrum of approaches, including licensing agreements, joint ventures, or the establishment of startups. By forging these strategic partnerships, TTOs facilitate the transformation of innovative technologies into commercially viable products or services, ensuring a dynamic and mutually beneficial synergy between the academic and commercial spheres.

Technology licensing. The process of technology licensing ensures that formal agreements are established to authorise third parties to utilise, develop, and market the technology in question. These licensing arrangements typically entail financial considerations, such as the payment of royalties or other mutually agreed upon financial arrangements. Through these contractual agreements, the originators of the technology grant permission for its utilisation, fostering wider dissemination and commercialisation under specified terms and conditions.

Startup incubation. In certain instances, the technology transfer process culminates in the establishment of startups. These nascent enterprises may receive support during their initial stages of development through incubators and accelerators. This phase of startup incubation is instrumental in providing the necessary resources, mentorship, and infrastructure to facilitate the growth and sustainability of these emerging ventures, thereby contributing to the successful integration of transferred technologies into the commercial landscape.

Industry adoption. The penultimate phase involves industry adoption, wherein established industries and companies embrace the transferred technologies, seamlessly integrating them into their operational frameworks. This adoption is driven by the recognition of the potential to enhance productivity and efficiency or to expand product offerings. Through this assimilation, industries leverage the transferred technologies to stay abreast of advancements, thereby contributing to their sustained competitiveness and growth.

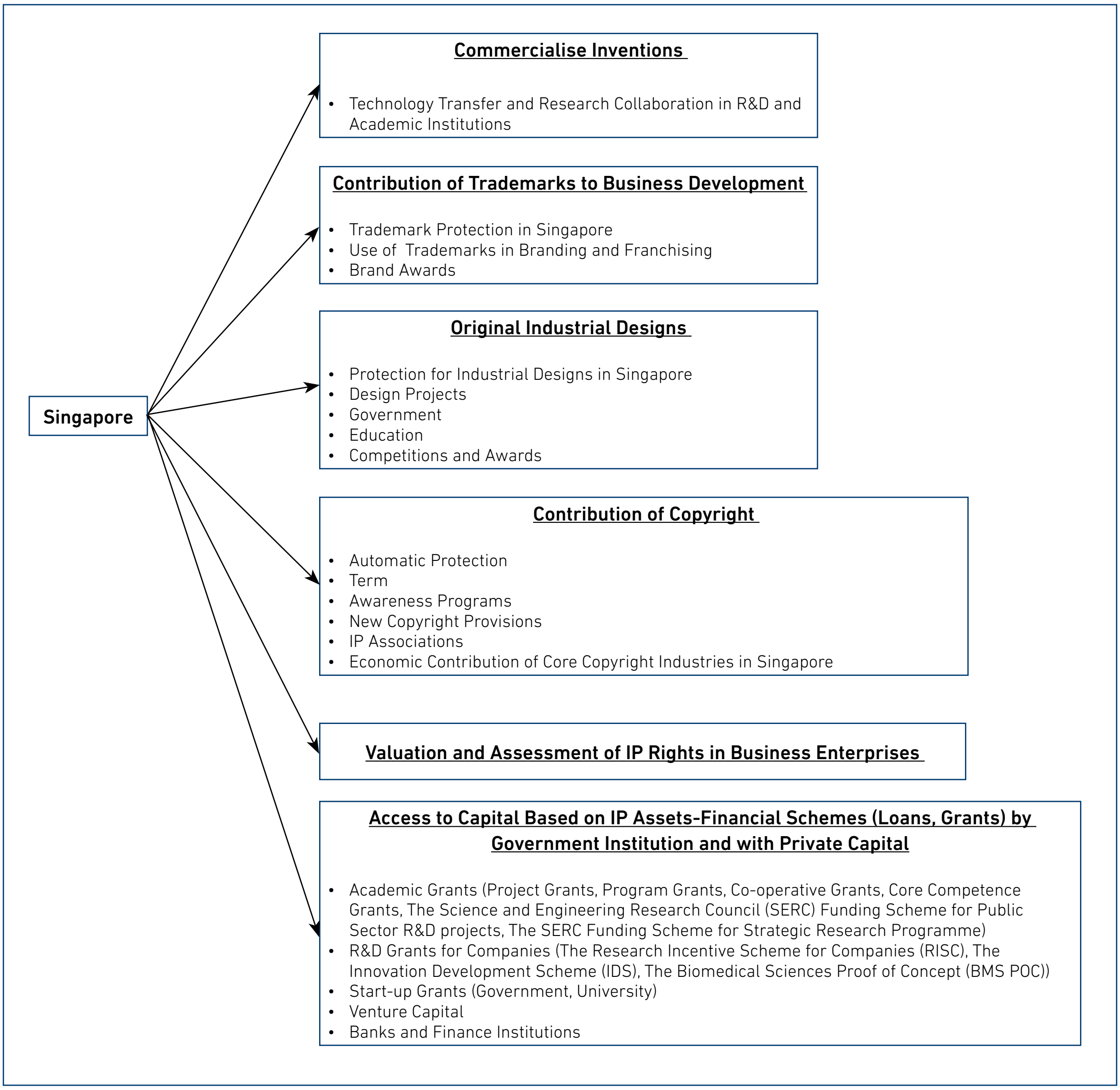
Knowledge exchange. The final stage underscores the significance of knowledge exchange, where sustained collaboration and information sharing persist amongst academia, research institutions, and industry. This ongoing exchange of knowledge serves as a catalyst for continued technology transfer and innovation, fostering a dynamic ecosystem that perpetuates advancements and synergies between the academic and industrial realms. This iterative process ensures a perpetual cycle of learning, adaptation, and progress within the broader landscape of technology transfer.

Government support. The government must assume a pivotal role in underpinning and incentivising technology transfer activities. The formulation and implementation of supportive government policies and initiatives constitute a cornerstone of this process. Such initiatives may encompass financial backing, grants, and the establishment of regulatory frameworks conducive to the seamless transfer of technology. The proactive involvement of the government serves to create an enabling environment, fostering innovation, collaboration, and the effective dissemination of technological advancements across various sectors.

4. Technology Transfer Policy in Singapore

Singapore distinguishes itself amongst Association of Southeast Asian Nations (ASEAN) Member States for its success in implementing technology transfer policies. Within the country, the pivotal roles of technology transfer and collaboration with industry are evident in the country's two primary universities and five polytechnical schools. In addition to these higher education institutions, the Agency for Science, Technology and Research (A*STAR) oversees 12 research institutes. This organisational framework underscores the Government of Singapore's explicit commitment to advancing and cultivating technology transfer within the nation. Figure 12.2 shows the general overview of the technology transfer policy in Singapore.

Figure 12.2. Technology Transfer Policy in Singapore



IP = intellectual property, R&D = research and development.

Sources: Cheah, Bellavitis, Muscio (2021), Kian et al. (2017), WIPO (2020), Lee and Win (2004); Liu, Subramanian, Hang (2021).

4.1. Commercialising Inventions

In Singapore, the two primary universities and five polytechnical schools hold a central position in technology transfer and industry collaboration. Additionally, A*STAR oversees 12 research institutes beyond these higher education establishments.

4.2. Profiting from Original Industrial Designs

Protection for industrial designs. In Singapore, safeguarding industrial designs pertains to configurations, patterns, shapes, or ornaments applied to articles through industrial processes. To be eligible, the design must exhibit novelty, which must be applied to an article through an industrial process, indicating an intention to produce or to have produced more than 50 copies of the article for commercial purposes.

Government. The Ministry of Information, Communications, and the Arts serves as the primary coordinating agency for the advancement of the design industry in Singapore. Established in August 2003, the DesignSingapore Council leads a national endeavour aimed at the cultivation and advocacy of design within the country. The council is responsible for executing initiatives to cultivate design-centric sectors such as architectural services, advertising services, visual communications design, interior design, fashion design, and product and industrial design. Additionally, it promotes Singaporean design on the international stage. In pursuit of fostering a more pervasive design culture within Singapore, the council initiates programmes to enhance design awareness in educational institutions, public establishments, and various activities.

Education. The instruction in design is integrated into the mandatory design and technology curriculum in lower secondary school (i.e. ages 13–14 years) and is elective during upper secondary education (i.e. ages 15–16 years). Specialised institutions, such as polytechnical schools and art schools, like the Nanyang Academy of Fine Arts and Lasalle College of the Arts, confer diplomas across various design disciplines. Furthermore, design modules are incorporated into the engineering programmes at Nanyang Technological University and National University of Singapore (NUS), where a master's programme in design technology is offered at the Singapore University of Technology and Design in collaboration with the Eindhoven University of Technology within the NUS Faculty of Engineering. The NUS extends its academic offerings to include degrees in architecture and industrial design through its School of Design and Environment.

Competitions and awards. Singapore hosts a variety of design competitions, exemplified by an initiative conducted by Samsung Asia, which involved the conceptualisation of covers and accessories for Samsung's MP3 player. Additionally, the Singapore Design Award, established by Enterprise Singapore in 1988 and administered by the Design Business Chamber Singapore since 2000, stands out as a prestigious international accolade recognising exceptional innovations globally. Open to both Singaporean and foreign designers, it encompasses diverse competition categories, including product design, graphic design, interactive design, and packaging design.

Design projects. Numerous design initiatives receive support or sponsorship through the DesignSingapore initiative. An example is the Singapore Design Festival 2005.

4.3. Contribution of Trademarks to Business Development

Trademarks. These play a crucial role as indicators of the origin of goods or services, enabling consumers to recognise and to differentiate between various brands. They offer legal protection for owners by prohibiting others from using similar logos or names that could mislead or deceive consumers. Securing trademark rights allows businesses to exclusively use their brand, fostering brand recognition, credibility, and customer loyalty. Consequently, trademarks enhance a business's competitiveness and help preserve its market share.

Trademark protection. In Singapore, the registration of a trademark remains effective for 10 years from the date of application. Sustained protection beyond this period is contingent upon the regular payment of renewal fees and the continued appropriate utilisation of the trademark. Applicants seeking trademark protection can opt for online submission via eTradeMarks or choose the traditional route of submitting a paper application to the Registry of Trademarks at the Intellectual Property Office of Singapore. Following submission, the application undergoes a sequence of procedures, including formal examination, search, examination, and publication, before culminating in the registration process. The anticipated timeline for processing a trademark application is estimated to be 4–6 months.

Use of trademarks. Numerous small and medium-sized enterprises (SMEs) in Singapore have achieved notable success and robust business growth by strategically investing in branding. Particularly prominent in this success are companies within the food and beverage sector, such as Barang Barang, BreadTalk, Expressions, and Ya Kun. The prevalence of private enterprises specialising in branding services further underscores the significance of this practice. Enterprise Singapore, operating as a statutory board under the Ministry of Trade and Industry, offers a comprehensive directory featuring contact details for approximately 50 brand specialists on its official website. Recognising the pivotal role of branding in facilitating business expansion, Enterprise Singapore has inaugurated the Branding for Internationalisation Programme aimed at assisting Singapore-based firms in establishing a global footprint.

Brand awards. Annually, Enterprise Singapore conducts the Singapore Prestige Brand Award ceremony with the aim of honouring the 15 most valuable Singaporean brands. This award is determined through a desktop evaluation, relying solely on publicly accessible information. The valuation process adheres to the internationally recognised and accepted methodology consistent with the one employed in the annual Best Global Brand competition, a collaborative publication by *Business Week* and Interbrand.

4.4. Contribution of Copyright

Automatic protection. In Singapore, copyright protection is inherently granted to creators upon the creation and fixation of their work in a tangible form. Registration is not a prerequisite for securing copyright protection; it is automatically conferred to creators. Therefore, as long as a work is independently created, it enjoys copyright protection. If two distinct works, originating from the same idea, are independently created, each work is eligible for separate copyright protection.

Awareness programmes. The Honour Intellectual Property (HIP) Alliance is a collaborative entity comprising government agencies, private organisations, and industry associations united by a shared commitment to advance education on intellectual property. In conjunction with the Intellectual Property Office of Singapore, the HIP Alliance is dedicated to instilling a culture of respect and recognition for original creative works. Its mission is encapsulated in the campaign, 'Saying No! to Piracy', which aims to educate individuals on the importance of acknowledging and rewarding the efforts of creators while discouraging intellectual property infringement.

Circumvention of technological measures. Given the growing ease with which digital copyright works can be replicated and shared, there is a pressing need to extend legal protection to the technological measures employed by copyright owners. This protection aims to prevent unauthorised access and to restrict the unauthorised use of their works, recognising the imperative of safeguarding digital content in the contemporary landscape.

Rights management information. Rights management information encompasses details that identify the creator of a work and the terms and conditions governing the use of that work. In the electronic domain, this information may be affixed to or integrated into a copy of the work. Alternatively, it may be presented in conjunction with the communication or public dissemination of a copy of the work. This practice is essential for providing transparency and clarity regarding the ownership and usage parameters associated with a particular creative work.

Economic contribution of core copyright industries. In 2004, NUS Consulting conducted a study to assess the economic impact of the core copyright industries in Singapore (Kah et al., 2004).The evaluation focussed on three primary indicators – output, value added, and employment. It identified five key copyright industries – software and databases; press and literature; music, theatrical productions, and opera; advertising services; and radio and television. These sectors were central to the analysis, providing insights into their respective contributions to Singapore's economy through the mentioned indicators.

4.5. Valuation and Assessment of Intellectual Property Rights

Accounting firms and private consultants in Singapore – inclusive of the major international accounting firms – have traditionally provided intellectual property valuation services tailored for various business applications. Despite the availability of these services, SMEs and startups often perceive them as an additional financial burden, given their constrained budgets. Many prefer to utilise their own valuation methods, such as the market approach, cost approach, or income approach. However, it is important to note that these generic methods may not be universally applicable to every valuation scenario.

Challenges arise when dealing with sophisticated technical domains, such as emerging technology fields where there are no established benchmarks. In such cases, the valuation process becomes more intricate, relying heavily on the technology's positioning within the market. This complexity can pose a significant hurdle for businesses seeking accurate assessments of the value of their intellectual property.

Generally, except for select startups, smaller SMEs in Singapore tend to not perceive intellectual property as an asset that can be leveraged for securing funding. Instead, intellectual property is often viewed as an additional cost, incurring more expenditure, which is met with aversion. Consequently, intellectual property tends to have a lower priority for SMEs, given their focus on day-to-day survival.

The lack of a concrete policy on intellectual property asset security within banks further compounds this situation. The concept of intellectual property as a tangible asset is still relatively new in Singapore, and SMEs, as a result, do not habitually list intellectual property on their balance sheets. Notably, there has been a rise in startups, particularly spinoffs resulting from intellectual property generated during research at the two universities. However, even with this growing trend, the valuation for seed funding remains a complex process. NUS, in such cases, employs its in-house expertise, relying on a formula that integrates income projections, market trends, and the inventor-entrepreneur's track record and merchandising.

4.6. Access to Capital Based on Intellectual Property Assets

Singapore provides a diverse array of financial schemes tailored to entrepreneurs and researchers, encompassing various stages of business development and research endeavours. These schemes encompass the following.

(i) **Seed funding for startups**. Initiatives designed to provide initial capital and support to nascent businesses at their early stages of development.
(ii) **Research and development grants**. Funding programmes aimed at supporting research activities, encouraging innovation, and advancing technological capabilities.
(iii) **Loans and subsidies**. Financial assistance in the form of loans and subsidies, often sourced from public entities, to aid in business growth and innovation.
(iv) **Venture funding from private sources**. Support from private investors, such as venture capitalists, to fuel the growth and expansion of innovative ventures.

These financial schemes are instrumental in fostering a dynamic entrepreneurial ecosystem by providing crucial support across various facets of business and research initiatives in Singapore.

5. Enabling Factors to Advance Technology Transfer and Policy Implications

Effective communication and knowledge dissemination are imperative for the successful transfer of technology. Motivation plays a crucial role in driving increased licensing activity, emphasising the significance of their engagement in transfer activities (Cummings and Teng, 2004; Thomas et al., 2020). Informal interactions with industry contribute positively to research collaboration, underscoring the role of individual actors in academic entrepreneurship as facilitators in the journey from laboratory to market (Ponomariov and Boardman, 2008).

The competence and motivation of a team significantly influence the absorption of technology within an innovation alliance. Both research- and market-oriented TTOs have a favourable impact on licensing activities (Soares and Torkomian, 2021). Incubators are instrumental in new product development and economic growth. The licensor's knowledge about the technology source within the transferor positively affects technology licensing (Dos Reis and do Carmo Durate Freitas, 2014; Lopes et al., 2018; Murovec and Prodan, 2009; O'Kane et al., 2017).

Management support is identified as a vital factor for researchers' engagement in technology transfer, and its absence can act as an inhibitor (D'Este and Perkmann, 2011). Adequate training is essential for the absorption of technology in the industry (Sung, 2009). Technology transfer positively influences the quality and quantity of research and society and vice versa (Veiga et al., 2020). The quality of work in public institutions significantly affects entrepreneurship, innovativeness, and competitiveness (Berbegal-Mirabent, 2018; Bradley, Hayter, Lin, 2018; Heher, 2006; Scuotto et al., 2020).

Research and innovation serve as critical drivers for the economic development of both industry and a country (Bozeman, 2000). Innovativeness is a prerequisite for academic entrepreneurship, creating avenues for research opportunities (Bornmann, 2013). Proactive policies and actions enhance transfer efficiency, and the return on investment from research and development requires consistent policy support. Exploration of technology licensing modes, beyond traditional linear approaches, aims for more impactful technology transfer (Fini et al., 2018).

Financial support instruments facilitate the development of investment-ready products, contributing to potent technology transfer. In the quintuple helix paradigm, societal impacts are identified as drivers for technology generation and adoption. Globally, the success of technology transfer has been extensively examined across various parameters, including diffusion, commerce, politics, environmental benefits, replacement benefits, human resources, and economics. Recent attention has been given to public value, encompassing the entire spectrum of sustainability (Lema and Lema, 2012).

Moreover, the policy implications pertaining to technology transfer in ASEAN Member States regarding net-zero emissions targets are intricate and encompass a spectrum of strategic measures designed to cultivate sustainable and low-carbon practices (Ambashi, 2010). These policy considerations are instrumental in steering the transition towards cleaner technologies and ameliorating the impacts of climate change. The following delineates key policy implications:

Renewable energy transition policies. The imperative lies in the implementation and reinforcement of policies that advocate the transition to renewable energy sources, including solar, wind, hydro, and geothermal. The setting of ambitious targets, provision of incentives, and establishment of a regulatory environment conducive to the adoption of clean energy technologies are indispensable for accelerating this transition.

Energy-efficiency measures. Introducing and enforcing policies to enhance energy efficiency across diverse sectors such as industry, transport, and buildings are paramount. This involves the establishment of energy-efficiency standards, promotion of energy-efficient technologies, and incentivisation of energy-saving practices.

Decentralised energy systems. Policies supporting the development of decentralised and distributed energy systems assume significance in bolstering energy resilience and diminishing reliance on centralised fossil fuel-based power generation. Incentives for community-based renewable energy projects and the establishment of microgrids constitute potential avenues.

Carbon-pricing mechanisms. The implementation of carbon-pricing mechanisms, such as carbon taxes or cap-and-trade systems, is a strategic approach to create economic incentives compelling businesses and industries to curtail their emissions. This approach internalises the cost of carbon, thereby encouraging the adoption of cleaner energy alternatives.

Incentives for sustainable transport. Policies geared towards fostering the adoption of electric vehicles, enhancing public transport infrastructure, and endorsing non-motorised transport alternatives are integral components in abating emissions originating from the transport sector. Incentivisation mechanisms, such as tax breaks or subsidies, can galvanise the adoption of sustainable transport technologies.
Support for research and development. The pivotal role of investing in research and development on clean energy technologies is underscored. Policies that lend support and financial backing to research institutions, startups, and businesses engaged in the evolution of sustainable energy solutions serve as catalysts for expediting the transition towards a low-carbon economy.

International collaboration and cooperation. Collaborative initiatives and the exchange of information on best practices for realising net-zero emissions within the ASEAN context are emphasised. Regional cooperation serves as a facilitative mechanism for technology transfer, capacity building, and the reciprocal sharing of experiential insights.

Capacity building and education. Policies should be strategically formulated to orient efforts towards enhancing the capacity of institutions, industries, and the workforce to navigate the terrain of clean energy technologies. Educational programmes and training initiatives assume a pivotal role in preparing the workforce for the shift towards a low-carbon economy.

Adaptation and resilience policies. Policies are urged to incorporate measures for climate adaptation and resilience. Such policies entail strategies to contend with shifting weather patterns and potential repercussions on energy infrastructure.

Fiscal and financial incentives. The provision of fiscal and financial incentives, including subsidies, grants, and low-interest loans aimed at encouraging investments in clean energy projects, is posited as a mechanism to entice private sector engagement and to stimulate economic growth concurrently with the pursuit of net-zero emissions.

Collectively, these policy implications constitute a comprehensive framework that, if implemented cohesively, can strategically guide Lao PDR and ASEAN Member States towards the realisation of their technology transfer. This approach not only promotes sustainability within the region but also contributes substantively to global endeavours aimed at combatting climate change.

6. Conclusion

This chapter has presented a nuanced understanding of the factors propelling technology transfer and the intricate policy landscape essential for fostering a sustainable and low-carbon future in ASEAN Member States, including Lao PDR. The plausible enabling factors for advancing technology transfer underscore the significance of effective communication; motivation; research collaboration; and the pivotal roles played by TTOs, incubators, and management support. These factors contribute to the journey from laboratory innovation to market application, emphasising the intricate interplay required for successful technology transfer.

The policy implications for technology transfer in ASEAN Member States towards achieving net-zero emissions present a comprehensive framework encompassing strategic measures aimed at cultivating sustainable practices. The policies cover renewable energy transitions, energy-efficiency measures, decentralised energy systems, carbon-pricing mechanisms, sustainable transport incentives, research and development support, international collaboration, capacity building, education, and adaptation and resilience policies. This holistic framework, if implemented cohesively, serves as a strategic guide to realise net-zero emissions, promoting sustainability within the region and contributing to global climate-change mitigation efforts, with technology transfer as an enabler.

The identified policy implications offer tangible pathways for ASEAN Member States to navigate the complex challenges associated with technology transfer and energy sustainability. The success of these policies hinges on their effective implementation, fostering collaborative efforts, and adapting strategies in response to evolving technological landscapes and socio-economic conditions. Regular monitoring and evaluation are paramount to ensuring that policies remain adaptive and efficacious in navigating the complex terrain of technology transfer and energy sustainability.

7. Remarks

Advancing technology transfer and attaining net-zero emissions in ASEAN Member States demand a systematic integration of plausible enabling factors and strategic policy measures. This imperative underscores the need for a concerted effort from diverse stakeholders, including academic institutions, industry entities, policymakers, and the broader community. This chapter delineates key considerations for the strategic trajectory ahead:

(i) **Strengthen collaboration and communication**. Advocate for the creation of collaborative platforms facilitating effective communication and knowledge dissemination amongst academia, industry, and policymakers; and emphasise interdisciplinary collaboration to address intricate challenges and to amplify the impact of technology transfer initiatives.

(ii) **Motivate engagement**. Implement targeted strategies to augment motivation, recognising their pivotal role as drivers in technology transfer; and institute reward mechanisms, recognition programmes, and career development opportunities for personnel actively engaged in technology transfer activities.

(iii) **Enhance team competence**. Invest judiciously in continuous training programmes aimed at enhancing the competence of technology transfer teams within innovation alliances; and promote cross-functional teams, amalgamating diverse expertise for a comprehensive approach to technology transfer.

(iv) **Optimise TTOs and incubators**. Reinforce both research- and market-oriented TTOs, ensuring their proactive involvement in facilitating licensing activities; and harness the catalytic potential of incubators for fostering new product development, economic growth, and the transition to a low-carbon economy.

(v) **Promote management support**. Advocate fervently for robust management support for researchers involved in technology transfer, recognising its pivotal role in overcoming barriers; and incorporate considerations of technology transfer into institutional management strategies.

(vi) **Invest in research and development**. Prioritise strategic investments in research and development for clean energy technologies, fostering innovation aligned with sustainability goals; and institute funding mechanisms supporting startups and research institutions dedicated to clean energy solutions.

(vii) **Foster international collaboration**. Strengthen collaborative ties with international partners to promote joint research, technology transfer, and knowledge exchange; and actively participate in global initiatives focussing on sustainable development and technology transfer for climate-change mitigation.

(viii) **Build capacity**. Develop and implement targeted policies for capacity building at institutional, industrial, and workforce levels; and expand educational programmes and training initiatives to equip the workforce with the requisite skills for transitioning to a low-carbon economy.

(ix) **Develop climate-change adaptation and resilience policies**. Integrate climate-change adaptation and resilience measures into technology transfer policies, considering potential climate-change impacts on energy infrastructure; and develop comprehensive strategies to enhance the resilience of clean energy systems to changing environmental conditions.

(x) **Provide fiscal and financial incentives for clean energy investments**. Provide well-targeted fiscal and financial incentives, including subsidies, grants, and low-interest loans, to attract private sector engagement in clean energy projects; and align financial incentives with broader goals, emphasising the attainment of net-zero emissions and sustainable economic growth.

Hence, the successful integration of these strategies necessitates a collaborative and adaptive approach, marked by continuous monitoring and evaluation. This adaptive approach ensures the refinement of policies based on evolving technological landscapes and socio-economic conditions. By addressing the identified enabling factors and policy implications, Lao PDR can strategically navigate challenges, aligning with its energy goals and ASEAN chair roles in 2024, fostering a sustainable and resilient future, thereby significantly contributing to global climate-change mitigation efforts through effective and innovative technology transfer policy.

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H2
GREEN

Chapter 13

Latest Developments in Carbon Capture, Utilisation, and Storage and Hydrogen in ASEAN – Lessons for Lao PDR

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1. Introduction

1.1. Carbon Capture and Storage and Carbon Capture, Utilisation, and Storage

Carbon capture and storage (CCS) and carbon capture, utilisation, and storage (CCUS) involve the activities of capturing carbon dioxide and storing it underground in efforts to reduce emissions. The capture activity is generally done in large point sources, such as power generation or industrial processes that utilise the combustion of fossil fuels and produce emissions. Regarding storage, there are two types: (i) saline aquifers, which can be classified under CCS; and (ii) depleted oil and gas wells, which can be classified under CCUS. Depleted oil and gas wells are supported by technology to improve the production of oil and gas while storing carbon dioxide underground, which is termed 'enhanced oil recovery' or 'enhanced gas recovery'. The locations of emissions sources and storage are not normally in close proximity, so carbon dioxide transport is also an important part of CCS/CCUS technology. Transport can be done either via shipping or pipelines.

In the Association of Southeast Asian Nations (ASEAN) region and East Asia, fossil fuels still play a significant role in the energy mix. Regarding power generation in a business-as-usual scenario, coal and natural gas are predicted to remain dominant, contributing 39.5% and 20.8%, respectively, to the energy mix in 2050 (Kimura, Phoumin, Purwanto, 2023). Even under a carbon-neutral scenario, the combined coal and gas power generation would remain at over 40% of the power mix with CCS in 2050.

The high share of coal and gas in the energy mix could be attributed to the fact that South-east Asia has relatively new coal-fired power plants, with an average age of only 11 years. In India and China, these are about 13 years old. For Indonesia, 58% of coal-fired power plants are 10 years old and below; another 22% of them are 10 to 20 years. With such a high dependency on fossil fuels, ASEAN and East Asia must rely on CCS/CCUS in the future.

Lao People's Democratic Republic (Lao PDR) is also expected to keep using fossil fuels within its energy mix. In 2019, coal accounted for 38.4% thanks to the Hongsa coal-fired power plant; this share is expected remain at 30.0% in 2050 (Kimura, Phoumin, Purwanto, 2023). Looking at the high share of fossil fuels in electricity generation and its energy mix, CCUS will be crucial for Lao PDR to reach its carbon-neutrality targets.

1.2. Hydrogen

The ASEAN region has significant renewable energy resources that can be utilised for green hydrogen[1] generation, including solar, wind, hydropower, biomass, and geothermal energy. The region possesses vast potential for harnessing these renewable resources, which presents a highly attractive prospect for sustainable hydrogen production in the long run. The ASEAN Centre for Energy (2021) posited that ASEAN has a total of 229 gigawatts (GW) of wind energy resources, 158 GW of hydropower resources (including small hydro), 61 GW of biomass resources, and 200 GW of geothermal resources. Hydrogen presents a prospect for ASEAN Member States to broaden their energy portfolios, decreasing reliance on imported fossil fuels. Such diversification can improve energy security and increase resilience to global energy market fluctuations.

Hydrogen also serves as an energy storage medium, aiding in the equilibrium of supply and demand in power networks that have a significant presence of intermittent renewable energy sources such as solar and wind. It is an important and versatile technology with the potential to transform various sectors, including transport, power generation, and industry. There are numerous methods of producing hydrogen, each having various impacts on the environment and technological maturity levels. The primary methods for producing hydrogen are divided into groups based on the energy source and on the emissions that are released throughout the process:

(i) **Electrolysis**. Utilising electricity, electrolysis converts water into hydrogen and oxygen. The procedure takes place in an electrolyser, which can range in size from massive industrial facilities to small appliances.

(ii) **Steam methane reforming**. This is the most widely used technique, producing over 95% of the hydrogen made worldwide (Moore et al., 2022). To make hydrogen and carbon monoxide, fossil fuels – mostly natural gas – are reacted with steam at a high temperature.

(iii) **Coal gasification**. By burning coal with oxygen and steam at high temperatures and pressures, syngas – a mixture of hydrogen, carbon monoxide, and carbon dioxide – is produced. This technology is generally used in regions with large coal deposits and well-developed coal usage infrastructure. It is also employed in industries that need hydrogen for chemical operations like ammonia synthesis.

(iv) **Others**. Other hydrogen production includes biomass gasification, which involves utilising heat, steam, and oxygen without combustion.

[1] Green hydrogen is named as such since no greenhouse gases are released during the process in which electricity is obtained from renewable sources. Blue hydrogen is generated mainly from natural gas, and emissions are captured using CCS. Grey hydrogen is produced from natural gas without using CCS.

2. Carbon Capture, Utilisation, and Storage Implementation in ASEAN

ASEAN has focussed on CCS for over 1 decade, but its implementation has been slow compared to other parts of the world. Developments regarding regulations, policies, and cooperation on CCUS have recently arisen across the region.

2.1. Geological Storage Resource Potential

ASEAN has an estimated 200 gigatonnes of storage resources (ERIA and GCCSI, 2024). This estimation was done by assessing the storage data from six countries – Brunei Darussalam, Indonesia, Malaysia, Philippines, Thailand, and Viet Nam (Table 13.1).

Table 13.1. Estimated Storage Resources in ASEAN Member States

Country	Saline Formation – P50 Net Storage Resources ($MtCO_2$)	Depleted Field – P50 Net Storage Resources ($MtCO_2$) and Fields (number)	CO_2 Stored through EOR – P50 ($MtCO_2$) and Fields (number)
Indonesia	49,000	2,275 / 42	153 / 6
Malaysia	127,000	1,773 / 41	105 / 9
Brunei Darussalam	18,000	579 / 7	200 / 1
Thailand	15,000	1,024 / 27	0
Viet Nam	5,000	303 / 9	56 / 3
Philippines		67 / 1	0
Total	**214,000**	**6,021 / 127**	**514 / 19**

CO_2 = carbon dioxide, $MtCO_2$ = million tonnes of carbon dioxide.

Source: ERIA and GCCSI (2024).

Indonesia, Malaysia, and Thailand are the most advanced regarding suitable and highly suitable offshore and onshore basins, gigatonne storage resources, and active CCS facilities. However, only Indonesia has a national regulatory framework to enable CCS. Brunei Darussalam has a suitable offshore basin with gigatonne storage resources, but storage development and CCS deployment have not commenced; the nation also lacks a dedicated regulatory environment for storage exploration. Viet Nam and the Philippines have potential storage basins, but there is no storage development in key areas near strategic industrial emissions clusters.

For estimated storage resources, around 98% is in saline formations. This estimate is remarkable as only nine saline formations in nine basins were reviewed. Yet this estimate is uncertain since storage resources for saline formations are for theoretical storage, whereas the hydrocarbon field storage estimates use field data. In Indonesia alone, the storage resources were estimated up to 69 gigatonnes in the selected saline aquifers. Indonesia has significant storage potential in both deep saline aquifers and hydrocarbon fields.

The resources of Cambodia, Lao PDR, and Myanmar were not assessed in the study due to a lack of data; the storage potential of those countries has never been reviewed.[2] Lao PDR could move towards CCUS by conducting studies on this matter. Understanding potential storage is key for how the country could utilise CCUS in terms of emissions reduction, especially from coal-fired power plants.

2.2. Regulatory Frameworks and Policies

The approach to regulating CCS is an important consideration for governments seeking to develop a CCS-specific legal framework. Regulators and policymakers may decide to expand the focus of regulatory frameworks to include the broad suite of applications that constitute CCS technologies across the industrial and power sectors.

Within the region, the experiences of Indonesia and Thailand offer examples of the processes involved in developing regulatory frameworks for CCS. Both countries have undertaken collaborative, iterative processes that have engaged a diverse group of stakeholders across various levels of government. There is a risk of delay or a disconnect within the regulatory process, as stakeholders must take time to familiarise themselves with the technology and new regimes.

Activities involving the transport of carbon dioxide across international maritime zones and marine areas have implications under a broad range of international agreements, including those relating to the pollution of the marine environment, safety of maritime transport, transport of dangerous goods, and carriage of compressed gases. The London Protocol[3] removed barriers to the technology's deployment and provides a basis for the regulation of carbon sequestration in sub-seabed geological formations.

2 Singapore does not have a storage basin within its borders.
3 Protocol to the Convention of Marine Pollution by Dumping of Wastes and Other Matter from 1996.

Recent amendments to this agreement offer an important pathway for facilitating the transboundary transport of carbon for geological storage. For many ASEAN Member States, existing oil and gas operations will provide a good analogue for the various regimes that may also apply to CCS activities. Compliance with CCS-specific legal and regulatory regimes is an important feature of many carbon-crediting schemes that offer support for CCS activities.

The detailed reporting and accounting of stored carbon, as part of geological storage operations, is a key aspect of ensuring compliance with CCS-specific legislation and for ensuring the wider integrity of CCS operations. The 2006 IPCC guidelines demonstrate how national accounting schemes can manage the reporting of transboundary CCS operations (Eggleston et al., 2006). Legal and regulatory issues will arise in the context of transboundary project models, which will trigger obligations under international, regional, and national regimes. The absence of clear legal and regulatory frameworks for these operations within international and national law, however, suggests that this issue should be addressed in the pre-injection phase and prior to operation.

The responsible and safe closure of a carbon storage site is the focus of regulatory requirements during the closure phase. Legislation should require project operators to seek authorisation to close a storage site upon the fulfilment of prescribed criteria and may include well decommissioning and plugging requirements. Regulatory obligations during the post-closure phase should include long-term monitoring and responsible site care to ensure the safety and security of storage sites.

2.3. Value Chain Centre

The development of CCS hubs and clusters – bringing together several different emissions sources and/or storage sites in a connected network – offers several advantages over vertically integrated CCS projects. These benefits include reducing costs and risks, enabling more cost-effective transport and storage from small-volume sources, and maintaining investment and jobs in high-emitting industrial regions.

Large-scale deployment of CCS in the region will require a coordinated effort amongst countries in South-east Asia to develop frameworks and platforms for successful and timely project delivery. Integrated upstream policy and robust institutional frameworks are key to underpin regional project implementation. In addition, coordinated institutional frameworks, including coherent decarbonisation strategies, project approval and procurement strategies, and investment plans, will reduce project risk and enable capital investment.

The establishment of a centralised body, such as a CCS value chain centre (VCC), to coordinate and to administer regional efforts could accelerate CCS deployment in the region. The VCC could review and make recommendations on how existing national policies, legislation, and regulatory frameworks could be adapted to accommodate regional CCS activities, including identification of near- and mid-term activities to support national regulators and policymakers to align national CCS policies to enable collaboration in the region. With national policymakers and regulators, the VCC could implement the ASEAN CCS roadmap currently under development by the ASEAN Centre for Energy. As a regional body, the VCC could act as an advisory body, tasked with monitoring national CCS legislation and regulation development in the region, in line with the ASEAN CCS roadmap, and make recommendations to regulators as appropriate.

In addition, the VCC could coordinate the development of ASEAN CCS regulatory guidelines, based on the existing *ASEAN Guidelines on Good Regulatory Practices* to provide guidance on the approach to developing CCS-specific regulation for the region. The VCC could also play a role in the standardisation of CCS across the region, based on international standards and global best practices and through collaboration with other associations in the climate-change space. It could also become the official custodian of an ASEAN geological storage calculation engine and database, accessible to project proponents in the region, and coordinate the development of a regional framework for risk assessment and management of carbon storage in geological formations.

To support investment in CCS projects in the region and to provide certainty to project sponsors and financiers, the VCC could act as a representative body for ASEAN Member States, seeking foreign direct investment and other forms of climate finance. A coordinated multi-national approach will enhance negotiation power and reduce counterparty risk for investors.

2.4. Financing Challenges

Using the Global Economic Net Zero Optimisation (GENZO) model, the capital investment required to establish CCS to transition towards carbon neutrality would be about US$880 billion to 2065, starting at US$420 million per year in the 2020s, rising to US$15.6 billion per year in the 2030s, and peaking at over US$40.0 billion per year in the 2040s. It would then decline to almost US$25.0 billion per year in the 2050s and to US$6.5 billion per year in the 2060s based on the GENZO Accelerated Storage Scenario (ERIA and GCCSI, 2024).

Mobilising the capital for CCS requires both public and private finance. However, the private sector can only invest where there is an appropriate risk-weighted return on investment. Private investment is incentivised by the expectation of future profits. Applied to CCS, this condition would only be met if the unit cost of CCS (per tonne of emissions avoided) is less than the cost of emissions plus the value of any revenue generated (e.g. in enhanced oil recovery) through CCS.

The unit cost of CCS varies considerably, depending on the capture source and scale, transport distance, and storage resource quality. The lowest cost applications may have a full value chain cost of less than US$25/tonne of carbon dioxide (tCO_2) including the cost of compression transport and storage. However, in most industrial applications, full value chain CCS will cost US$40–US$100/tCO_2; application in power generation, US$60–US$200/tCO_2; and over US$200/$tCO_2$ for direct air capture (ERIA and GCCSI, 2024). CCS is required to be applied across all of these applications to deliver net-zero emissions at the lowest overall cost. Private sector investment incentives are currently insufficient to mobilise the necessary capital, except in the lowest cost applications.

This presents a fundamental problem for governments that are charged with achieving net-zero emissions to stabilise the global climate – a significant public good. The cost of emissions – climate change, surging insurance and disaster relief costs, and loss of life and property – are increasing rapidly. Yet these costs are dispersed, unevenly distributed, and back-ended, while abatement costs are front-ended. Governments face the classic economic problem of internalising negative externalities to incentivise removing emissions. Policies are thus required to align private investment incentives with public good investment incentives. This can be done through any combination of (i) increasing the cost of emissions (e.g. carbon taxes or emissions trading), (ii) instituting command and control mechanisms (e.g. prohibition or mandates through regulation), (iii) reducing the cost of CCS to private investors (e.g. through capital grants or concessional finance), and/or (iv) increasing the revenue created through CCS (e.g. through payments per tCO_2 stored or operational subsidies)

CCS has little economic value compared with freely emitting into the atmosphere, and that calculus can only change through policies and regulations. The challenge is how to reflect the cost of emissions in prices so that a low-carbon product is cheaper than its high-carbon substitute. This would drive the demand for abatement technologies and enable their applications to earn a profit. Policies on their own cannot tackle this financing challenge. Lao PDR can also find avenues to address the challenge, such as multi-lateral development banks, voluntary carbon markets, and sustainable financing such as green and climate bonds.

2.5. Asia Carbon Capture, Utilisation, and Storage Network

The Economic Research Institute for ASEAN and East Asia (ERIA) is the secretariat of the Asia CCUS Network (ACN), with a vision to contribute to the decarbonisation of the region through collaboration and cooperation on development and deployment of CCUS. The three main missions of ACN are (i) promoting knowledge sharing through annual fora, conferences, and workshops; (ii) conducting research studies and surveys on technical, economic, and legal standards, especially the common rules of CCUS in the region; and (iii) holding capacity-building workshops to bridge the knowledge gap on CCUS. ACN also supports various countries to identify the pilot CCUS projects until 2025 and is aiming to deploy and commercialise CCUS by 2030.

Necessary studies have been identified in collaboration with knowledge partners. In 2023, ACN commissioned four studies by the Global CCS Institute (GCCSI) and one study from *Bandan Reset dan Inovasi Nasional* (National Research and Innovation Agency, BRIN) (ERIA and GCCSI, 2024; ERIA and BRIN, 2024). Collectively, these studies assess the role of CCS in South-east Asia to support the achievement of net-zero emissions targets, review the policy and legal frameworks necessary to enable CCS, examine the need for collaboration amongst South-east Asian nations on institutional frameworks, and discuss options to facilitate the financing of CCS in the region. The five studies focussed on the geological storage potential in South-east Asia, establishment of an Asia CCS/CCUS value chain as a collective framework in the region, legal and policy framework for deployment of CCUS, financial framework for deployment of CCUS, and establishment of basin-scale storage in Indonesia.

3. Hydrogen Development across ASEAN

ERIA (forthcoming) conducted a study on the hydrogen demand and supply in the East Asia Summit region, taking into account government policies and patterns observed in national energy policies, particularly regarding the dependence on imported natural gas. Table 13.2 shows the projected demand and supply potential of hydrogen in the East Asia Summit region in 2040. In the ASEAN region, the biggest hydrogen demand potential comes from Indonesia, Malaysia, Singapore, and Thailand. ASEAN also lags behind in terms of its potential for hydrogen generation.

Table 13.2. Hydrogen-producing Potential from Unused Energies Compared to Hydrogen Demand Potential in the East Asia Summit Region in 2040
(million normal cubic metres)

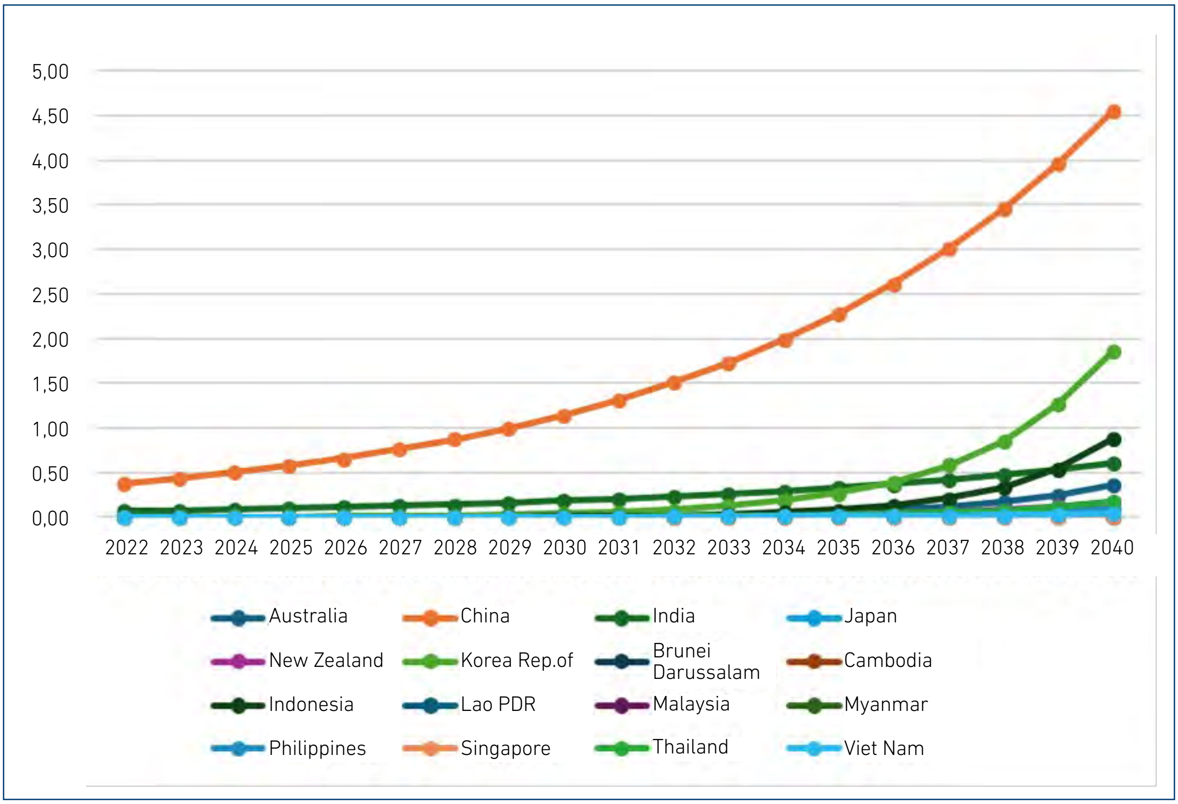
	Production Potential		Demand Potential	Self-sufficiency Rate from Previous ERIA Study		Self-sufficiency Assumptions in the Study
	Max	Min		Max	Min	
Australia	21,502	7,169	13,974	154%	51%	154%
Brunei Darussalam	1	1	1,775	0%	0%	0%
Cambodia	5	1	352	1%	0%	100%
China	1,204	395	163,408	1%	0%	95%
India	1,057	352	11,990	9%	3%	100%
Indonesia	1,501	500	44,807	3%	1%	100%
Japan			29,252	0%	0%	5%
Korea, Republic of			41,558	0%	0%	76%
Lao PDR	13	3	9	137%	34%	137%
Malaysia	42	16	24,034	0%	0%	100%
Myanmar	49	12	1,263	4%	1%	100%
New Zealand	3,370	1,123	1,065	317%	106%	317%
Philippines	49	16	4,551	1%	0%	100%
Singapore			15,098	0%	0%	1%
Thailand	192	63	12,993	1%	0%	70%
Viet Nam	85	29	3,668	2%	1%	100%
Total	**29,070**	**9,681**	**369,796**	**8%**	**3%**	

ERIA = Economic Research Institute for ASEAN and East Asia, Lao PDR = Lao People's Democratic Republic.

Source: ERIA (forthcoming).

The study also estimated the green and blue hydrogen production outlook by country in the East Asia Summit region (ERIA, forthcoming). Green and blue hydrogen are expected to see exponential growth until 2040 (Figures 13.1 and 13.2). These patterns have been noted due to the advancement of renewable energy during the last few decades. By 2040, the production of blue hydrogen is expected to be nearly double that of green hydrogen.

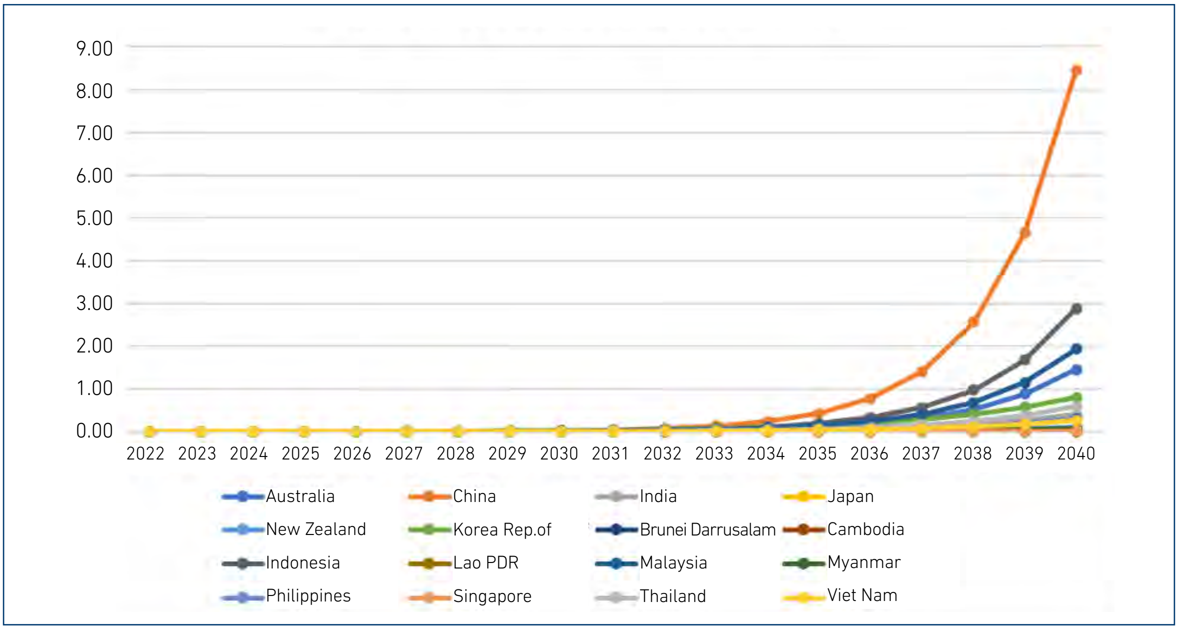
Figure 13.1. Green Hydrogen Production Outlook by Country
(million tonnes)



Lao PDR = Lao People's Democratic Republic.

Source: ERIA (forthcoming).

Figure 13.2. Blue Hydrogen Production Outlook by Country
(million tonnes)



Lao PDR = Lao People's Democratic Republic.
Source: ERIA (forthcoming).

Referring to ERIA (2022; forthcoming), the ASEAN region possesses significant potential for the production of green, blue, and grey hydrogen. However, the current capital expenditure for hydrogen production, transport technology, and fuel cells – along with the relatively high levelised cost of electricity for renewables – makes it uneconomical to utilise hydrogen energy in the power and transport sectors (ACE, 2021). Thus, enabling a hydrogen economy entails implementing several strategies and initiatives to foster the production, shipping, and use of hydrogen as a clean and sustainable energy carrier.

Hydrogen energy is becoming an important part of ASEAN's plan to improve energy security and shift towards cleaner energy sources, but hydrogen in ASEAN is at an initial stage of development. ACE has presented a systematic and gradual strategy for the implementation of hydrogen utilisation (ACE, 2021):

(i) **Phase I (2020–2025)**. The primary objective is to generate and to distribute grey hydrogen by utilising current fossil fuel resources and infrastructure for exportation purposes.
(ii) **Phase II (2026–2030)**. The objective is to shift towards the production of blue hydrogen using CCS technology.
(iii) **Phase III (post-2030)**. Here, there will be a notable transition towards green hydrogen as the costs of renewable energy decrease and infrastructure becomes more developed.

There are multiple initiatives underway to investigate the potential for hydrogen advancement in the region. Brunei Darussalam is at the forefront of exporting hydrogen to Japan. The process is made possible by a cutting-edge technology, liquid organic hydrogen carriers, which offers a practical solution for storing and transporting hydrogen.

Only three ASEAN Member States have hydrogen national strategies – Singapore, Malaysia, and Indonesia, outlined below.

3.1. Singapore

In 2022, Singapore implemented a national hydrogen strategy to accelerate the shift towards achieving net-zero emissions and enhancing energy security. Hydrogen can enhance the country power combination in conjunction with solar energy, imported electricity, and other possible sources of low-carbon energy, such as geothermal energy. By 2050, hydrogen has the potential to meet up to 50% of Singapore's power requirements, contingent upon advancements in technology and the emergence of alternative energy sources (EMA, 2022).

Singapore is actively engaging in partnerships with Japanese companies to investigate the potential of hydrogen as a clean fuel alternative. The primary objectives are to reduce emissions in the economy and to foster the development of new industries. Through its national hydrogen strategy, Singapore is aiming to produce 50% of its energy from low-carbon hydrogen by 2050.

Singapore will prioritise the development of expertise in industry, human resources, and the government in areas that are crucial for promoting the use of hydrogen. Based on Singapore's national strategy, the efforts will be centred around five main areas: (i) conducting trials of cutting-edge hydrogen technologies that are on the verge of being commercially viable through pilot projects, (ii) allocating resources to research and development to overcome significant technological obstacles, (iii) engaging in international partnerships to establish efficient networks for the production and distribution of low-carbon hydrogen, (iv) engaging in extensive land and infrastructure planning for the long term, and (v) providing assistance for workforce training and the growth of Singapore's overall hydrogen industry.

3.2. Malaysia

Malaysia is implementing a thorough plan to advance its hydrogen economy, as detailed in the *Hydrogen Economy and Technology Roadmap* (MOSTI, 2023). The main objectives of this plan are to integrate hydrogen into Malaysia's emerging energy sector, encourage a sustainable energy mix, and allocate resources towards hydrogen technologies to enhance both domestic and international energy stability and to reduce emissions.

Malaysia's objective is to establish a robust hydrogen supply chain, intending to export to China, Japan, Republic of Korea, and Singapore. As mentioned in the *Hydrogen Economy and Technology Roadmap*, the country is expected to become a prominent exporter in the region, with a predicted income of RM400 billion by 2050 (MOSTI, 2023). The funds generated will contribute to the advancement of infrastructure for both export and domestic sectors as well as creating new opportunities for job growth.

The roadmap is based on five major objectives with the goal of establishing hydrogen as a feasible energy source: advancement of infrastructure, promotion of technological innovation, generation of market demand, establishment of regulatory frameworks, and improvement of international cooperation. Sarawak State is leading this initiative with the H2biscus project in Bintulu. The project aims to generate an annual production of 220,000 tonnes of green hydrogen, principally intended for sale to the Republic of Korea, while also allocating a portion for domestic consumption. Sarawak is making progress in developing its hydrogen infrastructure, which includes the establishment of multi-fuel stations and hydrogen production facilities for public transport (Lye, 2022).

3.3. Indonesia

In late 2023, Indonesia established a national hydrogen strategy based on three principles – diminishing dependence on fossil fuels to guarantee energy security, fostering the growth of the domestic hydrogen market, and exporting hydrogen and its byproducts to the international market (MEMR, 2023). Presently, the development of hydrogen technology in Indonesia is limited to research and pilot projects. It is, however, expected to experience significant growth after 2030 (MEMR, 2023). Its applications will expand to include hydrogen vehicles (powered by fuel cells or synthetic fuels); electricity generation; energy storage; and decarbonisation of sectors such as shipping, aviation, steel production, manufacturing, and long-distance transport.

4. Lessons Learned and Key Directions for Lao PDR

4.1. Enabling Carbon Capture, Utilisation, and Storage

CCUS will be an avenue for Lao PDR to reach a carbon-neutral future. Several key directions could be adopted to realise the enablement of CCUS technologies:

(i) **Conduct a national storage resources assessment**. To understand the total potential amount of carbon that can be stored in Lao PDR, an assessment should be conducted. Due to currently limited data on storage resources, Lao PDR will be overlooked in providing potential storage. This study will require a substantial amount of investment; hence, cooperation schemes and international support are required.

(ii) **Develop regulatory frameworks for CCS/CCUS activities**. Regulating CCS/CCUS projects and activities will be the next key step to help diminish uncertainties and attract more investment to enable the development of CCS/CCUS projects. Indonesia's example can be adopted, where regulations began regulating enhanced oil recovery and enhanced gas recovery activities (i.e. CCUS), which then expanded towards storage in saline aquifers (i.e. CCS). Specific regulations on capture; transport; storage; measurement, reporting, and validation; and post-closure should be addressed in later stages of regulatory frameworks development.

(iii) **Pilot project development**. CCUS pilot projects are crucial to demonstrate economic viability and to improve the effective and efficient technology in terms of storage. Pilot projects also showcase and inform the community regarding the environmental benefits of carbon injections. The successful implementation of such projects encourages investors to develop and to fund more CCUS projects in the country.

(iv) **Financing CCUS**. To fully develop CCUS as a viable business, the price of emitting needs to be higher than capturing and storing carbon. This can be done by increasing the price of emitting (i.e. carbon pricing), instituting prohibition or mandating mechanisms, reducing the cost to private sector investors of CCS (e.g. through capital grants or concessional finance), and/or increasing the revenue created through CCS (e.g. through payments per tCO_2 stored or operational subsidies). In terms of financing CCUS technology deployment, Lao PDR can request the assistance of multi-lateral development banks, create a voluntary carbon market, and use sustainable financing such as green and climate bonds.

(v) **Develop interconnected CCUS networks**. Connecting with ASEAN Member States to develop a regional CCUS network would be beneficial, especially for countries with limited amount of storage. Lao PDR, in the long term, should aim to tap into this to gain access to lower-cost storage options. Cross-border mechanisms should be addressed at the national, bilateral, and regional level to enable the option. This option, however, will need high-level coordination in terms of planning and development.

4.2. Hydrogen Potential for Lao PDR

To make hydrogen a feasible alternative, it is imperative to implement specific policies such as subsidies, tax incentives, and international collaboration for infrastructure development. Implementing these methods will effectively reduce the financial disparity and improve the competitiveness of hydrogen technologies, especially during the initial phases of implementation.

Lao PDR is aggressively investigating the potential of hydrogen energy as a key component of its renewable energy plan. The country possesses substantial capacity for renewable energy, particularly hydropower, which can be used to generate hydrogen. Indeed, Lao PDR has the potential to become a significant participant in the regional hydrogen economy by exporting hydrogen generated from the country's renewable resources.

Multiple endeavours are in progress to foster the growth of the hydrogen industry in Lao PDR. For instance, the government is currently collaborating with international partners such as the Asian Development Bank and Global Environment Centre Foundation to develop a power-to-gas master plan. This strategy's purpose is to delineate the necessary procedures for implementing hydrogen production and utilisation on a large-scale commercial level. This involves the implementation of regulations, infrastructure, and business plans to facilitate the growth of the hydrogen economy, as recommended by the Asian Development Bank and the Climate Technology Centre and Network.[4]

In addition, collaborations with the Electricity Generating Authority of Thailand and Mitsubishi are being pursued to investigate the establishment of green hydrogen and ammonia production plants in collaboration with the Government of Thailand. These facilities will harness Lao PDR renewable energy potential to produce hydrogen. This programme is a component of a wider plan aimed at augmenting the proportion of renewable energy sources in energy composition and diminishing dependence on imported fossil fuels (EGAT, 2024).

To conclude, Lao PDR has significant potential to develop green hydrogen in the future, as its hydropower potential capacity is predicted to be approximately 26.5 GW, which is far more than its present energy requirements (UNESCAP, 2022). The country can leverage this excess to generate hydrogen, establishing itself as a prominent player in the hydrogen supply chain.

[4] CTCN, 'Developing a Power to Gas Masterplan in Lao PDR', https://www.ctc-n.org/technical-assistance/projects/developing-power-gas-masterplan-lao-pdr

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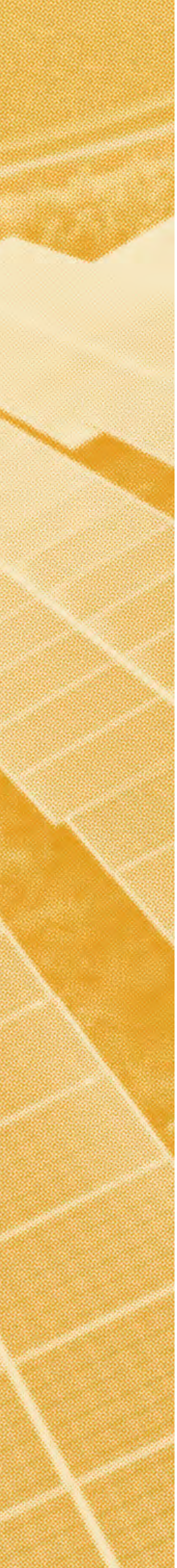


Chapter 14

Ways to Finance Energy Supply Security in Lao PDR and Implications for ASEAN

Farhad Taghizadeh-Hesary

1. Introduction

Lao People's Democratic Republic (Lao PDR) – known as the 'Battery of South-East Asia', thanks to the development of numerous hydropower projects – is in dire need of energy security, specifically regarding diversification of energy sources. The country's reliance on hydropower is currently raising questions about the sustainability of its long-term energy plans (Blake and Barney, 2021). The rapid acceleration of development in hydropower has led to the inevitable decline of fisheries and tourism and has raised concerns about dam safety (Nhiavue et al., 2022). Issues include sediment reduction, poor soil fertilisation, and nearby active earthquake faults, which could significantly affect the safety of nearby households and result in the loss of, for example, UNESCO World Heritage status for the historic capital, Luang Prabang.

Although Lao PDR is admired for its electricity generation from its highly developed hydropower system, it is still saddled by its reliance on fossil fuels for various industries, including transport and agriculture. Moreover, despite the significant export of electricity, there is a risk of over-reliance on very few customers, making energy security and sustainability in the energy sector crucial (Käkönen and Kaisti, 2012). Proposing financial solutions represents a significant step in bringing investment towards energy security and sustainability in Lao PDR (Nhiavue et al., 2022).

Accordingly, Lao PDR must consider introducing more green finance instruments – such as green credit guarantee schemes (GCGSs), green bonds, and government subsidies – to attract investments. Such a strategy would encourage an environmentally sustainable energy sector and attract environmentally and socially conscious investors. Secondly, issuing bonds in domestic currency rather than foreign currencies should be emphasised, because issuing bonds in domestic currency enhances financial stability by mitigating currency exchange rate risks and boosting consumer confidence in investors, leading to the development of a self-sufficient financial ecosystem. Additionally, strategies must be proposed to encourage the accumulation and circulation of domestic savings for green projects rather than relying on external borrowing, which generates outstanding national debt in the long term. Finally, it is crucial to recognise the importance of institutional investments – such as pension funds, insurance companies, and credit unions – in long-term financing. This fosters a collaborative approach towards sustainable development between the public and private sectors.

This chapter aims to propose solutions and policy directions for elevating energy supply security in Lao PDR and consider its wider implications for the Association for Southeast Asian Nations (ASEAN). These solutions will promote sustainable energy resources and include financial instruments that leverage the energy transition, such as GCGSs to reduce risk, tax refunds to raise rates of return, and funds or investments to facilitate access to financing sustainable practices.

2. Current Energy Landscape and Challenges in Lao PDR

Compared to neighbouring nations, Lao PDR does not have ample fossil fuel resources; hence, it relies on imports for most of its fossil fuel energy. However, the nations' hydropower development has led the energy sector to become a key driver of economic growth (Wu et al., 2018). Over 95% of electricity is generated from hydropower in Lao PDR. The abundance of water resources allows it to be a favourable energy source, specifically around the Mekong River, known as the 'Mother of Water'. Indeed, the nation aims to become the 'Battery of South-East Asia' by exporting electricity to various neighbouring countries (Oum, 2019). Several projects, such as the Xayaburi and Nam Theun 2 hydropower projects, facilitate this ambition to cover energy needs domestically as well as those of neighbouring nations while simultaneously reducing fossil fuel dependency. However, financial, environmental, and social challenges surround this objective (Wong et al., 2023).

First, the river's capacity to support life is being undermined, as more than 160 dams operate throughout the Mekong River Basin, including 13 on the river's mainstream, with hundreds more either planned or currently under construction. Inevitably, this impacts water quality and causes a decline in fisheries. Chen, Khalili, and Pumaneratkul (2019) highlighted locals' perspective of the socio-economic impacts produced by the dams in the Lower Mekong River Basin. Although they mentioned that the impact on citizens living in the Lower Mekong River Basin area vary, they highlighted that fishers who manage caged floating fish farms along the riverbank are significantly more vulnerable to changes in water levels caused by discharges from dams in the Upper Mekong River Basin. However, at the same time, such fishing methods allow them to overlook the reduced sediment in the riverbed. Fishers using traditional fishing methods are more sensitive to the changes in the sediment and fish amounts, with many claiming that they have observed a decline in both since the dams have been constructed.

Lower fishing yields lead to health concerns for the population. According to Yoshida, Taghizadeh-Hesary, and Nakahigashi (2020), the population of Lao PDR would lose up to 30% of its annual protein intake ultimately due to the impacts of hydropower dams. Statistically, approximately 2.1 million people in Lao PDR would suffer direct and indirect livelihood losses due to hydropower development. Soukhaphon, Baird, and Hogan (2021) also found that toxic blue-green algae have been found in reservoirs and dams, which leads to illnesses and deaths amongst the human and animal populations. Additionally, children who spend time at the river to bathe and to swim are more susceptible to diseases, indicating potential health risks associated with water quality.

The uncertainty of the water quality has led many indigenous communities to relocate to areas deeper in forested or agricultural areas (Soukhaphon, Baird, Hogan, 2021). This leads to another challenge of energy access – in rural areas, many lack access to electricity due to poor grid infrastructure, as building power plants, transmission lines, and distribution networks in rugged terrain is costly and logistically difficult. Furthermore, service disruptions often occur as dense forests complicate maintenance and repairs (Suhardiman and Mayvong, 2015).

Several of Lao PDR's rural provinces have experienced low levels of economic development due to limited economic activity and lack of private investment. Power generation there has benefited disproportionately from investments; transmission and distribution projects account for just 1% of the pipeline's total value of power projects (Kamal Chowdhury et al., 2020). With adequate investment and infrastructure development, however, these provinces could cease the regional disparities in energy access and economic growth (Saleh and Liquin, 2023).

3. Role of Green Finance and Investment in Sustainable Energy Development

Green finance can be defined as any structured financial activity, product, or service designed to produce better environmental results. It consists of various loans, debt structures, and investments that are recycled to promote the growth of green initiatives, lessen the climate effect of more conventional enterprises, or a mix of the two (Chien, 2022a). Furthermore, green finance refers to using financial products, services, and investment strategies to support projects and initiatives with positive environmental benefits (Chien, 2022b). Hence, the relationship between green finance and sustainable energy development goes hand-in-hand with achieving national environmental and economic objectives.

Green bonds are a financial instrument, which comprise debt securities issued by governments, municipalities, or corporations that raise and collect funds for sustainable projects. The funds and proceeds from these bonds are designated for specific green initiatives, including the construction of renewable energy infrastructure or improvement of water conservation measures (Shibli et al., 2021). Green finance also involves incorporating sustainability principles into banking services, including offering loans and credit to green businesses.

Moreover, implementing policies and incentives through the government to accelerate green finance practices is a crucial green finance aspect. This includes tax incentives, subsidies, and regulations that force financial institutions to disclose their exposure to climate-related risks (Bai et al., 2022). Public credit guarantee schemes are also widely utilised political instruments that support firms in accessing finance while limiting the fiscal burden (World Bank, 2020). This instrument is typically effective when there is sufficient liquidity in the financial system, but it only flows to specific sectors or segments due to a high level of credit risk. Public credit guarantee schemes can help mitigate this credit risk and, therefore, facilitate the flow of bank finance.

By promoting renewable energy projects, green finance can contribute to economic growth and stability, which align with the nation's energy goals. In Lao PDR, given that the country relies on exports, investments in these projects offer significant benefits to enhance energy access, economic development, and environmental stability. Not only do green investments yield financial returns but they can also improve the livelihoods of the populations affected by the damaged water quality and economic instability.

To promote green finance in Lao PDR, policymakers can incentivise green bonds and implement financial incentives for renewable energy projects. In addition, strengthening regulatory frameworks and enhancing the transparency in green investments can attract private capital and accelerate the transition.

Case studies of successful green finance initiatives in Lao PDR provide insight into good practices and lessons learned. For instance, Lao Environmental Protection Fund (EPF) represents a green finance initiative that combines endowments and sinking funds for direct financial assistance for biodiversity conservation, pollution control, water resources management, and sustainable land resources management (UNDP, 2015). It is a government fund created to mobilise domestic and foreign funds to contribute to the management of natural resources and to protect the environment effectively and sustainably.

Although the EPF's achievement of international standards in financial integrity and social environment safeguards are successful aspects of the project, several challenges must be noted, such as limitations on quantitative data on government spending, allocation of resources in environmental protection, and reliance on external sources for capital spending (UNDP, 2015). Lessons highlighted are the importance of sustainable revenue sources, adherence to international standards, and continuous support for local beneficiaries, offering valuable insights for policymakers looking to establish comparable green finance mechanisms for sustainable development.

Although the EPF demonstrates the feasibility and positive impact of utilising green finance for sustainable energy development, challenges in implementing green finance initiatives, such as regulatory guidance and resource constraints, still impede market development in Lao PDR. Financial barriers, technological challenges, and limited local capacity have been highlighted as three central challenges to green energy investments (UNDP, 2015). Through a deeper understanding of green finance instruments as well as the strengths and weaknesses of Lao PDR, the implementation and integration of green finance to leverage investment will be clear for advancing development and energy supply security. Implementing country-specific policies and initiatives to utilise green finance is essential. By leveraging green finance instruments, addressing regulatory challenges, and fostering stakeholder collaboration, Lao PDR can unlock the potential of sustainable energy investments and advance its green growth agenda.

4. Policy Direction for Financing Energy Supply Security

The International Energy Agency defines energy security as the continuous supply of energy sources at a reasonable price.[1] In the long term, energy security involves making timely investments to deliver energy in accordance with environmental regulations and economic trends. In the short term, however, it focusses on the capacity of energy systems to respond to abrupt shifts in the supply–demand balance.

Enhancing energy security for Lao PDR – a landlocked nation primarily dependent on hydropower – requires an adjustment in strategy towards diversification, the use of renewable energy, and investments in clean energy technology. This strategy must aim to address these challenges and to reduce risks associated with energy investments' financial, technical, and regulatory aspects.

First, there is a need to promote and to implement green finance instruments, such as green bonds, GCGSs, and green investment funds, to stimulate new investments in renewable energy projects in Lao PDR (Xia, Liu, Yang, 2023). These initiatives align with the world's sustainability agenda and represent a responsible and sustainable investment commitment. To control regulatory risks, the country also requires a robust and transparent regulatory framework (Sulaksana, 2023). It also necessitates coherent regulations, including those focussed on the simplification of permits, policy coordination amongst administrations, an atmosphere that provides confidence to investors, and support for sustainable energy investment (Sholoiko, 2023). Lastly, it is essential to design training programmes that focus on developing skills in project management, renewable energy systems, and financial risk assessment to enable local actors to manage energy projects, leading to self-sufficiency and sustainability in the energy sector.

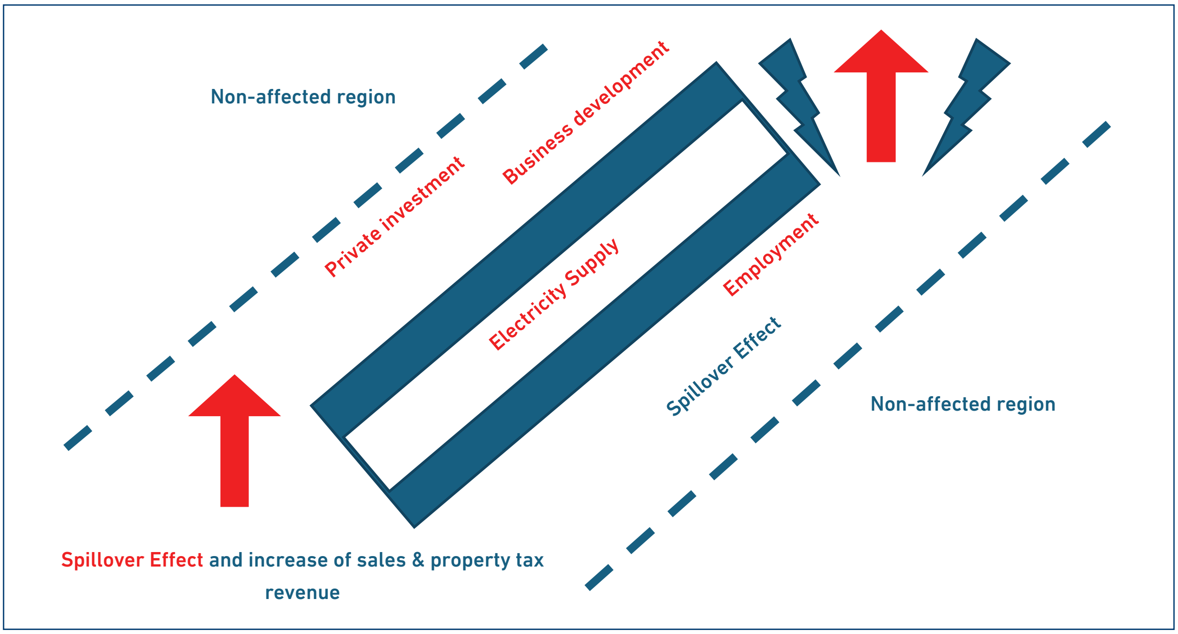
[1] IEA, Energy Security, https://www.iea.org/topics/energy-security

5. Key Recommendations

5.1. Utilise the Spillover Effect

To increase the investment incentives for funding sustainable energy development, the government should utilise the spillover effects created by energy supplies and refund the tax revenues to the investors of the energy projects. This is suggested as the government often regulates electricity tariffs, and private financial institutions struggle to finance these infrastructure projects (Figure 14.1).

Figure 14.1. Spillover Effects of Electricity Supply



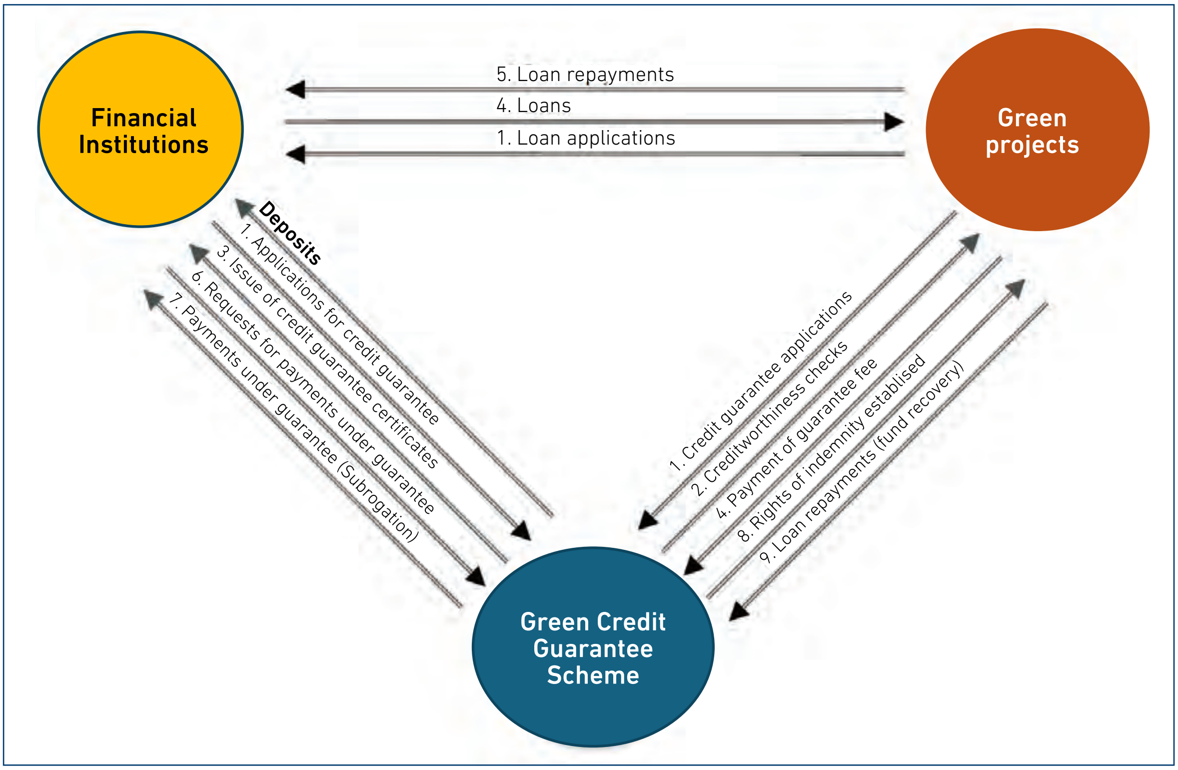
Source: Yoshino, Taghizadeh-Hesary, Nakahigashi (2019).

There are three significant reasons why utilising spillover effects will benefit Lao PDR. First, private investors will be given further incentives to invest in sustainable energy initiatives by being able to leverage tax revenues and business development. Hence, this would lead to higher rates of return on investments and projects that are more attractive to private investors. Second, utilising the effect will aid in mitigating risks associated with sustainable energy investments. By providing sources of additional revenue through increased sales and property tax revenue, there would be less risk posed to private investors, making investment more attractive. Third, the spillover effects will contribute to energy development in the region by creating jobs, increasing employment opportunities, and stimulating the business economy (Yoshino, Taghizadeh-Hesary, Nakahigashi, 2019). Not only will this benefit the energy sector of Lao PDR, but it will also positively impact the overall economic stability in the long term.

5.2. Establish a Green Credit Guarantee Scheme

The establishment of a tailored GCGS will reduce the risk in investment and information asymmetry associated with sustainable energy projects. A GCGS is crucial in improving the creditworthiness of low-carbon projects, which often lack physical collateral and tend to have weak credit standings (Taghizadeh-Hesary, Phoumin, Rasoulinezhad, 2022). A GCGS serves as a safeguard by covering a portion of the risk imposed and smoothing access to private financial institutions' financing, increasing investor confidence in unlocking private capital for sustainable energy projects (Figure 14.2).

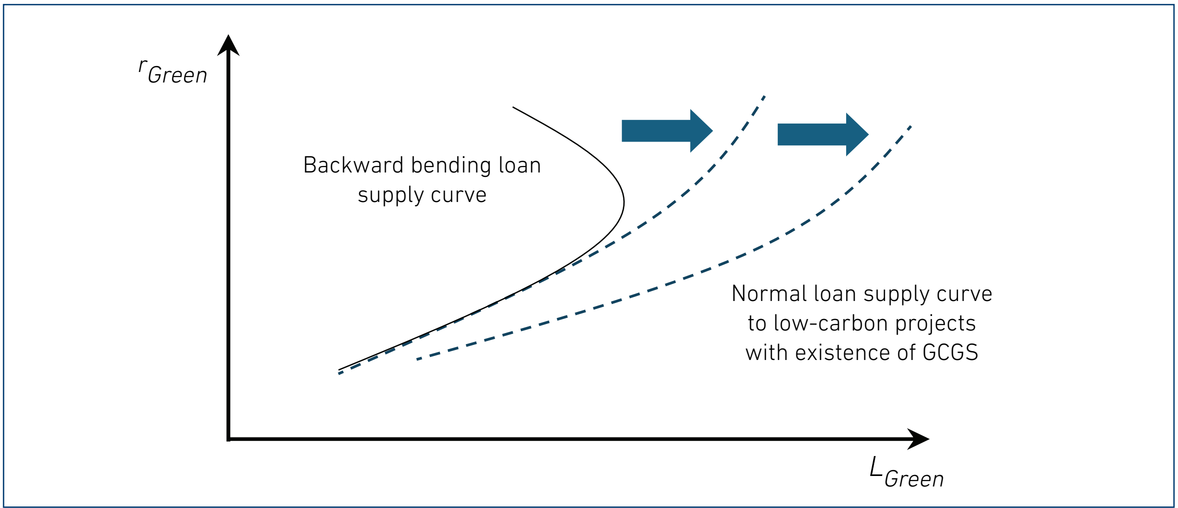
Figure 14.2. Green Credit Guarantee System Flow of Operations



Source: Taghizadeh-Hesary, Phoumin, Rasoulinezhad (2022).

A GCGS for low-carbon projects will reduce information asymmetry and the expected default losses because the credit guarantee corporation – the government – guarantees a portion of loan default. Therefore, banks want to lend money to these projects (Figure 14.3).

Figure 14.3. Green Credit Guarantee Scheme and Loan Supply to Low-Carbon Projects



GCGS = green credit guarantee scheme, L_{Green}= amount of loan to green projects, r_{Green} = lending interest rate to green projects.
Source: Taghizadeh-Hesary, Phoumin, Rasoulinezhad (2022).

To achieve financial sustainability for a GCGS, several key points need consideration:

(i) **Sufficient capital**. A GCGS must possess adequate capital to guarantee projects for the energy transition. This ensures that the GCGS can support a wide range of projects, providing the necessary financial backing to foster growth and development in the energy sector.

(ii) **Independent assessment body**. The assessment body should operate independently from the GCGS to ensure impartial evaluation of projects. This independence is crucial for maintaining objectivity and fairness in the selection process.

(iii) **Assessment**. The role of the assessment process is pivotal in selecting projects with higher creditworthiness and a greater likelihood of success. Accurate and thorough assessments help mitigate risks and ensure that only viable projects receive support.

(iv) **Variable guarantee fees**. The GCGS should vary guarantee fees based on the soundness and creditworthiness of projects. Projects demonstrating higher soundness and lower risk should be charged lower fees, incentivising quality and reliability in project proposals.

(v) **Local offices**. A GCGS needs to establish local offices nationwide or in major cities. This local presence allows the GCGS to have direct access to information and to monitor the progress of projects. It also facilitates better communication and support for regional initiatives, ensuring projects are on track.

By addressing these points, a GCGS can build a robust framework for financial sustainability, supporting the successful transition to sustainable energy solutions.

5.3. Maximise Non-Debt Financing

Relying on external debt for energy generation puts Lao PDR at risk of being vulnerable to global financial market changes and fluctuations in currency exchange rates. Additionally, the accumulation of foreign debt may create economic and political risks for the country.

Lao PDR could develop its sustainable energy sector without heavy external borrowing by maximising non-debt financing modalities, such as foreign direct investment and remittances and relying more on domestic savings. Notably, foreign direct investment often implies technology transfer, managerial expertise, and direct and indirect access to foreign markets; thus, it boosts the competitiveness of renewable energy. Remittances represent a stable source of income and, if channelled into sustainable energy projects, may substantially reduce the country's external debt. Additionally, the circulation of domestic finance and savings into investments will align with economic stability objectives by retaining capital within the country and stimulating economic activity.

As previously mentioned, effective instruments – such as green bonds and GCGSs – should be emphasised in ensuring an adequate level of finance and funding for development without the need to compromise the financial stability of Lao PDR. By expanding the green bond market, Lao PDR gains access to a new source of funding that supports its sustainability goals and is attractive to socially conscious investors. At the same time, GCGSs address the reluctance of private financial institutions to lend the necessary funds due to perceived risks by acting as an insurance policy against default on the loans covering renewable energy projects.

An integrated approach would grant access to financial resources for renewable energy projects and increase the nation's economic resilience. In particular, using various financial instruments from multiple sources reduces the dependence on volatile external debt markets and ensures adequate investment. By maximising the use of non-debt financing sources (e.g. foreign direct investment and remittances) as well as tapping into financial instruments (e.g. green bonds and GCGSs), Lao PDR would minimise the contribution of overseas finance to risks, decrease the impact of external debt, and secure the inflow of funds for energy projects.

5.4. Attract Institutional Investors

Institutional investors – such as insurance companies and pension funds – hold large pools of capital, which desire long-term investments with stable returns. Given that the investment requirements for renewable projects need to be long-term, have relatively stable cash flow, and adhere to sustainability goals, institutional investors appear well-suited to play a substantial role in financing them. Investing institutional capital in the renewable energy sector represents a strategic option for Lao PDR to mobilise a considerable amount of capital during its energy transition (Kaminker and Stewart, 2012).

Collaboration amongst the government, financial institutions, and institutional investors is critical to realising the potential of institutional capital in financing renewable energy projects. Partnerships may come in different forms, such as joint ventures, co-investment arrangements, or specialised investment funds, which could be used to leverage the expertise and resources provided by institutional investors. Through this, project viability, mitigation of risks, and acceleration of deployment of renewable energy infrastructure could be possible.

Furthermore, designing investment vehicles that cater to institutional investors' preferences and risk profiles is indispensable to attract participation. Typically, institutional investors prioritise stable returns, long investment horizons, and low levels of risk. Investment vehicles such as renewable energy funds, infrastructure bonds, or asset-backed securities may be appealing to institutional investors by offering them exposure to renewable energy projects while addressing risk–return preferences. Incorporating and involving institutional investors are critical to securing long-term financial support for large-scale infrastructure projects. Institutional investors can contribute to the financial sustainability of renewable energy ventures by providing stable, patient capital. Their involvement can attract additional private capital, catalysing further investment and fostering a vibrant renewable energy market ecosystem in Lao PDR.

5.5. Note Implications for ASEAN

Implications for ASEAN of policy recommendations issued in Lao PDR include the spillover effect of tax refunds to private investors, a GCGS, non-debt financing opportunity maximisation, and institutional investors. In addition, ASEAN would benefit from having a regional GCGS that can make the energy transition more accessible and favour regional economic integrity.

Although most recommended policies concern Lao PDR specifically, spillover effects can be implemented in other ASEAN Member States. Spillover effects from tax refunds can be utilised to close financial gaps in energy sectors to attract investors to build financial blocks for infrastructure. Therefore, ASEAN Member States expecting similar issues to Lao PDR can apply this policy to commit to sustainable expansion. Moreover, the recommended establishment of a GCGS facilitates mitigating risk for green investments and enhances access to finance for sustainable energy projects. The scheme can present a blueprint across ASEAN for promoting green finance instruments as a tool for regional collaboration and supporting sustainable energy development. Furthermore, broader participation of institutional investors within the ASEAN region will promote stable and long-term sustainable energy initiatives in the region. The expertise, significant capital, and long-term investment horizons can contribute to the region's energy transition and foster energy supply security while simultaneously building a culture of sustainable energy practices.

Overall, the policies tailored to Lao PDR focus on expanding the energy sector through green finance mechanisms and strategic partnerships to bring in investment. Through showcasing the successful use of risk-mitigating financial instruments, incentivising green investments, and diversifying financial sources, Lao PDR can lead as an example and collaborate with neighbouring nations to advance regional energy security and financial stability.

5.6. Build Capacity

Below are a few key capacity-building recommendations involving the technologies, capacity, and experience in sustainable energy development for Lao PDR.

(i) **Technical training programmes**. Implementing a specialised training programme that is focussed on hydropower technologies as well as on solar and wind would be beneficial in improving the technical capacity of local professionals. These programmes can include skills development initiatives or hands-on workshops to improve expertise in renewable energy systems. These are recommended due to the need to enhance the domestic workforce's expertise in renewable energy systems. Hence, these will drive innovation while reducing reliance on external expertise, facilitating the growth of skilled and qualified workers in the energy sector.

(ii) **Financial literacy workshops**. A financial literacy workshop for stakeholders concerning investment opportunities, risk management, and financial modelling specific to sustainable energy projects will allow policymakers and decision-makers to gain financial knowledge, make informed investment decisions, assess project viability, and manage financial resources effectively. Improved financial literacy and decision-making are essential to attract investments, ensure sustainable funding, and promote energy security and economic development.

(iii) **Regulatory compliance training**. It is recommended that training sessions be offered on regulatory compliance and legal frameworks relevant to sustainable energy development. By educating stakeholders on regulatory requirements, laws, and standards and sharing industry best practices, they can navigate complex regulatory rules effectively. Enhanced knowledge will reduce legal risks, enrich information disclosure, and heighten project sustainability.

6. Conclusion

The energy landscape of Lao PDR encompasses both significant opportunities and challenges. Although hydropower has catalysed growth significantly, it also ushered in environmental and social – as well as energy supply security – issues. The risks suggest diversifying energy sources and financial solutions to sustainable energy development. Investment can be attracted through collaboration with institutional investors, a GCGS, and other non-debt financing mechanisms. Moreover, building capacity through technical training or workshops will allow stakeholders to increase engagement with and knowledge of sustainable energy initiatives. Tackling technical and regulatory aspects simultaneously, Lao PDR will unlock the full potential of renewable energy resources to create a sustainable future, both environmentally and financially.

Ultimately, securing the energy supply demands a strategy that caters to diverse stakeholder needs, encourages innovation, and prioritises environmental and social sustainability. By focussing on investments, Lao PDR has the potential to become a key player in the advancement of sustainable energy. This will help enhance energy security in the country and the region and support the worldwide shift towards a more sustainable future.

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Chapter 15

Capacity-Building Needs for Energy Security for Lao PDR

Jeremy Gross

1. Introduction

There is no one definition of capacity building, but generally, it refers to enhancing existing – or providing new – skills, methodologies, approaches, and processes to relevant stakeholders, both at the level of the individual and organisation who are responsible for developing, implementing, and monitoring particular tasks or fields of work associated with all elements of obtaining a particular policy outcome. Capacity building is wide-ranging, taking various forms at different times and along a temporal timescale. Whilst some technical skills needed can be identified in advance, implementation requires the agility to react and to adapt to changing circumstances, both at the technical skills level and to changing social, political, and economic contexts. This is especially true of policies that are many years in the making. Capacity building therefore has an inherent dynamic to it; it is neither a simple, predetermined checklist of trainings to be provided nor an exercise detached from real-time feedback loops affecting policy implementation.

Capacity building is also more than specific skills needed to carry out particular technical tasks; it is needed around the whole policy ecosystem to support a desired outcome. Identifying technical skills needed for a specific task can often be done with ease, but identifying the skills needed around a policy environment – rather than scientific and technical training needs – can be more difficult. For example, imparting knowledge about how to operate an infrastructure facility must run in parallel to ensuring that the facility complies with local and national laws and regulations as well as international obligations.

To cover all aspects of capacity building, capacity building cannot be an afterthought but must be integral to the design and adoption of policy. It can contribute to forestalling certain pitfalls at a later stage. Thinking through the types of support likely to be needed is important, as what may initially appear to be an ideal policy may – on a more thorough evaluation – reveal a potential level of complexity and support needed. Indeed, ideal policies may not be practical policies if they demand levels of human and capital resources beyond the means available or be practical for implementation.

This brings into focus further important aspects of capacity-building planning. First, policy planning must include not just a cost–benefit analysis of expected outcomes but also the cost of capacity-building support. It may be necessary to develop different sets of options to support implementation, which should be considered as part of the decision-making process. Such planning for capacity building helps ensure that an outcome being pursued can be achieved and that resources available are in equilibrium with resources needed for implementation.

2. Types and Targets of Capacity Building

As already noted, capacity building comes in various forms, is targeted towards different stakeholders, must be provided by different experts, and takes place at various times along the policy development/implementation lifecycle. The most common types of capacity building required are:

(i) conducting policy modelling and/or cost–benefit analyses;
(ii) undertaking domestic regulatory mapping to understand which laws and regulations need to be reformed to implement new policies or to remove regulations acting as barriers to more dynamic reform and regulatory compliance;
(iii) undertaking international regulatory mapping (e.g. non-tariff measures);
(iv) conducting advocacy, including support for particular stakeholders to know how to share their findings on a particular issue;
(v) providing issue-specific technical training;
(vi) developing implementation work plans;
(vii) creating monitoring and evaluation frameworks;
(viii) monitoring policy implementation;
(ix) conducting outreach and awareness-raising activities; and
(x) sharing lessons learned and comparative experiences.

It is beneficial to bear in mind the range of possible support that exists. From this menu of capacity-building activities, certain amounts of knowledge and competency will already exist and be institutionalised amongst sets of stakeholders experienced in a particular field. However, any new policy or effort to innovate is likely to necessitate more people who need to be brought into the project circle. Thus, certain requisite skills – whether in relation to policy development within amongst policy officials or technical staff in relation to policy roll-out – must be prepared for. Neither the resources nor the time needed for this should be underestimated.

With capacity building likely needed for a wide and large number of stakeholders – including government officials, legislators, independent regulators, oversight agencies, state-owned enterprises, the private sector, and community groups – the burden of who is responsible for providing the capacity building to different target audiences must also be considered. It is incumbent on the government, which establishes policy, to be aware of its own resource limitations as well as those of counterpart stakeholders who will play a vital role in the success of a policy.

Another type of capacity building support emanates from the benefit of learning from others. Developing policies around energy security is not unique to Lao People's Democratic Republic (Lao PDR). Whilst there will be differences in various countries' experiences – for example, access to energy supplies based on whether the country has its own energy sources or it is an energy importer – there are issues that all countries must address, such as improving the energy efficiency of appliances. How countries tackle these issues is ripe for information sharing and standardisation.

3 . Examples of Capacity Building

The chapters of this paper resonate with the various forms of capacity building listed previously; others may become apparent on policy adoption and roll out. From the chapters, it is clear that the target audience for capacity building in Lao PDR will be varied, based around the many different objectives to be achieved.

As several authors note, capacity building is an ongoing affair rather than a one-time event. Leong Siew Meng, in his chapter on end-use sector energy efficiency, is explicit about success depending on the success of capacity building, starting from structured continuous professional development programmes and awareness campaigns, broken out into immediate and long-term measures. Chin Loon Ong, in his chapter on energy management systems and energy service companies, also notes the ongoing nature of capacity building through short and medium- and long-term policies.

Alloysius Joko Purwanto, Ryan Wiratama Bhaskara, and Citra Endah Nur Setyawati, in their chapter on a sustainable transport system and power market, note that capacity building will be needed to strengthen technical expertise on electric vehicles and low-carbon transport. Priority needs to be given to government officials to elaborate regulations, especially in term of standardisation, vehicle registration, charging infrastructure, and policy alignment amongst related ministries. This, in turn, must be followed by capacity building for officials to implement associated programmes, monitor impacts, and enforce regulations. Capacity building is also needed for private sector players and potential private investors to take part in government electric vehicle-related programmes.

Concerning biofuel development, capacity building is needed by smaller businesses in rural areas to improve their efficiency in producing biofuels for their feedstock, meet the required standards, access financial resources, and participate in the biofuel industry supply chain. Regarding the development of logistics and distribution centres, capacity building needs to be given to government officials to better understand the economic roles of logistics and distribution centres for the movement of goods and to formulate policy measures to increase the efficiency and sustainability of the movement of goods within Lao PDR. Capacity-building efforts must focus on logistics, distribution centre owners and operators, as well as trucking companies to understand governments strategies, measures, and regulations and to help improve their management capacity. From just this one chapter, it is clear that stakeholders with many types of expertise are needed to provide capacity building in many fields.

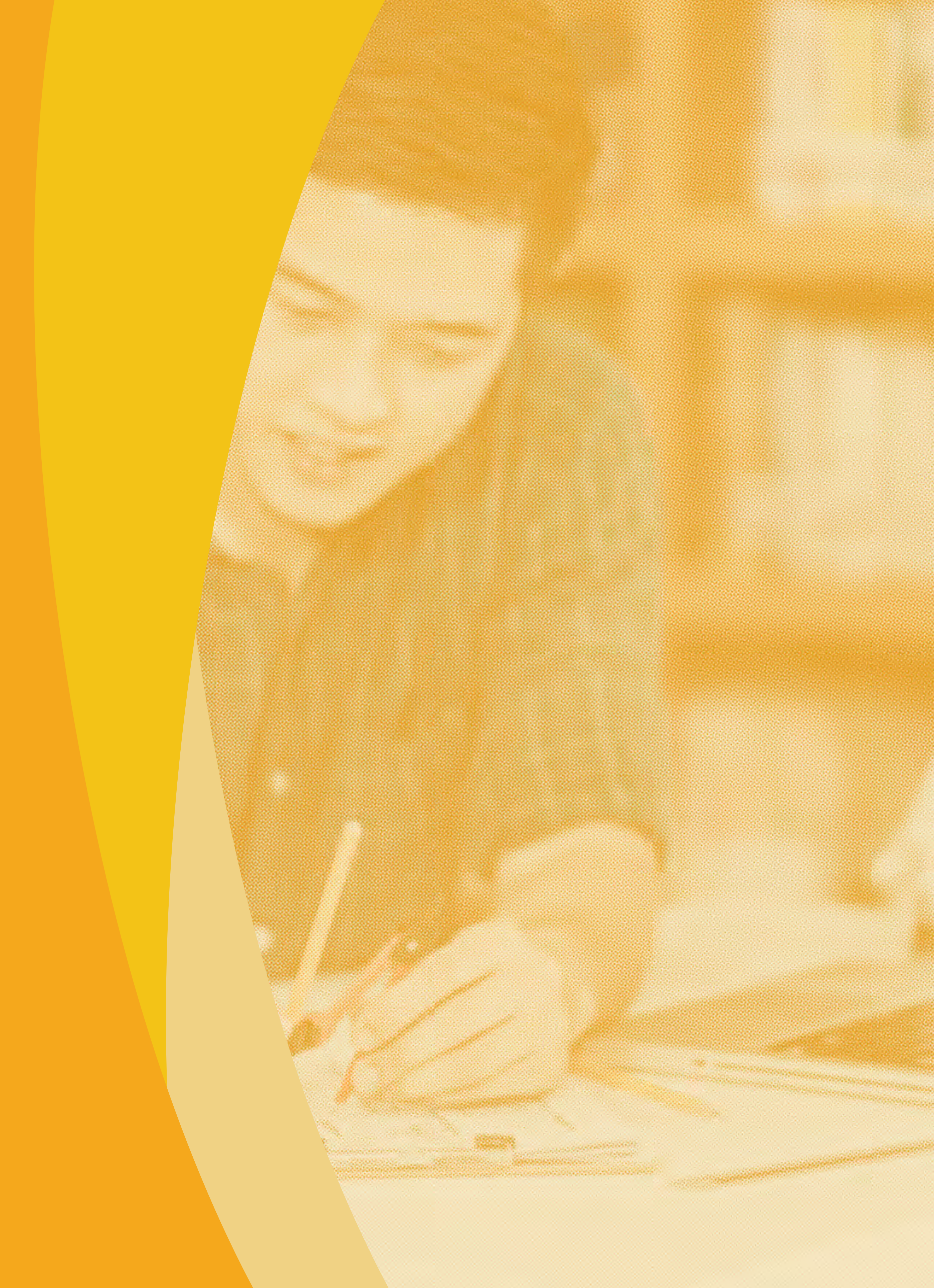
Financial literacy for stakeholders – including the government, banks, financial institutions, and potential investors – concerning investment opportunities, risk management, and financial modelling specific to sustainable energy projects, is a theme Farhad Taghizadeh-Hesary touches upon in his chapter on financing energy supply security in Lao PDR. Financial literacy workshops will allow policymakers and decision-makers make informed investment decisions, vital for fostering private investment in green energy projects. Bolstering this literacy can effectively drive the transition to sustainable energy by creating an environment conducive to private sector involvement in green energy initiatives. Improved financial literacy and decision-making are essential to attract private investment, ensure sustainable funding, and promote energy security and economic development.

Taghizadeh-Hesary also notes the specific technical training needed by local professionals at the state-owned and private electricity companies to develop and to maintain solar, wind and hydropower technologies. Whilst various international organisations and institutions have organised training programmes on green energy in Lao PDR, especially hydropower, this knowledge needs to be expanded to include energy alternatives like solar and wind power. Such capacity building is important for professionals in Lao PDR to design, implement, and maintain sustainable energy projects cost-effectively; drive innovation; and reduce reliance on external expertise. A longer-term positive outcome of developing this expert workforce is that they can become leaders in a particular field, exporting their technical skills and expertise in the future.

Hoyyen Chan, in her chapter on voluntary carbon markets, notes financing around capacity building emanating from international sources, such as those tied to international agreements and bilateral and regional sources. For example, there is support available for mitigating greenhouse gas emissions under Article 6.4 of the Paris Agreement. At the regional level, the Association of Southeast Asian Nations (ASEAN) provides capacity-building opportunities to support its various regional frameworks. In addition to benefitting from these funds, buying into regional standards ensures that national standards are compatible and compliant with those of other ASEAN Member States. In addition, there are global funds through initiatives such as the Global Green Growth Institute, which can be tapped for developing carbon markets.

4. Summary

This chapter serves to highlight the variety of potential types of capacity building that exist and the importance of planning for capacity building needs as part of policy design. This type of forwards planning helps ensure that policies identified are better thought through and costed, contributing to the likelihood of a positive policy outcome. It also helps policymakers consider all stakeholders associated with the policy, their potential roles, and their contributions. If this can be done for all sectors of energy security for Lao PDR, this will contribute significantly to the success of the country's energy security.



Annex: Summary

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Lao PDR's energy landscape is characterised by its vast renewable resources, particularly hydropower, which enables the country to serve as a net exporter of electricity in the ASEAN region. Despite this, Lao PDR remains heavily dependent on imported petroleum products for transport and residential use, leaving it exposed to global market volatility. While the potential for diversification through solar, wind, and biomass exists, these sectors are underdeveloped. Emerging technologies like green hydrogen and ammonia offer promising solutions for decarbonising the power sector, and regional power grid integration could further enhance energy and economic security.

However, Lao PDR faces several immediate and long-term challenges. Its reliance on imported oil, coupled with unsustainable electricity subsidies, strains the financial viability of the energy sector. Infrastructure inefficiencies, limited energy diversification, and the need to decarbonise coal-fired power plants add complexity to its pathway toward carbon neutrality. Additionally, developing infrastructure for electric vehicles (EVs) and securing financing for renewable projects present significant hurdles. To address these challenges, Lao PDR must invest in bioenergy, reform electricity tariffs, expand renewable energy, and develop EV infrastructure. Through these efforts, the country can strengthen its energy security while contributing to ASEAN's sustainable development goals.

1. Energy Landscape in Lao PDR

The energy landscape of Lao PDR is shaped by its vast renewable energy resources, particularly hydropower, which plays a key role in domestic energy supply and serves as a significant export to neighbouring ASEAN countries. Other renewable energy sources, such as solar, wind, and biomass, offer considerable potential but are currently underdeveloped.

- Hydropower: Lao PDR is rich in hydropower resources and has utilised this to become a net electricity exporter, contributing to ASEAN's energy security. Hydropower supplies most of the country's electricity, positioning it at the core of Lao PDR's domestic energy system and export earnings.

- Renewable Energy Potential: Beyond hydropower, Lao PDR has substantial solar, wind, and biomass potential. Biomass is particularly important in rural areas, where traditional biomass, such as wood, is still widely used for cooking and heating.

- Electricity Export: Lao PDR exports significant electricity to neighbouring countries, particularly Thailand and Viet Nam. This regional energy trade is expected to increase as ASEAN moves toward greater power grid connectivity.

- Import Dependency: Despite its strength in renewable electricity generation, Lao PDR remains highly dependent on imported petroleum products, such as gasoline, diesel, and LPG, for transport and residential use, making the country vulnerable to global market fluctuations and supply disruptions.

- Emerging Technologies: Lao PDR is exploring new technologies like green hydrogen and ammonia to decarbonise its power sector. Green hydrogen production from surplus renewable electricity could be used in transportation and industry.

2. Strengths of Energy-Related Issues in Lao PDR

Lao PDR's energy sector has multiple strengths, positioning the country as a potential leader in renewable energy within ASEAN:

2.1. Abundant Renewable Resources

- Hydropower: With substantial hydropower capacity, Lao PDR remains a net exporter of electricity, contributing energy to ASEAN neighbours and generating significant revenue. It is expected to export around 161 TWh of electricity by 2050.

- Solar and Wind Potential: While underdeveloped, solar and wind energy hold promise, especially as costs decrease and technologies advance.

- Biomass Energy: Biomass has great potential to enhance energy security, particularly in rural areas, and as a substitute for imported fossil fuels.

2.2. Regional Energy Integration

- ASEAN Power Grid: Lao PDR plays a critical role in the ASEAN Power Grid initiative, promoting multilateral power trading across the region. Strengthening Lao PDR's role as an electricity exporter through regional grid connectivity could provide both economic and energy security benefits.

2.3. Carbon Neutrality Potential

- Decarbonisation: Lao PDR is well-positioned to contribute to ASEAN's carbon neutrality goals by 2050 through its renewable energy resources. The country can decarbonise the regional grid by exporting renewable electricity and green hydrogen.

2.4. Electricity Access

- Growing Access: Electrification initiatives are expanding access to electricity, particularly in rural areas, a growing strength for Lao PDR.

2.5. Policy and Collaboration

- Policy Development: The government of Lao PDR is collaborating with international organisations like the Economic Research Institute for ASEAN and East Asia (ERIA) to develop policies supporting energy security and sustainable development.

3. Challenges Lao PDR Faces in the Near and Long-Term Future

Despite its strengths, Lao PDR faces several challenges in its energy sector:

3.1. Near-Term Challenges

- Dependence on Imported Oil: Lao PDR imports 100% of its gasoline, diesel, and LPG, leaving it vulnerable to global price fluctuations and supply disruptions. This poses a risk to energy security, particularly in the transport sector.

- Electricity Subsidies: The current electricity pricing structure relies on unsustainable subsidies, creating financial strain on Électricité du Laos (EDL) and limiting investment in energy infrastructure.

- Energy Infrastructure Inefficiencies: The electricity grid suffers from significant transmission losses, reducing efficiency and increasing costs. Modernising the grid is necessary to better integrate renewable energy.

- Limited Diversification: Heavy reliance on hydropower creates vulnerability, particularly during seasonal water shortages, due to a lack of diversification in the energy mix.

3.2. Long-Term Challenges

- Decarbonising Coal Power: Lao PDR faces the challenge of decarbonising coal-fired power plants like the Hongsa plant. Options such as co-firing with biomass or ammonia and deploying Carbon Capture, Utilisation, and Storage (CCUS) technologies are being explored but remain costly.

- Electric Vehicle (EV) Infrastructure: Although Lao PDR has a target of 30% EV market share by 2030, the infrastructure needed to support this goal, such as charging stations, is lacking. Policies and financing mechanisms for EV adoption also need development.

- Financing the Energy Transition: Attracting investment for renewable energy projects, grid modernisation, and clean technologies such as green hydrogen and CCUS presents a significant challenge.

- Human Resource and Technical Capacity: Lao PDR requires the development of technical expertise to manage smart grids, integrate renewable energy, and deploy advanced technologies like hydrogen and CCUS.

4. Recommendations to Tackle Energy Challenges

To address these challenges, the following recommendations are proposed:

4.1. Replacing Imported Oil with Bioenergy

- Develop Biofuel Production: Lao PDR should promote domestic biofuel production to reduce its reliance on imported petroleum products. Fiscal incentives and capacity-building initiatives could encourage private sector investment in biofuels.

- Promote Biomass Use: Lao PDR should incentivise biomass-based energy systems for residential and industrial use to reduce dependence on imported LPG and petroleum. Biomass can also be integrated into power generation, co-firing with existing coal plants.

4.2. Electricity Pricing Reform

- Restructure Electricity Tariffs: Electricity tariffs should move toward a market-based structure that reflects seasonal variations in hydropower supply and demand, reducing the financial burden on EDL and ensuring sustainable pricing.

4.3. Diversify Power Generation Mix

- Accelerate Solar and Wind Projects: The government should prioritise the development of solar and wind energy projects to diversify the energy mix and reduce reliance on hydropower.

- Expand Battery Storage: Deploy battery energy storage systems to manage the intermittency of solar and wind power. Pumped hydro energy storage could also be a viable solution for Lao PDR.

4.4. Develop EV Infrastructure

- Invest in Charging Networks: Lao PDR should prioritise building EV charging infrastructure to support the growth of electric vehicles. International partnerships could help finance this development.

- Incentivise EV Adoption: Fiscal incentives and policy frameworks should encourage EV adoption, particularly in public transportation.

4.5. Strengthen Energy Security

- Strategic Petroleum Reserves: Establishing a strategic petroleum reserve would mitigate risks from supply disruptions and price volatility.

- Enhance Grid Resilience: Upgrading the national grid to reduce transmission losses and improve renewable energy integration will bolster energy security. Investing in smart grids and advanced energy management systems is essential.

Conclusion

Lao PDR's energy sector is at a pivotal point. With abundant renewable resources, the country has the potential to play a leading role in ASEAN's decarbonisation efforts. However, challenges related to import dependency, infrastructure, financing, and policy reform must be addressed. By focusing on energy diversification, electricity pricing reform, and promoting bioenergy, Lao PDR can enhance its energy security and advance toward a sustainable, low-carbon future.