Energy Transition Pathways for the 2030 Agenda

SDG 7 Roadmap for the Lao People's Democratic Republic

UNITED NATIONS
ESCAP
Economic and Social Commission for Asia and the Pacific

NEXSTEP
National Expert SDG Tool for Energy Planning

Energy Transition Pathways for the 2030 Agenda

SDG 7 Roadmap for the Lao People's Democratic Republic

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

The shaded areas of the map indicate ESCAP members and associate members.*

The Economic and Social Commission for Asia and the Pacific (ESCAP) serves as the United Nations' regional hub, promoting cooperation among countries to achieve inclusive and sustainable development. The largest regional intergovernmental platform with 53 member States and 9 associate members, ESCAP has emerged as a strong regional think-tank offering countries sound analytical products that shed insight into the evolving economic, social and environmental dynamics of the region. The Commission's strategic focus is to deliver on the 2030 Agenda for Sustainable Development, which it does by reinforcing and deepening regional cooperation and integration to advance connectivity, financial cooperation and market integration. The research and analysis undertaken by ESCAP, coupled with its policy advisory services, capacity building and technical assistance to governments aims to support countries' sustainable and inclusive development ambitions.

Energy Transition Pathways for the 2030 Agenda
SDG 7 Roadmap for the Lao People's Democratic Republic

Photo Credits:
Chapter 1: balein/shutterstock; Chapter 2: Sergey Nivens/shutterstock; Chapter 3:Nikada/iStock;
Chapter 4: phive2015/iStock; Chapter 5: Chicetin/iStock; Chapter 6: zhengzaishuru/shutterstock;
Chapter 7: anncapictures/pixabay; Chapter 8: tomasz jagla/pixabay; Chapter 9: Tomas Luka/shutterstock.

Table of Contents

4. SDG scenario – achieving SDG 7 by 2030   23

5. Energy transition pathway with increased ambitions   33

6. Scenario ranking   41

7. Policy recommendations   43

List of figures

List of tables

Acknowledgements

Foreword: ESCAP

The top priority of Lao PDR's energy policy is to provide reliable, affordable, and sustainable energy to ensure economic growth and reduce poverty.

Lao PDR achieved 100 percent electricity access in 2020. More efforts are needed to provide access to clean cooking fuel to more than 90 percent of the population who are still reliant on polluting cooking fuels and technologies. Improving energy efficiency also should be given high priority, particularly in the transport sector, which needs to shift away from its dependence on imported fossil fuels.

Lao PDR is endowed with renewable energy resources and has been the leader in electricity exports in the Greater Mekong Subregion. Exports of hydroelectric power to neighbouring countries have been contributing substantially to the national economy. Therefore, the continued development of sustainable energy in Lao PDR is a key to the country's ongoing prosperity.

This Road Map for achieving the Sustainable Development Goal 7 presents a detailed assessment of the energy system of Lao PDR. It offers a least-cost pathway to providing universal access to clean cooking fuels and technologies, growing the share of renewable energy across all sectors, and doubling the historical rate of energy efficiency improvement. Taking a holistic approach to the energy system by using the National Expert SDG Tool for Energy Planning (NEXSTEP), the Road Map was developed in close consultation with national policymakers and experts. The Road Map presents a range of opportunities to achieve Goal 7 while improving energy security and improving the health of its citizens through reduced indoor air pollution. It sets out four key policy recommendations - to increase access to clean cooking fuels and technologies, electrify the transport sector, implement a whole-of-economy approach to energy efficiency, and decarbonize the power sector.

The successful collaboration between the Ministry of Energy and Mines of Lao PDR and the United Nations Economic and Social Commission for Asia and the Pacific is a testament to our shared ambition to deliver on the vision for energy towards the Sustainable Development Goals. The Road Map presents a pathway for Lao PDR to continue to prosper while building back better in the recovery from COVID-19.

I look forward to the implementation of the Road Map and to its continued success in delivering a secure, sustainable, and healthy energy future in Lao PDR.

Hongpeng Liu
Director, Energy Division, ESCAP

Foreword: Lao People's Democratic Republic

Lao PDR is committed to pursuing and achieving the Sustainable Development Goals (SDGs) by 2030. Global ambitions of SDG are broadly aligned with Lao PDR's development plans and priorities. SDGs deal with global and local development issues relating to poverty and social concern, natural resources and environment, technological and economic aspirations and finally global cooperation and access to knowledge. Among all 17 SDGs, this report deals with SDG 7 comprising three thematic goals i) universal access to affordable, reliable and modern energy services, ii) substantially increase the share of renewable energy in the global energy mix, and iii) double the global rate of improvement in energy efficiency. As energy is the prerequisite in achieving many of other SDG goals, timely meeting of the SDG 7 goals is of paramount importance.

The development of the SDG 7 Road Map using the National Expert SDG Tool for Energy Planning (NEXSTEP) is very timely. It enables policymakers to make informed policy decisions supporting the achievement of the SDG7 targets as our emission reduction targets (NDCs).

I am pleased to see that a very important analysis on the Road Map to achieve SDG 7 has taken a final shape. The study has been made possible with technical support and guidance of the Energy Division of the Economic and social Commission for Asia and the Pacific (ESCAP). It has been prepared in collaboration with the Department of Planning and Cooperation (DPC), Ministry of Energy and Mines, Government of Lao PDR.

I am glad to note that this document was formulated through an open, transparent, inclusive and participatory consultation process with all stakeholders.

The collaboration and technical support of UN ESCAP to accomplish this important endeavour is highly commendable. The Government of Lao PDR is thankful for the support and looking forward to continued collaboration with Un ESCAP in materializing SDG 7 targets in the country. Officials of the Ministry of Energy and Mines, unabated guidance and contributions of international and local experts are all praiseworthy for completing this very important study.

I commend that the SDG 7 Road Map as the way forward to marshal our efforts towards transforming our power sector and achieving our Sustainable Development Goal 7 and its target.

Dr. Akhomdeth VONGSAY
Director General of Department of Planning and Cooperation
Ministry of Energy and Mines

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
$MTCO_2$-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 the Lao People's Democratic Republic (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 of the Lao PDR 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

The Lao PDR's access to electricity was 93.5 per cent in 2018. Based on the historical trend, it is estimated that the Lao PDR will achieve universal access to electricity by 2025. Universal access to clean cooking technology and fuel, however, has been and is likely to remain very low in the current policy scenario (it was 8 per cent in 2018, increasing to 20 per cent by 2030). It remains a challenge for the country's 5.6 million population 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 achieve the SDG 7 target for energy efficiency, this needs to be reduced to 4.0 MJ/US$ by 2030.

The Lao PDR has abundant renewable energy resources – apart from large hydropower resources, it has also significant potential of solar PV and biomass resources. Nevertheless, the Lao PDR lacks petroleum fuel resources and thus requires imports of 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 the Lao 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 also challenges posed by heavy reliance solely on one technology, e.g., the reduction of resources in the dry season requiring the Lao PDR to import a part of its domestic electricity demand. As such, the Lao PDR has added a small amount of coal to the energy supply fleet, and which has been planned to increase in the near future. The NEXSTEP analysis has examined the potential of diversifying the energy sources, e.g., by increasing renewable energy technologies, both for the demand and supply sides.

---

2   The NEXSTEP tool has been specially designed to perform analyses of the energy sector in the context of SDG 7 and NDC, with the 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.

B.   Achieving the Lao PDR's SDG 7 and NDC targets by 2030

1. 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 universal 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 connection as per the World Bank's Multi-Tier Framework of access to energy.

2. 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 per cent of the population had access to clean cooking fuels and technologies, and is estimated to increase to 20 per cent by 2030 when considering the historical trend as well as different programmes and projects that are currently being implemented. This will leave 5.6 million people (more than 1 million households) still relying 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 cooking stoves and improved cooking stoves can be used to uplift the access rate to 100 per cent by 2030 (figure ES1).

Figure ES 1.   Lao PDR access to clean cooking under the CPS and SDG scenarios
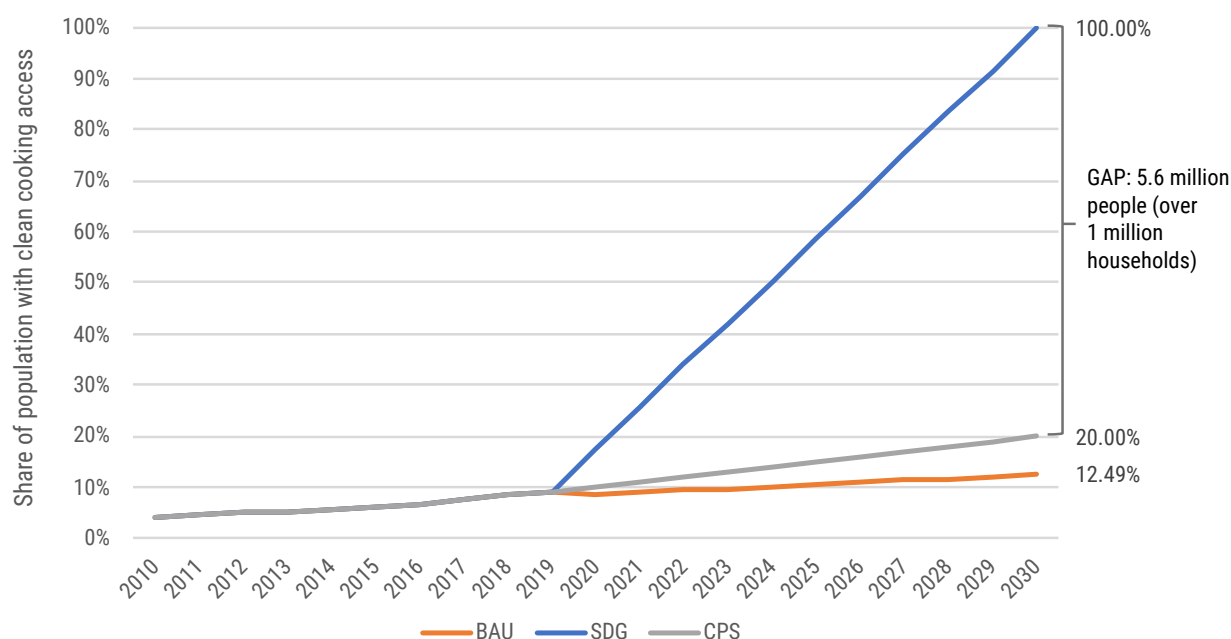
3. Renewable energy

The share of renewable energy in the total final energy consumption (TFEC) was 16.8 per cent in 2019, 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 20 per cent by 2030. In the SDG scenario, the share of renewable energy is further increased to 26.5 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.

(i) Energy efficiency

The Lao PDR's energy intensity in 2018 was 5.8 MJ/US$_{2017}$. Energy Intensity in the Lao PDR has been increasing since 2011 at an average annual rate of 10.2 per cent between 2012 and 2018. This poses a challenge to achieving the SDG 7 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 7.5 per cent rate decrease between 2018 and 2030. Correspondingly, the energy intensity in 2030 should be 0.95 MJ/US$_{2017}$ to achieve the SDG 7 target. Such a reduction has been found very difficult for the Lao PDR; the target has been aligned with the global improvement rate of 3 per cent per year resulting in a revised target of 4 MJ/US$.

Figure ES 2. Lao PDR energy efficiency improvement rate
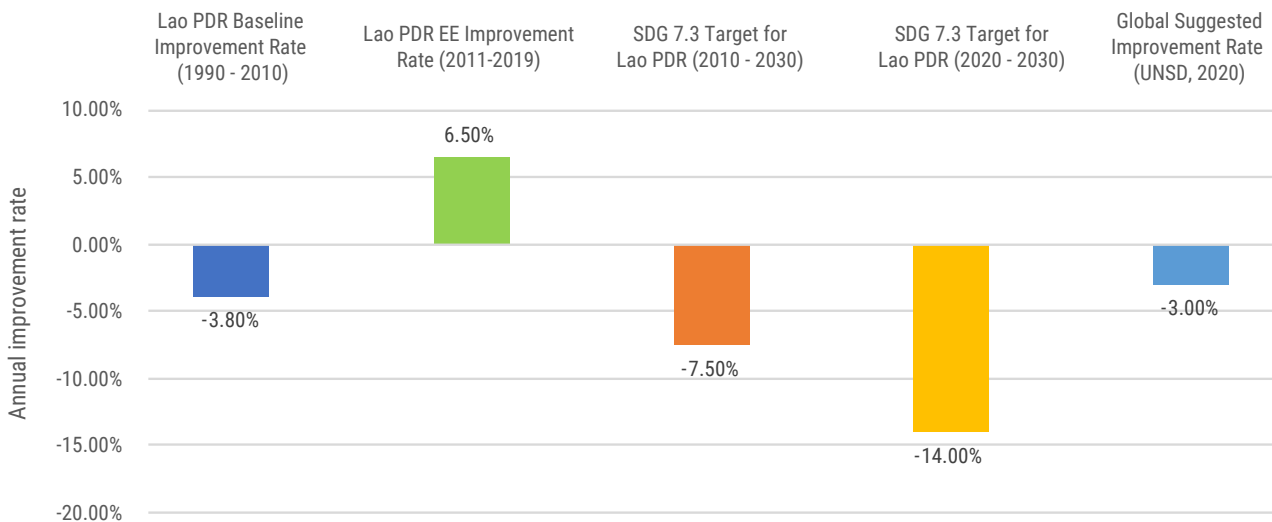
Under the current policy settings, the energy intensity is projected to be 5.32 MJ//US$_{2017}$. The energy efficiency target is not achieved in the SDG scenario; however, a higher level of energy efficiency measures, as discussed in the ambitious scenarios, will enable achievement of the target.

4. Nationally Determined Contribution (NDC)

The Lao PDR does not have 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 MtCO$_2$-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 domestic resources i.e., the unconditional target. For the conditional target, the Lao PDR aims to add an additional 1 GW of solar and wind (combined) to the national power generation, and 300 MW of biomass. In addition, targets have been mentioned in the demand side, e.g., the adoption of 30 per cent of electric vehicles for two-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

This roadmap sets out four key policy recommendations to help the 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 seems to be one of the biggest challenges for the 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 suggests 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 SDG 7 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 the 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 the Lao PDR's energy transition. This would also be in alignment with the global move to phasing out coal as well as progressing towards net zero carbon by 2050. This scenario ranked the highest when analysed using the Multi-Criteria Decision Analysis tool. The 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 having an impact on the electricity export market. While there are challenges to doing so, international experiences and lessons learnt 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.

1.1   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 as well as consider and capitalise on the interlinkages between Sustainable Development Goal 7 (SDG 7) 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 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 the Commission Resolution 74/9, which endorsed its outcomes. 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 ministerial declaration advises ESCAP to support its member States, upon request, in developing national SDG 7 roadmaps.

1. Introduction

1.2   SDG 7 targets and indicators

SDG 7 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 2017 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, the 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 was reduced to 13 GW by 2030. The 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, the 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 two-wheelers and passenger cars. Biofuel will be increased to 10 per cent of the fuel mix in the transport sector. In addition, 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 to design the type and mix of policies that would enable the achievement of the SDG 7 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 SDG 7 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 to policymakers in making an informed policy decision.

III.   Scenario and policy analysis

Using the 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
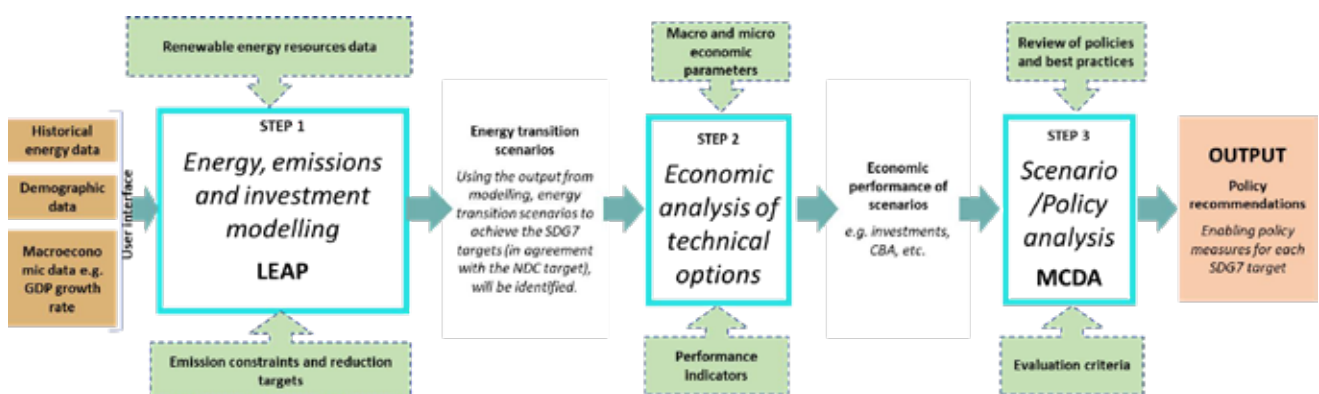
This tool is unique in a way that no other tools look at developing policy measures to achieve SDG 7. The key feature that makes it different is the back-casting approach for energy and emissions modelling. This is important when it comes to planning for SDG 7 as the targets for the final year (2030) are already given; 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); and (c) Sustainable Development Goal (SDG) scenario. In addition, two ambitious scenarios have been modelled, which look to raise the Lao PDR's ambition beyond the SDG and the NDC targets:

(a) 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.

(b) 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.

(c) 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 stoves, LPG cooking stoves and improved cooking stoves)

have been assessed, with a subsequent recommendation of the uptake of the most appropriate technology. Energy intensity has been modelled to help achieve the SDG 7 target.

(d) Ambitious scenario. 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 the 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 its 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 the combustion process emit

particulate matter which is inhaled by the local population, causing health damage and which 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 no additional investment is required for the project.

(e) External cost – refers to any additional externalities that place costs on society.

(f) (f)GHG abatement – avoided cost of CO_2 generation is calculated in monetary value based on the carbon price. The 2016 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories are 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 means to suggest the best way forward for the countries by prioritising the several scenarios. Nevertheless, it has not been applied to the Lao PDR, as a limited number of scenarios are available, which makes a decision easier.

3. Overview of the Lao PDR's energy sector

3.1. Current situation

Geography and climate. Located in the South-East Asia region, the Lao PDR is a landlocked country and is situated in mountainous areas. It has abundant natural resources, specifically water resources with various significant streams such as the Mekong River and its river basin. It is surrounded 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 sector for decades. The country covers an area of 236,800 square kilometres, about 70 per cent of which is mountainous. The country's geographical administration comprises 18 provinces, with Vientiane as the capital.

Population. In 2019, the country had a population of 7.12 million people, with an average of 5.5 person per household, which amounted to an estimated 1,276,867 households. The population recorded in 2000 was 5.3 million (ESCAP, 2021a), which translates into an annual growth rate of 1.8 per cent between 2000 and 2019. The urbanization rate in 2019 was 36.50 per cent, which is projected to grow to 44.55 per cent in 2030 (ESCAP, 2021a).

Economy. The economic growth of the Lao PDR has been remarkable in recent years, with the GDP growth rate averaging about 7 per cent since 2000. The GDP growth rate in 2019 was 5.5 per cent with a national GDP of US\$ 18.9 million in 2019. However, like other countries in the region, the 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, but forecasts suggest that it would 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, the Lao PDR is classified as lower-middle income economy as of the 2021 fiscal year (World Bank, 2021). Nevertheless, with an average of more than 7 per cent GDP growth during the past two decades, the Lao PDR is one of the world's fastest growing economies.

Climate change risks. The Lao PDR is vulnerable to extreme events, such as drought 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 the Lao PDR as key industrial sectors depend on natural resources, i.e., 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 (2019)	Unit
Population	7.123	Million
Household	1,278,774	Households
Household size	5.57	Persons/household
GDP	18.875	Billion US dollars
Per capita	2,649,9	US$
Population growth rate	1.61	Per cent
GDP growth rate	5.5	Per cent
NDC emissions target	N/A	
Commercial floor space	100	Million m^2
Domestic electricity tariff*	0.085	US$/kWh
Export electricity tariff**	0.055	US$/kWh

Source: Laos Statistical Yearbook 2019.

* Domestic tariff differs by sector and level of usage. For simplicity, an average tariff has been estimated from different tariff brackets, 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.

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

3.2. Data availability

NEXSTEP modelling utilizes 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; and population data and predicted population growth rate. Two important documents were consulted for target setting for the current policy scenario – the second 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 obtaining 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 have concluded that further data will be collected through literature review and consultation with the Ministry (DPC). The absence of a full suite of data, required for an in-depth NEXSTEP analysis, has limited the level of analysis for the Lao PDR. For example, detailed end-use or process-level energy efficiency improvement in the industry sector was not possible, which resulted in the 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 are available. Similar impacts also have been experienced in other sectors.

3.3. National energy profile

The electrification rate in the Lao PDR was 93.5 per cent in 2018. This leaves around 83,000 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 the population is reliant on using biomass in traditional cooking stoves for their cooking needs, while the remainder use a combination of LPG and improved cooking stoves.

3.4. National energy policies and targets and development plans

The 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, in order to identify gaps in achieving the SDG 7 targets. The following major policies or strategic documents were consulted.

The Eighth National Socio-Economic Development Plan NSEDP (2016-2020) paves the way towards the graduation from least developed country (LDC) 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 per cent), 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 Nineth NSEDP (2021-2030) is currently being developed.

The Renewable Energy Development Strategy in the Lao PDR was issued in 2011. It aims to develop new renewable energy resources that have not yet been widely explored in the Lao PDR in order 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 per cent of the total energy consumption in 2025. The Government is also encouraging 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 the Lao PDR 2011).

The Second 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 the 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 $MtCO_2$-e emission reduction, compared to BAU. These are unconditional targets and will be achieved with domestic resources. For the conditional target, the 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. In addition, a 10 per cent 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:

- Reducing fuel imports by increasing EV in the transport sector;
- Increasing coal utilization for power generation through clean coal technology;
- Increasing RE share by up to 30 per cent of total energy consumption by 2025;
- Increasing the diversity of energy generation capacity: hydropower 75 per cent, coal 14 per cent and RE 11 per cent;
- Interconnecting 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. 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 the Lao PDR's exploitable hydro resources, the country has estimated resources for generating electricity with a theoretical hydropower potential of 26.5 GW (IHA, 2016), of which 5.5 GW hydropower capacity had 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, Viet Nam, 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 the Lao PDR is relatively high enough to provide electricity generation throughout the year. With a moderate to 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 being 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 the Lao PDR. Studies show that the south-central and a few northern parts of the Lao PDR appear to have greater potential for wind energy exploitation than other areas. These include high mountain zones along the border between the Lao PDR and Viet Nam, especially in Savannakhet and Khammouane provinces, where wind resources have been identified as the highest and most effective electricity generation in the Lao PDR. The technical specifications of those areas demonstrate that at a height of 50 metres 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 non-technically feasible for large-scale electricity generation.

Hydropower

The country's exploitable hydropower potential is estimated to be around 26,500 MW, 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 around 68 per cent of the country's land was covered by forest in 2010 (FAO, 2015). Biomass continues to be a significant resource as it can produce waste from fuelwood and charcoal derived from agricultural and forestry sectors. This waste includes rice straw and husks, sawdust, corn cobs and sugar cane peel, which are estimated to produce up to 500 million tons of oil equivalent (MTOE) (ADB, 2019). This advantage enhances the potential for electricity generation both from 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 milling (720 GWh/year), non-utility scale includes secondary milling residues, rice husks and sugar cane bagasse (805 GWh/year) (NREL, 2018). Moreover, 80 per cent of the total population is relying on biomass as the main source for daily life applications such as cooking, heating and other related activities, due to its obtainability everywhere as most of the population lives in rural areas (ERIA, 2018).

The Lao PDR is currently operating two bagasse power plants that generate power from sugar cane with a subtotal installed capacity of 25 MW. At this time, a feasibility study is in the process on estimating power plant-generated electricity from biomass out of the total potential power generation of around 1,000-2,500 MW (IRENA, 2016).

Coal

Coal reserves range between 600 and 700 million tons and mostly comprise lignite and small amounts of anthracite. The Lao PDR's lignite resources are concentrated at Hongsa in Xayabuli Province to the north-west, where reserves are estimated to contain greater than 400 million tons (ADB, 2019). Coal is primarily used by cement factories together 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 – Thailand, 90 per cent and Viet Nam, 10 per cent (ERIA, 2019). The main use of petroleum in the Lao PDR is by the transport sector as gasoline, diesel oil, and jet fuel. The demand for petroleum products is growing consistently as the affordability of private cars and motorcycles is increasing (Kouphokham, 2019).

3.6. National energy balance, 2019

The official national energy balance is not available for 2019. The following describes the estimated national energy consumption built up using data collected from various sources, mainly the Energy Outlook Report of the Economic Research Institute for ASEAN and East Asia (ERIA) (ERIA 2020) and Asia Pacific Energy Portal (ESCAP 2021a).

In 2019, the total final energy consumption (TFEC) was 4,449 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 was the dominating energy source in TFEC, with a share of 44 per cent, followed by biomass (34 per cent), electricity (11 per cent) and coal (11 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). Figures 2 and 3 illustrate the total final energy consumption by consuming sector and fuel type.

Figure 2.   **Total final energy consumption by sector, 2019**

Agricultural 0.04%
Transport 42.7%
Residential 29.3%
Industry 18.3%
Commercial 9.7%
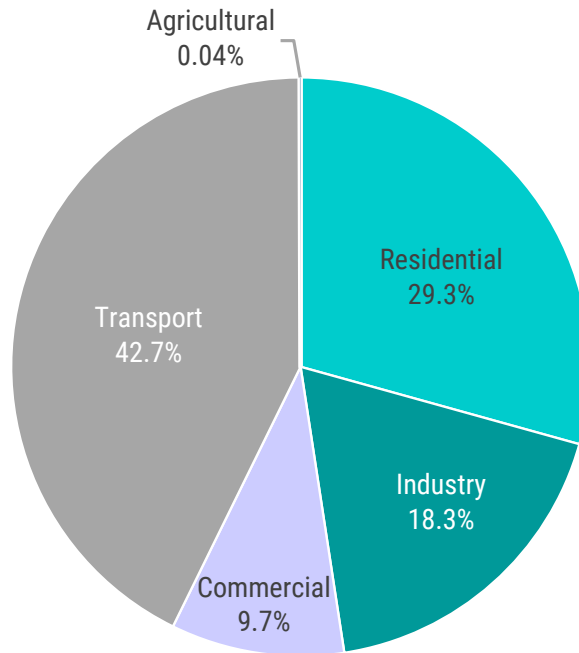
Figure 3.   **Total final energy consumption by fuel type, 2019**

Electricity 11%
Coal 11%
Biomass 34%
Oil Products 44%
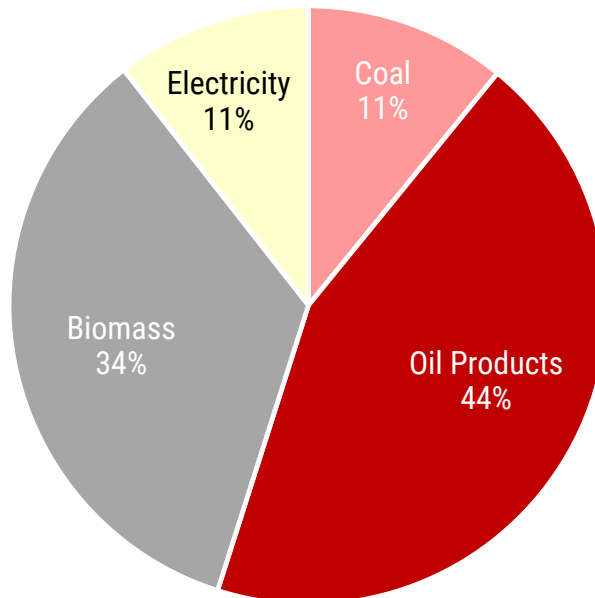
The total primary energy supply (TPES) in 2019 was 10,011 ktoe. Coal contributed the highest amount (46 per cent), followed by hydro (19 per cent) and oil products (19 per cent), as shown in (figure 4). The Lao PDR exported 2,433 ktoe electricity to neighbouring countries and imported 26 ktoe.

3. Overview of the Lao PDR's energy sector

Figure 4.   Total primary energy supply by fuel type, 2019
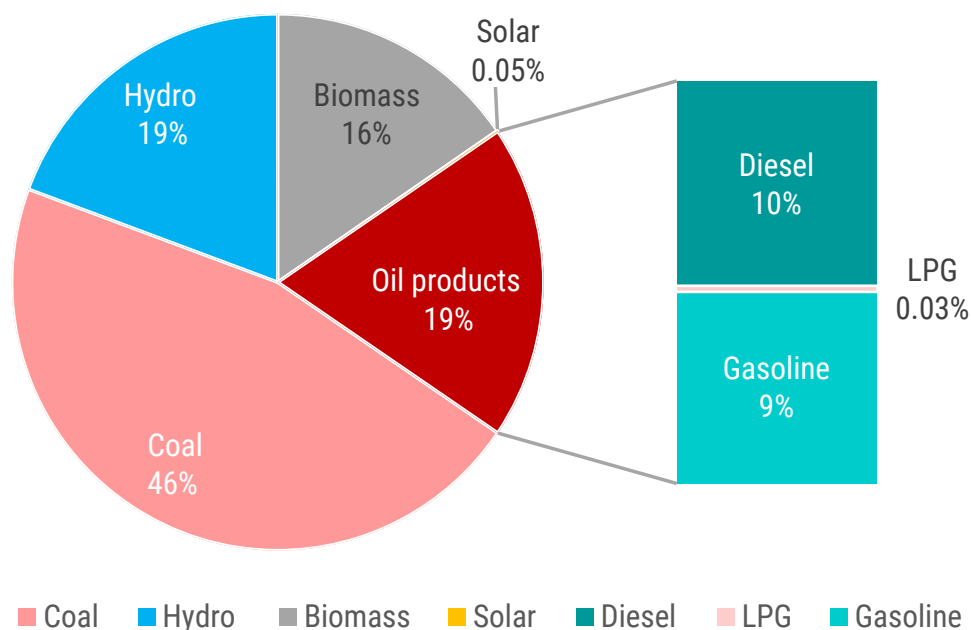
3.7. Power generation

The total installed capacity in 2019 was 7,422 MW, comprising 73.7 per cent hydropower, 25.3 per cent coal (predominantly lignite), 0.5 per cent biomass and 0.4 per cent solar PV.

In 2019, total electricity generation was 31,232 GWh, of which about 24,390 GWh was exported to Thailand, Cambodia, Myanmar, Malaysia and Viet Nam. The remaining amount was consumed domestically. The 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.   Lao PDR electricity export, import and domestic consumption, 2016-2020

Year	Production	Export					Import			Domestic consumption
		Thailand	Cambodia	Myanmar	Malaysia	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 scenario
Economic growth	GDP in 2019 was US$ 18.88 billion and the GDP growth rate was 5.5 per cent.		
Population growth	Population in 2019 was 7.12 million, population growth rate was 1.61 per cent per year[4]		
Household size	Household size is assumed constant throughout the analysis period at 5.57 people per household. This corresponds to a total of 1,278,800 households in 2019.		
Urbanisation rate	36.3 per cent in 2019, gradually increasing to 44.5 per cent in 2030[5]		
Commercial floor space	100 million m^2 in 2019, increasing at the same growth rate as GDP		
Transport activity	Transport activities in 2019 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	2019: 93.5 per cent. 2025: 100 per cent	2019: 93.5 per cent. 2025: 100 per cent	2019: 93.5 per cent. 2025: 100 per cent
Access to clean cooking fuels	Access rate was 8 per cent in 2019, based on historical trend and using a 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 cooking stoves in reaching a 100 per cent access rate.
Energy efficiency	In 2018, the energy intensity was 5.8 MJ/US$. Additional energy efficiency measures not applied	Improvement based on current policies	Energy efficiency measures enhanced and EI reached 4.99 MJ/US$ in 2030.
Power plant	Based on 2019 capacity share	Power generation capacities have 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, the SDG scenario followed the plan of RE capacity expansion as in the second NDC.

4   Based on historic growth between 2000 and 2019.
5   Based on historic growth between 2000 and 2019.

3.9. Energy demand outlook – BAU scenario

The BAU scenario forecasts a hypothetical energy scenario if no actions or polices have been taken to help advance 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 per cent 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 6,976 ktoe in 2030, an average annual growth rate of about 5 per cent. In 2030, the transport sector consumption will be by far the largest at 47.5 per cent, followed by the residential sector at 24 per cent, the industry sector at 19 per cent and commercial sector at 10.4 per cent. Figure 5 shows the forecast of TFEC by sector under the BAU scenario.

Figure 5.   Final energy demand, 2022-2030, by sector, BAU scenario
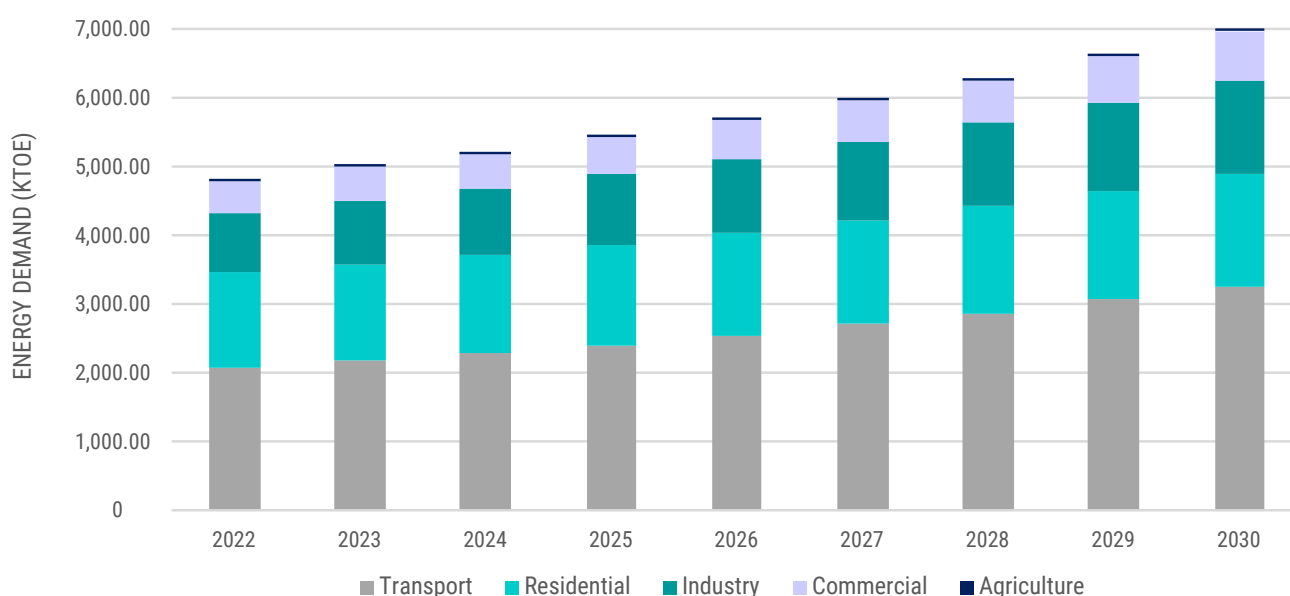
3.9.2. Renewable Energy

The RE share in power generation in this scenario remains almost the same throughout the analysis period at about 65 per cent. The RE share in TFEC is projected to be 16.8 per cent in 2030. This share (RE in TFEC) excludes traditional use of biomass, which if included, will reach 36.5 per cent in 2030.

3.9.3. Energy efficiency

The total primary energy supply in 2019 was 7,635 ktoe, which will increase to 14,401 ktoe in 2030, including the primary energy supply for electricity export. This corresponds to an energy intensity of

$3.11 MJ/US\$_{2017}$, compared to 5.8 MJ/US\$ in 2018. It should be noted that growth in energy demand as well as supply in the BAU scenario is projected to be very low; therefore, the energy intensity is estimated to be low. However, the growth rate changes significantly in the subsequent scenario, as discussed in the following sections.

3.9.4. Power generation

Electricity demand is expected to rise from 5.8 TWh in 2019 to 9.1 TWh in 2030. Figure 6 shows the electricity demand by sector. The electricity exports in this scenario are projected to increase to 72.6 TWh by 2030.

Figure 6. Electricity demand by sector, 2022-2030, BAU scenario
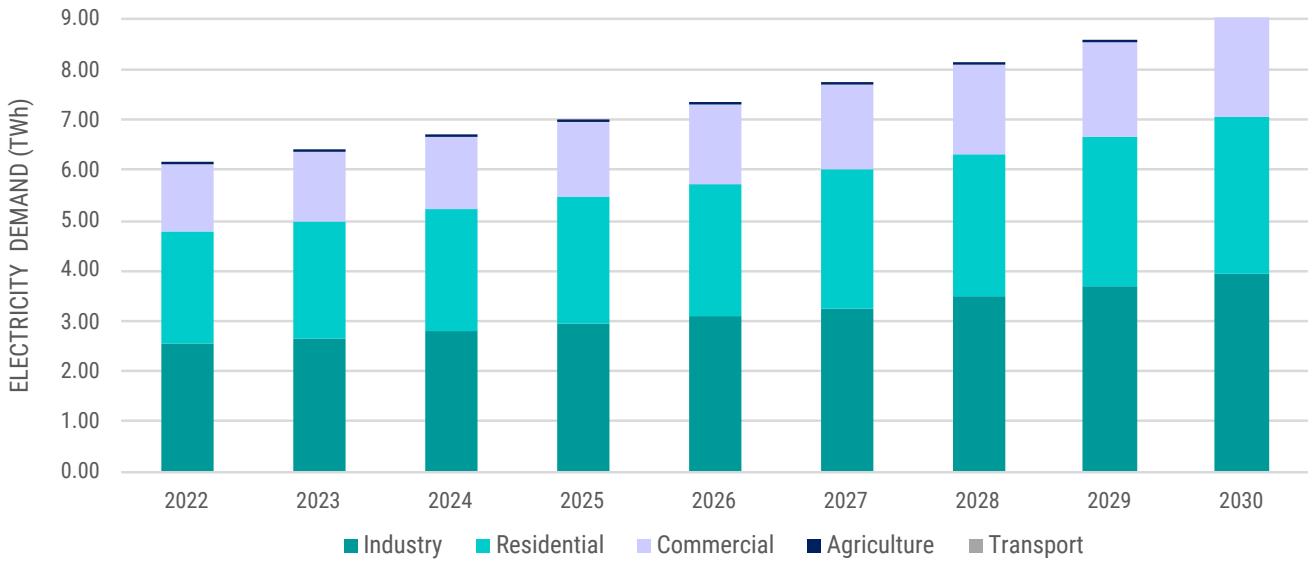
3.9.5. GHG emissions

Figure 7 shows the GHG emission trajectory. GHG emissions are expected to rise gradually from 24.7 MtCO2-e in 2019 to 51.8 MtCO2-e in 2030. A total of 73 per cent of emission is from electricity generation (mainly by coal) and the remainder from petroleum fuel consumption, mainly in the transport sector.

Figure 7. GHG emissions by type, 2021-2030, BAU scenario
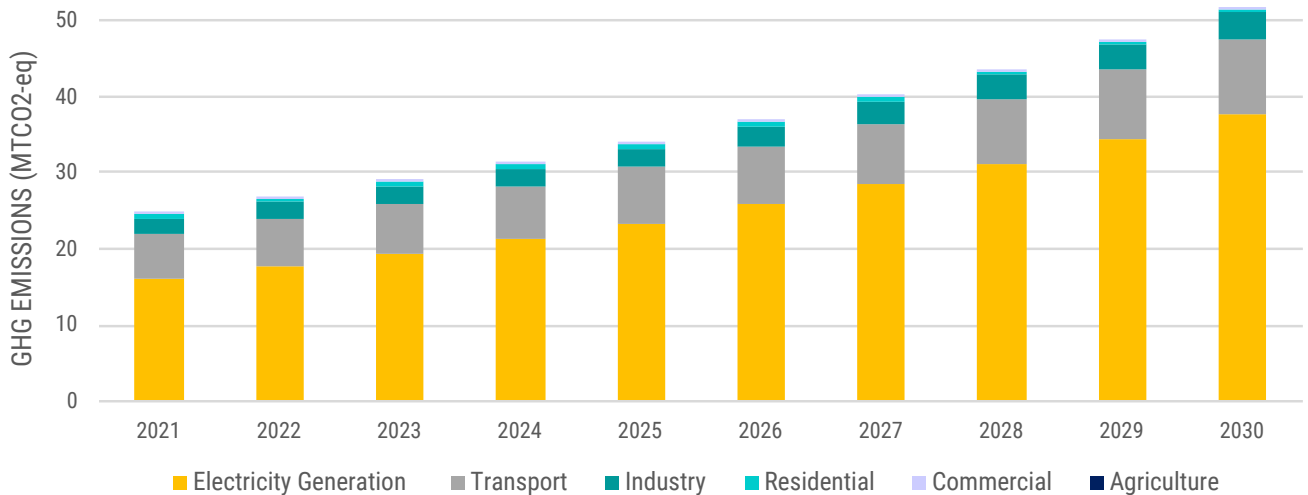
3.10. Energy demand outlook – current policy scenario

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

- 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 20.7 GW by 2030, increase in coal power capacity to 3.9 GW and Wind 600 MW (as per NPDP) to achieve energy diversification targets, which are 75 per cent hydropower, 14 per cent coal power plant, and 11 per cent renewable energy. No specific capacity expansion plan for solar or biomass has been mentioned in NPDP. Lao PDR will export all electricity after meeting the domestic demand.

- Transport sector. A new bus rapid transit (BRT) system in Vientiane and associated non-motorized transport components will be introduced (as per the second NDC. The BRT is expected to reach 30,000 passenger trips per day by 2030.

- Energy efficiency. Energy efficiency is expected to remain minimal in the absence of any major energy efficiency and conservation policy being put in place. No major energy efficiency initiative is to be introduced in the industry, commercial and agriculture sectors.

- Clean cooking. The World Bank supported project aims to introduce 50,000 ICS by 2025 (World Bank, 2018 AND 2019). The second NDC also mentions this as a measure.

In the current policy settings, TFEC is projected to increase from 4.4 Mtoe in 2019 to 6.5 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 of 3.05 Mtoe (46.7 per cent), followed by the residential sector at 1.42 (21.7 per cent), industry sector at 1.35 Mtoe (20.6 per cent) and commercial sector at 0.72 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 a very small amount of energy (about 3.5 ktoe) which is not shown in figure 8.

Figure 8. **Energy demand outlook, 2021-2030**
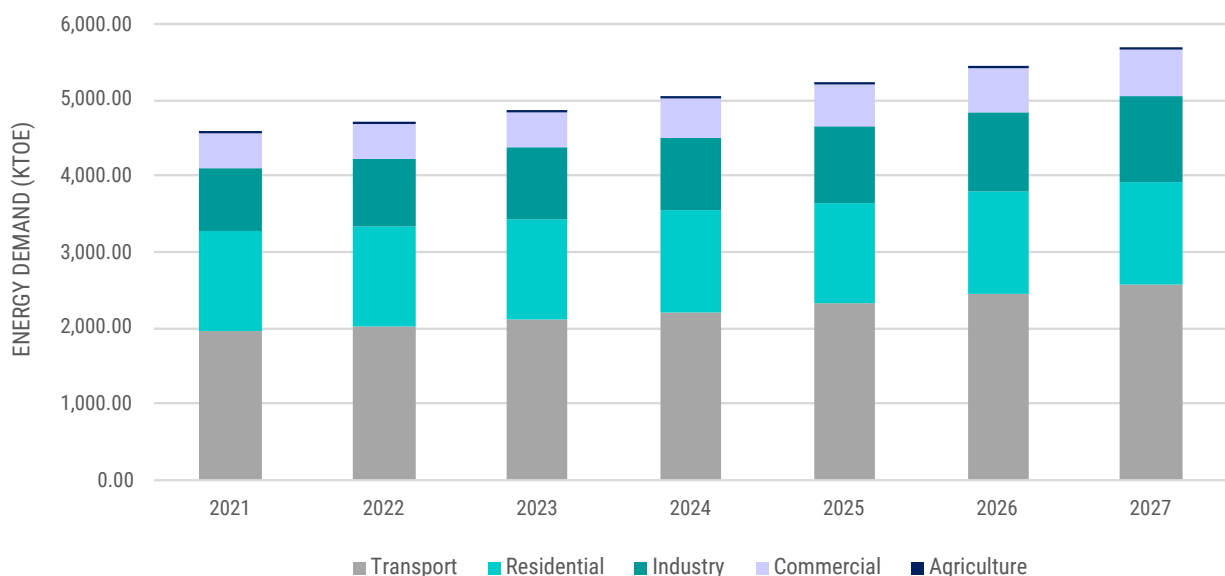
(a) Transport

Consisting predominately of internal combustion engines, the Lao PDR's transport sector is divided into passenger road transport, and freight road transport categories. The total energy demand is projected to be 3.1 Mtoe in 2030, increasing from 2 Mtoe in 2019. This sector will continue to dominate the Lao PDR's TFEC with a share of 46.7 per cent in 2030. Among the passenger vehicle categories in 2030, motorcycles will consume the most at 1,069 ktoe (46 per cent), followed by private cars at 504 ktoe (21.7 per cent), vans at 2,766 ktoe (11.4 per cent), pick-ups at 316 ktoe (13.6 per cent), three-wheelers at 78 ktoe (3.4 per cent) and buses at 63 ktoe (2.7 per cent).

(b) Residential

In 2030, the residential sector will consume 1,419 ktoe, an annual growth rate of about 1 per cent, up from 1,304 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 be the main source of energy at 80.8 per cent and most of the remaining (18.7 per cent) will be electricity. A very small amount of LPG (4.1 ktoe) will be used in the residential sector.

(c) Industry

TFEC in the industry sector will have a 20.6 per cent share in 2030. The subsectoral demand will be mainly dominated by two industry subsectors – the food processing (40.4 per cent) and glass and cement industries (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 715 ktoe in 2030. In this sector, biomass will be the key energy supply at 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 9.5 Terawatt-Hours (TWh), increasing from 5.5 TWh in 2019. Demand will be the highest in the industry sector at 3.9 TWh (41.3 per cent), followed by the residential sector (3.1 TWh, 32.6 per cent), the commercial sector (2 TWh, 20.9 per cent) and transport sector (0.5 TWh, 4.8 per cent).

The Lao PDR's installed electric power generation capacity in 2019 was 7,422 MW, of which 73.7 per cent was hydro, 25.3 per cent was 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 of the Lao PDR with neighbouring countries, by 2025 the following export targets have been set: 9,000 MW to Thailand, 5,000 MW to Viet Nam, 3,000 MW to Cambodia and 500 MW to Myanmar (as per the draft NPDP 2020-2030). The Government also aims to increase both solar PV and wind capacities to 600 MW each by 2030 and 2023, respectively. 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 biomass capacity expansion; therefore, the base year capacity is assumed as remaining the same. The coal expansion plan has been estimated using the coal power plants that are either under construction or have been awarded contracts 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	20,773	75
Coal	1,878	3,878	14
Solar PV	32	2,406	8.7
Biomass	40	40	0.1
Wind	0	600	2.2
Total	**7,422**	**27,697**	**100.00**

Figure 9. **Power capacity installed, CPS scenario**
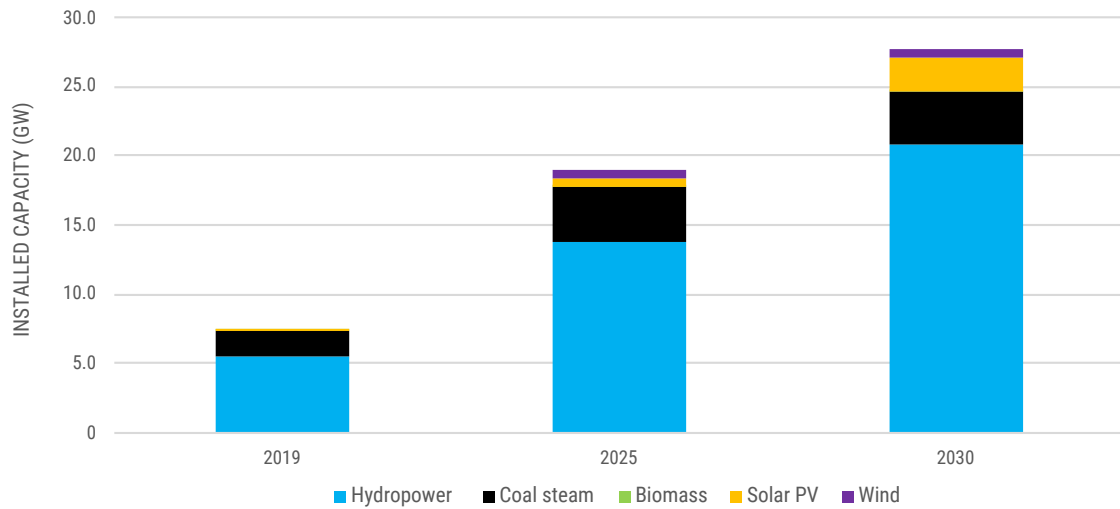
Note: Biomass capacity is too small to appear in this graph.

The projected generation by technology type is as illustrated in figure 10. Hydropower will continue to dominate the electricity system, with coal being second. Of the total generation of 99.4 TWh in 2030, 89 TWh will be exported to the neighbouring countries where export mechanisms are already in place.

Figure 10. **Electricity output by technology type, CPS scenario**
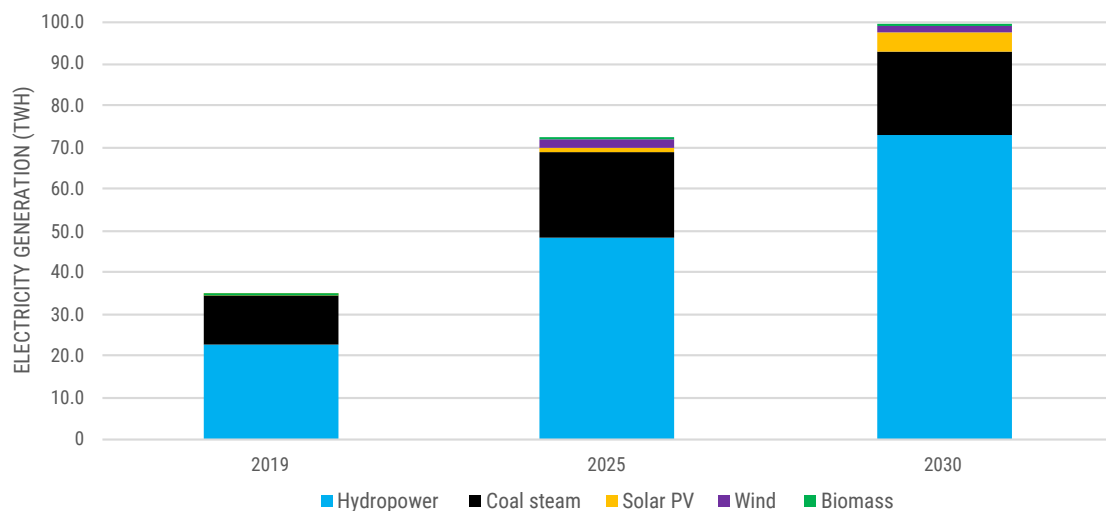
3.12. Energy supply outlook

As briefly mentioned in section 3.6, in the current policy scenario TPES is forecast to increase from 10,011 ktoe in 2019 to 24,614 ktoe in 2030. This sharp increase is obviously due to the increased power generation capacity to support the increase in the electricity export target. The fuel shares in 2030 are projected to be oil products (3,113 ktoe), biomass (1,857 ktoe), hydro (18,966 Mtoe), coal (7,814 ktoe) and solar (362 ktoe). The substantial increase in coal and hydro is due to the need to meet the rising power export target. While the share of biomass in the total primary energy supply is likely to be reduced with the increase in urbanization (more than half of the population is

expected to live in rural areas by 2030), its supply will remain significant due to most people in the Lao PDR continuing to rely on cooking with traditional biomass.

3.13. Energy sector emissions outlook

The energy sector emissions, from the combustion of fossil fuel, are 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 are accounted for 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, the 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 emissions will 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, which include:

(a) An addition of 13 GW[7] hydropower capacity by 2030;

(b) An addition of 1 GW of solar and wind (combined) to the national power generation;

(c) An addition of 300 MW of biomass power plant output;

(d) The adoption of 30 per cent of electric vehicles for two-wheelers and passenger cars;

(e) A biofuel increase to 10 per cent of the fuel mix in the transport sector; and

(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 24.7 MtCO2-e in 2019 to 40.5 MtCO2-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 by the demand side, whereas figure 12 shows emissions from the power sector (supply side), which is from coal only.

Figure 11. Emissions from the demand side under the current policy scenario

---
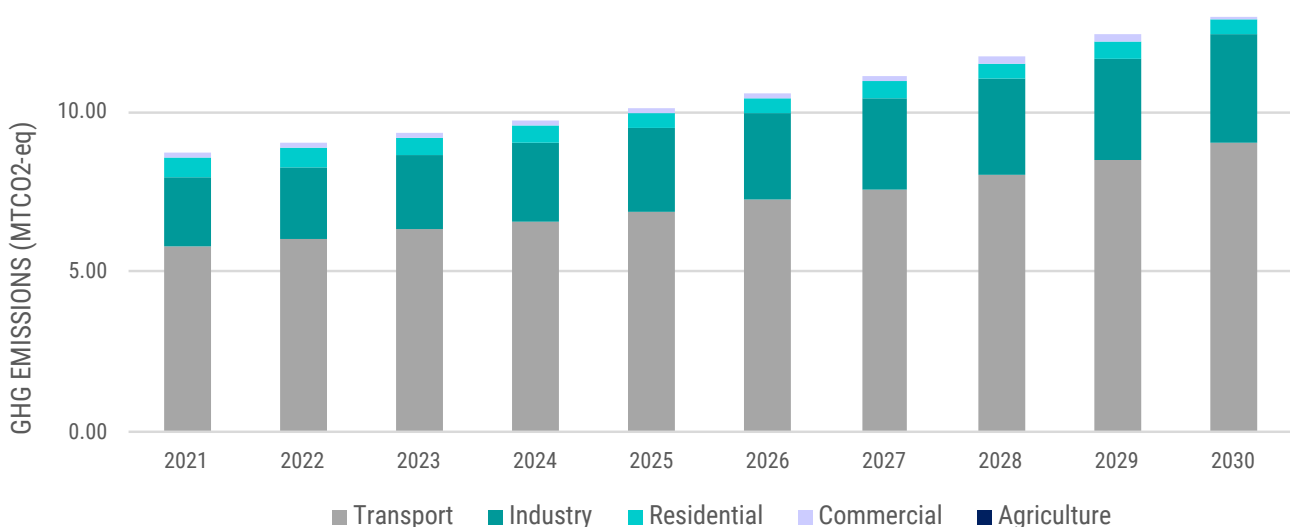
6   The AFOLU sector is not within the scope of NEXSTEP.

7   Note that the Ministry has advised that the NPDP target of 20 GW should be used in the modelling

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

4.
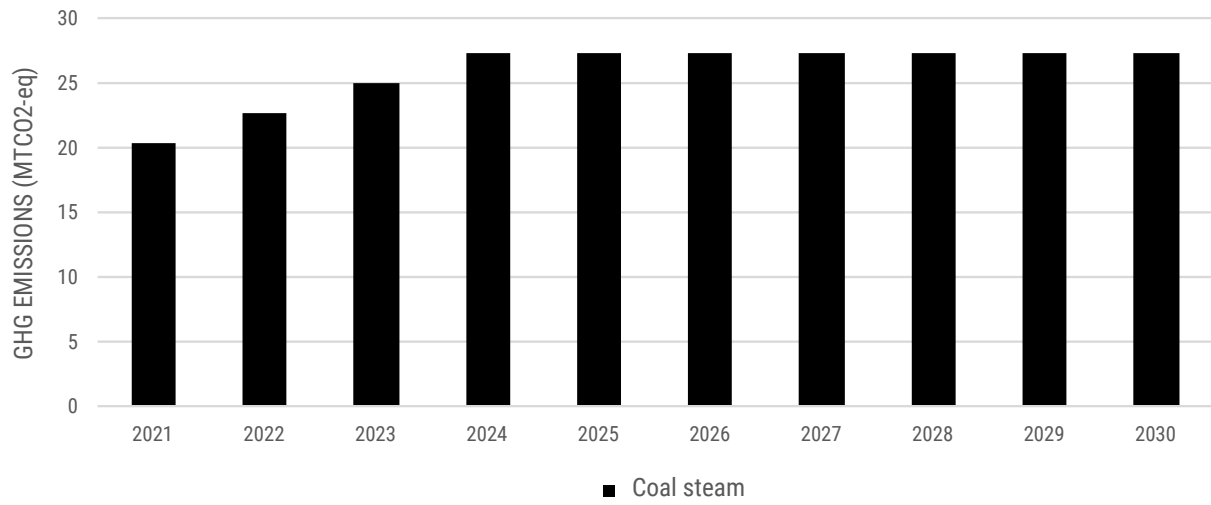
SDG scenario –
achieving SDG 7 by 2030

Access to affordable, reliable, sustainable and modern energy is essential to achieving the 2030 Agenda for Sustainable Development and the Paris Agreement on climate change. The Lao PDR is expected to achieve universal access to electricity by 2025 in the BAU scenario. Nonetheless, 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. The renewable energy share in TFEC in 2019, excluding biomass, was 17 per cent, and 41 per cent when biomass is 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$, which will need to be reduced to 4MJ/US$, at an annual rate of 3 per cent (in alignment with the global improvement rate), to enable achievement of the SDG 7 target for energy efficiency improvement. All these have been modelled and analysed in the SDG scenario to ensure that the Lao PDR achieves the SDG 7 targets. These are discussed further in this chapter.

4.1. SDG energy demand outlook

In the SDG scenario, TFEC increases to 4,963 ktoe in 2030, a drop of 1,567 ktoe compared with the current policy scenario (about a 24 per cent reduction). This decrease has been due to the switch from inefficient biomass cooking stoves to more efficient electric cooking stoves as well as energy efficiency has improvement across different sectors, e.g., through Minimum Energy Performance Standards (MEPS) in the residential sector (discussed later in this report), energy efficiency in the industry sector and a partial switch from internal combustion engines to electric vehicles in the transport sector.

In 2030, the transport sector will continue to have the largest share of TFEC at 2,628 ktoe (53 per cent), followed by the industry sector (1,141 ktoe, 23 per cent), the commercial sector (643 ktoe, 13 per cent), the residential sector (548 ktoe, 11 per cent), and the agriculture sector (3 ktoe, 0.1 per cent). , 13 shows the projected TFEC by sector under the SDG scenario.

Figure 13. Projection of TFEC, by sector, in different scenarios
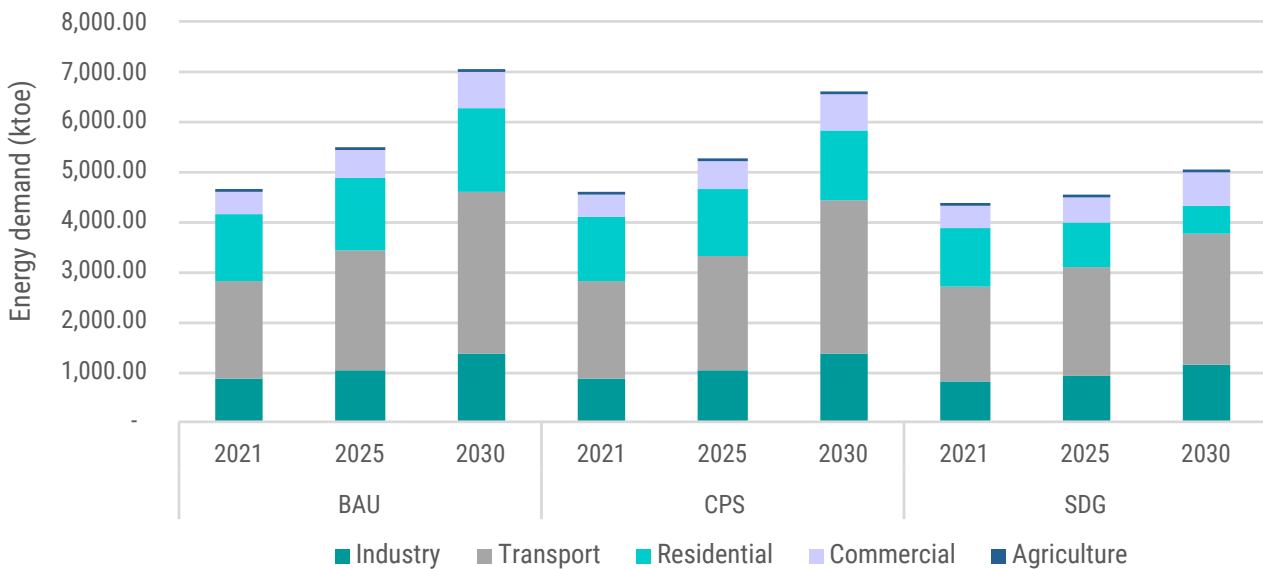
4.2. SDG 7 targets

4.2.1. SDG 7.1.1 – access to electricity

The 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 of the level and quality of access would be appropriate In order 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**
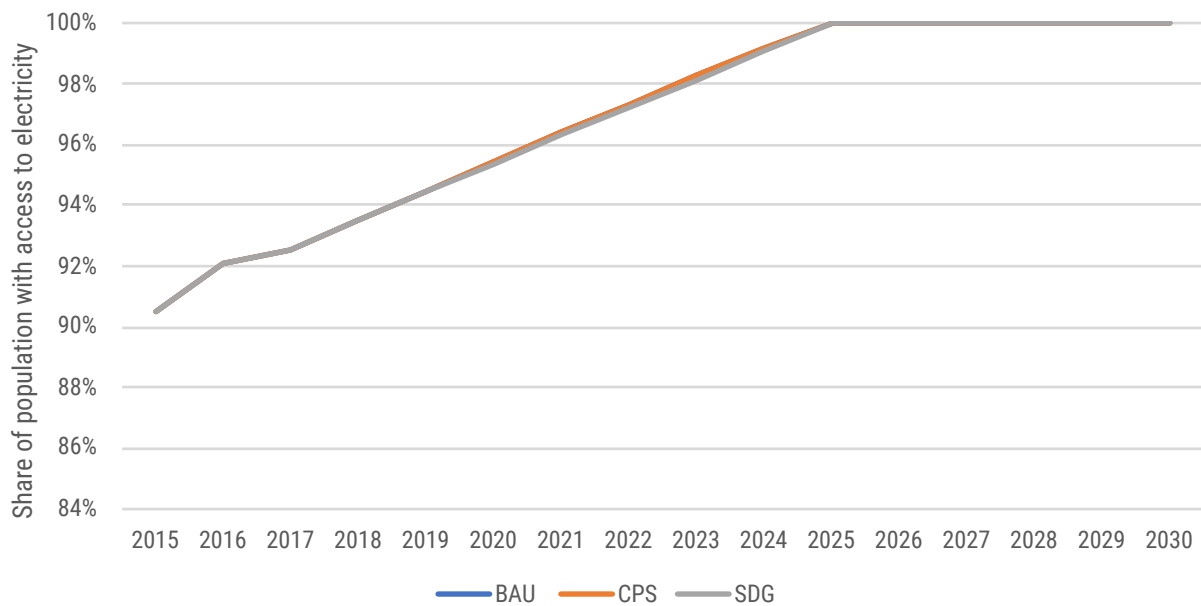
4.2.2. SDG 7.1.2 – access to clean fuel and technologies for cooking

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 cooking stoves (ICS) under the project, supported by the World Bank, that aims to distribute 50,000 ICSs (World Bank, 2018 and 2019). The current dominant clean cooking technology is the biomass stove, which had a share of more than 97 per cent in 2018, an average in both urban and rural areas. While providing 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 the Lao PDR uses other technologies to increase the share of access to clean cooking, in an attempt to reduce the use of LPG cooking stoves over time.

Based on evaluation of the annualized cost of operation of different cooking technologies and considering the fact that the Lao PDR generates enough electricity largely from hydropower, this roadmap suggests the use of high-efficiency induction type cooking stoves for about 70 per cent households – mostly those that are located in urban and peri-urban areas. Considering the remote rural locations of many households where access to electricity may not be as reliable as in urban areas, the roadmap suggests LPG cooking stoves for 20 per cent of households and a further ICS for the remaining 10 per cent of households. The following section presents a summary of quantitative and qualitative analyses of different cooking stove technologies.

Figure 15. Access to clean cooking fuels and technologies, by scenario
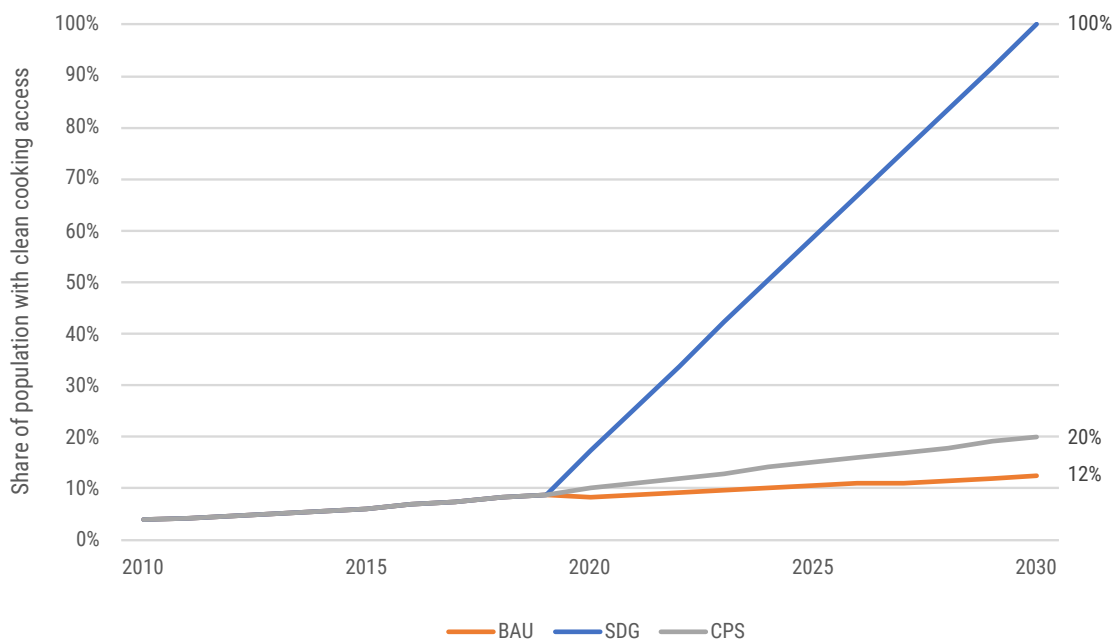
Clean cooking technologies evaluated

(a) Electric cooking stoves

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

(b) Improved cooking stoves

Studies suggest that ICS programmes often have low adoption rates due to inconvenience in use, preference for traditional cooking stoves, 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. In addition, based on the WHO guidelines for emission rates for clean cooking, only certain types of ICS technology comply,

particularly when considering that cooking stove emissions in the field are often higher than they are in the laboratory settings used for testing.

(c) Biogas digesters

Biogas digesters have high upfront capital costs (about US$1,000 for a standard size that is suitable 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 use animal or human waste for cooking. In addition, a standard size biogas digester requires two to four cows, depending on the size of the cow, to produce enough feedstock for a household's daily gas demand.

(d) LPG cooking stove

LPG in the Lao PDR is constrained due to fuel import dependency and supply chain challenges. LPG cooking stoves generate lower indoor air pollution compared to ICS and are classified as Level 4 in the World Bank Multi-Tier Framework (MTF)[8] for cooking exposure, and they reduce indoor air pollution by 90 per cent compared to traditional cooking stoves. Table 5 summarizes the estimated annualized cost of different cooking technologies in the context of the Lao PDR.

---

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

Table 5.   Annualized cost of cooking technologies

Technology	Annualized cost (US$)
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 the optimum renewable energy share in TFEC.

In the context of the 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 26.5 per cent in 2030, whereas the share of renewables in power generation mix will increase from 65.5 per cent in 2018 to 86 per cent in 2030 (figure 16).

Figure 16.   Renewable energy shares in TFEC and power generation
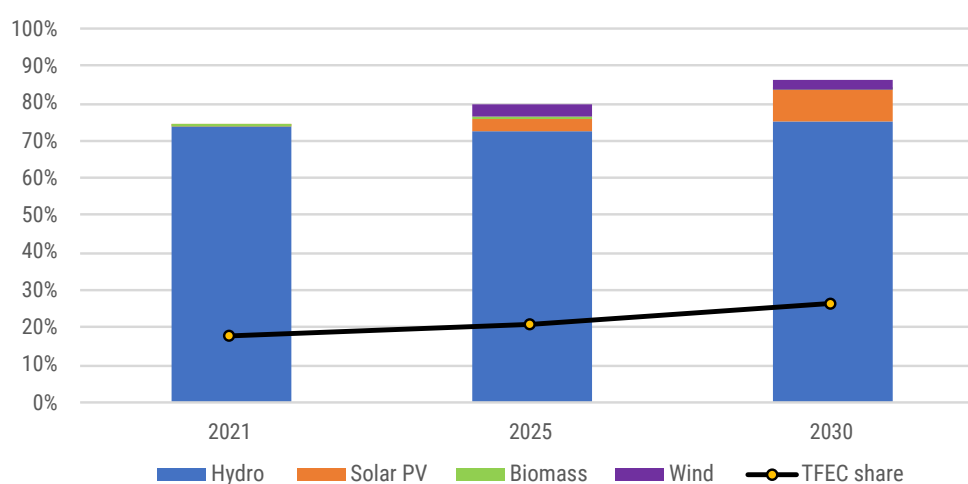
Note: Biomass has too small a share to appear on this graph.

4.2.4. SDG 7.3 – energy efficiency

The total primary energy supply in the SDG scenario will be 23,096 ktoe in 2030, including primary energy supply for electricity export. This corresponds to an energy intensity (EI) of 4.99 MJ/US$_{2017}. The EI of the Lao PDR has been increasing since 2000 and reached 5.8 MJ/US$ in 2018 (figure 17). This is in contrast to the regional EI which has been declining over this period.

Figure 17. Energy intensity in the Lao PDR, 2000-2018
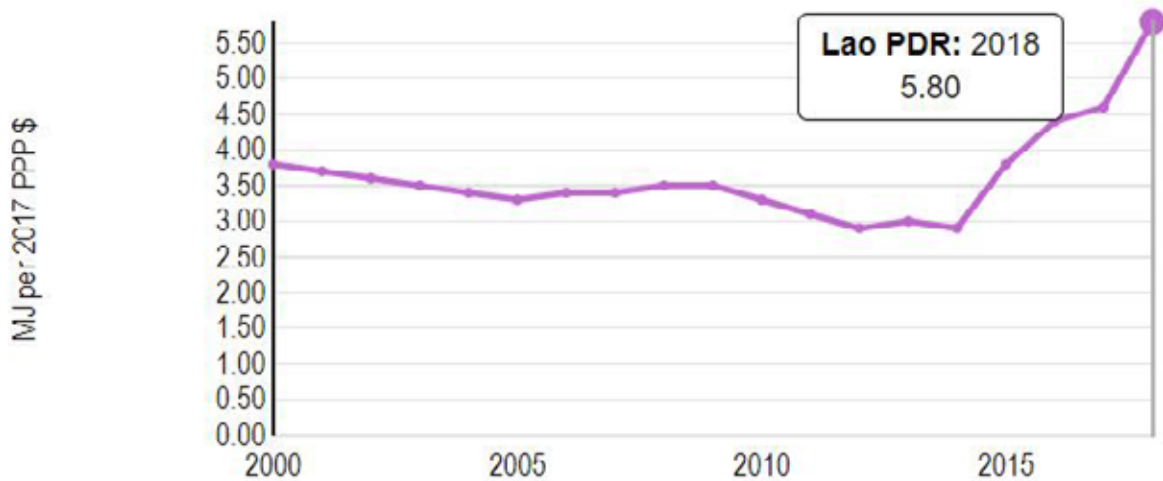
Source: Asia Pacific Energy Portal,(ESCA,P 2021a)

With possible energy efficiency measures applied in this scenario, the EI is unlikely to achieve the SDG 7 target of 4 MJ/US$. This is primarily due to the contraction of GDP as a result of the COVID-19 pandemic. If the impact of the pandemic is ignored, the EI target (4 MJ/US$) 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 SDG 7, the Lao PDR would need to further increase energy efficiency, which is discussed in the ambitious scenario.

Box 1. The Lao PDR's energy efficiency target explained

The energy intensity of the Lao PDR declined at an average annual rate of 3.76 per cent between 1990 and 2010. A doubling of the 1990-2010 improvement rate is required to achieve the SDG 7.3 target, corresponding to an average annual rate of 7.52 per cent between 2010 and 2030. However, energy intensity increased between 2011 and 2019 at an annual rate of 6.50 per cent. Consequently, the energy intensity in 2030 should be 0.95 MJ/US$_{2017}. Such a high rate of energy efficiency improvement and a low energy intensity is challenging and unlikely to be achieved, even with ambitious energy efficiency improvement measures. Therefore, the NEXSTEP analysis suggests that the Lao PDR's energy intensity target be aligned with the global target of 3 per cent annual improvement (UNSD, 2021). This corresponds to a 2030 energy intensity target of 4 MJ/USD_{2017}.

Global energy efficiency improvement rate explained

The historical energy intensity improvement rate between 1990 and 2010 was 1.3 per cent. Preliminary estimates for 2018 and 2019 are 1.3 per cent and 2 per cent, respectively. This suggests that the improvement rate would reach approximately 2.1 per cent between 2010 and 2019, thus falling below the annual 2.6 per cent target rate. Therefore, meeting the SDG target will require an improvement rate of at least 3 per cent (figure 14) per year from now until 2030 (UNSD, 2021).

Figure 14. Improvement rate of primary energy intensity, 1990-2017 and 2017-2030 target rate
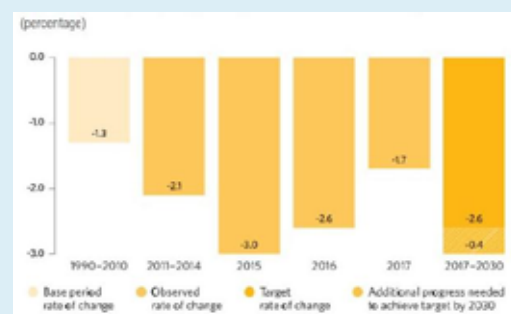
The decrease in energy intensity, compared with the CP scenario, has been due to the energy efficiency improvement in the SDG scenario. As mentioned above, several energy efficiency measures have been implemented in this scenario, which have resulted in energy savings in different sectors. These are:

Residential (additional savings relative to the CP scenario)

A 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)

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

Industry (additional savings relative to CP scenario)

Energy efficiency improvement across all subsectors 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 – an estimated reduction of 212 ktoe in 2030. Subsector specific energy efficiency measures identification was not possible due to 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 subsector is comprised of and what type of appliances are used.

Commercial (additional savings relative to CP scenario)

Encouraging adoption of energy efficiency through energy management in the commercial sector – an 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**
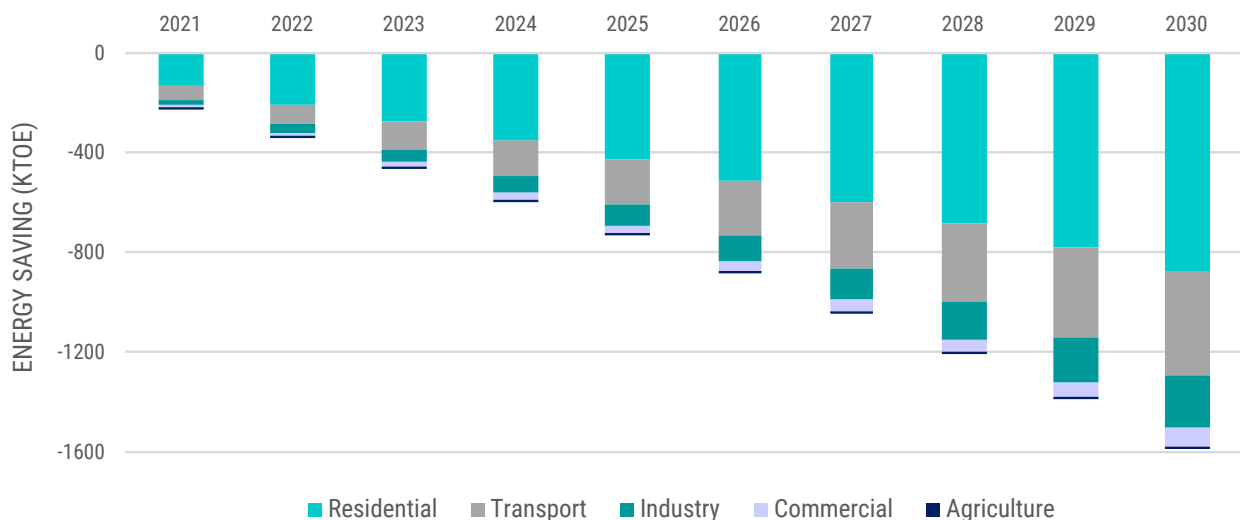
4.2.5. GHG emissions

The emissions from the BAU and CP scenarios are projected to reach 51.8 $MtCO_2$-e and 40.5 $MtCO_2$-e in 2030, respectively. The emission in the SDG scenario is projected to reach 38.4 $MtCO_2$-e in 2030. Figure 19 shows the sectoral emissions (demand side) and total emission in the power sector by scenarios.

Figure 19. Sectoral emission and power sector emissions, by scenario, 2030
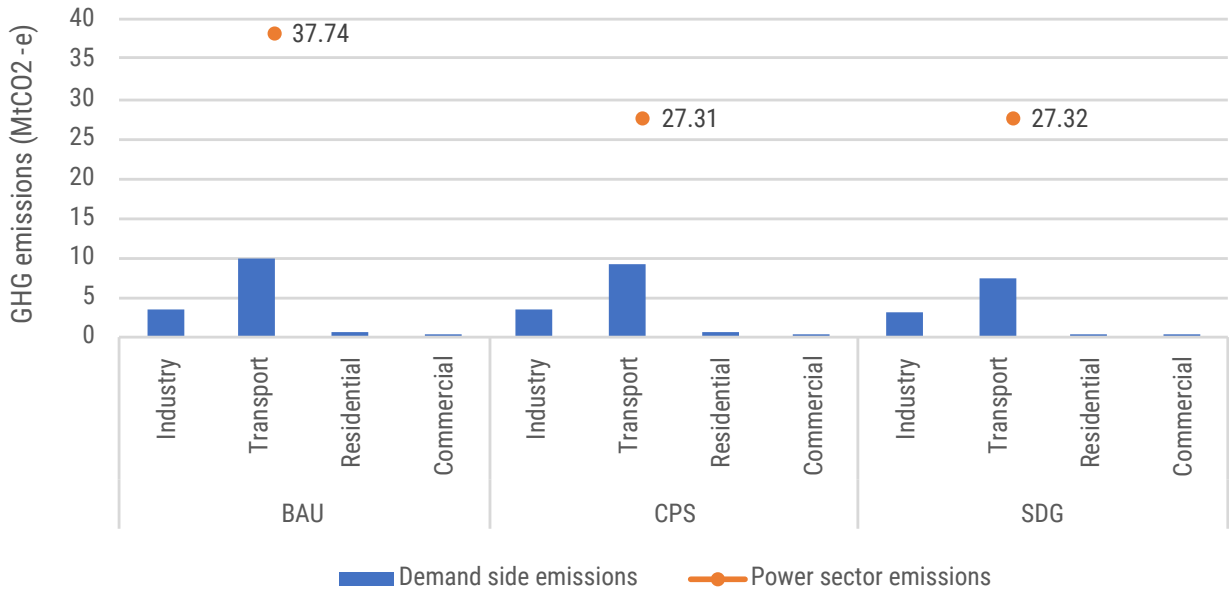
4.3. Power generation in the context of SDG 7

The electricity generation in the SDG scenario is projected to increase from 34.7 TWh in 2019 to 99.7 TWh in 2030. This considered the assumed growth in different economic sectors, the increased power export capacity of the Lao PDR, reaching 88 TWh in 2030. This compares with the 2019 export amount of 28.3 TWh in 2019.

The total generation in 2030 in this scenario is kept at the 99.7 TWh level, to allow optimum export capacity at about 88 TWh in 2030 (figure 20). Figure 21 shows the distribution of total generation, domestic requirement and export in the SDG scenario.

Figure 20. Power capacities, 2021-2030, SDG scenario
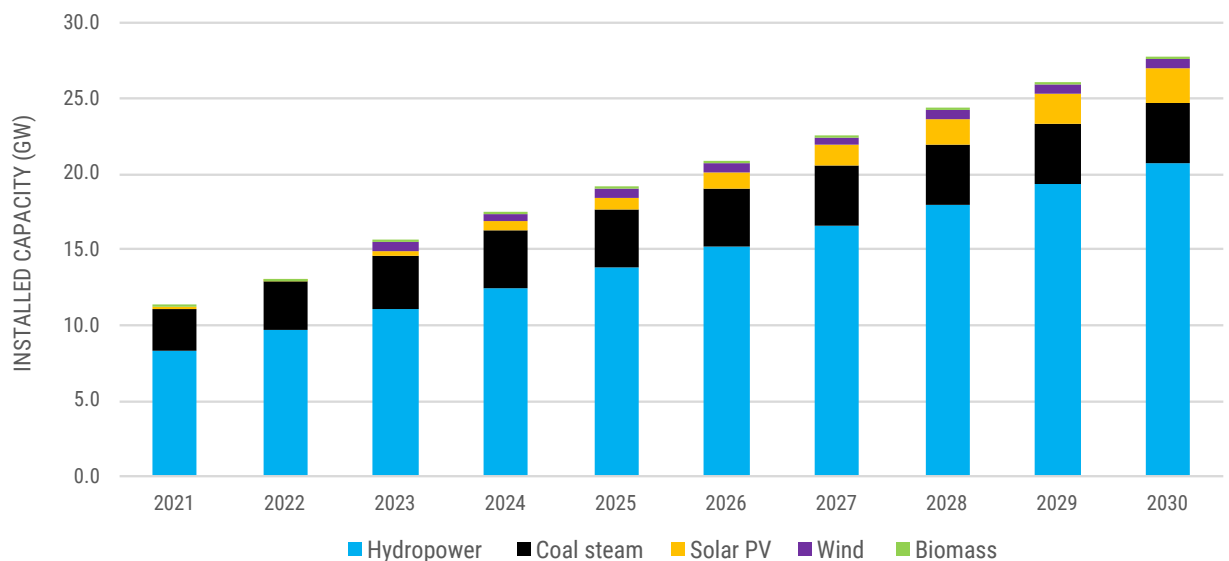
Figure 21. Electricity production, domestic requirement and export, 2021-2030, SDG scenario
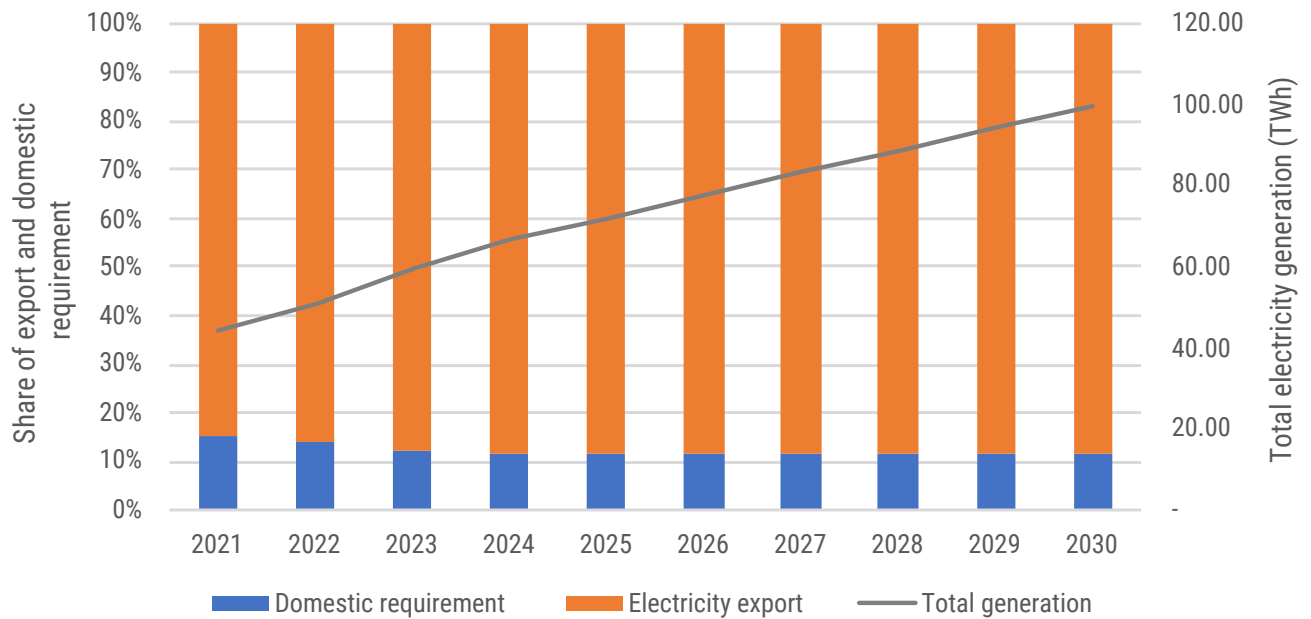
4.4. Investment cost in the power sector

The total investment cost incurred during 2021-2030 stands at around US$ 32 billion. The total net benefit is US$ 18.4 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 the Lao PDR to raise its ambition beyond just achieving the SDG 7 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 SDG 7 targets. These scenarios are expected to provide the Government of the Lao PDR with sufficient 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 the Lao PDR with insights on energy saving potential in different sectors and subsectors. 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 that 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 for reducing 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 the Lao PDR 2011). Energy efficiency improvement also enables the Lao PDR to earn more foreign revenue from exporting electricity to neighbouring countries.

In the BAU and CP scenarios, there has been significant use of traditional biomass in the residential sector (more than 80 per cent), while the SDG scenario replaces all biomass-based cooking with clean fuels and technologies, largely with electric cooking stoves. 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 (the energy saving opportunity in 2030, compared to the CP scenario, is also presented). Table 6 presents key results of the high-energy efficiency scenario.

Residential (additional savings relative to the CP scenario)

A 100 per cent energy efficient appliance penetration by 2030 through minimum energy efficiency performance (MEPS), resulting in savings of 931 ktoe by 2030.

Transport (additional savings relative to CP scenario)

Encouraging the adoption of electric vehicles in the passenger vehicles category, which increases to 50 per cent of market sales by 2030 – an estimated reduction of 948 ktoe in 2030.

Industry (additional savings relative to CP scenario)

The same as in the SDG scenario, i.e., energy efficiency improvement across all subsectors 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 – an estimated reduction of 209 ktoe in 2030

Commercial (additional savings relative to CP scenario)

Encouraging adoption of energy efficiency through energy management in the commercial sector to realise 50 per cent electricity reduction across the sector – an estimated reduction of 140 ktoe in 2030

Table 6. 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 decline to 4,310 ktoe, a reduction of 35 per cent compared to the CP scenario.
Renewable energy	The RE share in TFEC is projected to reach 28.9 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 supply will be 22,441 ktoe in 2030, including primary energy supply for electricity export. This corresponds to an energy intensity of 4.85 MJ/US$$_{2017}$.
Emissions	The overall emissions (including demand and supply) in this scenario would be 36.5 MtCO$_2$-e in 2030 – a reduction of 4.9 per cent compared with the SDG scenario and 9.9 per cent compared with the CP scenario. This corresponds to a 30 per cent emission reduction by the demand sector.
Electricity generation and export	Total electricity generation in this scenario in 2030 is 99.7 TWh, the same as in SDG scenarios. Note that the total generation has been maintained at about the same level to maximise electricity export. In this scenario, electricity available for export would be 88.5 TWh in 2030.
Investment	Total investment in the power sector in this scenario is US$ 32 billion
Net benefits	Total net benefit (difference between revenue and expenditure) is US$ 18.4 billion, the same as in the SDG scenario

5.2. Coal phase-out scenario

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

A 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 7 shows further coal-fired plants in pipeline:

Table 7.   **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 Fired 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 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 utilized 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: (a) no new coal generation after 2020; (b) a reduction in coal for power generation by 63 per cent below 2010 levels in non-OECD countries by 2030; and (c) full phase-out across Asia-Pacific by 2040 (ESCAP, 2021b).

5.2.3. Coal-fired power plants pose future economic risks

Apart from GHG emissions (in the CP scenario, coal-fired power plants will be responsible for 67 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 reductions of renewable energy technologies. Solar Photovoltaic (PV) onshore wind are already cheaper than coal-fired power (IEA, 2020). In addition, recent auctions and power purchase agreements (PPAs) indicate that based on competitive procurement, the average LCOE of solar PV would be 39 US$/MWh for the projects commissioned in 2021, more than one-fifth less than coal-fired power plants (IRENA, 2019). Evidence of auction prices for solar PV in Abu Dhabi, Chile, Ethiopia, Mexico, Peru and Saudi Arabia show that 30 USD/MWh is already possible. A recent ADB-supported RE auction in Cambodia has seen a utility-scale solar PV price of 30 US$/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 plants and an increase in renewables in power generation, mainly solar and biomass. Wind technology is seen as not having much potential in the Lao PDR.

5.2.4. Power sector strategy in the coal phase-out scenario

Tables 8 and 9 show the power capacity mix and generation mix in this scenario. The existing coal (1,878 MW) plant will remain in the system, but generation will 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 8. Power capacity mix in the coal phase-out scenario (GW), 2021-2030

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hydro	7.2	8.0	10.7	13.3	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	0.0	0.1	0.2	0.3	0.5	0.5	0.6	0.7	0.8	0.9
Solar	0.0	1.0	3.3	5.6	7.9	8.6	9.3	10.0	10.8	11.5
Wind	-	-	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Total	**9.1**	**11.0**	**16.6**	**21.7**	**26.8**	**29.0**	**31.2**	**33.4**	**35.7**	**37.9**

Table 9. Generation mix in the coal phase-out scenario (TWh), 2021-2030

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hydro PP	25.1	28.0	37.4	46.7	56.1	61.0	65.9	70.8	75.7	80.6
Coal steam	-	-	-	-	-	-	-	-	-	-
Biomass	0.2	0.5	1.0	1.6	2.2	2.6	3.0	3.5	3.9	4.3
Solar PP	0.1	1.8	5.8	9.8	13.8	15.0	16.3	17.6	18.9	20.1
Wind	-	-	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Total	**25.3**	**30.3**	**46.0**	**59.9**	**73.8**	**80.4**	**87.0**	**93.6**	**100.2**	**106.9**

5.2.5. Resources potential check

Hydropower resources in the country are 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, a 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 at the Nam Ngoma 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 the Lao PDR, the solar PV capacity in this scenario has been extended to 11.5 GW. Table 10 presents key results and findings of the coal phase out scenario.

Table 10. Key results of the coal phase-out scenario

Indicators	Results and observations
Energy demand outlook	Same as in the SDG scenario
Renewable energy	The RE share in TFEC is projected to reach 34.1 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 supply will be 19,218 ktoe in 2030, including primary energy supply for electricity export. This corresponds to an energy intensity of 4.1 MJ/US$$_{2017}$. The SDG 7 energy efficiency target is almost achieved in this scenario.
Emissions	This scenario achieves a significant reduction in emissions – it reaches 9.3 Mt-CO_2-e in 2030, a drop of 84 per cent compared to the CP scenario. This is due to the removal of coal from the power sector.
Electricity generation and export	The power sector is fully decarbonised in this scenario, with generation from hydro, solar and biomass. Total electricity generation in this scenario in 2030 is 106.9 TWh,
Investment	Total investment in the power sector in this scenario is US$ 44.1 billion
Net benefits	Total net benefit (difference between revenue and expenditure) is US$ 11.9 billion, which is 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$ 30.5 billion, 54 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 the 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 have an impact on the socio-economic condition of people who are already in this sector.

The Government of Lao the 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 term. 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 will be critical.

3. Establish funds and authority for a just transition. Specialist funds are being established to oversee, develop and implement coal transition programmes. The European Commission's Coal and Carbon-intensive Regions in Transition initiative is investing funds in 13 coal regions.

The current policy, SDG and the ambitious scenarios have been evaluated and ranked, using the Multi- Criteria Decision Analysis (MCDA) tool, with a set of 12 criteria and weights assigned to each criterion (table 11). While the criteria and weights have been selected based on expert judgement, ideally the process should use a stakeholder consultation. If deemed necessary, this step can be repeated using the NEXSTEP tool in consultation with stakeholders where the participants may want to change weights of each criterion. The following factors have been considered to assume comparative weights across the set of criteria, where the total weight needs to be 100 per cent:

(a) Universal access to electricity to be achieved;

(b) Universal access to clean cooking fuel to be achieved;

(c) Renewable energy share in the total final energy consumption to increase;

(d) Energy efficiency improvement should be doubled and, where there is an economic benefit, it should be further enhanced;

(e) The unconditional NDC target should be achieved. Where possible, the conditional target should be achieved, if it is economically viable;

(f) Total investment should be kept low, but the net benefit should be high. This was done by assigning both indicators the same weight to ensure that a scenario is chosen on the value-for-money basis; and

(g) Carbon pricing should be introduced to encourage investments in clean energy.

6. Scenario ranking

Table 10. Criteria with assigned weights for MCDA

Criterion	Weight (%)
Access to clean cooking fuel	10
Energy efficiency	10
Share of renewable energy	11
Emissions in 2030	10
Alignment with PA	10
Fossil fuel subsidy phased out	5
Price on carbon	3
Fossil fuel phase-out	5
Cost of access to electricity	7
Cost of access to clean cooking fuel	7
Investment cost	10
Net benefit from the power sector	10

Table 12 shows the summary of results obtained through this evaluation process. The scenario recommendation suggests that the ambitious scenario, "coal phase out" scenario, is the highest-ranked energy transition pathway for the Lao PDR.

Table 11. Scenario ranking based on MCDA

Scenario	Weighted scores	Rank
Coal phase out scenario	39.1	1
High energy efficiency scenario	36.2	2
SDG scenario	26.8	3
Current policy scenario	24.5	4
Business-as-usual scenario	18.6	5

Based on the above analysis, this roadmap recommends that the Lao PDR consider the adoption of the Coal Phase-Out scenario.

The Lao PDR has progressed well with access to electricity but is lagging with other SDG 7 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 suite of SDG 7 targets.

7.1. 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 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 will be 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 seems to be one of the biggest challenges for the Lao PDR, as it has one of the lowest access rates to date. Immediate well-planned policy measures need 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 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.

7.2. Economy-wide intensive energy efficiency improvement is needed

Economy-wide intensive energy efficiency improvement is needed to achieve the energy

7. Policy recommendations

intensity reduction target. Achievement of the energy efficiency target is considered to be the second-biggest challenge for the Lao PDR. Energy efficiency has been going in the wrong direction for the Lao PDR since 2011 and 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 needed with a whole-economy approach. Energy intensity in the country has been going upwards instead of declining as required in the SDG 7 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 the Lao PDR should at least aim for the global improvement rate by setting the target of 4 MJ/US$. 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.

7.3. Transport electrification strategies provide multi-fold benefits

Rapid promotion of electric vehicles should be considered as an important element not only to reduce energy consumption' but also to reduce reliance on imported fuel. The 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. The 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 the Lao PDR's reliance on imported petroleum fuels. At the same time, it can contribute to climate mitigation and improvement of the local air quality.

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

Phasing out coal from the power sector should be considered in order to benefit from the lower cost of electricity generation, reduce the risk of stranded assets and to align the energy transition with the global call for coal phase-out. The Lao PDR's power sector has been largely reliant on hydro with a small amount of coal recently added to the fleet, which has been planned for expansion in near future. However, while coal-based power generation is not only hazardous to the environment and public health, it is also uneconomic in the long term. Currently, more than 65 per cent emission of the power sector is from coal burning, and estimated to rise to more than 80 per cent in 2030. Furthermore, there are global calls for coal phase-out, suggesting that countries in the Asia-Pacific region 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 a justified choice for the Lao PDR's energy transition. This would also be in alignment with the global move to phasing out coal as well as progressing towards net zero carbon by 2050. The Lao PDR's coal industry is relatively new and thus it would be easier to transition to alternative energy sources and technologies, particularly 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 having an impact on the electricity export market. While there are challenges to be faced in doing so, international experiences and lessons learnt from other countries suggest that an early start in planning, detailed consultations with stakeholders and international communities, and developing a well thought-out, long-term 'just' transition plan will minimize socio-economic risks.

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 the Lao PDR, albeit less intensively than other countries. The Lao PDR's economy contracted to 4.7 per cent in 2019 and then dived deep to -0.5 per cent in 2020. Nevertheless, the economy is projected to return to a 6.5 per cent growth rate in 2030, according to the Asian Development Bank (ADB, 2021).

Experts believe that transitioning to a sustainable energy future, e.g., planning the energy sector in alignment with SDG 7, NDC and the Paris Agreement's long-term temperature goal, can help countries to 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 which 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.

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

8.1. 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.

The 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.

8.2. Savings from the energy sector will help to build other sectors

The NEXSTEP analysis shows that there are ample opportunities for the 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. In addition, reducing coal burning and increasing renewables in the power sector will further improve public health and local environment, while it will also bring positive economic return.

8.3. 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 targeted and thus lead to unintended consequences, as they 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.

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 to create a more sustainable and resilient society. This roadmap has presented five different scenarios together 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 as well as reducing coal-fired power generation in line with the global call for coal phase-out.

The 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 programme for improving this area, except ad hoc programmes to provide improved cooking stoves 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 cooking stoves would help in reaching out to people at different levels and locations. While electric cooking stoves 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 to reach out to households that do not have reliable electricity connection. A deeper study to better formulate the policy intervention would an ideal pathway, but it needs to be done immediately.

Energy efficiency in the Lao PDR has been travelling in the wrong direction compared to the global trend and the SDG 7 target – the energy intensity has been gradually increasing since 2011. This poses a huge challenge in achieving this target.

9. Conclusion

The NEXSTEP analysis suggests that it would be difficult for the Lao PDR to achieve the SDG 7 target for energy efficiency, as defined by the SDG 7 methodology. In this regard, the roadmap suggests that the Lao PDR should at least aim for the global improvement rate by setting the target of 4 MJ/US$. 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.

The Lao PDR's NDC does not explicitly 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 67 per cent of 40.5 $MtCO_2$-e in 2030 under the current policy scenario. Therefore, an emission reduction target is unlikely to be possible without reducing or eliminating coal from the energy system. This analysis has found that if a coal phase-out is implemented as suggested in this roadmap, then Lao PDR can commit up to an 84 per cent emission reduction. This can be a conditional target as the Government will require international support in transitioning away from coal. Based on the scenario ranking using the Multi-Criteria Decision Analysis tool, the coal phase out scenario ranks the highest in terms of socio-economic and environmental benefits. The Lao PDR should consider adopting this scenario.

The Lao PDR's power sector has been largely reliant on hydro, with a 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 to the environment and public health but also it is uneconomic in the long term. Currently, more than 70 per cent emissions by the power sector are from coal burning which will rise to more than 71 per cent in 2030 in the SDG scenario. Furthermore, there are global calls for coal phase-out, suggesting countries in the Asia-Pacific region to phase out coal by 2040. Technology-wise, with a very large renewable energy resources potential, the Lao PDR is well-positioned to take this journey. Policymakers need to start the transition plan early by consulting with stakeholders and international communities in developing 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.

References

ADB (2019a). "ADB-Supported Solar Project in Cambodia Achieves Lowest-Ever Tariff in ASEAN." Asian Development Bank. Cambodia. 5 September 2019. Available at https://www.adb.org/news/adb-supported-solar-project-cambodia-achieves-lowest-ever-tariff-asean

––– (2019b). "Lao People's Democratic Republic Energy Sector Assessment, Strategy, and Road Map." Available at https://www.adb.org/sites/default/files/institutional-document/547396/lao-pdr-energy-assessment-2019.pdf

––– (2021). "Economic Indicators for the Lao PDR." Asian Development Bank. Lao People's Democratic Republic. 14 May 2021. Available at https://www.adb.org/countries/lao-pdr/economy

AGEP (2018). "ASEAN-German Energy Programme - Country Profile: Lao PDR." 2018. Available at https://agep.aseanenergy.org/wp-content/uploads/2018/05/2017_Country-Profile_LA-Lao-PDR_RF-HF-2.pdf

ERIA (2020). "Lao PDR Energy Outlook 2020." Jakarta: Economic Research Institute for ASEAN and East Asia.

ESCAP (2021a). "Asia Pacific Energy Portal." 2021. Available at http://asiapacificenergy.org/#en

____ (2021b). "Coal Phase out and Energy Transition Pathways for Asia and the Pacific." Available at https://www.unescap.org/kp/2021/coal-phase-out-and-energy-transition-pathways-asia-and-pacific

ESMAP (2015). "Multi-Tier Framework for Measuring Energy Access." Available at https://www.esmap.org/node/55526

GCF, Lao (2019). "GCF Readiness Proposal - Lao PDR." Green Climate Fund.

GIZ (2021). "10 Facts on Climate Change in the Lao PDR - ProCEEd." Available at https://www.giz.de/en/downloads/giz2014-en-10-facts-climate-change-laos.pdf

Government of the Lao PDR (2011). "Renewable Energy Development Strategy in the Lao PDR."

IEA (2020). "Projected Costs of Generating Electricity 2020." Available at https://www.iea.org/reports/projected-costs-of-generating-electricity-2020

IRENA (2019). "Renewables Increasingly Beat Even Cheapest Coal Competitors on Cost." Available at https/Newsroom/Pressreleases/2020/Jun/Renewables-Increasingly-Beat-Even-Cheapest-Coal-Competitors-on-Cost. 2019. /newsroom/pressreleases/2020/Jun/Renewables-Increasingly-Beat-Even-Cheapest-Coal-Competitors-on-Cost

Ministry of Planning and Investment (2016). "8th Five-Year National Socio-Economic Development Plan (2016-2020)." Available at https://laopdr.un.org/sites/default/files/2019-08/2016_8th%20NSEDP_2016-2020_English.pdf

Pham, Long (2019). "Can Nam Ngum Solar Replace Mekong Hydro in Laos?" Pv Magazine International. November 2019. Available at https://www.pv-magazine.com/2019/11/01/can-nam-ngum-solar-replace-mekong-hydro-in-laos/

Tran, Bach Xuan and others (2020). "Impact of COVID-19 on Economic Well-Being and Quality of Life of the Vietnamese During the National Social Distancing." Frontiers in Psychology 11. Available at https://doi.org/10.3389/fpsyg.2020.565153

World Bank 2018). "Super-Clean Cookstove, Innovative Financing in Lao PDR Project Promise Results for Women and Climate." Text/HTML. Available at https://www.worldbank.org/en/news/feature/2018/04/20/clean-cookstove-innovative-financing-lao-pdr-project-promise-results-women-climate

––– 2019. "Lao PDR Clean Cook Stove Initiative." Text/HTML. Available at https://projects.worldbank.org/en/projects-operations/project-detail/P169538

––– (2021). "World Bank Country and Lending Groups." \Available at https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.