Energy Transition Pathways for the 2030 Agenda

SDG 7 Roadmap for Lao PDR

Developed using National Expert SDG7 Tool for Energy Planning (NEXSTEP)

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SDG7 Roadmap for Lao PDR

United Nations publication

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Table of Contents

List of Figures

List of Tables

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Abbreviations and acronyms

BAU	business-as-usual
CBA	cost benefit analysis
CO2	carbon dioxide
CPS	current policy scenario
EE	energy efficiency
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
EV	electric vehicle
GDP	gross domestic product
GHG	greenhouse gas
ICS	improved cooking stove
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
$MTCO_{2\text{-}e}$	million tonnes of carbon dioxide equivalent
ktoe	thousand tonnes of oil equivalent
kWh	kilowatt-hour
LCOE	Levelized Cost of Electricity
LEAP	Long-range Energy Alternatives Planning
LPG	liquified petroleum gas
MCDA	Multi-Criteria Decision Analysis
MEPS	minimum energy performance standard
MJ	megajoule
MTF	Multi-Tier Framework
MW	megawatt
MWh	megawatt-hour
NDC	nationally determined contributions
NEMO	Next Energy Modelling system for Optimization
NEXSTEP	National Expert SDG Tool for Energy Planning
OECD	Organisation for Economic Co-operation and Development
PP	power plant
RE	renewable energy
SDG	Sustainable Development Goal
TFEC	total final energy consumption
TPES	total primary energy supply
US$	United States Dollar
WHO	World Health Organization

Executive Summary

Transitioning the energy sector to achieve the 2030 Agenda for Sustainable Development and the objectives of the Paris Agreement presents a complex and difficult task for policymakers. It needs to ensure sustained economic growth as well as respond to increasing energy demand, reduce emissions and consider and capitalize on the interlinkages between Sustainable Development Goal 7 (SDG 7) and other SDGs. To address this challenge, ESCAP has developed the National Expert SDG Tool for Energy Planning (NEXSTEP).[2] This tool enables policymakers to make informed policy decisions to support the achievement of the SDG 7 targets as well as emission reduction targets (NDCs). The initiative has been undertaken in response to the Ministerial Declaration of the Second Asian and Pacific Energy Forum (April 2018, Bangkok) and Commission Resolution 74/9, which endorsed its outcome. NEXSTEP also garnered the support of the Committee on Energy in its Second Session, with recommendations to expand the number of countries being supported by this tool.

The key objective of this SDG 7 roadmap[3] is to assist the Government of Lao PDR to develop enabling policy measures to achieve the SDG 7 targets. This roadmap contains a matrix of technological options and enabling policy measures for the Government to consider. It presents several scenarios that have been developed using national data, and which consider existing energy policies and strategies, and reflect on other development plans. These scenarios are expected to enable the Government to make an informed decision to develop and implement a set of policies to achieve SDG 7 by 2030, together with the NDC.

A. Highlights of the roadmap

Lao PDR's access to electricity was 93.5 per cent in 2018. Based on the historical trend, it is estimated that Lao PDR will achieve universal access to electricity by 2025. Universal access to clean cooking technology and fuel, however, has been and likely to remain very low in the current policy scenario (was 8 per cent in 2018 increasing to 20 per cent by 2030). It remains a challenge for the country 5.6 million population will still relying on polluting cooking fuels and technology in 2030. Well-planned and concerted efforts will need to be made to achieve universal access to clean cooking by 2030. Energy intensity, the indicator used to measure energy efficiency, has been increasing since 2012 and reached 5.8 MJ/US$ in 2018. To

[2] NEXSTEP tool has been specially designed to perform analyses of the energy sector in the context of SDG 7 and NDC with an aim that the output will provide a set of policy recommendations to achieve the SDG 7 and NDC targets.

[3] This roadmap examines the current status of the national energy sector and existing policies, compares them with the SDG 7 targets, and presents different scenarios highlighting technological options and enabling policy measures for the Government to consider.

achieve the SDG 7 target for energy efficiency, this needs to reduce to 5.1 MJ/US$ by 2030 corresponding to 1.1 per cent annual improvement.

Lao PDR has abundant renewable energy resources – part from large hydropower resources it has also significant potential of solar PV and biomass resources. Nevertheless, Lao PDR lacks petroleum fuel resources and thus requires importing oil products to meet its increasing demand in the transport sector. The country's power sector is heavily reliant on hydropower. Most of the power generated by Lo PDR is exported to neighbouring countries and a small part of the generation is consumed domestically. In addition to the opportunities that hydropower brings to the power sector, there are challenges as well to heavily rely solely on one technology e.g. the reduction of resources in the dry season requiring Lao PDR to import a part of its domestic electricity demand. As such Lao PDR has added a small amount of coal in the fleet, which has been planned for increase in near future. The NEXSTEP analysis has examined the potential of diversifying the energy sources, e.g. by increasing renewable energy technologies both in the demand and supply sides.

B. Achieving Lao PDR's SDG7 and NDC targets by 2030

Universal access to electricity

Based on the 2018 rate of 93.5 per cent and using a linear forecasting method, the roadmap estimates that the access to electricity will be achieved by 2025. However, further study should be undertaken to examine the quality and reliability of access, particularly in rural areas, to ensure that households enjoy a minimum of Tier 3 level connection as per the World Bank's Multi-Tier Framework of access to energy.

Universal access to clean cooking

Access to clean cooking, on the other hand, has been and is likely to remain poor in the absence of strong policy measures. In 2018, only 8 pe cent of population had access to clean cooking fuels and technologies and is estimated to increase to 20 per cent by 2030 considering the historical trend as well as different programs and projects that are currently being implemented. This will leave 5.6 million people (more than 1 million households) still relaying on polluted cooking practices in 2030, leading to severe health hazards from indoor air pollution, particularly for women and young children. The NEXSTEP analysis suggests that a combination of electric cooking stoves, LPG cookstoves and improved cookstoves can be used to uplift the access rate to 100 per cent by 2030.

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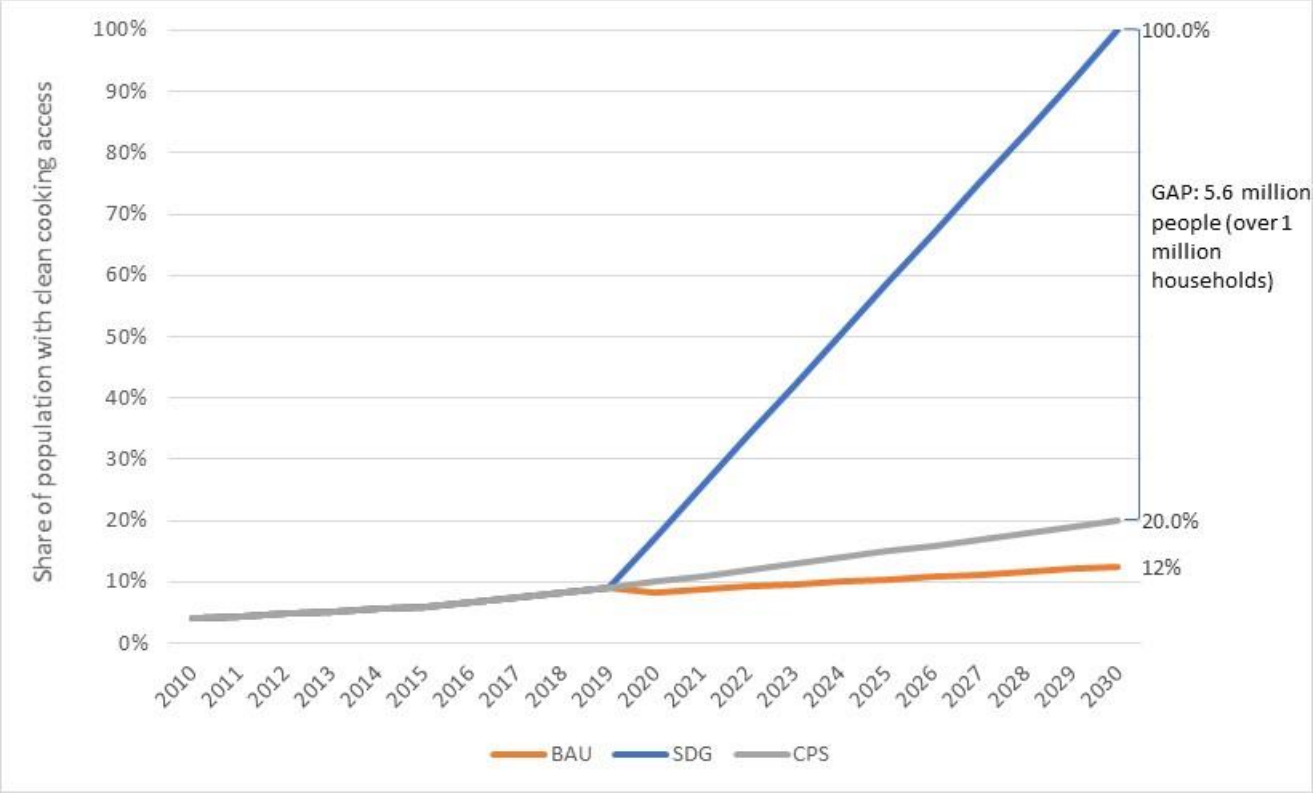

Figure ES 1: Lao PDR access to clean cooking under CPS and SDG scenarios

Renewable Energy

The share of renewable energy in the total final energy consumption (TFEC) was 16.8 per cent in 2018, excluding traditional use of biomass. This share becomes 41 per cent when biomass is included. Based on current policies, the share of renewable energy is projected to increase to 18.9 per cent by 2030. In the SDG scenario, the share of renewable energy is further increased to 25.6 percent of TFEC in 2030. This improvement is solely due to the increased renewable energy mix in power generation as well as the adoption of electric stoves whilst phasing out of traditional biomass usage, which also decreases the total final energy consumption.

Energy Efficiency

Lao PDR's energy intensity in 2018 was 5.8 MJ/USD_{2011}. Energy Intensity in Lao PDR has been increasing since 2011 with an average annual rate of 17 per cent between 2012 and 2018. This poses a challenge to achieve the SDG7 target for energy efficiency which requires the energy intensity to halve by 2030, compared to the average improvement between 1990-2010. This corresponds to an average annual rate of 5.4 per cent decrease between 2018 and 2030. Correspondingly, the energy intensity in 2030 should be 3.0 MJ/USD_{2011} to achieve the SDG7 target. Such a reduction has been found to be very difficult for Lao PDR and thus the

target has been aligned with the global improvement rate of 2.9 per cent per year resulting in revised target of 4.1 MJ/US$.

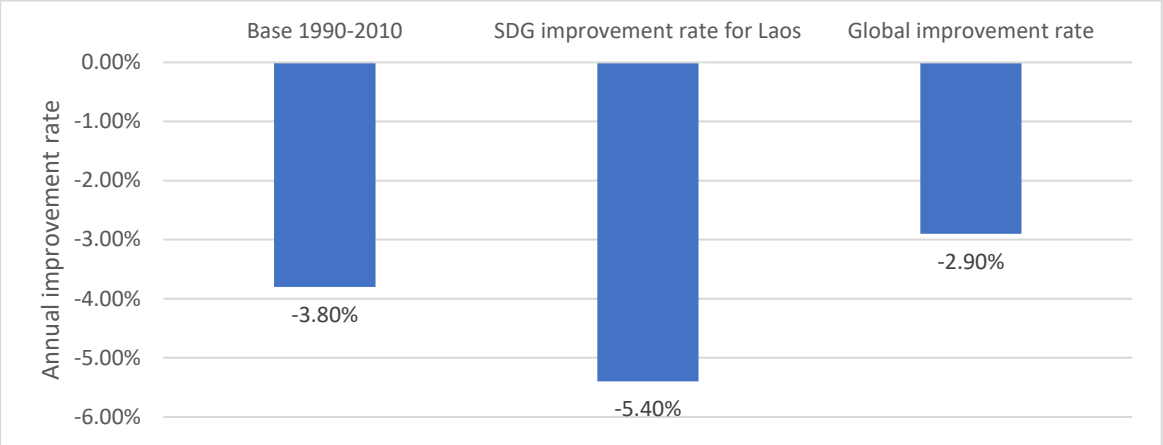

Figure ES 2: Lao PDR energy efficiency improvement rate

Under the current policy settings, the energy intensity is projected to increase to 6.13 MJ//USD$_{2011}$. The energy efficiency target is not achieved in the SDG scenario, however, a higher level of energy efficiency measures, as discussed in the igh Energy Efficiency scenario, will enable achievement of the target of 4.1 MJ//USD$_{2011}$.

Nationally Determined Contribution (NDC)

Lao PDR does not make any explicit target for emission reduction from the energy sector in the second NDC, however, the measures mentioned for the energy sector suggest an emission reduction of 28.75 MtCO2-e, compared to BAU. In the second NDC, submitted in March 2021, the unconditional target aims to increase hydropower capacity to 13 GW by 2030. This target would be achieved with the domestic resources i.e. the unconditional target. For the conditional target, Lao PDR aims to add an additional 1 GW of solar and wind (combined) to the national power generation, and 300 MW of biomass. Additionally, targets have been mentioned in the demand side e.g. the adoption of 30 per cent of electric vehicles for 2-wheelers and passenger cars; increasing biofuel to 10 per cent of the fuel mix in the transport sector; and a 10 per cent energy efficiency improvement (to the final energy consumption, compared to BAU) across the economy. These targets have been included in the SDG scenario and the high energy efficiency scenario.

C. Important policy directions

The Road map sets out four key policy recommendations to help Lao PDR achieve the SDG 7 targets, as well as reduce reliance on imported energy sources:

1) Strong policy measures are required to address the huge gap in clean cooking by 2030. Achieving access to clean cooking fuels and technologies seem to be one of the biggest challenges for Lao PDR, as it has one of the lowest access rates to date.

Immediate well-planned policy measures are to be put in place to ensure achievement of this target by 2030. NEXSTEP analysis suggest a combination of electric cooking stoves, LPG cooking stoves and ICS should be used to achieve the universal access to clean cooking fuels and technologies. Choice of these technologies has been based on health benefits as well as cost effectiveness, as suggested by the annualized cost of technologies.

2) **Achievement of the energy efficiency target is considered to be the second biggest challenge for Lao PDR. Several measures are need with a whole-economy approach.** Energy intensity in the country has been going upwards instead of declining as required in the SDG7 target. With the contraction of GDP growth due to the impact of COVID-19, this is likely to worsen in the future, as energy intensity is measured as the amount of energy per unit of GDP. The NEXSTEP has found that it is rather difficult for Lao PDR to achieve its needed energy efficiency target but it can be aligned with the global improvement rate, even that would be possible with extensive energy efficiency measures across all sectors, as discussed in the high energy efficiency scenario.
3) **Transport electrification strategies provide multi-fold benefits.** Vigorous adoption of electric vehicles reduces the demand for oil products, hence reducing Lao PDR's reliance on imported petroleum fuels. At the same time, it can contribute to climate mitigation and improving the local air quality.
4) **Lao PDR should focus on phasing out coal from the power sector.** On the basis of economic, environmental and social benefits and the country's vast renewable energy resources, including solar PV and biomass, phasing out coal would be the justified choice of Lao PDR's energy transition. This would be also in alignment with the global move to phasing out coal as well as progressing towards net zero carbon by 2050. Lao PDR's coal industry is relatively new and thus it would be easier to transition to alternative energy sources and technologies, particularly to solar PV and biomass, in addition to further increasing the hydropower capacity. Analysis has revealed that such a transition is technically and economically possible without impacting the electricity export market. While there are challenges in doing so, international experiences and lessons learned from other countries suggest that an early start in planning, detailed consultations with stakeholders and international communities, and developing a well-thought long-term 'just' transition plan will minimize socio-economic risks.

1. Introduction

1.1. Background

Transitioning the energy sector to achieve the 2030 Agenda for Sustainable Development and the objectives of the Paris Agreement presents a complex and difficult task for policymakers. It needs to ensure a sustained economic growth, respond to increasing energy demand, reduce emissions and, as well as it considers and capitalises on the interlinkages between Sustainable Development Goal 7 (SDG7) and other SDGs. In this connection, the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) has developed the National Expert SDG Tool for Energy Planning (NEXSTEP). This tool enables policymakers to make informed policy decisions to support the achievement of the SDG7 targets as well as emission reduction targets (NDCs). The initiative has been undertaken in response to the Ministerial Declaration of the 2nd Asian and Pacific Energy Forum (April 2018, Bangkok) and the Commission Resolution 74/9 which endorsed its outcomes. NEXSTEP has also garnered the support of the Committee on Energy in its Second Session, with recommendations to expand the number of countries being supported by this tool. The ministerial declaration advises ESCAP to support its member States, upon request, in developing national SDG 7 roadmaps.

1.2. SDG 7 Targets and Indicators

SDG7 aims to ensure access to affordable, reliable, sustainable and modern energy for all. It has three key targets, which are outlined below.

- Target 7.1. “By 2030, ensure universal access to affordable, reliable and modern energy services.” Two indicators are used to measure this target: (a) the proportion of the population with access to electricity; and (b) the proportion of the population with primary reliance on clean cooking fuels and technology.
- Target 7.2. “By 2030, increase substantially the share of renewable energy in the global energy mix”. This is measured by the renewable energy share in total final energy consumption (TFEC). It is calculated by dividing the consumption of energy from all renewable sources by total energy consumption. Renewable energy consumption includes consumption of energy derived from hydropower, solid biofuels (including traditional use), wind, solar, liquid biofuels, biogas, geothermal, marine and waste. *Due to the inherent complexity of accurately estimating traditional use of biomass, NEXSTEP focuses entirely on modern renewables (excluding traditional use of biomass) for this target*.
- Target 7.3. “By 2030, double the global rate of improvement in energy efficiency”, as measured by the energy intensity of the economy. This is the ratio of the total primary

energy supply (TPES) and GDP. Energy intensity is an indication of how much energy is used to produce one unit of economic output. As defined by the IEA, TPES is made up of production plus net imports minus international marine and aviation bunkers plus stock changes. For comparison purposes, GDP is measured in constant terms at 2011 PPP.

1.3. Nationally Determined Contribution (NDC)

NDCs represent pledges by each country to reduce national emissions and are the stepping stones to the implementation of the Paris Agreement. Since the energy sector is the largest contributor to GHG emissions in most countries, decarbonizing energy systems should be given a high priority. Key approaches to reducing emissions from the energy sector include increasing renewable energy in the generation mix and improving energy efficiency.

In its first NDC, Lao PDR had set a target of 30 per cent renewable energy share in power generation (including large hydro) by 2030, which further delineated that it would expand the large hydropower capacity to 20 GW by 2030. In the second NDC, submitted in March 2021, the unconditional target is reduced to 13 GW by 2030. Lao PDR does not make any explicit target for emission reduction from the energy sector in the second NDC, however, the measures mentioned for the energy sector suggest an emission reduction of 28.75 MtCO2-e, compared to BAU. This target would be achieved with the domestic resources i.e. the unconditional target. For the conditional target, Lao PDR aims to add an additional 1 GW of solar and wind (combined) to the national power generation, and 300 MW of biomass. The transport sector aims to adopt 30 per cent of electric vehicles for 2-wheelers and passenger cars. Biofuel will be increased to 10 per cent of the fuel mix in the transport sector. Additionally, a 10 per cent energy efficiency improvement (to the final energy consumption, compared to BAU) will be implemented across the economy.

2. NEXSTEP Methodology

The main purpose of NEXSTEP is to help design the type and mix of policies that would enable the achievement of the SDG7 targets and the emission reduction targets (under NDCs) through policy analysis. However, policy analysis cannot be done without modelling energy systems to forecast/backcast energy and emissions, and economic analysis to assess which policies or options would be economically suitable. Based on this, a three-step approach has been proposed. Each step is discussed in the following sections.

2.1. Key methodological steps

I. Energy and Emissions Modelling

NEXSTEP begins with the energy systems modelling to develop different scenarios to achieve SDG7 by identifying potential technical options for each scenario. Each scenario

contains important information including the final energy (electricity and heat) requirement by 2030, possible generation/supply mix, emissions and the size of investment required. The energy and emissions modelling component use the Long-range Energy Alternatives Planning (LEAP). It is a widely used tool for energy sector modelling and to create energy and emissions scenarios. Many countries have used LEAP to develop scenarios as a basis for their Intended Nationally Determined Contributions (INDCs). Figure 1 shows different steps of the methodology.

II. Economic Analysis Module

The energy and emissions modelling section selects the appropriate technologies, and the economic analysis builds on this by selecting the least cost energy supply mix for the country. The economic analysis is used to examine economic performances of individual technical options identified and prioritize least-cost options. As such, it is important to estimate some of the key economic parameters such as net present value, internal rate of return, and payback period. A ranking of selected technologies will help policymakers to identify and select economically effective projects for better allocation of resources. The economic analysis helps present several economic parameters and indicators that would be useful for policymakers in making an informed policy decision.

III. Scenario and policy Analysis

Using Multi-Criteria Decision Analysis (MCDA) tool, this prioritised list of scenarios is assessed in terms of their techno-economic and environmental dimensions to convert to a policy measure. The top ranked scenario from the MCDA process is essentially the output of NEXSTEP, which is then used to develop policy recommendations.

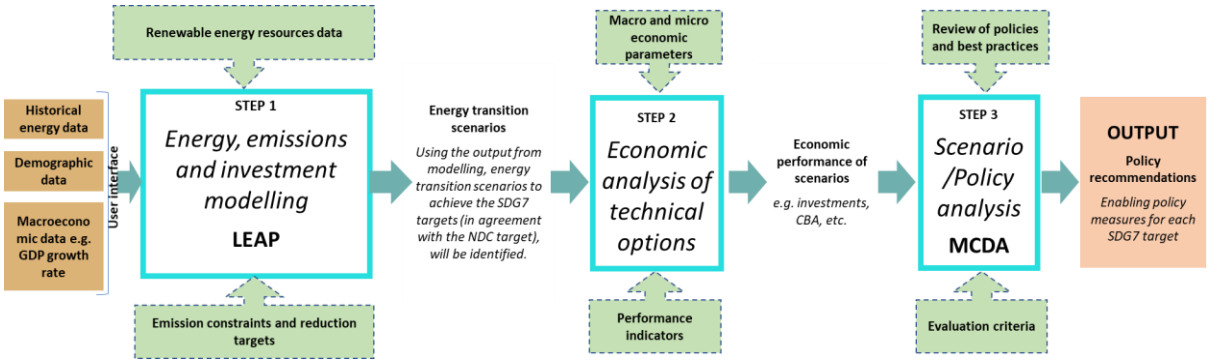

Figure 1: Different components of the NEXSTEP methodology

This tool is unique in a way that no other tools look at developing policy measures to achieve SDG7. The key feature that makes it different is the backcasting approach for energy and emissions modelling. This is important when it comes to planning for SDG7 as the targets for the final year (2030) is already given and thus the tool needs to be

able to work its way backward to the current date and identify the best possible pathway.

2.2. Scenario definitions

The LEAP modelling system is designed for scenario analysis, to enable energy specialists to model energy system evolution based on current energy policies. In the NEXSTEP model for Lao PDR, three main scenarios have been modelled: (a) a Business As Usual scenario; (b) Current Policy Scenario (CPS); (c) Sustainable Development Goal (SDG) scenario. In addition, two ambitious scenario have been modelled, which look to raise Lao PDR's ambition beyond the SDG and the NDC targets:

I. *The BAU scenario*: This scenario follows historical demand trends, based on growth projections, such as using GDP and population growth. It does not consider emission limits or renewable energy targets. For each sector, the final energy demand is met by a fuel mix reflecting the current shares in TFEC, with the trend extrapolated to 2030. Essentially, this scenario aims to indicate what will happen if no enabling policies are implemented or the existing policies fail to achieve their intended outcomes;
II. *Current policies scenario*: Inherited and modified from the BAU scenario, this scenario considers all policies and plans currently in place. These are, for example, the emission reduction measures and power capacity expansion plan stipulated in the proposed draft National Power Development Plan (NPDP) 2020-2030.
III. *SDG scenario*: This scenario aims to achieve the SDG 7 targets, including universal access to electricity and clean cooking fuel, substantially increasing renewable energy share and doubling the rate of energy efficiency improvement. For clean cooking, different technologies (electric cooking stove, LPG cooking stove and improved cooking stove) have been assessed, subsequently recommending the uptake of the most appropriate technology. Energy intensity has been modelled to help achieve the SDG 7 target.
IV. *Ambitious scenarios*: Like the SDG scenario, the ambitious scenario aims to achieve the SDG 7 targets. In addition, this scenario also looks to increase the socio-economic and environmental benefits for the country from raising its ambition beyond just achieving the SDG 7 targets. Two additional scenarios have been developed, (a) the high energy efficiency scenario and (b) coal phase out scenario, to explore how Lao DPR could further leverage the benefits of increasing its ambition in the energy sector.

2.3. Economic Analysis

The economic analysis considers the project's contribution to the economic performance of the energy sector. The purpose of a Cost-Benefit Analysis (CBA) is to make better informed policy decisions. It is a tool to weigh the benefits against costs and facilitate an efficient distribution of resources in public sector investment.

2.3.1. Basics of Economic Analysis

The economic analysis of public sector investment differs from a financial analysis. A financial analysis considers the profitability of an investment project from the investor's perspective. In an economic analysis the profitability of the investment considers the national welfare, including externalities. A project is financially viable only if all the monetary costs can be recovered in the lifetime. Project financial viability is not enough in an economic analysis, contribution to societal welfare should be identified and quantified. For example, in the case of a coal power plant, the emissions from combustion process emits particulate matter which is inhaled by the local population causing health damages and accelerates climate change. In an economic analysis a monetary value is assigned to the GHG emission to value its GHG emissions abatement.

2.3.2. Cost parameters

The project cost is the fundamental input in the economic analysis. The overall project cost is calculated using the following:

a) Capital cost – capital infrastructure costs for technologies, these are based on country-specific data to improve the analysis. They include land, building, machinery, equipment and civil works.

b) Operation and Maintenance Cost consists of fuel, labour and maintenance costs. Power generation facilities classify operation and maintenance costs as fixed (US$/MW) and variable (US$/MWh) cost.

c) Decommissioning Cost - retirement of power plants costs related to environmental remediation, regulatory frameworks and demolition costs.

d) Sunk Cost – existing infrastructure investments are not included in the economic analysis, since it does not have any additional investment required for the project.

e) External Cost – refers to any additional externalities which place costs on society.

f) GHG Abatement – avoided cost of CO_2 generation is calculated in monetary value based on carbon price. The 2016 Intergovernmental Panel on Climate Change (IPCC)

Guidelines for National Greenhouse Gas Inventories is followed in the calculation of GHG emission for the economic analysis. The sectoral analysis is based on the Tier 1 approach, which uses fuel combustion from national statistics and default emission factors.

2.3.3. Scenario analysis

The scenario analysis evaluates and ranks scenarios, using the Multi Criteria Decision Analysis (MCDA) tool, with a set of criteria and weights assigned to each criterion. The criteria considered in the MCDA tool can include the following, however, stakeholders may wish to add/remove criteria to suit the local context.

- Access to clean cooking fuel
- Energy efficiency
- Share of renewable energy
- Emissions in 2030
- Alignment with Paris Agreement
- Fossil fuel subsidy phased out
- Price on carbon
- Fossil fuel phase-out
- Cost of access to electricity
- Cost of access to clean cooking fuel
- Investment cost of the power sector
- Net benefit from the power sector

This step is generally applied to all countries utilizing NEXSTEP in developing the national SDG 7 Roadmap, as a mean to suggest the best way forward for the countries by prioritising the several scenarios. Nevertheless, it has not been applied to Lao PDR as a limited number of scenarios are available, which is easier to make a decision.

3. Overview of Lao PDR's Energy Sector

3.1. Current Situation

Geography and climate – Located in the Southeast Asia region, The Lao People's Democratic Republic (Lao PDR) is a landlocked country and is situated in the mountainous areas and is abundant with natural resources, specifically water resources with various significant streams such as the Mekong River and its River basin. It is bounded by five countries: China in the north, Viet Nam in the east, Cambodia in the south, and Thailand and Myanmar in the west. Water is a fundamental natural resource to generate electricity from hydropower plants and has been considered as the major national economic development for decades. The country has an area of 236,800 square kilometres, about 70 per cent of which is covered by mountains. The country's geographical administration comprises 18 provinces, with Vientiane as the capital.

Population – In 2018, the country had a population of 7.01 million people, with an average of 5.5 person per household, which estimates 1,276,867 households. The number of population recorded in 2000 was 5.3 million (ESCAP 2021), which translates into an annual growth rate of 1.8 per cent between 2000 and 2018. The urbanisation rate in 2018 was 36.30%, which is projected to grow to 44.55% in 2030 (ESCAP 2021).

Economy – The economic growth of Lao PDR has been remarkable in recent years, GDP growth rate averaging at about 7 per cent since 2000. The GDP growth rate in 2018 was 6.5 per cent with national GDP of US$ 18.3 million in 2018. However, like other countries in the region, Lao PDR's economy has been impacted by COVID-19. GDP contracted to 4.7 per cent in the last quarter of 2019, dived to -0.5 per cent in 2020, and forecasts suggest that it will rise to 4 per cent in 2021, 4.5 per cent in 2022, 5 per cent in 2025 and gradually rise to 6.5 per cent (pre-COVID level) by 2030 (ADB 2021). According to the World Bank's country classification, Lao PDR is classified as lower-middle income economy as of the 2021 fiscal year (World Bank 2021). Nevertheless, with an average of over 7 per cent GDP growth over the past two decades, Lao PDR is one of the fastest growing economy in the world.

*Climate Change Risk*s – Lao PDR is vulnerable to extreme events, such as droughts and floods. These disturbances are increasing in frequency and severity, affecting food security, drinking water supply and irrigation, public health systems, environmental management and lifestyle. According to GIZ, climate change will affect economic growth in Laos as key industrial sectors depend on natural resources: mining, hydropower and wood processing. Farming, animal husbandry, forestry and fisheries rely on land, appropriate temperature and rainfall. Water shortage and groundwater depletion can lead to reduced agricultural production. This

may cause food insecurity and an increase of poverty as the livelihood of most Lao people relies on agriculture (GIZ 2021).

Table 1: Key demographic and macroeconomic data

Indicators	Value	Unit
Population	7.01	Million
Household	1,276,867	Households
Household Size	5.5	Person / Household
GDP	18.30	Billion USD
Per Capita	2,610.56	US$
Population Growth Rate	1.6	Per cent
GDP Growth Rate	6.5	Per cent
NDC emissions target	N/A	
Commercial Floor Space	100	Million m2
Domestic electricity tariff*	0.1	US$/kWh
Export electricity tariff**	0.05	US$/kWh

* *Domestic tariff differs by sector and level of usage. For simplicity, an average tariff has been estimated from different tariff brackets. Source: (AGEP 2018). Assuming the tariff remains constant during the analysis period.*

** *Estimated using 2017 electricity export revenue of US$ 1,250 million and export amount of 24,875.37 GWh. Assuming the tariff remains constant during the analysis period.*

Low Emission Analysis Platform (LEAP) for modelling the scenarios.

3.2. Data availability

NEXSTEP modelling utilises data obtained from two sources – some data were provided by the national consultant in consultation with the Department of Planning and Cooperation (DPC) and the remaining data were collected from publicly available sources (literature review). Examples of collected data points include energy intensity data for the demand sectors (i.e. residential, commercial, transport and industry), production capacity and generation data for the power sector, electricity export, macroeconomic and demographic data such as GDP, predicted GDP growth rate, population data and predicted population growth rate. Two important documents were consulted for target setting for the current policy scenario- these are the 2nd Nationally Determined Contributions (NDC) published in March 2021 and the Draft National Power Development Plan 2020-2030, shared by DPC.

There has been a challenge to obtain data from the country. The national consultant provided some data which were not in full agreement with the Ministry. ESCAP's communications with the Ministry has concluded that further data will be collected through literature review and consultation with the Ministry (DPC). The absence of full suite of data, that are required for an in-depth NEXSTEP analysis, has limited the level of analysis for Lao PDR. For example, detailed end-use or process-level energy efficiency improvement in the industry sector was not possible which resulted in recommendation of a certain percentage of energy reduction

across the entire industry sector, compared to identification of end-use level EE measures if detailed data were available. Similar impacts also have been in other sectors.

3.3. National Energy Profile

The electrification rate in Lao PDR was 93.5 per cent in 2018. This leaves around 83 thousand households (about half a million people) yet to be connected to any form of electricity supply. The country is severely lacking access to clean cooking technologies and fuels which was 8 per cent in 2018 – significant efforts will need to be made to achieve the universal access by 2030. Approximately 90 per cent of its population is reliant on using biomass in traditional cookstoves for their cooking needs, while the remaining uses a combination of LPG and improved cook stoves.

3.4. National Energy Policies and Targets and development plans

Lao PDR's energy sector development is guided by several national policies and frameworks. These policies have been used as guiding references for the NEXSTEP modelling, to better understand the country context and to provide recommendations in adherence with the Government's overarching direction. Where applicable, the currently implemented and adopted policies or regulations are considered in the current policy scenario, to identify gaps in achieving the SDG 7 targets. Major policies or strategic documents consulted include the following:

The **8th National Socio-Economic Development Plan NSEDP (2016-2020)** paves the way towards the graduation from Least Developed Countries status and lays a strong foundation for the achievement of the 2025 National Strategy on Socio-Economic Development and the 2030 Agenda for Sustainable Development. The directions set forth in this document include ensuring continued economic growth (target growth rate 8%), ensuring sustainable development with harmonization among the economic development and socio-culturable development and environmental protection, strengthening human resources capacity, maintaining political stability and widening international cooperation (Ministry of Planning and Investment 2016). The 9th NSEDP (2021-2030) is currently being developed.

The **Renewable Energy Development Strategy in Lao PDR** was issued in 2011 and it aims to develop new renewable energy resources which are not yet widely explored in Lao PDR to replace resources that will be exhausted in the future, also known as "non-renewable energy". For access to electricity, it aims to encourage people in rural areas to use renewable energy to enhance self-sufficiency by developing small power systems using biofuels, solar and biomass technologies. For access to clean cooking fuel, the Government aims to promote the development and market deployment of the most efficient and appropriate cooking stoves in

the country, including carrying out market assessment and technical studies for improved cooking stoves (ICS). For renewable energy, the Government aims to increase the share of renewable energies to 30% of the total energy consumption in 2025. The Government also encourages the development of grid connected solar PV systems and solar PV hybrid systems, such as the integration with small hydropower and wind power, to sustain supply of electricity during the dry season (Government of Lao PDR 2011).

The **2nd Nationally Determined Contribution (NDC)** published in March 2021 sets forth strong and clear targets for 2030 to support the achievement of the Paris Agreement. while Lao PDR does not make any explicit target of emission reduction from the energy sector, however, different measures mentioned in the document suggest 28.75 MtCO2-e emission reduction, compared to BAU. These are unconditional targets and will be achieved with domestic resources. For the conditional target, Lao PDR aims to add an additional 1 GW of solar and wind (combined) to the national power generation, and 300 MW of biomass. The transport sector aims to adopt 30% of electric vehicles for 2-wheelers and passenger cars. Biofuel will be increased to 10% of the fuel mix in the transport sector. Additionally, a 10% energy efficiency improvement (to the final energy consumption, compared to BAU) will be implemented across the economy.

The **Draft National Power Development Plan (NPDP) 2020-2030** presents a detailed strategy for the power sector development for the next decade. Its objectives are to (a) ensure the reliability and security of the power system by diversifying electricity generation technologies, (b) expand the transmission and distribution system, (c) reduce power import during the dry season and (d) increase the power export to neighbouring countries. Some specific targets set in this plan include:

- reduce fuel import by increasing EV in the transport sector,
- increase coal utilization for power generation through clean coal technology,
- increase RE share by up to 30% of total energy consumption by 2025,
- increase the diversity of energy generation: hydropower 65%, coal 30% and RE 5%,
- interconnect the transmission line and combine the export and domestic to be one single transmission system.

Energy efficiency standards and labelling - to date, more than 400 national standards have been developed based on IEC and ISO standards and complied with ISO/IEC Guide 59 (code of good practice for standardization). All the existing national standards related to lighting, air-conditioners, refrigerators and other appliances focus on the safety aspect, and energy

performance testing standards (e.g., ISO 5151 and ISO 16358-1 for air-conditioner energy efficiency) which are required by MEPS and labelling have not yet been developed (GCF 2019).

3.5. National Energy Resource Assessment

According to Lao PDR's exploitable hydro resources, the country has estimated resources to generate electricity with a theoretical hydropower potential of 26.5 GW (IHA, 2016), of which 5.5 GW hydropower capacity has been installed up to 2018 (MEM, 2019). Furthermore, this source of energy is significant as it is conducive to generating national income by exporting to neighbouring countries such as Thailand, Vietnam, and Myanmar. In 2018, around 1.2 per cent of the country's Gross domestic product (GDP) was derived from exporting electricity (ADB, 2019).

Solar energy

The availability of solar energy in Lao PDR is relatively high to provide electricity generation throughout the year. With a moderate to the high potential of receiving sunlight annually for an average of 200-300 days or 1,800-2,000 hours, the country could gain solar energy within a range of 3.6 to 5.5 kWh/m2 per day (ADB, 2019). Currently, five solar power projects have operated with a total installed capacity of 32 MW, with a generation of 59.2 GWh per year (MEM, 2019).

Wind energy

There has not been any extensive study to assess the potential of wind energy in Lao PDR. Studies show that the south-central and a few northern parts of Lao PDR appearing to have greater potential for wind energy exploitation than other parts. These include high mountain zones along the border between Lao PDR and Vietnam, especially in Savannakhet and Khammouane provinces, where wind resources are identified to be the highest and most effective electricity generation in Lao PDR. The technical specifications of those areas demonstrate that at a height of 50 meters and above, wind speeds can reach up to 5.8 m/s (EEP, 2011). However, wind speed is not consistent and is considered to be not technically feasible for large-scale electricity generation.

Hydro

The country's exploitable hydropower potential is estimated to be around 26,500 MW, which is consisting of small-scale hydropower (installed capacity less than 15 MW), and large-scale hydropower (classified as above 100 MW). Moreover, there are 67 existing hydropower plants that have been commissioned since late 2019, with a total installed capacity of 7,614 MW and with an electricity generation of 37,759 GWh per year (MEM, 2019).

Biomass

Biomass sources are widely available across the country because it is covered by the forest around 68% of the country's land in 2010 (FAO, 2015). Biomass continues to be significant resource as it can produce wastes from fuelwood and charcoal deriving from agricultural and forestry sectors. These wastes include rice straw and husks, sawdust, corn cobs, and sugar cane peel, which are estimated up to 500 million tons of oil equivalent (MTOE) produced (ADB, 2019). This advantage enhances the potential for electricity generation from both biomass and biogas up to 1,525 GWh per year (utility-scale and non-utility-scale generation). While utility-scale ranges from logging and primary mill (720 GWh/year), nonutility-scale includes secondary mill residues, rice husk, and sugar cane bagasse (805 GWh/year) (NREL, 2018). Moreover, 80 per cent of the total population relying on biomass as the main source for daily life applications such as cooking, heating, and other related activities due to it is accessible and obtainable everywhere as most of the population living in rural areas (ERIA, 2018).

The Lao PDR is currently in the operation of two bagasse power plants and both generated power from sugarcane with a subtotal installed capacity of 25 MW. At this time, an estimation of power plants generated electricity from biomass is in the process of a feasibility study to forecasting of total potential for power generation is around 1,000 – 2,500 MW (IRENA, 2016).

Coal

Coal reserves range between 600 and 700 million tons and mostly comprise of lignite and small amounts of anthracite. The Lao PDR's lignite resources are concentrated in Hongsa in Xayabuli Province to the northwest, where reserves are estimated to contain greater than 400 million tons (ADB, 2019). Coal is primarily used by cement factories along with a few small industrial users, with consumption totalling about 300,000 tons per year. However, this pattern of coal use has changed markedly in recent years following the commissioning of the 1,878-megawatt (MW) lignite-fired thermal plant in Hongsa in 2015 (ADB 2019b).

Other petroleum fuels

All petroleum products are imported from neighbouring countries which is divided into Thailand 90% and Vietnam 10% (ERIA, 2019). The main use of petroleum in Lao PDR is in the transport sector as gasoline, diesel oil, and jet fuel. The demand for petroleum products is growing consistently as the affordability to by private cars and motorcycles is increasing (Kouphokham, 2019).

3.6. National Energy Balance 2018

The official national energy balance is not available for the year 2018. The following describes the estimated national energy consumption built up using data collected from various source,

largely from the Energy Outlook Report of the Economic Research Institute for ASEAN and East Asia (ERIA) (ERIA 2020) and Asia Pacific Energy Portal (ESCAP 2021).

In 2018, the **total final energy consumption (TFEC)** was 4,423 ktoe. Most of the demand came from the transport sector (43 per cent). This was followed by the residential sector (29 per cent), industry sector (18 per cent) and commercial sector (10 per cent). Petroleum oil product was the dominating energy source in TFEC with a share of 44 per cent, followed by biomass (35 per cent), electricity (11 per cent) and coal (10 per cent). The transport sector, which operates predominantly with internal combustion engine vehicles, is the main consuming sector for oil products (96.7 per cent). A small amount of oil products is also used the industry sector, and about 1.5 per cent is used as non-energy for industrial processes. Figure 2 and Figure 3 illustrates the total final energy consumption by consuming sector and fuel type.

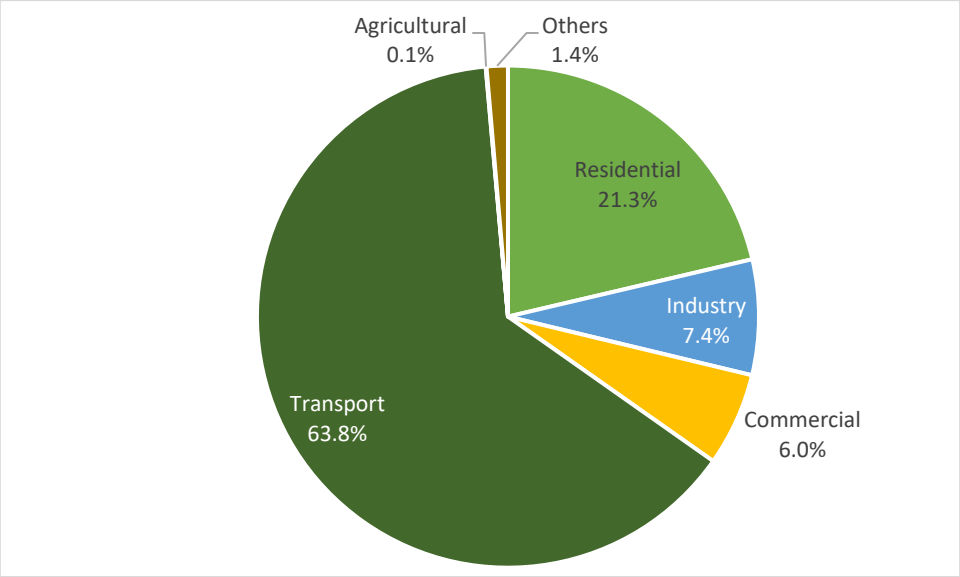

Figure 2 Total final energy consumption by sector, 2018

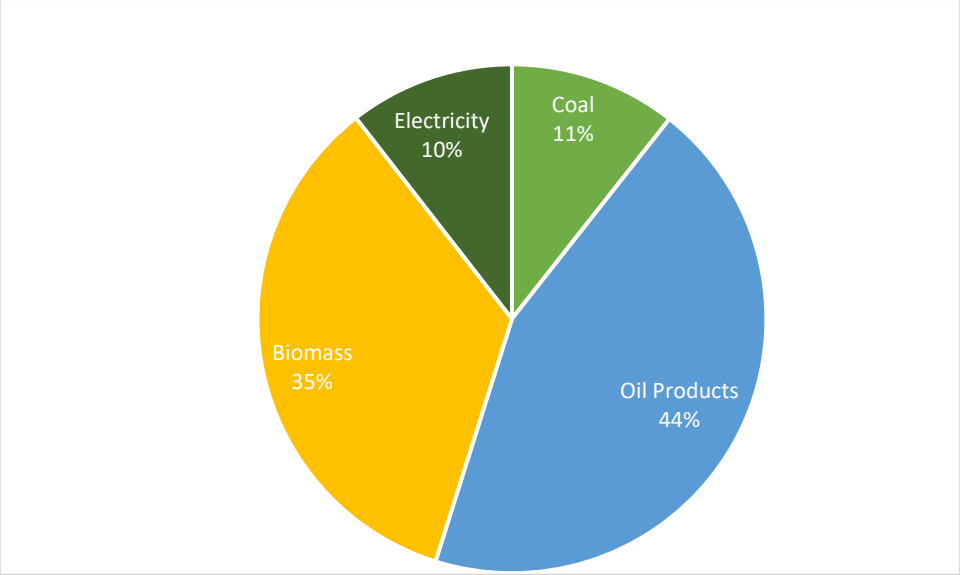

Figure 3 Total final energy consumption by fuel type, 2018

The **total primary energy supply (TPES)** in 2018 was 10,074 ktoe. Coal contributed the highest (39 per cent), followed by hydro (21 per cent) and oil products (20 per cent), as shown in Figure 4. Lao PDR exported 2440 ktoe electricity to neighbouring countries and also imported 26 ktoe.

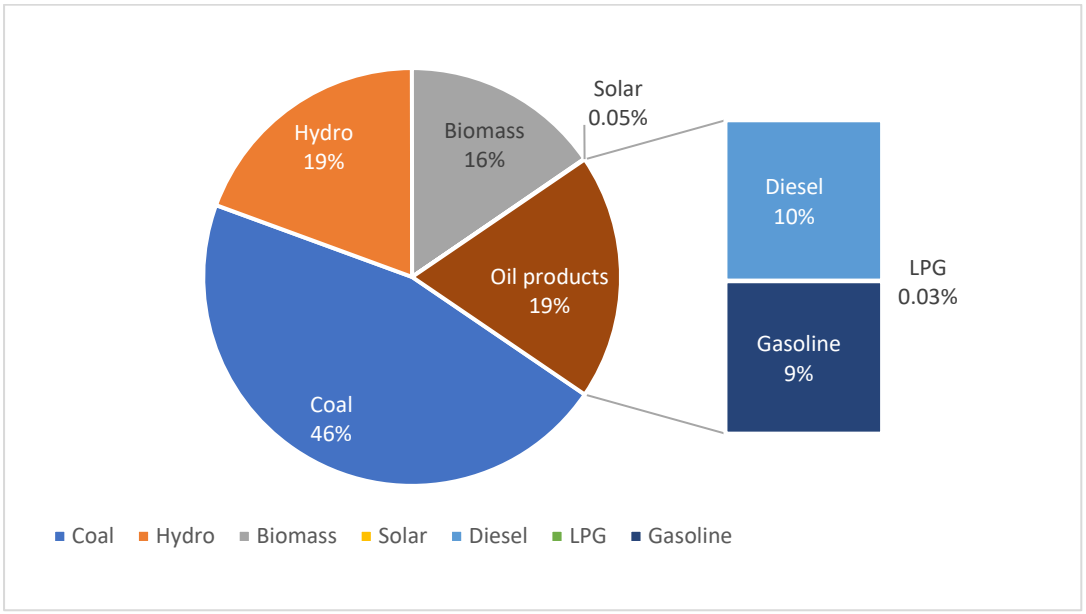

Figure 4 Total primary energy supply by fuel type, 2018

3.7. Power Generation

- The total installed capacity in 2018 was 7,422 MW comprised of 73.7% hydropower, 25.3% coal (predominantly lignite), 0.5% biomass and 0.4% solar PV.
- In 2018, total electricity generation was 34,665 GWh of which about 26,077 GWh was exported to Thailand, Cambodia, Myanmar, Malaysia and Viet Nam. The remaining amount was consumed in the country. Lao PDR also imported about 300 GWh of electricity from different countries to meet the shortfall in domestic demand arising from lower hydro resources availability during the dry season. Table 2 shows export, import and domestic consumption.

Table 2: Electricity export, import and domestic consumption 2016-2020

Year	Production	Export					Import			Domestic consumption
		Thailand	Cambodia	Myan-mar	Malay-sia	Viet Nam	Thailand	Viet Nam	China	
2016	24,878.76	19,106.48	37.37			413.46	659.28	45.14	113.22	4,603.12
2017	31,025.11	23,798.43	52.7	0.17		1,024.07	424.61	26.32	48.08	4,966.32
2018	33,946.18	24,614.40	58.2	0.7		1,404.24	260.68	25.58	14.24	5,376.93
2019	31,232.36	23,157.19	129.22	1.61	13.51	1,089.39	1,305.52	29.87	9.35	6,119.36
2020	39,967.27	31,411.34	1,818.03	1.91	1.72	1,119.03	1,371.96	21.17	95.98	7,778.69

3.8. Energy Modelling Projections

The energy demand is estimated using the activity level and energy intensity in the LEAP model. The demand outlook throughout the NEXSTEP analysis period is influenced by factors such as annual population growth and annual GDP growth. The assumptions used in the NEXSTEP modelling are summarized in

Table 3 for the three main scenarios (i.e. BAU, CPS and SDG scenarios).

Table 3: Important factors, targets and assumptions used in NEXSTEP modelling

Parameters	Business as Usual (BAU) scenario	Current Policy (CP) Scenario	Sustainable Development Goal (SDG) scenario
Economic Growth	GDP in 2018 was US$ 18.30 billion and the GDP growth rate was 6.5 per cent.		
Population Growth	Population in 2018 is 7.01 million, population growth rate was 1.6 per cent per year[4]		
Household size	Household size is assumed constant throughout the analysis period at 5.5 people per household. This corresponds to a total of 1276.9 thousand household in 2018.		
Urbanisation rate	36.3 per cent in 2018, gradually increasing to 44.5 per cent in 2030[5]		
Commercial Floor Space	100 million m^2 in 2018, increasing at the same growth as GDP		
Transport Activity	Transport activities in 2018 were 132 billion passenger-kilometres and 42.3 billion tonne-kilometres, assumed to grow as per GDP per capita and GDP respectively		
Access to Electricity	2018: 93.5 per cent. 2025: 100 per cent	2018: 93.5 per cent. 2025: 100 per cent	2018: 93.5 per cent. 2025: 100 per cent
Access to Clean Cooking Fuels	Access rate was 8 per cent in 2018, based on historical trend and using linear forecasting method, the rate would be 12 per cent in 2030.	In the absence of any strong policy measures, the access to clean cooking is expected to increase to 20 per cent.	Building on the Current Policy Scenario, NEXSTEP further recommends the use of a combination of electric, LPG and improved cookstoves in reaching a 100 per cent access rate.
Energy Efficiency	In 2018, the energy intensity was 5.8 MJ/US$. Additional energy efficiency measures not applied	Improvement based on current policies	Energy efficiency measures enhanced and EI reached 5.52 MJ/US$
Power Plant	Based on 2018 capacity share	Power generation capacities has been modelled as suggested in the draft National Power Development Plan (NPDP) 2020-2030, as discussed in section 3.3.	In the absence of any emission reduction target, SDG scenario followed the plan of RE capacity expansion as in the 2nd NDC.

[4] Based on historic growth between 2000 and 2018

[5] Based on historic growth between 2000 and 2018

3.9. Energy Demand Outlook – BAU Scenario

The BAU scenario forecasts a hypothetical energy scenario if no actions or polices were taken to help advancing the energy transition. This scenario assumes that energy demand follows the growth rate as discussed in section 4.2. The power generation capacities of hydro and coal will grow at about 10% to align with the forecast set out in the draft NPDP, while solar and biomass will remain constant.

3.9.1. Energy demand outlook

The demand for total final energy is expected to increase from 4,423 ktoe in 2019 to 7,719 ktoe in 2030, an average annual growth rate of about 6 per cent. In 2030, the transport sector consumption will be by far the largest at 47.5 per cent, followed by residential sector 23.1%, industry sector 19 per cent and commercial sector 10.4 per cent, Figure 5 shows the forecast of TFEC by sector under the BAU scenario.

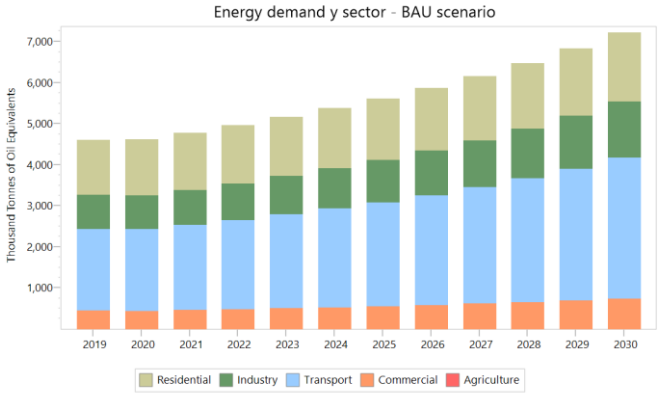

Figure 5: Final energy demand 2019-2030 by sector, BAU scenario

3.9.2. Renewable Energy

RE share in power generation in this scenario remains almost the same throughout the analysis period about 65 per cent. RE share in TFEC is projected to 16.8 per cent in 2030. This share (RE in TFEC) excludes traditional use of biomass, which if included, will become 36 per cent in 2030.

3.9.3. Energy Efficiency

The total primary energy supply in 2018 was 7,607 ktoe, which will more than double to 15,374 ktoe in 2030, including primary energy supply for electricity export. This corresponds to an energy intensity of 6.08 MJ/USD$_{2011}$, compared to 5.8 MJ/USD in 2018. In this scenario, energy intensity is likely to increase instead of decreasing.

3.9.4. Power generation

The electricity demand is expected to rise from 5.4 TWh in 2018 to 9.7 TWh in 2030. Figure 6 shows the electricity demand by sector. The electricity export in this scenario is projected to increase to 80.6 TWh by 2030.

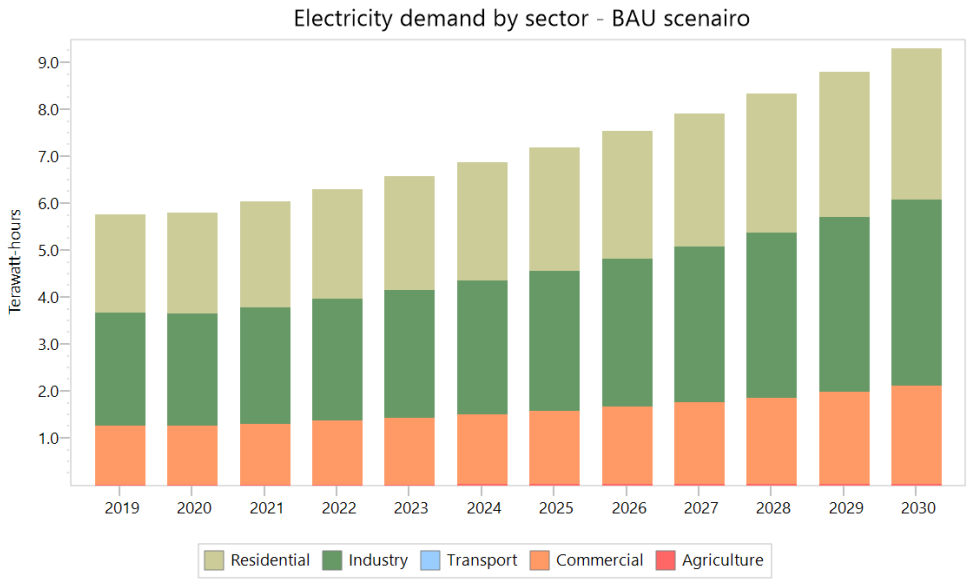

Figure 6 Electricity demand by sector 2019-2030, BAU scenario

3.9.5. GHG Emissions

Figure 7 shows the GHG emission trajectory. As observed, GHG emissions are expected to rise gradually from 23.4 MtCO2-e in 2019 to 56.1 MtCO2-e in 2030, 74 per cent of this emission is from electricity generation (mainly from coal) and the remaining is from petroleum fuel consumption, mainly in the transport sector.

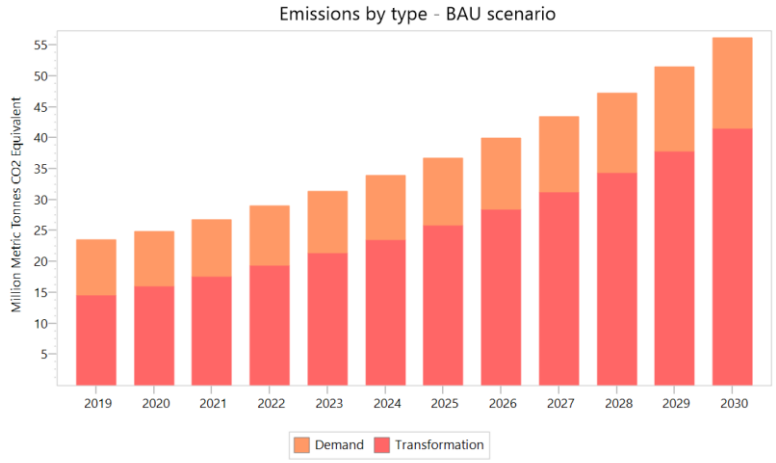

Figure 7 GHG emissions by type 2019-2030, BAU scenario

3.10. Energy Demand Outlook - Current Policy Scenario

The CP scenario takes into account several initiatives implemented or scheduled to be implemented during the analysis period 2019-2030. These include the following:

a) Power generation
    - A massive expansion of installed capacity, mainly to increase electricity export by about four-fold by 2030. This includes increase in hydropower capacity to 20 GW by 2030, increase in coal power capacity to 6.4 GW (as per NPDP). No specific capacity expansion plan for solar, wind or biomass has been mentioned in NPDP. Lao PDR will export all electricity after meeting the domestic demand.

b) Transport sector
    - Bus Rapid Transit (BRT): New BRT system in Vientiane and associated non-motorized transport component to be introduced (as per the 2nd NDC). The BRT is expected to reach to 30,000 passenger trips per day by 2030.

c) Energy efficiency: Energy efficiency is expected to remain minimal in the absence of any major energy efficiency and conservation policy in place. No major energy efficiency initiative is introduced in the industry, commercial and agriculture sectors.

d) Clean cooking: The world bank supported project aims to introduce 50,000 ICS by 2025 (World Bank 2018; 2019). The 2nd NDC also mentions this as a measure.

In the current policy settings, TFEC is projected to increase from 4.6 Mtoe in 2019 to 6.8 Mtoe in 2030. This corresponds to an average annual growth rate of about 4.3 per cent. In 2030, the transport sector will remain the main consuming sector, with an estimated TFEC at 3.20 Mtoe (47.4 per cent), followed by the residential sector at 1.44 (21.3 per cent), industry sector at 1.37 Mtoe (20.3 per cent), and commercial sector at 0.75 Mtoe (11 per cent). The sectoral overview of energy demand in the current policy scenario is discussed below and shown in Figure 8. The agriculture sector will consume very small amount of energy (about 3.5 ktoe) which is not shown in the figure.

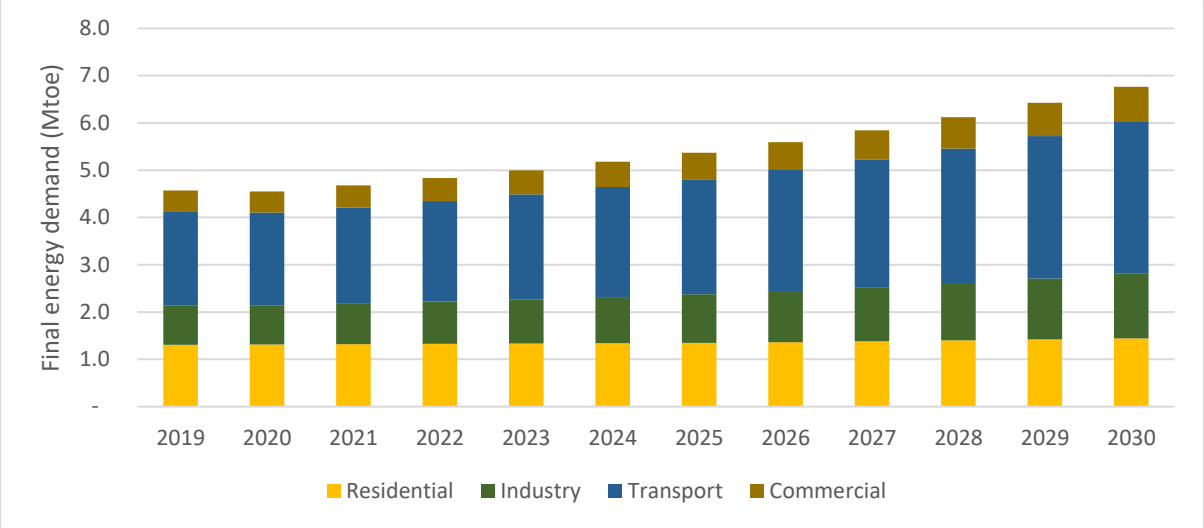

Figure 8: Energy demand outlook, 2019 - 2030

(a) Transport

Consisting of predominately internal combustion engine, Lao PDR's transport sector is divided into passenger road transport and freight road transport categories. The total energy demand is projected to be 3.2 Mtoe in 2030, increasing from 2.0 Mtoe in 2019. This sector will continue to dominate Lao PDR's TFEC with a share of 47.4 per cent in 2030. Among the passenger vehicle categories in 2030, motorbike will consume the most 1,120 ktoe (46 per cent), followed by private car 529 ktoe (21.7 per cent), van 278 ktoe (11.4 per cent), pick-up 331ktoe (13.6 per cent), three-wheeler 82 ktoe (3.4 per cent) and bus 66 ktoe (2.7 per cent).

(c) Residential

In 2030, the residential sector will consume 1,440 ktoe, an annual growth of about 1 per cent and up from 1,309 ktoe in 2019. The urban and rural split of energy consumption would be 49 per cent and 51 per cent respectively. In terms of fuel, biomass will the be the main source of energy with 80.8 per cent and most of the remaining (18.9 per cent) will be electricity. A very small amount of LPG (4.2 ktoe) will be used in the residential sector.

(b) Industry

TFEC in the industry sector will have 20.2 per cent share in 2030. The sub-sectoral demand will be mainly dominated by two industry sub-sectors - the Food Processing (40.4 per cent) and glass and cement industry (35 per cent).

(d) Commercial

Total energy consumption in the commercial sector will increase from 431 ktoe in 2019 at an average annual growth of 6 per cent to 749 ktoe in 2030. In this sector, biomass will be the key energy supply with 76 per cent followed by electricity 24 per cent.

3.11. Electricity Generation Outlook

The 2030 demand for electricity in the current policy scenario will be 9.7 Terawatt-Hours (TWh), increasing from 5.7 TWh in 2019. The demand will be the highest in the industry sector at 4.0 TWh (40.9 per cent), followed by the residential sector (3.2 TWh, 32.5 per cent), the commercial sector (2.1 TWh, 21.4 per cent) and transport sector (0.5 TWh, 4.9 per cent).

Lao PDR's installed electric power generation capacity in 2018 was 7,422 MW, of which 73.7 per cent was hydro, 25.3 per cent coal and small amounts of biomass (0.5 per cent) and solar PV (0.4 per cent). In accordance with the joint framework agreed by the government with neighbouring countries, by 2025, the following export targets have been set: 9,000 MW to Thailand, 5,000 MW to Vietnam, 3,000 MW to Cambodia, and 500 MW to Myanmar (as per the draft NPDP 2020-2030). The shares of the required capacity expansion are shown in Table 4 and Figure 9. In the current policy scenario, there is no plan for solar and biomass capacity expansion, and therefore, the base year capacities are assumed to remain the same. The coal expansion plan has been estimated using the coal power plants that are either under construction or contracts have been awarded, to be built by 2025.

Table 4: Power generation capacities in 2018 and 2030 and share of generation in 2030

Power generation technologies by fuel	Capacity in 2018 (MW)	Capacity in 2030 (MW)	Share of generation in 2030 (%)
Hydro	5,472	20,000	67.4
Coal	1,878	6,378	32.3
Solar PV	32	32	0.1
Biomass	40	40	0.2
TOTAL	**7,422**	**26,450**	**100.00**

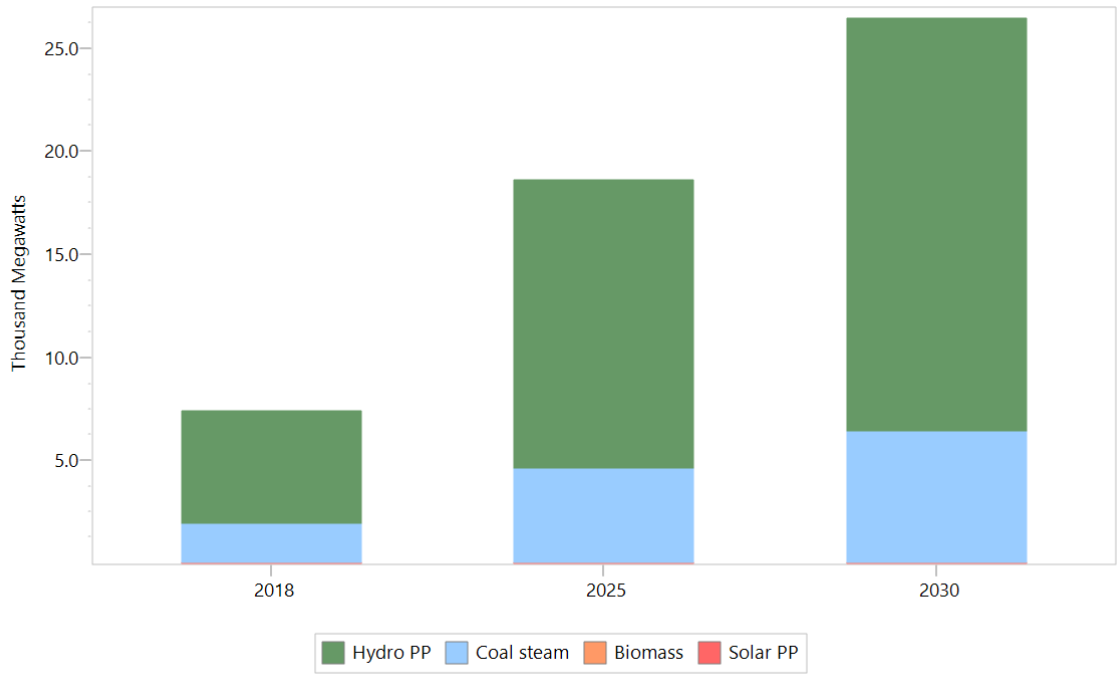

Figure 9: Power capacity installed, CPS scenario

Note: solar PV and biomass capacities are too small to appear in the graph

The projected generation by technology type is as illustrated in Figure 10. Hydropower will continue to dominate the electricity system, coal being the second. Of the total generation of 104 TWh in 2030, 93.2 TWh will be exported to the neighbouring countries where export mechanisms are already in place.

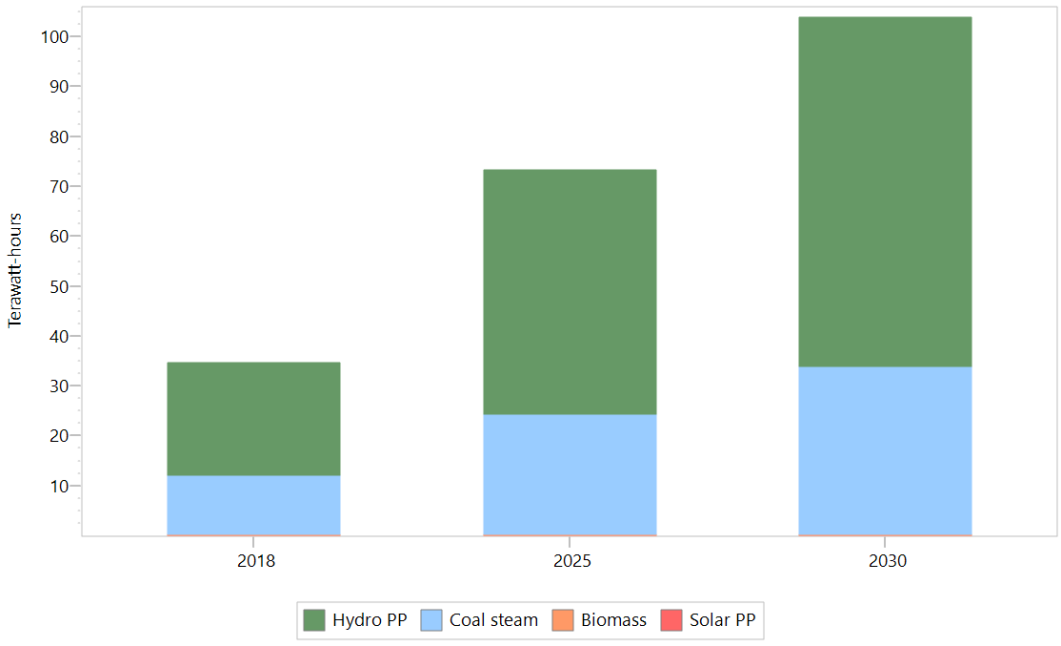

Figure 10: Electricity output by technology type, CPS scenario

3.12. Energy Supply Outlook

As briefly mentioned in section 3.6, in the current policy scenario, TPES is forecasted to increase from 10,047 ktoe in 2018 to 35,777 ktoe in 2030. This sharp increase is obviously due to the increased power generation capacity to support the increase in electricity export target. The fuel shares in 2030 are projected to be: oil products 3,268 ktoe, biomass 1,899 ktoe, hydro 18,260 Mtoe, coal 12,346 ktoe, and solar 5 ktoe. The substantial increase in coal and hydro has been to meet the rising power export target. While the share of biomass in the total primary energy supply is likely to reduce with the increase in urbanization (more than half of the population is expected to live in rural areas by 2030), its supply will still remain significant due to most people in Lao PDR will continue to relying on cooking with traditional biomass.

3.13. Energy Sector Emissions Outlook

The energy sector emissions, from the combustion of fossil fuel, is calculated based on IPCC Tier 1 emission factors assigned in the LEAP model and expressed in terms of 100-year global warming potential (GWP) values. For the combustion of biomass and biomass products, the carbon emissions are not attributed to the energy sector but is accounted in the Agriculture, Forest, and Land Use Change (AFOLU)[6] as per the accounting system suggested by IPCC. Nevertheless, the emissions of other GHGs such as methane and nitrous oxide are included in the total emissions in the energy sector.

In the second NDC document submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in 2020, Lao PDR did not stipulate an overarching quantitative GHG emissions target for 2030. It has instead specified several quantified targets for the energy sector by which it estimates that the total emission swill be reduced by 28.75 MtCO2-e by 2030 compared to the BAU scenario. For the conditional target on the other hand, the NDC documents lists a number of specific interventions for the energy sector, these include:

a) Addition of 13 GW[7] hydropower capacity by 2030.
b) Addition of 1 GW of solar and wind (combined) to the national power generation
c) addition of 300 MW of biomass power plant.
d) Adoption of 30 per cent electric vehicles for 2-wheelers and passenger cars.
e) Biofuel to be increased to 10 per cent of the fuel mix in the transport sector.

[6] AFOLU sector is not within the scope of NEXSTEP.
[7] Note that the Ministry has advised that the NPDP target of 20GW should be used in the modelling

f) A 10 per cent energy efficiency improvement (to the final energy consumption, compared to BAU) across the economy.

NEXSTEP analysis has used these targets in the current policy scenario, which resulted in total GHG emissions from the energy sector to increase from 24.6 $MtCO_{2\text{-}e}$ in 2019 to 58.6 $MtCO_{2\text{-}e}$ in 2030. The substantial increase is due to the increased amount of coal used in power generation, as well as increased petroleum fuel in the transport sector. Figure 11 shows emissions of the demand side, whereas Figure 12 shows emissions from the power sector (supply side), which is from coal only.

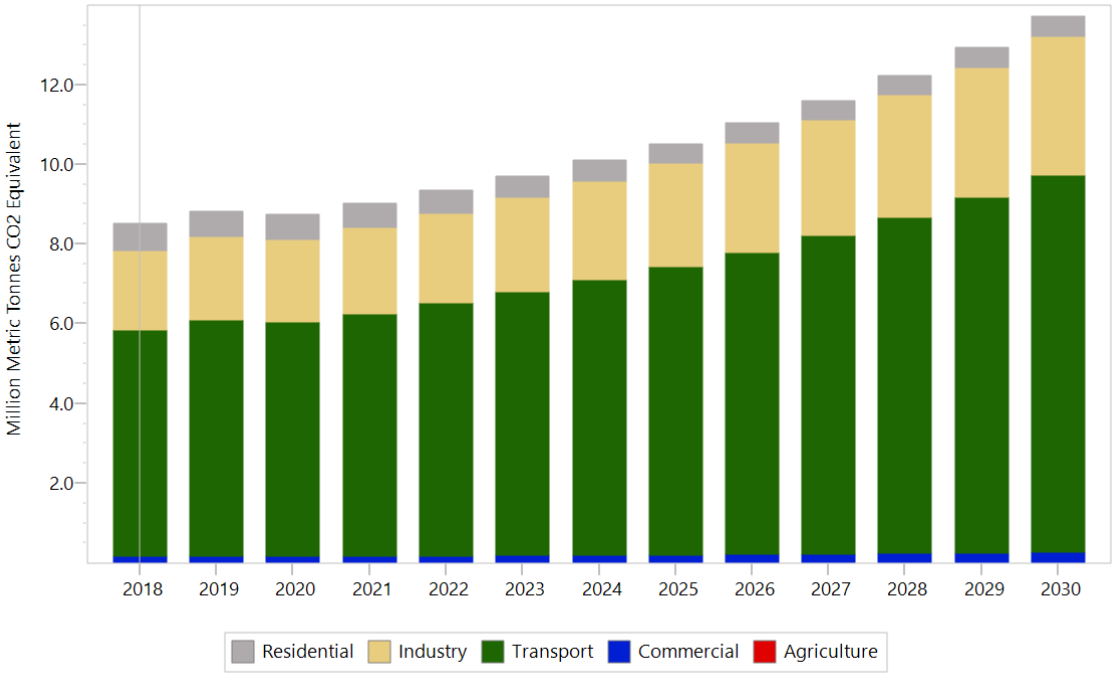

Figure 11: Emissions of the demand side under the current policy scenario

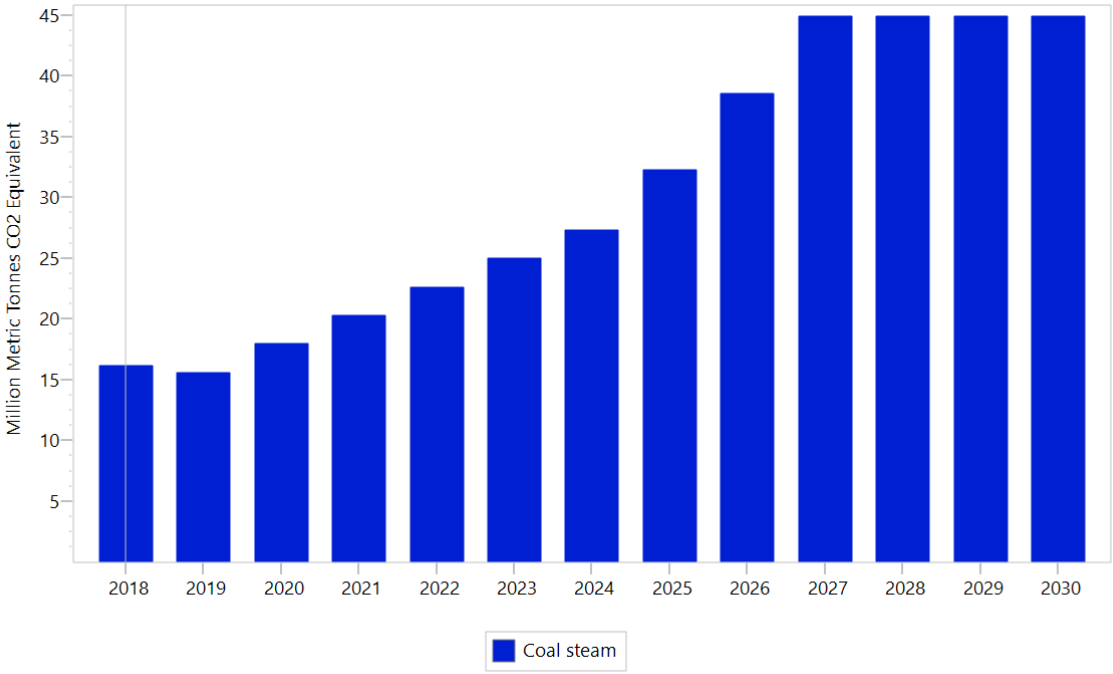

Figure 12: Emissions from the power sector under the current policy scenario

4. SDG Scenario - achieving SDG7 by 2030

Access to affordable, reliable, sustainable and modern energy is essential to achieve 2030 Agenda for Sustainable Development and Paris Agreement on climate change. Lao PDR is expected to achieve universal access to electricity by 2025 in the BAU scneario. Nonetheless, the access to clean cooking fuel remains very poor, recorded as 8 per cent in 2018, leaving about 1.2 million households still relying on cooking with biomass. Renewable energy share in TFEC in 2018, excluding biomass, was 17 per cent and 41 per cent when biomass included. The share of renewable energy in TFEC will need to increase further to achieve the SDG 7 target. Energy intensity in 2018 was 5.8 MJ/US$, which will need to reduce to 4.1 MJ/US$, at an annual rate of 2.9 per cent (in alignment with the global improvement rate), to be able to achieve the SDG 7 target for energy efficiency improvement. All these have been modelled and analysed in the SDG scenario to ensure Lao PDR achieves the SDG 7 targets. These are further discussed in this chapter.

4.1. SDG Energy Demand Outlook

In the SDG scenario, TFEC increases to 5,155 ktoe in 2030, a drop of 1,615 ktoe compared to the current policy scenario (about 23.9 per cent reduction). This decrease has been due to the switch from inefficient biomass cookstove to more efficient electric cookstoves, as well as energy efficiency has improvement across different sectors e.g. through Minimum Energy Performance Standards (MEPS) in the residential sector (further discussed later), energy efficiency in the industry sector and partial switch from internal combustion engine to electric vehicles in the transport sector.

In 2030, the transport sector will continue to have the largest share of TFEC 2,762 ktoe (54 per cent), followed by the industry sector (1,158 ktoe, 22 per cent), the commercial sector (674 ktoe, 13 per cent), the residential sector (558 ktoe, 11 per cent), and agriculture sector (3 ktoe, 0.1 per cent). Figure 13 shows the projected TFEC by sector under the SDG scenario.

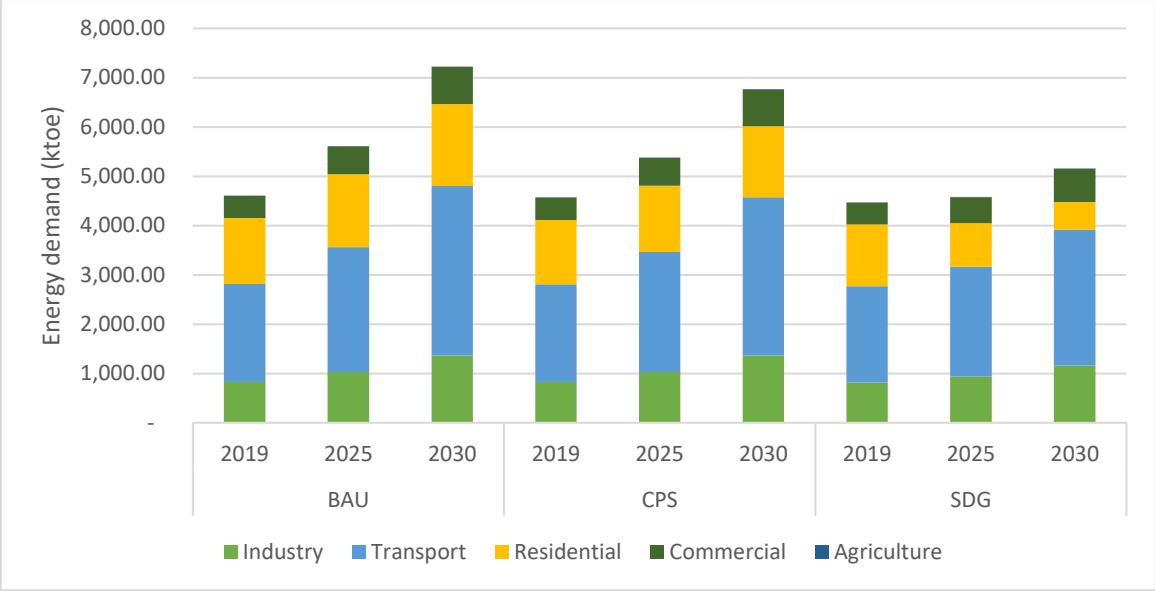

Figure 13: Projection of TFEC by sector in different scenarios

4.2. SDG7 Targets

4.2.1. SDG 7.1.1 Access to electricity

Lao PDR's access to electricity in 2018 was 93.5 per cent. It is estimated that in the BAU scenario, the country will achieve universal access to electricity by 2025 (Figure 14). Therefore, this roadmap does not further discuss this indicator, however, a deeper study into the level and quality of access would be appropriate to ensure that households continue to enjoy reliable access, and not just connection, as stipulated in Tier 3 of the World Bank's Multi-Tier Framework for access to electricity (ESMAP 2015).

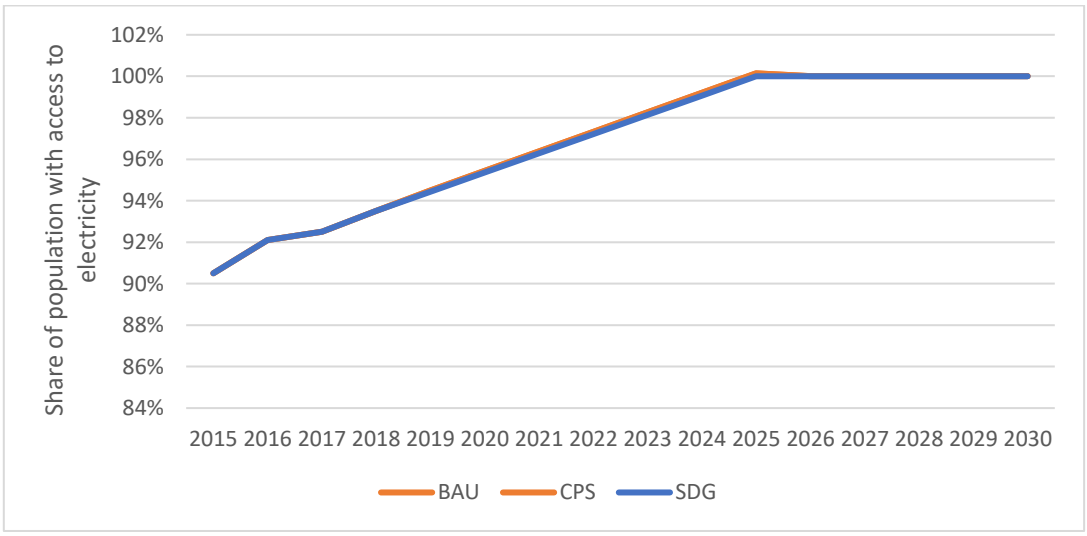

Figure 14: Progress of access to electricity by scenario

4.2.2. SDG 7.1.2 Access to Clean Fuels and Technologies for Cooking

Under the current policy setting, using the historical trend and linear forecasting method, it is estimated that the clean cooking access rate will increase from 8 per cent in 2018 to 20 per cent by 2030 (Figure 15). This estimate has taken into account the promotion of improved cookstoves (ICS) under the project, supported by the World Bank, that aims to distribute 50,000 ICSs (World Bank 2018; 2019). The current dominant clean cooking technology is the biomass stove, which has a share of over 97 per cent in 2018, an average of both urban and rural areas. While being a clean and convenient solution, the popularity of LPG stoves presents a risk to the country due to potential price and supply shocks, as LPG is largely imported. Henceforth, it is important that Lao PDR uses other forms of technologies to increase the share of access to clean cooking, in an attempt reduces the use of LPG cookstove over time. Based on evaluation of annualized cost of operation of different cooking technologies and considering the fact that Lao PDR generates enough electricity which is largely from hydropower, this roadmap suggests the use of high efficient induction type cookstove for about 70 per cent households – mostly that are located in urban and peri-urban areas. Considering rural remote locations of many households where access to electricity may not be as reliable as urban areas, the roadmap suggests LPG cookstoves for 20 per cent households and a further ICS for the remaining 10 per cent households. The following section presents a summary of quantitative and qualitative analyses of different cookstove technologies.

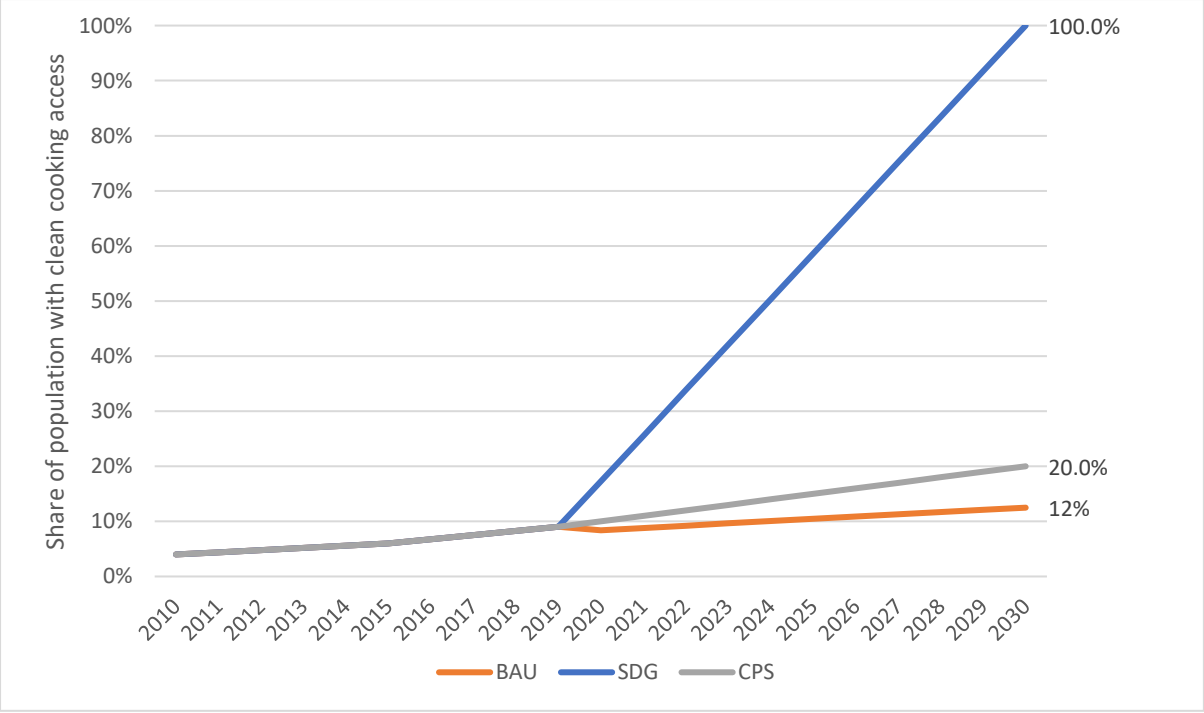

Figure 15: Access to clean cooking fuels and technologies by scenario

Clean Cooking Technologies Evaluated

Electric Cook Stoves

Electric cooking technology is classed as Level 5 in the World Bank MTF for Indoor Air Quality Measurement. Electric cookstoves are more efficient than other cookstoves, including gas stoves. Electric cookstoves can be generally divided into two types – solid plate and induction plate. While solid plate cookstoves use a heating element to transmit radiant energy to the food and reaches about 70 per cent efficiency, induction plate cookstoves, on the other hand, uses electromagnetic energy to directly heat pots and pans and can be up to 90 per cent efficient.

Improved Cook Stoves

Studies suggest that ICS programs often have low adoption rates due to inconvenience of use, preference for traditional cookstoves and the need for frequent maintenance and repairs. ICS programmes initially require strong advocacy to promote adoption, after which they require ongoing follow-up, monitoring, training, maintenance, and repairs in order to facilitate continuing usage. Additionally, based on the World Health Organization (WHO) guidelines for emission rates for clean cooking, only certain types of ICS technology comply, particularly when considering that cookstove emissions in the field are often higher than they are in the laboratory settings used for testing.

Biogas Digester

Biogas digesters have high upfront capital costs (about $1,000 for a standard size that is suited for a four-member family) and require substantial subsidy due to their longer payback period. The technology is not favoured in rural areas due to the cultural reluctance to using animal or human waste to use for cooking. Additionally, a standard size biogas digester requires 2 to 4 cows, depending on the size of the cow, to produce enough feedstock for daily gas demand for a household.

LPG Cook Stove

LPG in Lao PDR is constrained due to fuel import dependency and supply chain challenges. LPG cook stoves generate lower indoor air pollution compared to ICS and are

classified as Level 4 in World Bank Multi-Tier Framework (MTF)[8] for cooking exposure and reduces indoor air pollution by 90 per cent compared to traditional cook stoves.

Table 5 summarizes the estimated annualized cost of different cooking technologies in the context of Lao PDR.

Table 5: Annualized cost of cooking technologies

Technology	Annualized Cost
ICS	$41
Electric Stove	$108
Biogas Digester	$131
LPG Stove	$154

4.2.3. SDG 7.2 Renewable Energy

SDG 7.2 does not have a quantitative target but encourages a "substantial" increase of renewable energy share in TFEC. In normal circumstances, the NEXSTEP methodology first estimates the net increase in energy demand in response to universal energy access (both electricity and clean cooking) and energy efficiency improvement. It then uses the unconditional NDC target for the energy sector to estimate optimum renewable energy share in TFEC.

In the context of Lao PDR, there is no overarching NDC reduction target stipulated in the second NDC document published in March 2021. As such, the renewable energy share in the SDG scenario reflects the share that is projected based on the targets and ambitions stipulated in the draft NPDP 2020-2030, while at the same time, raising the access to clean cooking to 100 per cent. These measures together have led to increasing the share of renewable energy in TFEC to 25.6 per cent in 2030, whereas the share of renewables in power generation mix will increase from 65.3 per cent in 2018 to 68 per cent in 2030 (Figure 16).

[8] http://documents.worldbank.org/curated/en/937711468320944879/pdf/88699-REVISED-LW16-Fin-Logo-OKR.pdf

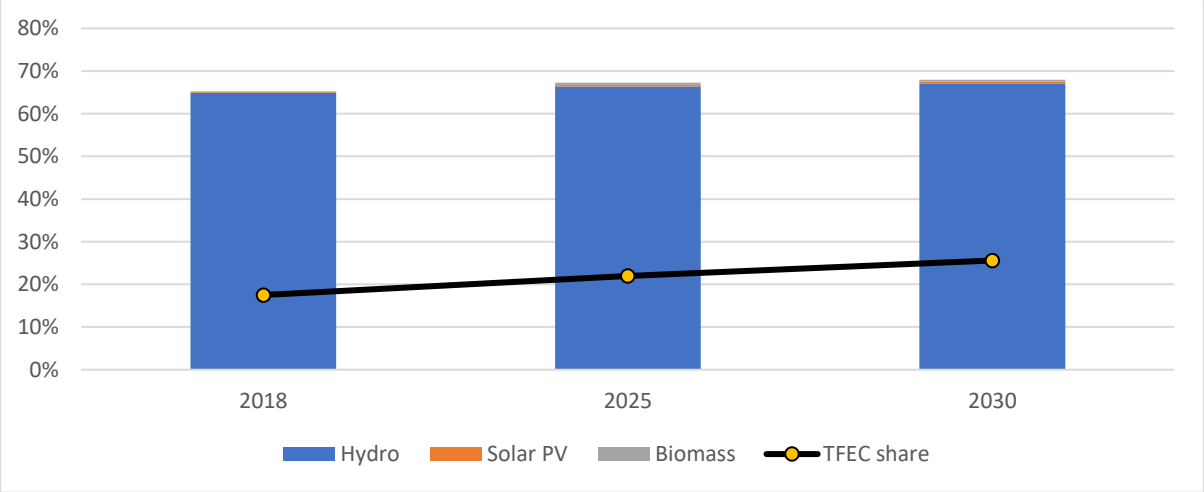

Figure 16: Renewable Energy shares in TFEC and power generation, 2030

Note: Solar PV and biomass have too small shares to appear on the graph

4.2.4. SDG 7.3 Energy efficiency

The total primary energy use will be 13,973 ktoe in 2030, including primary energy supply for electricity export. This corresponds to an energy intensity of 5.5 MJ/USD$_{2011}$. The EI of Lao PDR has been increasing since 2000 and has reached 5.8 MJ/US$ (as shown in Figure 17), compared to the global EI which has been declining.

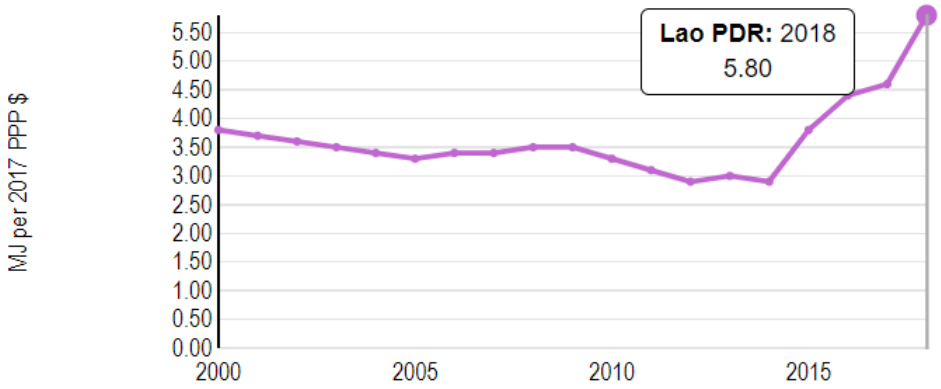

Figure 17: Energy intensity in Lao PDR 2000-2018

Source: Asia Pacific Energy Portal (ESCAP 2021)

The 2030 EI target for SDG7 has been calculated to be 5.1 MJ/US$, based on the method suggested by the SDG7 definition for energy intensity. With possible energy efficiency measures applied in this scenario, the EI is unlikely to achieve the target. This is primarily due to the contraction of GDP due to the COVID-19. If the impact of the pandemic is ignored, the

EI target (5.1 MJ/US$) would be achieved with a GDP growth of 6.8 per cent, which is similar to the pre-COVID rate. Therefore, in order to achieve the EI target for SDG7, Lao PDR would either need to further increase energy efficiency, which is discussed in the ambition scenario (high energy efficiency scenario), or to increase the GDP to an average of 6.8 per cent between 2021 and 2030.

The decrease in energy intensity, compared to the CP scenario, has been due to the energy efficiency improvement in the SDG scenario. As mentioned earlier, several energy efficiency measures have been implemented in this scenario, which have resulted in energy savings in different sectors. These are:

Residential (additional savings relative to CP scenario):

i. 50 per cent energy efficient appliance penetration by 2030 through the minimum energy efficiency performance (MEPS), resulting in savings of 883 ktoe by 2030

Transport (additional savings relative to CP scenario):

i. Encouraging the adoption of electric vehicles in the passenger vehicles category, which increases to 25 per cent of market sales by 2030 – estimated reduction of 445 ktoe in 2030

Industry (additional savings relative to CP scenario):

i. Energy efficiency improvement across all sub-sectors by 10 per cent, 30 per cent and 50 per cent energy demand reduction in the thermal processes, electric motor drive and lighting respectively by 2030– estimated reduction of 212 ktoe in 2030. *Sub-sector specific energy efficiency measures identification was not possible due to the data limitation. For example, the industry-sector data obtained from the country suggests that "other processing industry" constitutes 83.7 per cent of the industrial GDP. However, there is no mention of what this sub-sector is comprised of and what type of appliances* are used.

Commercial (additional savings relative to CP scenario):

i. Encouraging adoption of energy efficiency through energy management in the commercial sector – estimated reduction of 75 ktoe in 2030

Figure 18 shows the energy savings by sector, relative to the CP scenario.

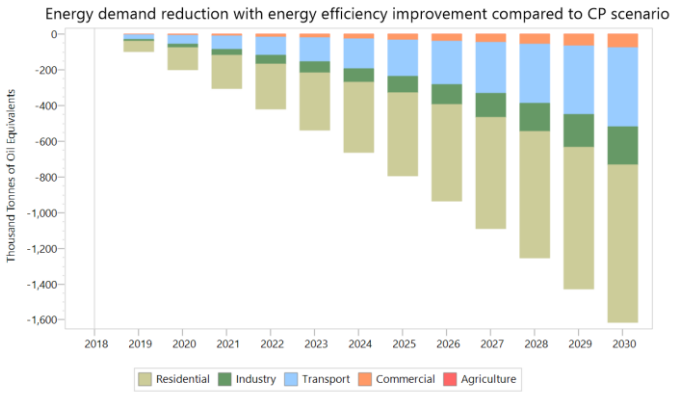

Figure 18 Energy savings by sector, relative to the CP scenario

4.2.5. GHG Emissions

The emissions from the BAU and CP scenarios are projected to reach 564 $MtCO_{2\text{-}e}$ and 534 $MtCO_{2\text{-}e}$ in 2030, respectively. The emissions in the SDG scenario is projected to be 413 $MtCO_{2\text{-}e}$ in 2030, much higher reduction than the unconditional NDC target of 512 MtCO2-e. In fact, this amount is slightly less than the conditional target of 408 MtCO2-e. Figure 19 shows sectoral emissions (demand side) and total emission in the power sector by scenarios.

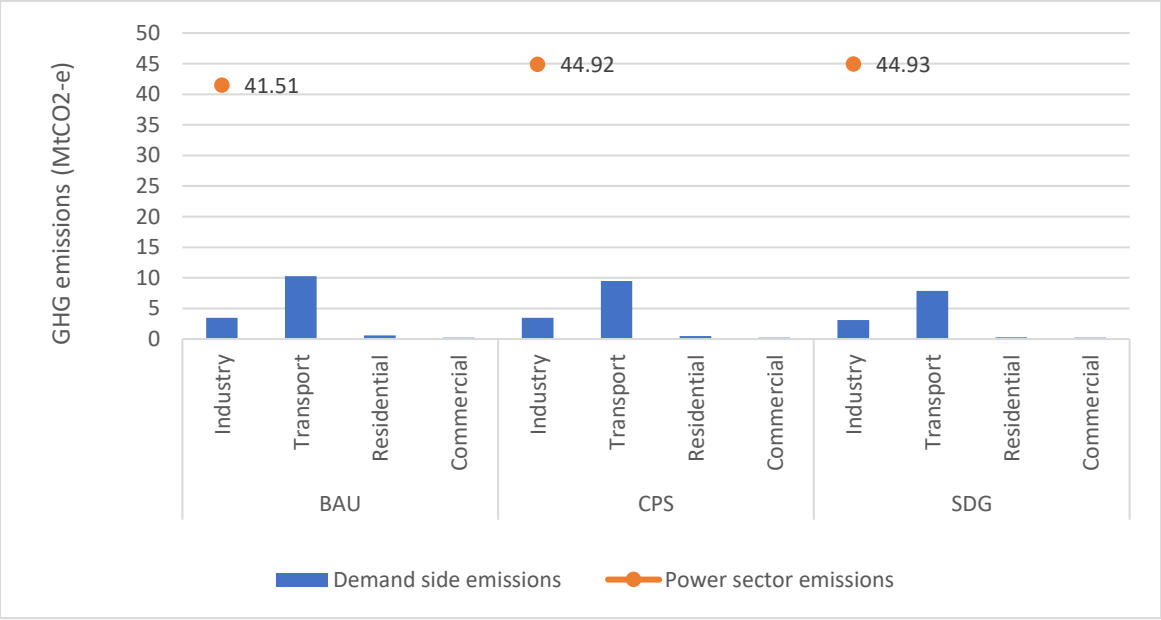

Figure 19: Sectoral emissions and power sector emissions by scenario, 2030

4.3. Power generation in the context of SDG7

The electricity demand in the SDG scenario is projected to increase from 35.3 TWh in 2019 to 104.6 TWh in 2030. This has considered the assumed growth in different economic sectors, the increased power export capacity of Lao PDR, reaching to 93 TWh in 2030. This compares with the 2018 export amount of 28.7 TWh in 2019.

The total generation in 2030 in this scenario (as well as in all scenarios) is kept at the same level to 105 TWh, to allow optimum export capacity at about 93 TWh in 2030 (Figure 20). Figure 21 shows distribution of total generation, domestic requirement and export in the SDG scenario.

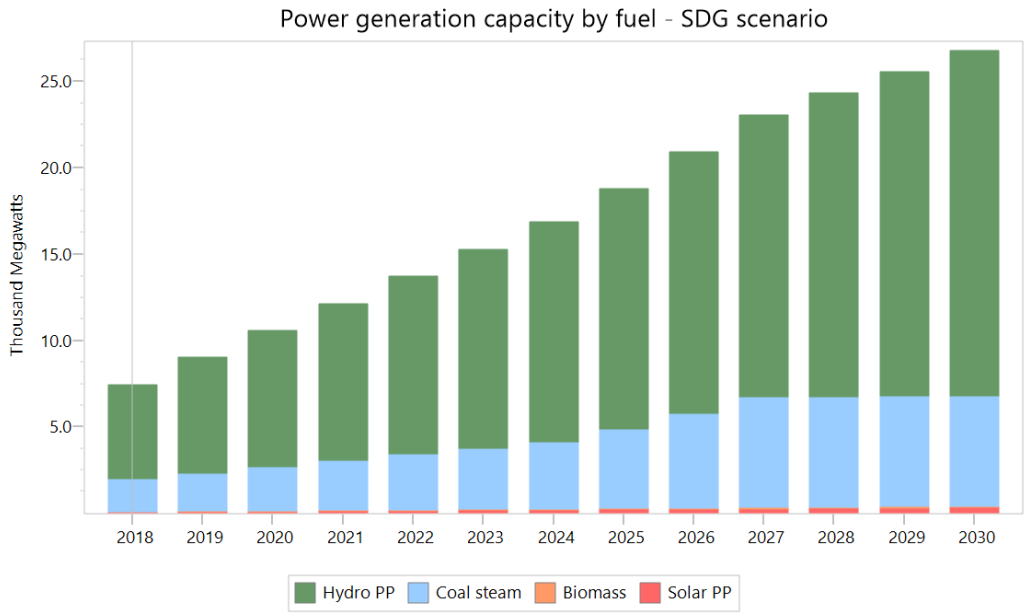

Figure 20 Power capacities 2019-2030, SDG scenario

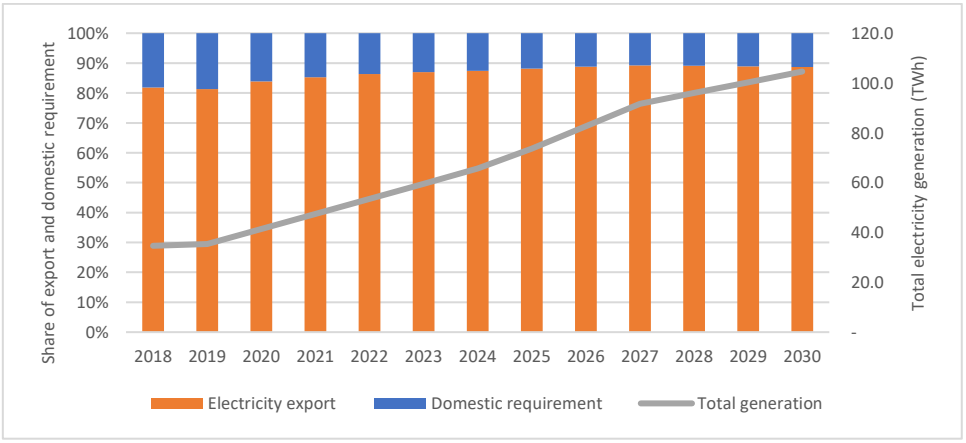

Figure 21 Electricity production, domestic requirement and export 2019-2030, SDG scenario

4.4. Investment cost in the power sector

The total investment costs incurred throughout the analysis period stands at around US$ 34.8 billion. The total net benefit is US$ 17.4 billion. The net benefit has been calculated as the difference between total revenue and total costs. Revenue has been separately calculated for domestic consumption using the domestic tariff and for export using the export tariff. Estimation of total costs included capital costs, fixed O&M costs and variable O&M costs.

5. Energy transition pathway with increased ambitions

The SDG scenario builds on the current policy settings to provide recommendations in achieving the SDG 7 targets. Further analysis shows that there are ample of opportunities for Lao PDR to raise its ambition beyond just achieving the SDG7 targets. As such, in addition to the three scenarios mentioned above, two ambitious scenarios have been developed to examine the opportunities for the Lao PDR energy sector to go beyond just achieving the SDG7 targets. These scenarios are expected to provide the Government of Lao PDR with analytical information to make an informed decision on raising ambition for the energy sector.

5.1. High energy efficiency scenario

This scenario aims to implement a higher level of energy efficiency measures, which are additional to the SDG scenario. The purpose of such a high-level energy efficiency scenario exploration is to offer the Government of Lao PDR with insights on energy saving potential in different sectors and sub-sectors. These measures have been based on various studies and best practices implemented or identified elsewhere, largely in the ASEAN or Asia-Pacific region, or the ones are well established globally, e.g. minimum energy performance standard (MEPS) in the residential and commercial sectors.

Reduction of electricity consumption through energy efficiency is important to reduce greenhouse gas (GHG) emissions from fossil fuels in electricity generation and to meet the target of 10 per cent reduction in energy consumption by 2030 as outlined in the Renewable Energy Development Strategy (Government of Lao PDR 2011). Energy efficiency improvement also enables Lao PDR to earn more foreign revenue from exporting electricity to neighbouring countries.

In the BAU and CP scenarios, there have been significant use of traditional biomass in the residential sector (more than 80 per cent), the SDG scenario replaced all biomass-based cooking with clean fuels and technologies, largely with electric cookstoves. This has increased electricity consumption in the SDG scenario by about 50 per cent, which further reinforces the need for a higher EE scenario.

The following EE measures have been included in this scenario (energy saving opportunity in 2030, compared to the CP scenario, is also presented):

Residential (additional savings relative to CP scenario):

ii. 100 per cent energy efficient appliance penetration by 2030 through minimum energy efficiency performance (MEPS), resulting in savings of 945 ktoe by 2030

Transport (additional savings relative to CP scenario):

ii. Encouraging the adoption of electric vehicles in the passenger vehicles category, which increases to 50 per cent of market sales by 2030 – estimated reduction of 445 ktoe in 2030

Industry (additional savings relative to CP scenario):

ii. Same as in the SDG scenario i.e. energy efficiency improvement across all sub-sectors by 10 per cent, 30 per cent and 50 per cent energy demand reduction in the thermal processes, electrical motor drive and lighting respectively by 2030– estimated reduction of 212 ktoe in 2030

Commercial (additional savings relative to CP scenario):

ii. Encouraging adoption of energy efficiency through energy management in the commercial sector to realise 50 per cent electricity reduction across the sector – estimated reduction of 146 ktoe in 2030

Table 3: Key results of the high energy efficiency scenario

Indicators	**Results and observations**
Energy demand outlook	The demand for total final energy in 2030 is expected to reduce to 4,472 ktoe, a reduction of 34 per cent compared to the CP scenario.
Renewable energy	RE share in TFEC is projected to reach 29.1 per cent in 2030. This increase, compared to the SDG scenario, is due to the further increase in energy efficiency.
Energy efficiency	Total primary energy use will be 13,288 ktoe in 2030, including primary energy supply for electricity export. This corresponds to an energy intensity of 4.1 MJ/USD_{2011}.
Emissions	The overall emissions (including demand and supply) in this scenario would be 54.5 MtCO2-e in 2030 – a reduction of 3.4 per cent compared to the SDG scenario and 7 per cent compared to the CP scenario. This corresponds to 30 per cent emission reduction from the demand sector.
Electricity generation and export	Total electricity generation in this scenario in 2030 is 105 TWh, the same as in other scenarios. Note that the total generation has been maintained about the same in all scenarios to maximise electricity export. In this scenario, electricity available for export would be 93 TWh in 2030.

Investment	Total investment in the power sector in this scenario is US$ 34.8 billion
Net benefits	Total net benefits (difference between revenue and expenditure) is US$ 17.4 billion, same as in the SDG scenario

5.2. Coal phase out scenario

5.2.1. Coal-fired power plant expansion plan in Lao PDR

Coal-fired power plant was first introduced in 2016 with the start of the country's highest-capacity 1,878 MW Hongsa power plant. Table 6 shows further coal-fired plants in pipeline:

Table 6: Coal-fired power generation expansion plan

Project name	Capacity (MW)	Energy output (GWh)	Expected year of operation
Xekong Mine Mouth Thermal Power	1800	13,403	2027
Lamam Coal Fire Power Plant	700	4,238	2025
Boualapha Thermal Power	2000	14,866	2024
Huaphan Coal-fired Power Plant	600	3,600	2030 (tentative)
Total	**5,100**	**36,107**	

5.2.2. Global drivers for shifting away from coal

Globally, coal power use needs to fall by 80 per cent by 2030 to keep global warming below 1.5°C, according to the Intergovernmental Panel on Climate Change, and the United Nations has called for 2020 to be the global end date for new coal plant proposals (Shearer et al., 2020). To be consistent with the Paris Agreement, a large part of the current coal capacity in the Asia region, would need to retire early, well before the assumed lifetime of 40 years, and/or utilised less than the assumed 50 per cent. In order to be in line with GHG emissions reductions that would meet the Paris Agreement's temperature goals the following key benchmarks have been identified for coal use in power generation in Asia: no new coal generation after 2020; reduction in coal for power generation by 63 per cent below 2010 levels in non-OECD countries by 2030; and full phase out across Asia-Pacific by 2040 (UNESCAP 2021).

5.2.3. Coal-fired power plants pose future economic risks

Apart from GHG emissions (in the CP scenario, coal-fired power plant will be responsible for 77 per cent of energy sector's emissions in 2030) and local air pollution, coal-fired power generation is increasingly becoming cost-ineffective. Most renewables-based generations are already cheaper than coal-fired generation and the gap is likely to widen with further expected cost reduction of renewable energy technologies. PV and onshore wind is already cheaper than coal-fired power (IEA 2020). Further, recent auctions and power purchase agreements (PPAs) indicate that based on competitive procurement, the average LCOE of solar Photovoltaic (PV) would be 39 USD/MWh for the projects commissioned in 2021, more than one-fifth less than coal-fired power plants (IRENA 2019). Evidences of auction prices for solar PV in Abu Dhabi, Chile, Ethiopia, Mexico, Peru and Saudi Arabia show that 30 USD/MWh is already possible. Recent ADB-supported RE auction in Cambodia has seen a utility-scale solar PV price of 30 US$/MWh (ADB 2019a).

Furthermore, experts believe that soon there will be a point when it will be more economic to stop a coal-fired power plant and build a new solar PV plant, as the operating cost of a coal plant will outstrip the economic benefits. Financial institutions and investors are increasingly moving away from coal and explicitly committing to divest from, ban or restrict financing of thermal coal including 40 per cent of the top 100 global banks and 20 globally significant insurers (e.g. Norway's Sovereign Wealth Fund, World Bank, ING, Suncorp, Chubb, AXA and Zurich). This indicates that soon there will be a point when coal-fired power plants will become stranded assets.

In line with this development, this scenario recommends an immediate stop in investment in new coal-fired power plant and to increase renewables in power generation, mainly solar and biomass. Wind technology is seen not to have much potential in Lao PDR.

5.2.4. Power sector strategy in the coal phase out scenario

Table 7 and Table 8 show power capacity mix and generation mix in this scenario. The existing coal (1,878 MW) plant will remain in the system, but the generation would discontinue from 2021, and no new coal power plant will be built. Instead, hydro, solar PV and biomass will need to increase to 23 GW, 11.5 GW and 0.9 GW respectively by 2030.

Table 7: Power capacity mix in the coal phase out scenario (GW)

Branch	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hydro PP	8.9	10.0	12.0	14.0	16.0	17.4	18.8	20.2	21.6	23.0
Coal steam	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Biomass	0.2	0.3	0.4	0.5	0.6	0.6	0.7	0.8	0.8	0.9
Solar PP	2.6	3.5	5.0	6.4	7.9	8.6	9.3	10.0	10.8	11.5
Wind										

Total	13.6	15.7	19.2	22.7	26.3	28.5	30.7	32.9	35.1	37.3

Table 8: Generation mix in the coal phase out scenario (TWh)

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hydro PP	23.1	27.1	31.1	35.0	42.0	49.1	56.1	61.0	65.9	70.8	75.7	80.6
Coal steam	6.6	3.3	-	-	-	-	-	-	-	-	-	-
Biomass	0.5	0.8	1.1	1.4	1.8	2.2	2.6	3.0	3.3	3.7	4.0	4.3
Solar PP	1.6	3.1	4.6	6.1	8.7	11.2	13.8	15.0	16.3	17.6	18.9	20.1
Total	31.8	34.3	36.8	42.6	52.6	62.5	72.5	79.0	85.5	92.0	98.6	105.1

5.2.5. Resources potential check

Hydropower resources in the country is estimated to be 26.5 GW. The other renewable energy resources include solar PV 8 GW (based on vacant land area) and biomass 3 GW (ERIA 2020). However, significant additional resource potential for floating solar PV exists, particularly at hydro reservoirs. For example, analysts estimate that the potential of floating solar energy projects on Nam Ngum reservoir can be as high as 11.4 GW when covering 30 per cent of the reservoir area (Pham 2019). Considering this huge potential for floating solar in Lao PDR, the solar PV capacity in this scenario has been extended to 11.5 GW. Table 9 presents key results and findings of the coal phase out scenario.

Table 9: Key results of the coal phase out scenario

Indicators	Results and observations
Energy demand outlook	Same as in the SDG scenario
Renewable energy	RE share in TFEC is projected to reach 34.9 per cent in 2030. This increase, compared to the SDG scenario, is due to the increase in renewables-based power generation.
Energy efficiency	Total primary energy use will be 13,482 ktoe in 2030, including primary energy supply for electricity export. This corresponds to an energy intensity of 5.3 MJ/USD_{2011}. Slight increase in EI, compared to the high-EE scenario is due to the increase in low capacity factor renewables in power generation.
Emissions	This scenario achieves a significant reduction in emissions – reaches 9.2 MtCO2-e in 2030, a drop of 83.5 per cent compared to the CP scenario. This is due to the removal of coal from the power sector.

Electricity generation and export	The power sector is fully decarbonised in this scenario, with generation from hydro, solar and biomass. Total electricity generation in this scenario in 2030 is 105 TWh, the same as in other scenarios.
Investment	Total investment in the power sector in this scenario is US$ 44.8 billion
Net benefits	Total net benefits (difference between revenue and expenditure) is US$ 9.2 billion, much lower than other scenarios. This is due to the higher investment in renewables which have lower capacity factor than coal. However, this can change significantly when a premium on electricity export tariff for 100 per cent RE electricity is considered. For example, if the export tariff is increased by 50 per cent, the net benefits will increase to US$ 26.7 billion, 53 per cent higher compared to the CP and SDG scenarios.

5.2.6. Managing the transition of the coal industry with 'just' transition

Coal fired power generation in Lao PDR is relatively new and therefore, it is believed that the industry has not been as critically important for the economy as it is in other countries. This gives an opportunity to act fast to transition this industry to alternative energy industries. Nevertheless, it is very important to ensure the transition does not impact the socio-economic condition of people who are already into this sector.

The Government of Lao PDR may work together with stakeholders, with support from the international community, to develop and implement a "just" transition plan for coal dependent areas/population affected by the phase out. Energy transitions are about people - workers, consumers, businesses, communities, taxpayers and voters - who make decisions that lead to transitions and are ultimately affected by them.

There are several examples in the world where such a transition has been very well managed. For example, in Australia's Latrobe Valley, Scotland's Just Transition Commission and Germany's Ruhr Valley and Lausitz/Lusatia where an inclusive, iterative, place-based, context-specific approach enabled by public investment provided the best outcomes, including the creation of low-carbon employment alternatives. Based on internal experience of managing 'just' transition, the following are a few key recommendations:

1. Build a social compact between the key parties to manage the conflicts that can emerge over a transition out of coal. Some countries e.g. Canada, Scotland and South Africa have commissioned a just transition commissions to manage this process.

2. It is advised that an early closure plan will help minimize severe impacts in the long run. If the transition planning is delayed, labour markets may not be able to cope with the volume of displaced workers. The La Trobe Worker Transfer Scheme is redeploying retrenched Hazelwood power station workers to other sites. Redeveloping skills of the existing workforce to align with new technologies would be critical.
3. Establish funds and authority for a just transition. Specialist funds are being established to oversee, develop, and implement coal transition programs. The European Commission's Coal and Carbon-intensive Regions in Transition initiative is investing funds in 13 coal regions.

6. Policy recommendations

Lao PDR has progressed well with the access to electricity but are lacking with other SDG7 targets, particularly in relation to access to clean cooking fuels and technologies and energy efficiency improvement. The NEXSTEP analysis suggests the following policy measures to achieve the full suit of SDG 7 targets.

6.1. Urgent focus on increasing access to clean cooking fuels and technologies

Strong and concerted efforts with well-planned policy measures to be implemented to achieve the access to clean cooking. Access to clean cooking fuels and technologies has been and is likely to remain very poor in the current policy settings. By 2030, Strong policy measures are required to address the huge gap in clean cooking by 2030, Lao PDR households need to switch from cooking with traditional biomass to cleaner fuels and technologies. Achieving access to clean cooking fuels and technologies seem to be one of the biggest challenges for Lao PDR, as it has one of the lowest access rates to date. Immediate well-planned policy measures are to be put in place to ensure achievement of this target by 2030. NEXSTEP analysis suggest a combination of electric cooking stoves, LPG cooking stoves and ICS should be used to achieve the universal access to clean cooking fuels and technologies. Choice of these technologies has been based on health benefits as well as cost effectiveness, as suggested by the annualized cost of technologies. A deeper study to better formulate the policy intervention would an ideal pathway but needs to be done immediately.

6.2. Economy wide intensive energy efficiency improvement is needed

Economy wide intensive energy efficiency improvement is needed to achieve the energy intensity reduction target. Achievement of the energy efficiency target is considered to be the second biggest challenge for Lao PDR. Energy efficiency has been going in the wrong direction for Lao PDR since 2011 and is therefore, poses a greater risk of failing to achieve this target. Even with all possible measures, the country is unlikely to attend to its required target and therefore, a revised target has been proposed in alignment with the global rate of improvement in energy efficiency. Several measures are need with a whole-economy approach. Energy intensity in the country has been going upwards instead of declining as required in the SDG7 target. With the contraction of GDP growth due to the impact of COVID-19, this is likely to worsen in the future, as energy intensity is measured as the amount of energy per unit of GDP. In this regard, the roadmap suggests that Lao PDR should at least aim for the global improvement rate by setting the target of 4.1 MJ/USD. Even this would

require an intensive effort by rolling out energy efficiency measures across all sectors, as has been suggested in the high energy efficiency scenario.

6.3. Transport electrification strategies provide multi-fold benefits

Rapid promotion of electric vehicles and should be considered as an important element not only to reduce energy consumption but also to reduce reliance on imported fuel. Lao PDR lacks petroleum fuel resources and therefore needs to import oil products to meet the demand of the transport sector, which is the largest energy consuming sector in the country. It is estimated that the demand in this sector will almost double by 2030, which will further increase the import of oil products. One important policy direction is to reduce the consumption of oil products by shifting towards electric vehicles. Lao PDR's cleaner electricity will also help reduction of greenhouse gas emissions. Vigorous adoption of electric vehicles reduces the demand for oil products, hence reducing Lao PDR's reliance on imported petroleum fuels. At the same time, it can contribute to climate mitigation and improving the local air quality.

6.4. Lao PDR should focus on phasing out coal from the power sector

Phasing out coal from the power sector should be considered to benefit from lower cost of electricity generation, reduce risk of stranded assets and to align the energy transition with the global call for coal phase out. Lao PDR's power sector has been largely reliant on hydro with small amount of coal recently added to the fleet, which has been planned for expansion in near future. However, coal-based power generation is not only hazardous for environment and public health but also it is uneconomic in the long run. Currently, over 65 per cent emissions of the power sector is from coal burning, estimated to rise to more than 80 per cent in 2030. Furthermore, there are global calls for coal phase out suggesting countries in the Asia-Pacific to phase out coal by 2040.

On the basis of economic, environmental and social benefits and the country's vast renewable energy resources, including solar PV and biomass, phasing out coal would be the justified choice of Lao PDR's energy transition. This would be also in alignment with the global move to phasing out coal as well as progressing towards net zero carbon by 2050. Lao PDR's coal industry is relatively new and thus it would be easier to transition to alternative energy sources and technologies, particularly to solar PV and biomass, in addition to further increasing the hydropower capacity. Analysis has revealed that such a transition is technically and economically possible without impacting the electricity export market. While there are challenges in doing so, international experiences and lessons learned from other countries suggest that an early start in planning, detailed consultations with stakeholders and

international communities, and developing a well-thought long-term 'just' transition plan will minimize socio-economic risks.

7. Building back better in the recovery from COVID-19 with the SDG 7 roadmap

Energy plays a key role in rebuilding better in the recovery from the COVID-19 pandemic. Energy services are essential to supporting health-care facilities, supplying clean water for essential hygiene, enabling communication and IT, and off-grid renewables refrigeration for vaccine storage. Economic challenges resulting from the pandemic have the potential to force countries in the Asia-Pacific region to focus on short-term fixes to revive GDP growth, potentially undermining long-term sustainable development. In the energy sector, this can result in the decline of investment in clean energy development – slowing progress on renewable energy and energy efficiency, and eventually, impeding national economic growth.

The COVID-19 pandemic has caused social and economic devastation globally, including in Lao PDR, albeit less intensively than other countries. Lao PDR's economy contracted to 4.7 per cent in 2019 and then dived deep to negative 0.5 per cent in 2020. Nevertheless, the economy is projected to return to 6.5 per cent growth rate in 2030, according to the Asian Development Bank (ADB 2021).

Experts believe that transitioning to sustainable energy future e.g. planning the energy sector in alignment with the SDG7, NDC and with the Paris Agreement's long-term temperature goal, can help countries recover easily. Thus, it has never been more important to design a well-planned energy transition pathway that enables the country's energy sector to shield itself from the likely impacts of the COVID-19 pandemic and helps in the recovery to build back better. The SDG 7 roadmap has identified several key areas that will assist policymakers in strengthening policy measures to help recover from the COVID-19 impacts while maintaining the momentum to achieving the 2030 Agenda for Sustainable Development and the Paris Agreement.

7.1. Accelerating access to clean and modern energy services

Access to clean and modern energy services is essential for helping rural populations to combat challenges related to COVID-19. Relying on traditional and hazardous technologies for cooking increases their susceptibility to the effects of the virus. It is important to consider how these seismic shifts in the energy sector from COVID-19 affect the most vulnerable people.

Lao PDR has about 6.5 million people who currently do not have access to clean cooking fuel. Access to clean cooking technologies is a development challenge that is often forgotten. WHO has warned about the severity of health impacts arising from the exposure to traditional use of biomass for cooking, and is encouraging policymakers to adopt measures to address this challenge. Moreover, scientists are investigating links between air pollution and higher levels of coronavirus mortality, with preliminary results showing a probable correlation between the two (Aarhus University, 2020)).

The SDG 7 roadmap has analysed and identified technical options for connecting the remaining population to cleaner fuel for cooking and has estimated the cost of the measure. The benefits resulting from this measure, in the form of reduced mortality and health impact, will exceed the needed investment to advance the clean cooking rate to 100 per cent.

7.2. Savings from the energy sector will help build other sectors

The NEXSTEP analysis shows that there are ample opportunities for Lao PDR to save energy by improving energy efficiency beyond the current practices. Several of these measures also provide cost-savings and strengthen the country's energy security, making it less susceptible to fuel supply and price shocks. Savings from this improvement can help investment in other sectors, such as health, social protection and stimulus, which are critical in responding to, and recovering from the COVID-19 pandemic.

The electrification of the transport sector, as highlighted in the SDG scenario, provides multiple additional related benefits (in addition to energy saving), including the reduction of expenditure on importing petroleum products and reducing local air pollution. Additionally, reducing coal burning and increasing renewables in the power sector will further improve the public health and local environment, not mention that it will also bring positive economic return.

7.3. Restructuring fiscal measures to invest where it is needed the most

Fossil fuel subsidies are often used by Governments to increase the affordability of energy services for the poor. Unfortunately, however, this supports the rich more than its intended target group because it is the rich segment of the population who use much more energy than the poor.

In most cases, subsidies are poorly target and thus leads to unintended consequences, do not reach the targeted segment of the population. In addition, the fossil fuel industry has been the major source of air pollution, causing severe health impacts, which is likely to increase the vulnerability of people to pandemics like COVID-19. Renewable energy technologies have multiple benefits – including improving health, increasing energy security by utilizing

indigenous energy sources, reducing import costs of feedstocks and technologies, and enhancing natural capital. While the cost of renewables has decreased significantly and LCOEs are already cheaper than their fossil fuel counterparts, the importance of putting a price on carbon should not be ruled out. The additional funds generated with such a fiscal instrument can be used to level the playing field for renewables as well as support economic recovery in cases like COVID-19.

8. Conclusion

The 2030 Agenda for Sustainable Development and Paris Agreement provide a common goal for all countries to achieve sustainability and climate objectives. Achieving the SDG 7 and NDC targets is not an easy feat but helps create a more sustainable and resilient society. This roadmap has presented five different scenarios along with their technical feasibility, investments, benefits, challenges and opportunities to inform policymakers of different pathways to energy transition. Two scenarios have looked beyond just achieving SDG 7 targets and explored the full potential of the country in relation to aiming high for energy efficiency improvement and reducing coal-fired power generation in line with the global call for coal phase out.

Lao PDR is expected to achieve universal access to electricity by 2025. However, access to clean cooking fuels and technologies is very poor and there is no specific policy or program improve this area, except ad hoc programs to provide improved cookstoves to rural remote areas by international agencies. Urgent well-planned policy intervention is required to address this target. This roadmap analysis suggests that a combination of electric, LPG and improved cookstoves would help reaching out to people at different levels and locations. While electric cookstove should be prioritized to take advantage of cleaner electricity and lower annualised cost as well as to reduce the import of LPG, other technologies can help reach out households that do not have reliable electricity connection. A deeper study to better formulate the policy intervention would an ideal pathway but needs to be done immediately.

Energy efficiency in Lao PDR has been travelling in the wrong direction compared to the global trend and the SDG7 target – the energy intensity has been gradually increasing since 2011. This poses a huge challenge in achieving this target. The NEXSTEP analysis suggests that it would be difficult for Lao PDR to achieve the SDG7 target for energy efficiency, as defined by the SDG7 methodology. In this regard, the roadmap suggests that Lao PDR should at least aim for the global improvement rate by setting the target of 4.1 MJ/USD. Even this would require an intensive effort by rolling out energy efficiency measures across all sectors, as has been suggested in the high energy efficiency scenario.

Lao PDR's NDC does not explicit mention an emission reduction target. The renewable energy targets for the power sector and energy efficiency measures in the demand sector have been included in the analysis and thus are expected to be achieved by 2030. The large part of the country's emissions come from burning coal in power plants, which will be 77 per cent of 58.6 MtCO2-e in 2030 under the current policy scenario. Therefore, an emission reduction target is unlikely to be possible without reducing or elimination coal from the energy system. This analysis has found that if coal phase out is implemented as suggested in this roadmap, Lao

PDR can commit for up to 83.5 per cent emission reduction. This can be a conditional target as the Government will require international support in transitioning away from coal.

Lao PDR's power sector has been largely reliant on hydro with small amount of coal recently added to the fleet, which has been planned for expansion in near future. However, coal-based power generation is not only hazardous for environment and public health but also it is uneconomic in the long run. Currently, over 65 per cent emissions of the power sector is from coal burning which will rise to more than 80 per cent in 2030. Furthermore, there are glwobal calls for coal phase out suggesting countries in the Asia-Pacific to phase out coal by 2040. Technology wise, with a very large renewable energy resources potential, Lao PDR is very well positioned to take this journey. Policymakers need start the transition plan early by consulting with stakeholders and international communities to develop a 'just' transition plan.

Finally, the energy transition pathway presented in this SDG 7 roadmap will support rebuilding better after the COVID-19 pandemic. The proposed energy transition presents opportunities to reduce economic risks, both for public and private investment, and identifies areas for financial savings in the energy sector that can support the recovery of other critical sectors, such as the health sector.

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