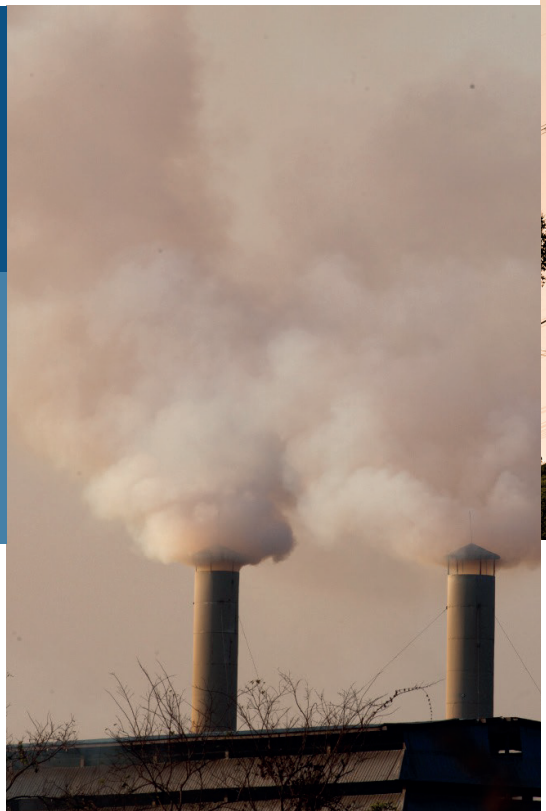
Public Disclosure Authorized
Public Disclosure Authorized
Public Disclosure Authorized





Technical Recommendations for Lao People's Democratic Republic Long-Term Low Emission Development Strategy





June 2024

THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP

COPYRIGHT

© 2024 The World Bank

1818 H Street NW, Washington DC 20433
Telephone: 202-473-1000; Internet: www.worldbank.org

Some rights reserved.

This work is a product of The World Bank. The findings, interpretations, and conclusions expressed in this work do not necessarily reflect the views of the Executive Directors of The World Bank or the governments they represent.

The World Bank does not guarantee the accuracy, completeness, or currency of the data included in this work and does not assume responsibility for any errors, omissions, or discrepancies in the information, or liability with respect to the use of or failure to use the information, methods, processes, or conclusions set forth. The boundaries, colors, denominations, links/footnotes and other information shown in this work do not imply any judgment on the part of The World Bank concerning the legal status of any territory or the endorsement or acceptance of such boundaries. The citation of works authored by others does not mean the World Bank endorses the views expressed by those authors or the content of their works.

Nothing herein shall constitute or be construed or considered to be a limitation upon or waiver of the privileges and immunities of The World Bank, all of which are specifically reserved.

RIGHTS AND PERMISSIONS

The material in this work is subject to copyright. Because The World Bank encourages dissemination of its knowledge, this work may be reproduced, in whole or in part, for noncommercial purposes as long as full attribution to this work is given.

Attribution—Please cite the work as follows: "World Bank. 2024. Technical Recommendations for Lao People's Democratic Republic Long Term Low Emission Development Strategy. © World Bank."

Cover images (from top, clockwise):
1. © World Bank / Bart Verweij; 2. © World Bank /Souksavanh Sombounkhanh; 3. © World Bank / Aiden Glendinning; 4. © World Bank / Bart Verweij; 5. © World Bank / Xaisongkham Induangchanthy.

Any queries on rights and licenses, including subsidiary rights, should be addressed to World Bank Publications, The World Bank, 1818 H Street NW, Washington, DC 20433, USA; fax: 202-522-2625; e-mail: pubrights@worldbank.org.

CONTENTS

ABBREVIATIONS AND ACRONYMS 4

INTRODUCTION 6

Purpose and Objectives 6
Overview 6

LT-LEDS TECHNICAL RECOMMENDATIONS DEVELOPMENT PROCESS 9

Approach and Phases 9
Stakeholder Participation 11
LT-LEDS Modelling Approach 11

BUSINESS AS USUAL (BAU) SCENARIO 20

Socio-economic Development Context 20
Energy Sector Context 21
Resource Sectors Context 22
Business-as usual GHG Emissions Estimates 23
Assumptions and Data Sources 28

LT-LEDS ACTIONS 30

ESTIMATED IMPACTS OF THE LT-LEDS ACTIONS 39

Overview 39
Estimated GHG Emission Impacts 39
Introduction 39
Economy-wide Results 40
Estimated Costs and Savings 43
Introduction 43
Economy-wide Results 43
The importance of decarbonizing electricity generation to achieve the net zero target and savings 48
The Proposed LT-LEDS Scenario for the Energy Sector 48
Implications of not replacing coal-generated electricity for export 51
The contribution of the transportation sector to achieve the net zero target 55
The contribution of the forestry sector to achieve the net zero target 56
Economic Implications 58
Lao PDR Macroeconomic Context 58
Methodology 59
Economy-wide Key Findings 61
Adaptation Co-benefits 64
Introduction 64
Economy-wide Key Findings 65

CONSIDERATIONS FOR IMPLEMENTATION 70

CONCLUSIONS AND RECOMMENDATIONS 79

LIST OF ANNEXES 81

ACKNOWLEDGMENTS

Technical Recommendations for Lao People's Democratic Republic Long-Term Low Emission Development Strategy is a sub-task of the programmatic Advisory Services, and Analytics called Supporting Climate Change and Green Growth Action in Lao People's Democratic Republic (the Lao PDR). This study was requested by the government of Lao PDR as part of the ongoing support of the World Bank to the government on Green Growth development.

A World Bank team carried out the task. However, it was only possible with the cooperation of government ministries and consultation with development partners, private sector actors, nongovernmental organizations and academia. The World Bank team also appreciates the close cooperation and engagement with the Ministry of Natural Resources and Environment and the Ministry of Planning and Investment.

The Climate Support Facility provided funding for the work. This was complemented by the World Bank operating budget. Strategic guidance was provided by World Bank management, including Mona Sur (Manager for Environment and Natural Resources for East Asia and Pacific).

Tao Wang and Maurice Andres Rawlins (Senior Environmental Specialists) led the World Bank team for this report. The team included Alexander Lotsch (Senior Climate Change Specialist); Shinya Nishimura (Senior Financial Specialist); Soudalath Silaphet (Engagement Specialist); Steve Long (Climate Change Specialist); Souksavanh Sombounkhanh (Program Assistant); and Anorath Douangphachanh (Program Assistant).

The Centre for Climate Strategies, with the support of Earth System and Care International Laos conducted the analysis and drafted the report.

ABBREVIATIONS AND ACRONYMS

$	USD
BRT	Bus Rapid Transit
CCS	Carbon Capture and Storage
CID	Climate Impact Drivers
CO2e	Carbon dioxide equivalent
DAFO	District Office of Agriculture and Forestry
DALAM-MAF	Department of Agricultural Land Management, Ministry of Agriculture and Forestry
DCC	Ministry of Natural Resources and Environment, Department of Climate Change
DEB-MEM	Department of Energy Business, Ministry of Energy and Mines
DEEP-MEM	Department of Energy Efficiency Promotion, Ministry of Energy and Mines
DHUP-MPWT	Department of Housing and Urban Planning, Ministry of Public Works and Transport
DIH-MOIC	Department of Industry and Handicraft, Ministry of Industry and Commerce
DOA-MAF	Department of Agriculture, Ministry of Agriculture and Forestry
DoC-MOF	Department of Customs, Ministry of Finance
DoIE-MOIC	Department of Imports and Exports, Ministry of Industry and Commerce
DOP	Ministry of Planning and Investment, Department of Planning
DoR-MPWT	Department of Roads, Ministry of Public Works and Transport
DOT-MPWT	Department of Transport, Ministry of Public Works and Transport
DSMEP-MOIC	Department of Small and Medium Enterprise Promotion, Ministry of Industry and Commerce
EV	Electric Vehicle
GACMO	Greenhouse Gas Abatement Cost Model
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
GOL	Government of Lao PDR
LT-LEDS	Long-Term Low Emissions Development Strategy
MAF	Ministry of Agriculture and Forestry
MEM	Ministry of Energy and Mines
MMtCO2e	Million metric tons of carbon dioxide equivalent
MOIC	Ministry of Industry and Commerce
MONRE	Ministry of Natural Resources and Environment
MPI	Ministry of Planning and Investment
MPWT	Ministry of Public Works and Transport
NDC	Nationally Determined Contribution
NPV	Net Present Value
NSEDP	9th National Socio-Economic Development Plan
PAFO	Provincial Office of Agriculture and Forestry

RCI	Residential, Commercial, and Institutional
RE	Renewable Energy
TWG	Technical Working Group
VCOMS	Vientiane City Office for Management and Service

1. INTRODUCTION

1.1. Purpose and Objectives

This report presents technical recommendations for the Lao People's Democratic Republic's Long-Term Low-Emission Development Strategy (LT-LEDS) and its implementation. An LT-LEDS is a strategic document that outlines a country's plan under the Paris Agreement for low-emission development by mid-century. The recommendations were developed based on Lao PDR's 2050 net-zero greenhouse gas (GHG) emissions target outlined in its revised nationally determined contributions (NDCs)[1] and in close consultation with the Department of Climate Change of the Ministry of Natural Resources and Environment (DCC-MONRE) and the Department of Planning of the Ministry of Planning and Investment as the government's designated leading agencies. The analysis takes the net-zero emissions target as a given parameter for modelling and recommendations but does not assess this target or its implications for Lao PDR's development. Similarly, actions included in the NDC Implementation Plan issued by the government are automatically included in the BAU scenario.

This report presents a comprehensive technical assessment and recommendations that inform the development of Lao PDR LT-LEDS, which can be submitted to the United Nations Framework Convention on Climate Change under Article 4, Paragraph 19 of the Paris Agreement.[2] Moreover, these recommendations can be incorporated into Lao PDR's forthcoming 10th National Socio-economic Development Plan.

Lao PDR's transition to a low-carbon development pathway has started to a certain extent through various policies, programs, and initiatives. These include the NDC, the National Green Growth Strategy of the Lao PDR until 2030,[3] the 9th National Socio-Economic Development Plan (NSEDP),[4] the National Strategy on Climate Change of the Lao PDR,[5] among others. **Delivering on the existing commitments and plans puts Lao PDR on track to low emissions development, but more needs to be done to achieve the 2050 Net Zero Target.**

1.2. Overview

Building on past, current, and planned efforts, **the LT-LEDS lays out a net zero emission development pathway for Lao PDR that includes a portfolio of 41 priority low-emission development actions and implementation considerations across economic sectors. The successful implementation of the LT-LEDS depends on the conditions that macroeconomic stability and fiscal space are restored, productive capabilities (e.g., skills, knowledge, and innovation potential) are improved, and significant policy reforms are carried out.**

[1] Lao PDR submitted its 1st INDC (Intended Nationally Determined Contribution) in 2015 and the 2nd NDC in 2020. The NDC 2020 sets out both unconditional and conditional GHG emission reduction targets to 2030 and indicates a nets zero 2050 target. The 2nd NDC tracks progress of measures specified in the INDC and also provides new, more specific targets that represent an increase in ambition from the INDC. 2020 GHG emissions estimates in the 2nd NDC are calculated using 2000 as the base year. The NDC is available at https://unfccc.int/sites/default/files/NDC/2022-06/NDC-2020-of-Lao-PDR-English%29%2C%2009%20April%202021%20%281%29.pdf

[2] In accordance with Article 4, paragraph 19, of the Paris Agreement, all Parties should strive to formulate and communicate mid-century long-term low GHG emission development strategies to the UNFCCC in the light of different national circumstances, Long-term strategies portal | UNFCCC.

[3] National Green Growth Strategy of the Lao PDR till 2030

[4] National Socio-Economic Development Plan (NSEDP)

[5] National Strategy on Climate Change of the Lao PDR

The net zero pathway for Lao PDR identifies key GHG emission reduction opportunities against the business-as-usual (BAU) scenario. They reflect the following **key cost-effective transformations of the Lao PDR's economy:**

Decarbonize electricity generation	• Increase of renewable electricity generation (solar and wind) with storage • Strengthening of the grid systems and regional interconncetion lines • Scale down operation and shut down existing coal plants (Hongsa and Sepon) and moratorium of installation of planned ones (Bualapha, Sekong- Kaleum, and Sekong-Lamam)
Electrify end- uses	• Replacement of wood/charcoal cookstoves in residential and commercial buildings • Expansion of electric vehicles (light-, medium- and heavy-duty) and charging infrastructures • Expansion of electrification of industrial end-uses
Reduce energy consumption	• Expansion of efficiency measures and upgrades for appliances, cookstoves • Expansion of efficiency measures and upgrades for buildings • Expansion of efficiency measures and upgrades for industrial processes
Expand climate-smart agriculture	• Expansion of agroforestry systems • Establishment of rice cultivation irrigation systems • Promotion of fertilizer management • Expansion of manure practices
Increase carbon sequestration	• Avoiding deforestation • Expanding forest management and restoration
Expand sustainable waste management	• Increase of composting and recycling • Expansion of waste reduction • Expansion of waste-to-energy systems

As detailed in the following sections of this report, **the implementation of the above transformations requires GoL to enhance its long-term planning, implement significant policy reforms and close institutional, regulatory, financial, and capacity gaps.** Of particular relevance is the need for Laos PDR to:

i. Restore *macroeconomic stability and fiscal space* to enable the needed investments across sectors and successful implementation of the LT-LEDS actions.

ii. Engage in *long-term power sector planning* with Thailand and other neighboring countries *scaling up solar and wind energy* and build the needed infrastructure for regional power trade (energy storage, such as pumped storage hydro and battery storage systems, regional interconnection lines, strengthened transmission and distribution grid). These steps will support the phase-out of the coal power plants by 2050 and the transition to export of renewable (solar and wind) generated electricity.

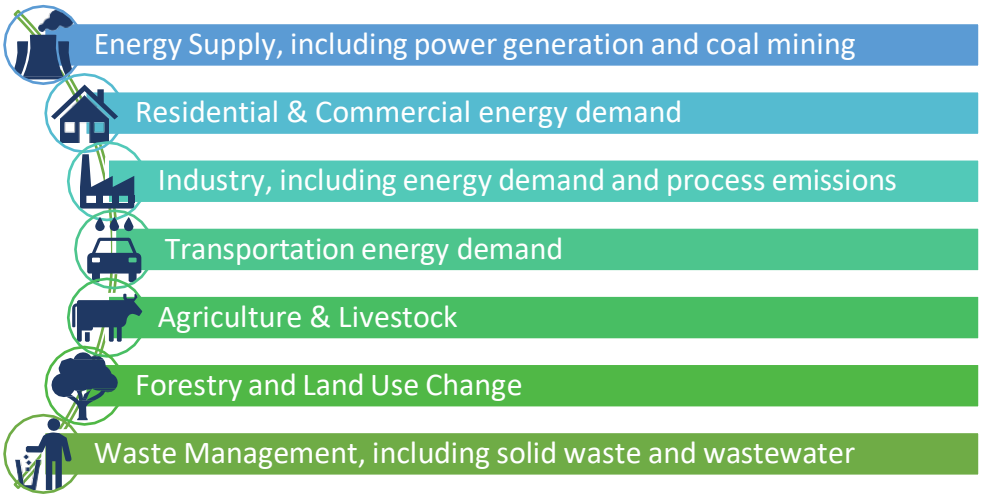
iii. Access *sustainable and impactful forms of financing* and *engage with the private sector* to incentivize the transition to new practices and technologies.

iv. Balance competing demands of multiple land uses and *address economic drivers of deforestation* while generating sufficient revenues and socio-economic opportunities; and

v. Improve *productive capabilities* (e.g., skills, knowledge, and innovation potential) through investments in *workforce development and education* to support new local supply chains and create new job opportunities.

It is recommended that the GoL starts the implementation of the LT-LEDS while working on the above conditions. The implementation of some LT-LEDS actions such as increased reforestation, expanded forest management and energy efficiency measures are less dependent on the above conditions to the extent that they do not require significant upfront investments or changes in the enabling environment.

The process for developing the LT-LEDS recommendations was launched in September 2022 and covered the following key economic sectors in Lao PDR:



Consultations were conducted with the governmental agencies through the Steering Committee and the sector-level technical working group (TWG). The TWG was formed in January 2023 and convened by DCC-MONRE to support collection of data and validation of assumptions and analytical findings. The inputs and comments provided by TWG were limited. The Steering Committee was established in November 2023 and provided comments to the proposed recommendations. In the above context, this report was developed based on the best available data, expert judgment, and assumptions. In February 2024, the Steering Committee endorsed the LT-LEDS technical recommendations laid out in this report.

The LT-LEDS is aligned with Laos' NDC Implementation Plan. As the NDC implementation plan was issued in August 2023 (i.e., after the LT-LEDS assessment was completed) and the underlying analysis was not made available, the actions indicated in the NDC Implementation Plan were incorporated into the LT-LEDS to the extent possible (see Section 3.5 for more details). **The LT-LEDS recommendations were developed building on the assumption that the NDC Implementation Plan will be fully carried out by 2030**.

2. LT-LEDS TECHNICAL RECOMMENDATIONS DEVELOPMENT PROCESS

2.1. Approach and Phases

The LT-LEDS recommendations were developed in coordination with DCC-MONRE and DOP-MPI through a phased, inclusive approach that:

- **Built on past, current, and planned strategies and assessments** (see section above). This streamlined the process of identifying a prioritized set of manageable and implementable low-emission development actions and key initial implementation recommendations.
- **Created opportunities for engagement with a broad set of stakeholders** across Lao PDR key sectors (such as forestry, agriculture, and industry) in an inclusive, effective, and tailored manner.
- **Used transparent methodologies** according to internationally recognized GHG accounting principles, IPCC guidelines, and best practices to enable review, validation, and future updates of LT-LEDS actions and analyses.

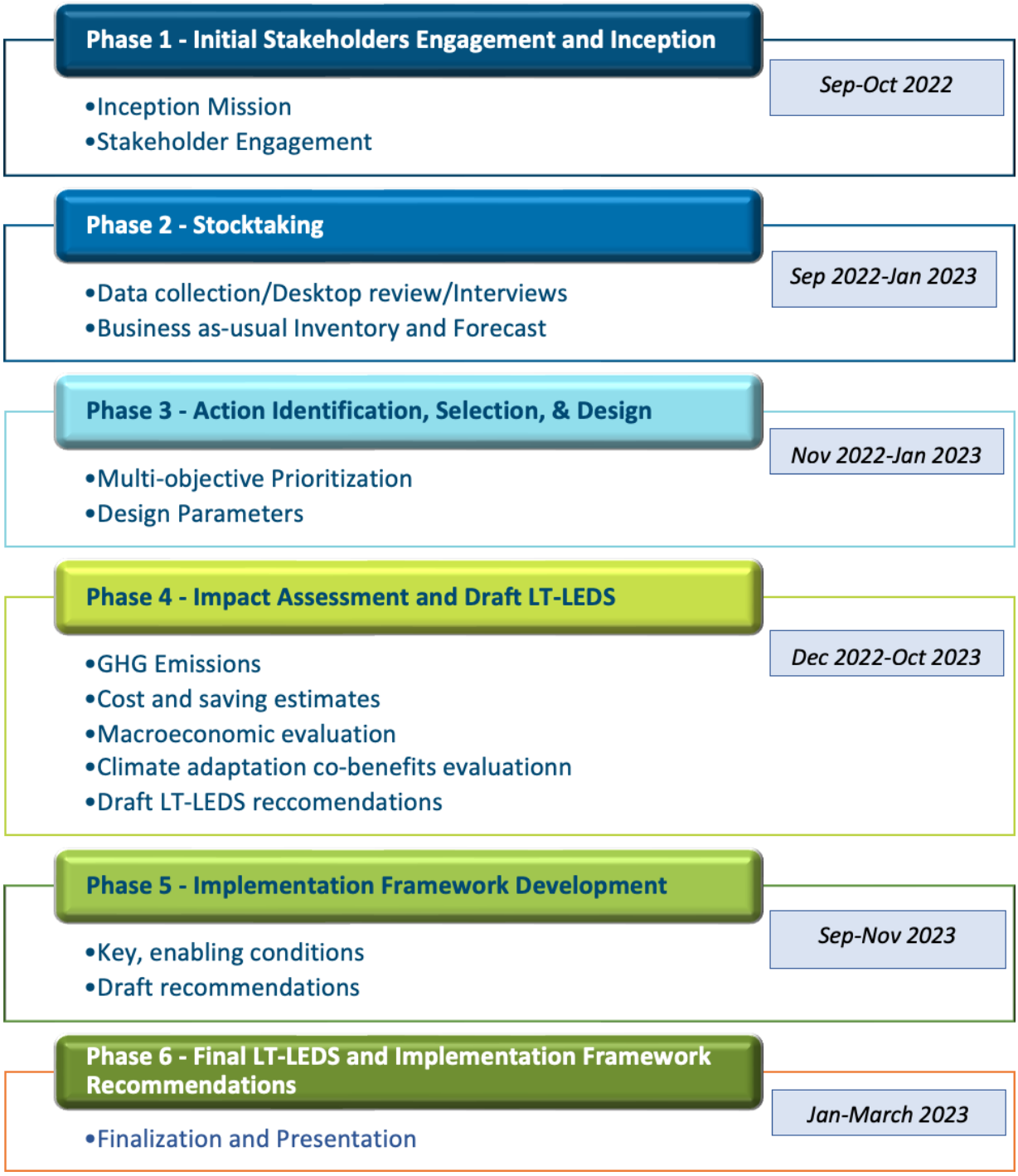
In consideration of the timeline and resources available, **the approach sought to balance the level of effort dedicated to *(i)* the stakeholders' engagement and *(ii)* the analysis/modelling component**. To this end:

- The **stakeholder engagement process was carried out in parallel with the analytical work** and focused on gathering initial inputs and targeted feedback on key milestones and deliverables.
- The **analysis leveraged models and tools, as well as data inputs previously used in Lao PDR**. In particular, the Greenhouse Gas Abatement Cost Model (GACMO)[6] was used to quantify GHG emission reductions, costs, and savings of the LT-LEDS actions. For more details see section 2-3 below

The LT-LEDS recommendations were developed through a **phased approach** summarized in Figure *2-1* below.

[6] The Greenhouse Gas Abatement Cost Model (GACMO) | NDC Action Project (unep.org)

FIGURE 2-1. Key Phases of the LT-LEDS Development Process



Source: Authors

2.2. Stakeholder Participation

A stakeholder engagement plan was developed during the inception phase of the project. It was implemented to facilitate an open and transparent two-way engagement with the GoL, non-government organizations, the private sector, and other interested parties. The key objectives of the stakeholder engagement were to:

- Ensure that all relevant stakeholders were well-informed of the LT-LEDS development process and its objectives.
- Understand the stakeholders' priorities and needs, as well as the challenges and issues they face in developing and implementing low emission projects and activities.
- Incorporate stakeholders' review and inputs into project deliverables, including the assumptions for analysis, the list of actions, and impact assessment results.

The full list of stakeholders engaged during the project is provided in Annex A. **In order to facilitate technical discussion and review, a TWG with seven sector-level sub-groups was established and convened by DCC-MONRE** to support the collection of data, definition of assumptions for analysis and identification of LT-LEDS actions in all sectors. **A steering committee - a governance body represented by high-level officials from the various ministries and governmental agencies – was established to review and validate the final LT-LEDS recommendations**. In February 2024, the Steering Committee endorsed the LT-LEDS technical recommendations laid out in this report.

Stakeholders were engaged through workshop meetings (in-person, remote and hybrid), bilateral discussions (in-person and remote), and remote working sessions. Details on stakeholder engagement activities are provided in Annex 2. **A targeted engagement was conducted for local communities** in order to gather their input, understand their challenges, and ensure that the LT-LEDS recommendations address their needs and priorities. In particular, communities from two sample provinces - one in Phongsaly in the north and one in Sekong in the south of the country - were selected for the consultation covering eight villages with different ethnic minority groups. **Their inputs were incorporated in the design and implementation assumptions of the LT-LEDS actions.** More details on the local communities' consultations and the inputs gathered are provided in Annex 3.

2.3. LT-LEDS Modelling Approach

As mentioned earlier, the GACMO[7] model was used to quantify GHG emission reductions and direct costs and savings (including investment needs) of the LT-LEDS actions. GACMO follows a bottom-up approach that does not account for macroeconomic impacts of the LT-LEDS actions. It should be followed by detailed sector-level assessments that may include for instance regional power trade analysis or least-cost energy optimization modeling, assessment of rail/routes capacity for the transportation sector or assessment of specific climate-smart agriculture practices. A subsequent assessment is also needed to determine the full spectrum of impacts of the LT-LEDS on economic development, taking into account potential rebounding effects, distributional effects, international trade effects, etc.

GACMO was previously used by GoL for the development of the NDC. Its selection for the LT-LEDS was decided in consultation with GoL and was driven by the ability of the model to facilitate **acceptance of the modelling approach and results from the various governmental agencies, ease of updates, transparency of methods, accuracy of results, and capacity in the country to access and employ the model in the future**.

The GACMO model was developed by UNEP DTU Partnership and was used by several countries for the development of their NDCs. It is a MS Excel-based tool, free to access and user-friendly. For the modelling of the Lao PDR LT-LEDS, the set of data from the GACMO model used for the NDC was initially considered. However, for the modelling of the LT-LEDS, the data set was improved (for instance, more accurate and

[7] The Greenhouse Gas Abatement Cost Model (GACMO) | NDC Action Project (unep.org)

recent data were used) and assumptions were updated (for instance, updated economic growth assumptions based on recent economic developments were incorporated). Additionally, data gaps were filled to the extent possible, and enhancements of the model were made to generate impact results of the LT-LEDS actions.

Key enhancements of the GACMO model undertaken include:

- Addition of new spreadsheets for the BAU scenario calculations of non-energy sector emissions, including historical activity data and emission factors. The version of GACMO used for the NDC only included the final calculated emissions for these sectors.
- Addition of a Net Present Value (NPV) calculation for each LT-LEDS action. For each action, the annual costs and savings were distributed over the forecast period (2024-2050) based on the assumed target phase-in schedule, discounted using an 8% discount rate, then summed across the whole period to estimate NPV.

The assessment of GHG impacts was conducted using a process commonly known as "baseline shift analysis", where potential changes in the BAU projections resulting from the implementation of an action are estimated. The evaluation involved applying the level of effort or target for each LT-LEDS action (as identified in Table 4-1. LT-LEDS Category A Action Design Targets

LT-LEDS CATEGORY A ACTION	DESCRIPTION	TARGET UNITS	2025 LT-LEDS TARGET	2030 LT-LEDS TARGET	2035 LT-LEDS TARGET	2050 LT-LEDS TARGET	2050 EMISSION REDUCTIONS
ENERGY SUPPLY SECTOR							
Utility-Scale Solar Scale with Battery Storage (4 hr)	Expand electricity production capacity to displace/avoid import of power to support domestic consumption in dry seasons and export renewable energy to displace fossil power generation in neighboring countries in wet seasons through centralized large solar systems connected to the grid (typically greater than 1 mega-watt (MW) in size).	Cumulative MW solar installed / Cumulative MWh storage installed	0 / 0	1,800 / 0	4,000 / 8,000	5,000 / 10,000	7.43 MMtCO2e
Solar Distributed Systems with Storage	Implement programs to increase distributed solar generation (e.g., <1 MW programs; <100 kilowatt (kW) projects), such as rooftop solar PV programs and community-solar projects.	Cumulative MW solar installed	0	75	450	1,200	1.99 MMtCO2e
Solar Mini-grid with Storage	Expand electricity production capacity through small-scale generators and energy storage systems interconnected to a distribution network that supplies electricity to a small, localized group of customers and operates independently from the national transmission grid.	Cumulative MW solar installed / Cumulative MWh storage installed	0 / 0	10 / 120	30 / 160	50 / 600	0.07 MMtCO2e
Agri-voltaic and/or Floating Solar	Expand electricity production capacity by: (i) using the same land for both agriculture and solar photovoltaic energy generation; and/or (ii) using floating on a body of water, such as hydropower reservoirs, for hybrid dispatching with hydropower.	Cumulative MW solar installed	0	1,500	3,500	5,000	7.43 MMtCO2e
On-shore Wind with Pumped Hydro Storage (12 hr.)	Expand electricity production capacity to support domestic consumption and displace power supply currently served by coal-based generation through large, centralized, grid-connected wind systems (typically greater than 1 MW in size).	Cumulative MW wind installed / Cumulative MWh storage installed	0 / 0	750 / 9,000	1,500 / 18,000	2,250 / 27,000	5.22 MMtCO2e

LT-LEDS CATEGORY A ACTION	DESCRIPTION	TARGET UNITS	2025 LT-LEDS TARGET	2030 LT-LEDS TARGET	2035 LT-LEDS TARGET	2050 LT-LEDS TARGET	2050 EMISSION REDUCTIONS
Methane Capture and Utilization at Coal Mines, Storage Facilities	Create a new supply of natural gas inputs for electricity generation through capture and combustion of fugitive methane while reducing emissions by avoiding atmospheric deposition of methane.	Cumulative MW installed capacity	0	3	5	5	0.04 MMtCO2e
Upgrades to Transmission and Distribution Systems	Upgrade transmission and distribution grid (lines and substations) to reduce electricity losses, optimize the grid upon the generation mix and power trade patterns. This efficiency gain will also result in reduced coal combustion for power generation and increase resilience to climate-related shocks.	Percent reduction in electrical losses	0%	10%	15%	25%	1.84 MMtCO2e
RCI SECTOR							
Residential Appliance Upgrades (Cooling, Lighting, Refrigerators)	Increase the efficiency of electricity use in urban and rural households through expanded improvements in cooling, lighting, and refrigerators (e.g., implement standards, codes, or incentives to replace old appliances with new ones).	Units replaced with higher efficiency models:					0.51 MMtCO2e
		Air conditioning	2,000	20,000	75,000	150,000	
		Lights	10,000	300,000	500,000	1,000,000	
		Refrigerators	10,000	150,000	400,000	750,000	
Residential Wood Cook Stove Upgrades	Reduce fuelwood demand by expanding upgrades to wood cookstoves (e.g., more efficient stoves).	Cookstoves replaced with upgraded ones	10,000	150,000	400,000	750,000	4.95 MMtCO2e
Residential Charcoal Cook Stove Upgrades	Reduce fuelwood demand by expanding upgrades to charcoal cookstoves (e.g., more efficient stoves).	Cookstoves replaced with upgraded ones	5,000	50,000	150,000	250,000	0.40 MMtCO2e

LT-LEDS CATEGORY A ACTION	DESCRIPTION	TARGET UNITS	2025 LT-LEDS TARGET	2030 LT-LEDS TARGET	2035 LT-LEDS TARGET	2050 LT-LEDS TARGET	2050 EMISSION REDUCTIONS
Efficiency of Residential Building Shell: Reflective Roofs	Increase building envelope energy efficiency by replacing rooftop surfaces with reflective ones to help keeping households cool	Residential roofs upgraded	2,000	50,000	250,000	500,000	0.42 MMtCO2e
Energy Efficiency in the Commercial /Service Sector	Increase the efficiency of electricity use in commercial buildings through improvements in appliances, fixtures, and building envelopes.	Percent reduction in electricity demand	0%	10%	20%	30%	1.78 MMtCO2e
INDUSTRY SECTOR							
Industrial Energy Efficiency – Electricity	Enhance energy efficiency of industrial processes to reduce the consumption of coal-based electricity (e.g., energy saving motors and transformers).	Percent reduction in electricity demand	0%	10%	20%	20%	3.61 MMtCO2e
Industrial Energy Efficiency - Fuel	Enhance the efficiency of industrial processes to reduce the direct consumption of fossil fuels, mainly petroleum-based products, including gasoline and diesel, (e.g., upgrades to efficient furnace burners, process heaters).	Percent reduction in fuel demand	0%	10%	20%	20%	2.90 MMtCO2e
Waste Heat Recovery Systems - Cement Plants	Install systems to generate on site electricity from waste heat from cement production to and reduce the use of current electricity from coal-based generation.	MW of electricity generated	0	0	15	30	0.14 MMtCO2e
Waste Heat Recovery Systems - Iron & Steel Plants	Install systems to generate on site electricity from waste heat from iron and steel production to and reduce the use of current electricity from coal-based generation.	MW of electricity generated	0	0	6	12	0.08 MMtCO2e

LT-LEDS CATEGORY A ACTION	DESCRIPTION	TARGET UNITS	2025 LT-LEDS TARGET	2030 LT-LEDS TARGET	2035 LT-LEDS TARGET	2050 LT-LEDS TARGET	2050 EMISSION REDUCTIONS
Cement Clinker Substitution	Use of slag, fly ash, and other wastes as input to cement clinker production to reduce the amount of input required by the waste-receiving industry sector and the associated GHG emissions for producing those inputs (for cement clinker, these inputs include limestone which produces CO2 during production).	Million tons of cement produced with clinker substitutes	0	5	6	8	3.77 MMtCO2e
TRANSPORTATION SECTOR							
Electric vehicles (High-, Medium-, Low-Duty vehicles) Expansion	Replace internal combustion engines (ICE) with electric vehicles (EVs) that have electric engines and battery storage, supported by electric charging infrastructure. The types of EVs involved in this technology shift include Electric Cars, Electric Light-duty Trucks, Electric 2-Wheelers, Electric 3-Wheelers, Electric Heavy Trucks, and Electric Buses.	Cumulative electric vehicles sold by that year:					11.71 MMtCO2e
		Cars	2,000	35,000	150,000	200,000	
		Light-duty trucks	5,000	250,000	500,000	1,200,000	
		2-wheelers	25,000	900,000	2,000,000	4,500,000	
		3-wheelers	1,800	3,500	8,000	18,000	
		Heavy-duty trucks	0	4,000	30,000	140,000	
		Buses	0	200	2,000	13,000	
Ethanol Use in on-road vehicles by Increasing Gas/Ethanol Blend	Expand the use of ethanol through a 15 percent blend for gasoline (e.g., establish blend requirements).	Percent of remaining on-road gasoline blended with 15% ethanol	0%	15%	35%	100%	0.04 MMtCO2e
Use of Biodiesel Use on-road vehicles by Increasing Diesel/Biodiesel Blend	Expand the use of biodiesel through a 10 percent blend (e.g., establish blend requirements).	Percent of remaining on road diesel blended with 10% biodiesel	0%	15%	30%	100%	0.16 MMtCO2e
Bus Rapid Transit (BRT) Expansion	Expand the use of BRT by increasing bus capacity and frequency and expanding transit infrastructure.	Million passenger-kilometers per year	0	5	25	50	0.11 MMtCO2e

LT-LEDS CATEGORY A ACTION	DESCRIPTION	TARGET UNITS	2025 LT-LEDS TARGET	2030 LT-LEDS TARGET	2035 LT-LEDS TARGET	2050 LT-LEDS TARGET	2050 EMISSION REDUCTIONS
Shift Passenger to Electric Rail	Encourage shifts of passengers and freight from gasoline-based road transport systems to electric rail through infrastructure improvements and incentives.	Million passenger-kilometers per year	0	0	200	400	2.60 MMtCO2e
		Million ton-kilometers of freight	0	0	500	800	
AGRICULTURE SECTOR							
Biofertilizers Use (Nitrogen Management)	Inoculate crops with nitrogen fixing microbes to reduce the need for chemical fertilizers, reduce the release of carbon from fertilized production and distribution, and reduce nitrous oxide emissions from field application.	Hectares	0	75,000	250,000	500,000	0.03 MMtCO2e
Adjusted water management practices in lowland rice cultivation	Reduce the flooded period in lowland rice cultivation to reduce methane emissions from the anaerobic decomposition of vegetation.	Hectares	5,000	50,000	75,000	110,000	0.31 MMtCO2e
Agroforestry systems	Plant woody crops along with annual crops to increase carbon sequestration on cropland and produce wood products that can be sold on the market.	Hectares	0	50,000	100,000	200,000	2.20 MMtCO2e
Mitigate Enteric Methane Emissions	Incorporate feed additives to reduce methane emissions from cattle.	Heads of cattle and buffalo	15,000	75,000	250,000	500,000	0.12 MMtCO2e
Manure Digesters	Produce and capture biogas from pig and poultry waste to reduce fugitive methane gas release and then use it for on-farm electricity generation to displace coal-based electricity use.	Percent of animal waste	0%	5%	10%	20%	0.87 MMtCO2e
FORESTRY SECTOR							
Avoided Deforestation Practices	Expand conservation and protection of forestland and the terrestrial carbon that it sequesters.	Cumulative Hectares by that 2050	10,000	100,000	300,000	500,000	3.06 MMtCO2e

LT-LEDS CATEGORY A ACTION	DESCRIPTION	TARGET UNITS	2025 LT-LEDS TARGET	2030 LT-LEDS TARGET	2035 LT-LEDS TARGET	2050 LT-LEDS TARGET	2050 EMISSION REDUCTIONS
Expand Forest Management /Restoration Practices	Expand management of land so that it can naturally regenerate into forest and sequester terrestrial carbon.	Cumulative Hectares by 2050	50,000	750,000	1,500,000	2,600,000	23.83 MMtCO2e
WASTE MANAGEMENT SECTOR							
Solid Waste composting and recycling	Expand composting of organic waste and recycling of solid plastic waste to reduce the level and costs of waste for subsequent treatment and to reduce fugitive emissions of carbon dioxide and methane.	Annual Tons of Waste	0	200,000	350,000	350,000	0.38 MMtCO2e
Refuse Derived Fuel Systems	Expand composting and energy recovery from solid waste to produce fuel and replace coal-based heat inputs to cement production and other industrial coal uses, as well as provide compost for agriculture.	Annual Tons of Waste	0	100,000	300,000	350,000	0.37 MMtCO2e
Landfill Gas Plant	Install plants to recapture methane gas produced through the natural decomposition of waste in landfills and use it as a replacement input to electricity generation through new gas-based power plants, thereby reducing the use of coal (i.e., fugitive gas power production).	Cumulative MW of Installed Generation	0	1	3	4	0.21 MMtCO2e
Install Biogas Latrines/biodigesters for households	Install wastewater biogas digesters for latrines to convert fugitive methane emissions from wastewater (whether treated or untreated) through equipment that captures fugitive gas and collects and concentrates it for direct fuel for woodstove cooking.	Households Served	200	10,000	100,000	200,000	1.05 MMtCO2e

Source: Authors' elaboration

TABLE 4-2. LT-LEDS Suggested Category B Actions

LT-LEDS Category B Action	Description	Assumed level of mitigation by 2050	Assumed 2050 Emission Reduction
InduStry Sector			
Industrial Fuel Interventions	Expand electrification, use of biomass and/or green hydrogen, depending on availability and end use needs.	Mitigate related remaining emissions in the industry sector after Category A actions by 95%	11.40 MMtCO2e
Process Emissions Interventions	Introduce emerging low- or zero-emission technologies for cement, iron and steel production.	Mitigate related remaining emissions in the industry sector after Category A actions by 95%	2.93 MMtCO2e
Agriculture Sector			
Enteric Fermentation	Introduce emerging feed supplement practices, new low-emission cattle breeds and/or shift to other types of livestock production (poultry, pork).	Mitigate related remaining emissions in the livestock sub-sector after Category A actions by 63%	7.52 MMtCO2e
Advanced Manure Management Practices	Introduce new manure management practices based on detailed assessment of current practices.	Mitigate related remaining emissions in the livestock sub-sector after Category A actions by 63%	11.40 MMtCO2e
Regenerative Agriculture Practices	Introduce new regenerative agriculture practices for crop production based on a detailed assessment of current practices.	Mitigate related remaining in the agriculture sector after Category A actions emissions by 63%	4.88 MMtCO2e
Other Sectors			
Transportation	Take action that reduce vehicle miles traveled (VMT), pursue electrification of marine vessels, use advanced aviation fuels, and consider emissions in urban planning	Mitigate related remaining emissions in the transportation sector after Category A actions by 95%	0.31 MMtCO2e
Residential & Commercial	Electrification of cooking and other end uses.	Mitigate remaining emissions in the RC sector after Category A actions by 95%	3.11 MMtCO2e
Wastewater	Collection and modern treatment practices.	Mitigate related remaining emissions in the waste sector after Category A actions by 63%	0.41 MMtCO2e

Source: authors' elaboration

3. BUSINESS AS USUAL (BAU) SCENARIO

3.1. Socio-economic Development Context

Lao PDR is a small landlocked country located in Southeast Asia with a total area of approximately 237,000 km^2. Approximately 80% of the country's land area is mountainous with the remaining 20% being low-lying plains along the Mekong River and its tributaries. The country has a population of just over 7 million in 2022 with a reasonably low population density of 32 persons per km^2.[8] Population growth was reported at 1.41% in 2021[9] and rural-to-urban migration has been steady between 2010 and 2020 with the percentage of the population living in urban areas increasing from 30% to 36% over that period.[10]

The 9th NSEDP defines the 5-year socioeconomic development objectives for the Lao PDR. These include the following outcomes:

1. Achieve continuous quality, stable and *sustainable economic growth*.
2. Improved *quality of human resources* to meet development, research capacity, science and technology needs, and creation of value-added production and services.
3. Enhanced *well-being of the people.*
4. *Enhanced environmental protections and reduced disaster risks.*
5. Enhanced engagement in *regional and international cooperation and integration* with robust infrastructure and effective utilization of national potentials and geographical advantages.
6. Improved *public governance and administration*, with society more equal, fair, and protected by effective rule of law.

Lao PDR has made significant achievements in terms of economic development and poverty reduction over the past few decades. Annual GDP growth averaged over 7% between 1999 and 2019 with average GDP per capita increasing from USD 2,025 in 2016 to USD 2,654 in 2019, according to a summary of the 8th NSEDP (2016-2020) outcomes in the 9th NSEDP.[11] However, **the country's current macroeconomic context and outlook are dominated by significant challenges** due to debt distress, limited fiscal space to support investments, slow economic growth, high inflation, and national currency depreciation. **Restoring macroeconomic stability and fiscal space are necessary conditions to generating positive macroeconomic impacts from the implementation of the LT-LEDS actions.**[12]

Lao PDR is **heavily dependent on natural resources and has significant gaps in human and institutional capacities and infrastructure**.[13] Lao PDR's socio-economic development is highly vulnerable to projected climate change impacts, particularly increased incidences of flooding and drought. Loss and damage from flash flooding as well as reduced crop yields from flooding, heatwaves, and drought tend to disproportionately affect poorer and marginalized sections of the population and exacerbate their already challenging socio-economic conditions. Mainstreaming climate adaptation into climate mitigation and socio-economic development will therefore be critical in addressing future climate impacts and ensuring climate resilient development as Lao PDR seeks to graduate from a least developed economy.

---

[8] Laos Population 2024 (Live) (worldpopulationreview.com)

[9] The 4th Population and Housing Census (PHC) 2015

[10] Lao PDR | Data (worldbank.org)

[11] 9th Five-Year National Socio-Economic Development Plan (2021-2025), March 2021

[12] Key reforms include "(i) improving debt transparency and management, through improved debt reporting, limits on non-concessional borrowing, and debt restructuring; (ii) creating fiscal space, predominately by enhancing domestic resource mobilization; and (iii) undertaking key financial sector reforms, including strengthened prudential regulation and supervision. Structural reforms will also be needed to support the economic recovery, especially in the non-resource sector amid heightened global risks and uncertainty." World Bank. 2022. Lao People's Democratic Republic Systematic Country Diagnostic: 2021 Update. Washington, DC: World Bank.

[13] Child stunting and low learning outcomes are particularly concerning. Malnutrition continues to undermine physical and cognitive development, with stunting affecting over 30 percent of children under five. Educational outcomes are also poor, with low attainment in harmonized test scores (365 within a range of 300–625) and high learning poverty (as 98 percent of 10-year-olds cannot read and understand a simple text by the end of primary school).

Strengthening governance and institutions is key to Lao PDR's sustainable socio-economic development. It is required "to support macroeconomic stability, private sector development, public service delivery, and natural resource management."[14] Lack of good governance and institutions may "lead to a sub-optimal allocation and management of public resources".[15]

3.2. Energy Sector Context

Lao PDR coal reserves are as much as 700 mt of ignite and small amounts of anthracite.[16] The power generation in Lao PDR is dominated by run-of-river hydropower capacity due to its high precipitation levels and mountainous topography, however, hydropower availability is not firm, largely fluctuating between dry and wet seasons in a year. Current electricity generation is comprised of mostly hydropower (over 70%), followed by coal thermal power (a little over 20%), and small amounts of biomass, solar, and wind. Due to seasonality of water availability, Lao PDR has a substantial surplus of power generation in wet seasons, exporting to neighboring countries, and shortage of power generation to supply domestic demand in dry seasons, importing power from Thailand.

Around 80% of the power generated in Lao PDR is exported to neighboring countries. In 2022, Lao PDR exported $2.38B in electricity, the top exported product. The main destinations of electricity exports were Thailand ($2.03B), Cambodia ($188M), Vietnam ($134M), Singapore ($24M), and China ($3.69M).[17] Lao PDR has plans to expand electricity exports over the next few years. It appears that an MOU was signed with Cambodia in March 2024 to export green power from several hydropower and wind projects in Lao PDR.[18] **Current domestic demand is met through hydropower and coal generation from the Sepon plant, with a small amount of power imports during dry seasons**.

There are currently two coal power plants operating in Lao PDR: Hongsa (1,878 MW, of which the majority of power is exported to Thailand) and Sepon (110 MW, used for domestic consumption), which complement the run-of-river hydropower generation to provide a more stable and firm power supply as needed for the domestic supply. **Three additional coal power plants are under consideration (construction has not started yet)**: Bualapha (2,000 MW) for export to Vietnam, and Sekong-Kaleum (1,800 MW) and Sekong-Lamam (700 MW) for export to Thailand, Cambodia, and Vietnam to complement run-of-river hydropower export to meet the requirements of these countries for firm power import. The Hongsa coal power plant was built under a 25-year concession that runs until 2040, but the plant could continue operating past that date. The power offtakers from the Hongsa coal plant are Electricite du Laos (EDL, the state utility) for a small portion of generated power, and Electricity Generating Authority of Thailand (EGAT) for the majority of power that is exported to Thailand. The operation of the Hongsa coal power plant is under dispatch of EGAT.

Construction of the new coal power plants has proved to be challenging. There are limited international funding opportunities available for fossil fuel investments. Additionally, "new investments in coal would jeopardize the country's reputation as a leader in clean energy production and green growth and ultimately result in losing market and financing options for the needed investments for the future. Countries like Singapore would be interested in importing power from Laos only if the energy mix remains predominantly clean".[19]

---

[14] World Bank 2021 Laos PDR SCD.
[15] *Ibid.*
[16] Asian Development Bank, Lao People's Democratic Republic Energy Sector Assessment Strategy, and Road Map, November 2019, available at https://www.adb.org/sites/default/files/institutional-document/547396/lao-pdr-energy-assessment-2019.pdf
[17] OEC, Electricity in Laos. Accessed April 2024, available at https://oec.world/en/profile/bilateral-product/electricity/reporter/lao
[18] Kingdom, Laos agree to widen energy cooperation, Khmer Times, March 26, 2024, available at https://www.khmertimeskh.com/501462332/kingdom-laos-agree-to-widen-energy-cooperation/
[19] World Bank 2021 Laos PDR SCD.

It should also be noted that new coal facilities could become costly carbon lock-ins and stranded investments. This can happen if Lao PDR focuses on long-term coal plant capacity expansion and locks in long-term high carbon capital commitments. In this case, the country risks having long term expenditures fail to match long term policy and investment preferences.

The past experience with hydropower development in Lao PDR has not shown great economic benefits for the country. "Many hydroelectric projects funded by the government or backed by public equity have been selected based on unsolicited proposals with limited investment rationale"[20] in addition to "lack of transparency and competition in the way Power Purchase Agreements (PPAs) between EDL and the private sector have been negotiated. This has resulted in over-investment in power generation and unfavorable PPA terms, some at a net loss for EDL, and have caused financial distress".[21]

The Lao PDR's transmission network is comprised of four regional grids across the north, central 1, central 2, and south. Most of the hydropower potential is in the more mountainous north and south, while more industrial and commercial demand exists in the flatter central region. More transmission capacity is needed between these regions to balance peak demand and capacity for the domestic market. Lao PDR also has over 30 cross-border high-voltage lines used for trade with Thailand, Cambodia, Vietnam, China, and Myanmar.[22] **Development of additional transmission infrastructure to improve resiliency in domestic supply and enable increased exports is needed.** The national power grid faced bottlenecks for evacuation of hydropower constructed, high distribution losses, affordability challenges for end users, and a lack of capacity to meet quickly growing demand.

3.3. Resource Sectors Context

Natural resources are critical for Lao PDR socioeconomic development, but also face several challenges. "In 2018, natural resource-based sectors contributed one-third of GDP, and the Lao natural capital value of assets was quantified at $149 billion, with 78 percent coming from water and forests and a further 22 percent from agriculture".[23] At the same time, the sectors face "inefficiencies, including overuse, under-budgeting, and unsustainable and unscientific management".[24]

Unsustainable resource-based growth driven by agricultural expansion, shifting cultivation, unsustainable timber harvesting and forest plantation had led to a high rate of deforestation. Forest loss has significant impacts, including on biodiversity, ecosystems, resilience to extreme climate events and low carbon development. Forest also helps "provide food, medicines and building materials from forests and support downstream industries like furniture production and reconstituted and fiber products and nature-based tourism in forest landscapes".[25]

The agriculture sector "plays an important role in the country's economy and contributed to GDP and employment at levels above the regional East Asia average of 11.5% for GDP and 25% for employment between 2015-2019. Also, the sector is a leading contributor to rising farm incomes and poverty reduction in the country".[26] However, the sector faces also important challenges including "vulnerability to climate hazards, deforestation, biodiversity loss and soil degradation, insufficient irrigation systems, low crop and livestock productivity, and low inputs use".[27]

---

[20] *Ibid.*
[21] *Ibid.*
[22] Asian Development Bank, Lao People's Democratic Republic Energy Sector Assessment Strategy, and Road Map, November 2019, available at https://www.adb.org/sites/default/files/institutional-document/547396/lao-pdr-energy-assessment-2019.pdf
[23] World Bank 2021 Laos PDR SCD.
[24] *Ibid.*
[25] *Ibid.* Public-Private Producer Partnerships in nature-based tourism and smallholder and industrial tree plantations that meet prerequisites for access to the global market could help facilitate benefit sharing and reduce operational costs and risks while improving the overall sustainability of investments.
[26] World Bank 2023. Resilient and Low Carbon Agriculture in Lao PDR. Priorities for a Green Transition, available at https://documents1.worldbank.org/curated/en/099092723043522698/pdf/P1775940fa70a20690a85c07c907d098a12.pdf
[27] *Ibid*

Decades of growth and urbanization have come with limited structural transformation and diversification away from agriculture. Workers have not moved "from relatively low-productivity agricultural sectors to higher-productivity non-agricultural sectors"[28] such as services and manufacturing. This has limited private sector development and agriculture has remained "a major source of income for more than half of all households and 94 percent of poor and rural households, most of whom rely solely on agricultural income, making them vulnerable to climate-related, weather- related, and price shocks"[29].

Improving the productivity of agricultural activities while ensuring a sustainable management of forest is important for Lao PDR socio-economic development. It is "critical to ensure that resources are used in a sustainable and suitable manner while delivering commensurate benefits to the population".[30]

3.4. Business-as usual GHG Emissions Estimates

Under business-as-usual (BAU) conditions, **the top GHG emitting sectors in 2050** are expected to be:

- *Agriculture* where emissions are mainly driven by livestock, soil inputs, cultivation, and rice paddies.
- *Industry* where emissions are mainly driven by industrial fossil fuel combustion.
- *Forestry* where emissions are mainly driven by deforestation and forest degradation.
- *Energy supply* where emissions come from the coal fired power plants (from coal electricity generation for export since domestic electricity demand is almost entirely met with hydro[31]).
- *Transportation* where emissions are mainly driven by fossil fuel combustion in vehicles.

In the remaining sectors, *Residential, Commercial, and Institutional (RCI), and Waste Management,* emissions are driven by biomass combustion, wastewater, and landfills.

Figure 3-1 below shows **the 2050 forecasted BAU economy-wide greenhouse gas (GHG) emissions, estimated at 111 million metric tons of carbon dioxide equivalent ($MMtCO_2e$).** It is followed by Table 3-1 which indicates the level of GHG emissions from each sector of the economy. The BAU scenario addresses projections through 2050. The BAU emissions are presented in a net accounting format, which means that both GHG sources and sinks (removals) are included. The emission unit is $MMtCO_2e$, and all GHGs are included. Each wedge in the chart represents the BAU GHG emissions level in a specific economic sector.

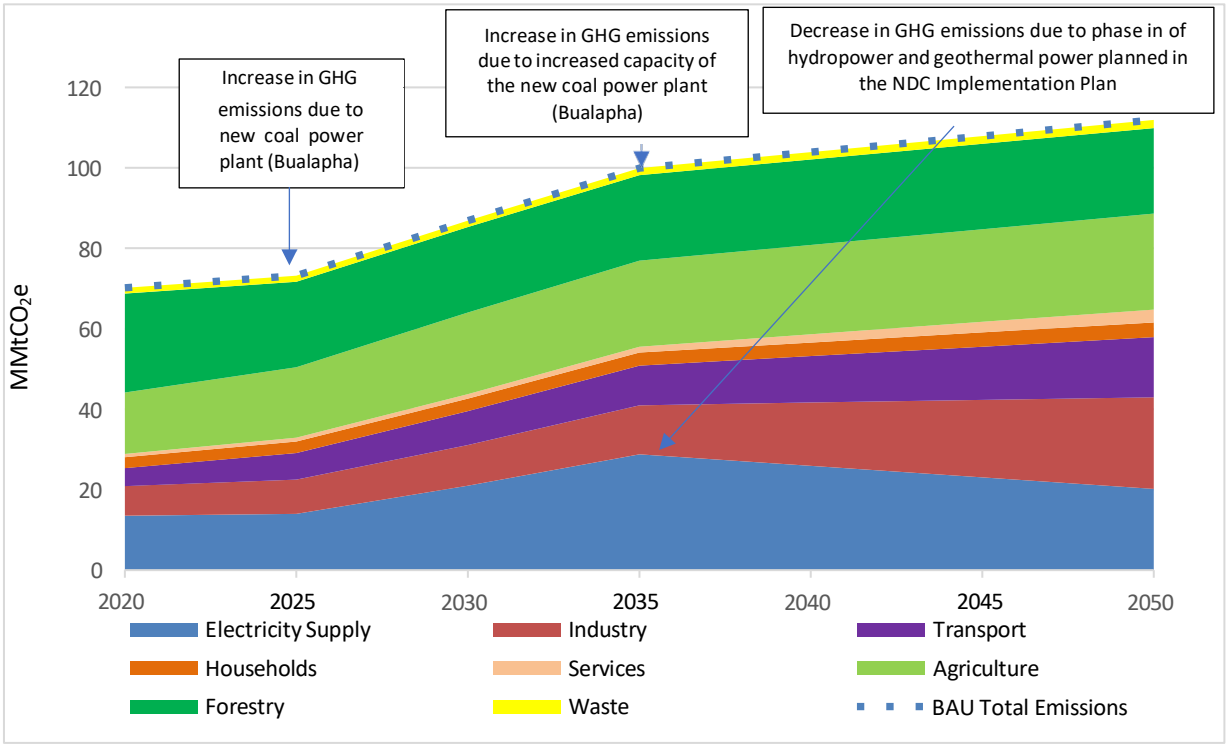
[28] World Bank 2021 Laos PDR SCD.

[29] *Ibid.*

[30] *Ibid.*

[31] Domestic electricity demand is estimated to be 6,119 GWh in 2019, compared to hydropower generation of 19,565 GWh.

FIGURE 3-1. Economy-wide Business as Usual GHG Emissions Scenario 2020-2050



Source: Authors' calculations. Hydropower and geothermal power are included in the BAU scenario rather than the LT-LEDS scenario for this analysis because they are part of the NDC Implementation Plan issued by the government. In case the geothermal power is not installed, additional solar and wind power should be considered in the BAU scenario. Please see more details on the BAU scenario assumption in the following paragraphs.

TABLE 3-1. Economy-wide Business as Usual Emissions for 2020 and 2050

Sector	Emissions ($MMtCO_2e$)		% of Total Emissions		Growth (%)
	2020	2050	2020	2050	2020-2050
Energy Supply	13.5	20.2	19.3%	18.2%	49%
Industry	7.3	21.9	10.5%	19.7%	202%
Transport	4.5	15.0	6.4%	13.5%	235%
Households	2.7	3.6	3.9%	3.3%	34%
Services	0.8	3.2	1.2%	2.9%	293%
Agriculture	15.3	23.9	21.8%	21.5%	56%
Forestry	24.6	21.2	35.1%	19.1%	-14%
Waste	1.4	2.0	2.0%	1.8%	44%
Total	**70.2**	**111**	**100%**	**100%**	**58%**

Source: Authors' calculations

Hydropower and geothermal power are included in the BAU scenario rather than the LT-LEDS scenario for this analysis because they are part of the NDC Implementation Plan issued by the government. In case the geothermal power is not installed, additional solar and wind power should be considered in the BAU scenario. Please see more details on the BAU scenario assumption in the following paragraphs.

The BAU projections are made based on the projected economic and population growth and the existing policies and development plans, including the NDC Implementation Plan.

As mentioned, there are currently two coal plants operating in Lao PDR, Hongsa (1,878 MW) and Sepon (110 MW), and three additional plants under consideration (only planned, construction has not started yet), Bualapha (2,000 MW), Sekong-Kaleum (1,800 MW), and Sekong-Lamam (700 MW). **The BAU scenario assumes that:**

a) **The existing coal power plants (Hongsa and Sepon) will continue to operate and the new planned power plant Bualapha will be installed and come online between 2025 and 2035.** This plant is estimated to have a capacity of 2,150 MW in 2035 to meet demand. As shown in
b) Figure *3-1* above, there is an increase in GHG emissions in 2025 and 2035 due to the estimated increase of coal power production from the Bualapha plant operation. The figure shows also a decrease in Energy Supply emissions between 2035 and 2050 due to the phase-in of additional hydropower and geothermal power indicated in the NDC Implementation Plan as offsets of coal-generated emissions.

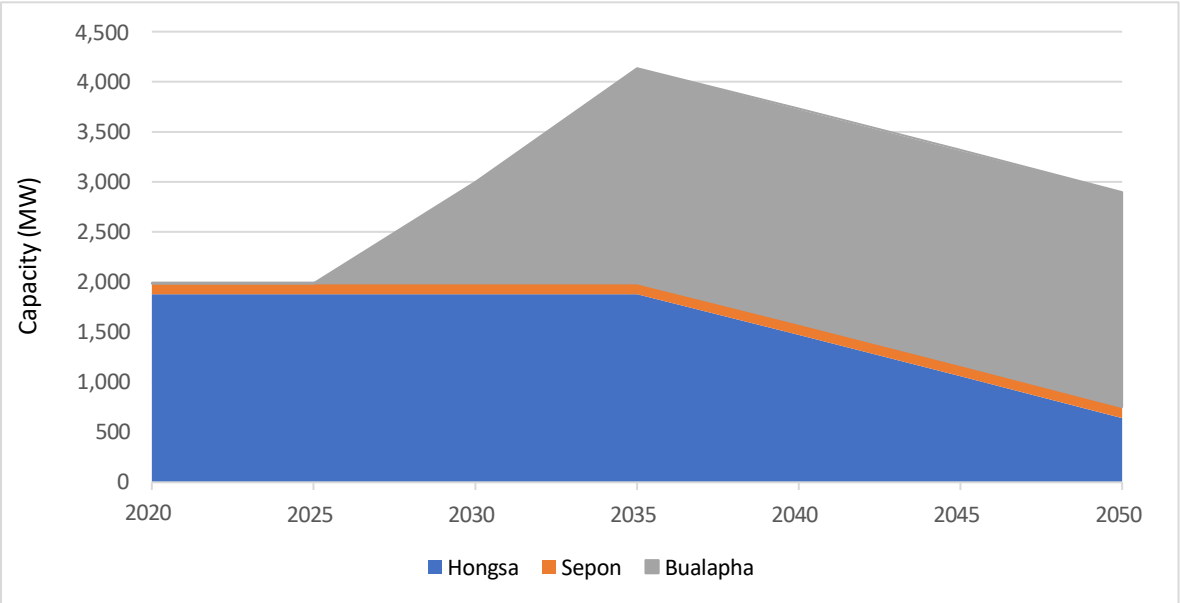
c) **The two other planned coal power plants (Sekong Kaleum and Sekong Lamam) won't be installed.** This assumption ensures consistency of the BAU scenario with the NDC Implementation Plan. The latter estimates that the GHG emissions from coal-generated electricity are offset by installing additional hydropower and 2 GW of geothermal power. If the Sekong Kaleum and Sekong Lamam coal power plants are installed, the GHG emissions from coal production will increase to a level that the GHG emissions reduced by the additional hydropower and geothermal power (as estimated in the NDC Implementation Plan) cannot offset. As a result, there won't be a complete offset of GHG emissions as claimed in the NDC Implementation Plan

d) **The generation at the existing Hongsa plant will decrease between 2035 and 2050 from around 1,900 MW in 2035 to around 1,400 MW in 2040, and to around 650 MW in 2050,** as shown in

e) Figure 3-2 below. This gradual decrease in generation is assumed because more hydropower and geothermal power start phasing in in 2035 as indicated in the NDC Implementation Plan and are expected to offset GHG emissions from coal generation. The phase-down of the Hongsa plant will require an agreement with EGAT to gradually decrease the coal-based power generation.

Figure 3-2 below shows the coal power generation in the BAU scenario consistent with the assumptions above.

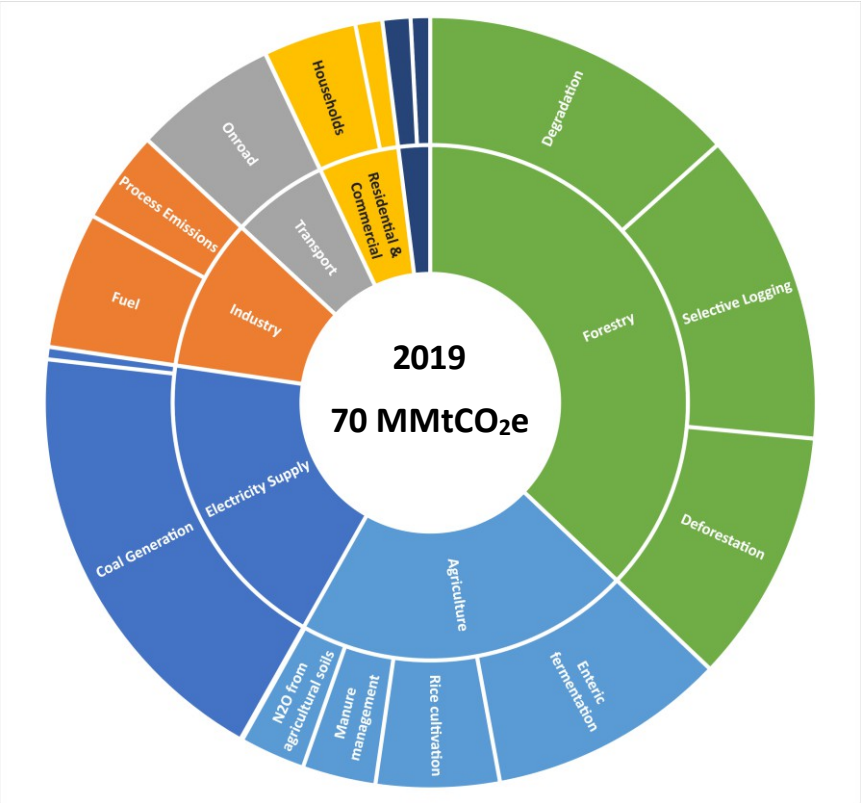
FIGURE 3-2. Business as Usual Coal Power Generation Capacity



The GHG emissions are accounted for on a production-basis both in the BAU scenario and the GHG impact analysis of the LT-LEDS actions, in compliance with international GHG accounting principles and guidance. Thus, **since coal power is generated in Lao PDR, the related GHG emissions are attributed to Lao PDR rather than the countries importing the power.**

The figure below provides contributions of different activities or subsectors to emissions in 2019 (total of 70 $MMtCO_2e$), which was used as the base year for developing the GHG emission inventory.[32]

FIGURE 3-3. 2019 Business as Usual Emissions by Sector and Subsector/Activities



Source: Authors' calculations

In Source: *Authors' calculations* above, emissions are presented on a net basis and include 8 $MMtCO_2$ of carbon removals in the forestry sector from reforestation and forest restoration.

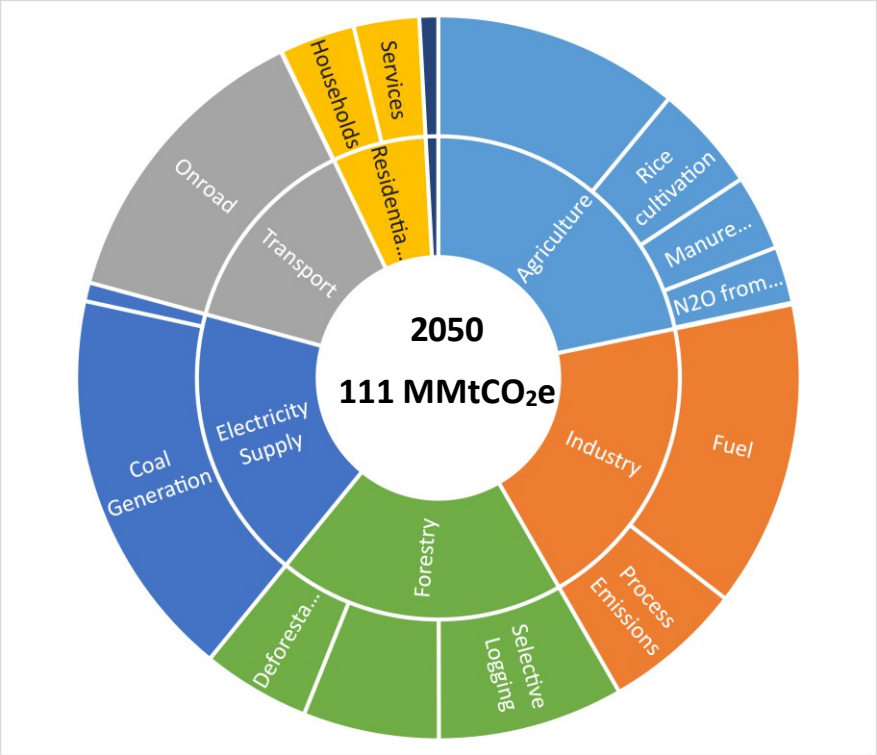
- In the forestry sector, emissions are a result of deforestation (11% of total emissions), forest degradation (13%), and selective logging (13%).
- In the agriculture sector, emissions come from enteric fermentation (10%), rice cultivation (5%), manure management (3%), and agricultural soils (3%).
- In the energy supply sector, emissions are mostly from electricity generation from coal (19%), with a small portion of emissions from coal mining (1%).
- In the transportation sector, emissions are generated mainly by road transportation (6%). Too small to be seen in this graph are emissions from off-road transport (0.01%).[33]
- In the industrial sector, emissions are generated from fuel consumption (6%) and process emissions (4%).
- In the residential and commercial sectors, household (residential) fuel combustion is the largest source (4%), followed by services (commercial) fuel combustion (1%).
- In the waste sector, emissions come from wastewater and solid waste (both at 1%).

[32] No emissions from hydro are included since there will be very small compared to coal, and the estimates would have a lot of uncertainty. In addition, according to the energy data available, air transport fuel usage is very small compared to road transport and rail is all electric.

[33] Off-road would normally include rail, marine, construction equipment, etc. but in this case is just aviation, since the data available doesn't have that much detail. It is not clear from the available data where marine and other offroad equipment are included in the energy balance.

The figure below provides contributions of different sectors and subsectors to GHG emissions in 2050 (total of 111 $MMtCO_2e$). The emissions from the Industry and Transportation sectors are expected to increase significantly, making them take larger shares than in 2019.

FIGURE 3-4. 2050 Business as Usual Emissions by Sector and Subsector/Activities



Source: Authors' calculations

In Figure *3-4*, emissions are presented on a net basis and include carbon removals in the forestry sector from reforestation and forest restoration.

- In the forestry sector, emissions are a result of deforestation (5% of total emissions), forest degradation (6%), and selective logging (8%).
- In the agriculture sector, emissions come from enteric fermentation (11%), rice cultivation (3%), manure management (5%), and agricultural soils (3%).
- In the energy supply sector, emissions are mostly from electricity generation from coal (17%), with a small portion from coal mining (1%).
- In the transportation sector, emissions are generated mainly by road transportation (14%). Too small to be seen in this graph are emissions from off-road transport (0.03%).
- In the industrial sector, emissions are generated from fuel consumption (14%) and process emissions (6%).
- In the residential and commercial sector, household (residential) fuel combustion is the largest source (3%), followed by services (commercial) fuel combustion (3%).
- In the waste sector, emissions come from wastewater and solid waste (both at 1%).

3.5. Assumptions and Data Sources

The BAU projections are linked to the following expected levels of growth in population and economic activity:

TABLE 3-2. Population and GDP Forecasts

Annual % increase in the period					
Indicator	**2019 to 2025**	**2025 to 2030**	**2030 to 2035**	**2035 to 2050**	
Urban Population		3.2%	2.9%	2.5%	2.0%
Rural Population	0.3%	0.06%	-0.2%	-0.6%	
Total Population		1.4%	1.2%	1.0%	0.74%
GDP growth	4.2%	4.5%	4.7%	4.7%	

Sources: Population growth rates were estimated from UN projections.[34] For 2019-2025, the Government of Laos GDP estimated growth rates were used[35], with World Bank projections used for the 2025-2050 period since the GOL projections and forecasts are carried out in five-year intervals and thus projections for years 2026-2030 are still under discussion as part of the 9th NSEDP mid-term review process.

Each of the economic sectors represented in

Table 3-2 above is supported by a sector-level GHG BAU scenario provided in Annexes 4 to 10 that document methods, data sources, and assumptions.

Key data sources used for the development of the BAU scenario include:

- Energy Supply and Demand:
  - Lao PDR National Power Development Strategy 2021-2030
  - Energy transition pathways for the 2030 agenda: SDG 7 roadmap for the Lao People's Democratic Republic | ESCAP (unescap.org)
  - The Mineral Industry of Laos, 2017-18 (PDF) | U.S. Geological Survey (usgs.gov)
- Industrial Process Emissions
  - Data for cement, iron and steel provided by MOIC (workbook: 9. Data of Cement, Iron, Steel.xlsx)
- Agriculture
  - 3rd Lao Census of Agriculture 2019/2020
  - MAF 5-year Plan (2021-2026)
  - Fertilizer data provided by MAF (workbook: FERTILIZER Import 2022.xls)
- Forestry
  - Forest Reference Emission Level and Forest Reference Level for REDD+ Results Payment under the UNFCCC, 2018 | MAF (redd.unfccc.int)
- Waste
  - Urban waste data from MPWT (workbook: Data2 on SWM in Laos from 2003 to 2020.xlsx)
- What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050| World Bank (worldbank.org)

The BAU scenario includes projects that are currently implemented or that will likely be implemented based on the information shared by the Governmental agencies, including funded projects from the NDC Implementation Plan. For each sector, these projects include:

[34] World Population Prospects, 2022.
[35] 9th NSEDP

- Energy Supply sector
    - All projects planned until 2030 from the Summary of Electricity Generation Projects provided by MEM
    - Existing coal plants still in operation plus the new proposed Bualapha plant that comes into operation
    - 2 GW Geothermal energy development as indicated in NDC Implementation Plan (Project M.EN6)
    - Hydropower generation after 2030 - NDC Implementation Plan, listed in MEM Summary of Projects report
- Residential & Commercial sector
    - Lao PDR Clean Cook Stove Initiative - NDC Implementation Plan Project M.EN2
- Industry sector
    - Reducing of greenhouse gas (GHG) emissions in the industrial sector through palletization technology in Lao PDR - NDC Implementation Plan Project M.EN9
- Transportation sector
    - Lao-China Railway - NDC Implementation Plan Project M.TR1
    - Vientiane Sustainable Urban Transport Project (VSUTP) - NDC Implementation Plan Project M.TR2
    - Premium Alternative Fuel Helimax - NDC Implementation Plan Project M.TR3
- Agriculture sector
    - Adjusted water management practices in lowland rice cultivation - It is listed as a conditional target in the NDC Implementation Plan Project, so it is included in the LT-LEDS Scenario rather than BAU scenario
- Forestry sector
    - Improved governance and sustainable forest landscape management (I-GFLL Project) - Lao PDR Emission Reductions Programme, NDC Implementation Plan Project M.AF1
    - Lao Landscapes - NDC Implementation Plan Project M.AF2
    - Improved governance and sustainable forest landscape management and Livelihoods Project (LLL) - Lao PDR Emission Reductions Program, NDC Implementation Plan Project M.AF3
- Waste Management sector
    - Mechanical and Biological Treatment facility in Vientiane - NDC Implementation Plan Project M.WA3.

4. LT-LEDS ACTIONS

The LT-LEDS for Lao PDR is comprised of 41 actions across the economic sectors. They were identified based on current national plans such as the NDC, the Climate Change Strategy, the National Green Growth Strategy, the 9th NSEDP and sector-level 5-year Development Plans **and through consultations with GoL and stakeholders**. Additional actions were selected based on the key GHG emissions drivers identified under the BAU forecast scenario.

Based on the availability and quality of information and data, the LT-LEDS actions were grouped into the following two categories:

- **Category A – Actions with reliable data sources and key assumptions**. For these actions, a complete impact assessment was conducted that included GHG emission reductions, costs/savings, economic implications, and adaptation co-benefits.
- **Category B – Actions lacking details on design and scope as well as reliable data and information**. For these actions, an initial estimate of their potential GHG emission impact at an aggregate level was conducted. However, no costs and savings were quantified, nor other impacts evaluated. Additional data or information from the GoL would be needed for a full analysis of these actions.

The tables below list the 41 LT-LEDS actions (Category A and B) for Lao PDR with descriptions and targets over time until 2050. This list includes only the actions additional to the BAU scenario. As a result, it does not include the additional hydropower and geothermal power that are covered in the BAU scenario as they are part of the NDC Implementation Plan issued by the government. More details on these actions including their implementation and leading agencies are provided in Annexes 4 to 10 to the report.

TABLE 4-1. LT-LEDS Category A Action Design Targets

LT-LEDS CATEGORY A ACTION	DESCRIPTION	TARGET UNITS	2025 LT- LEDS TARGET	2030 LT- LEDS TARGET	2035 LT- LEDS TARGET	2050 LT- LEDS TARGET	2050 EMISSION REDUCTIONS
ENERGY SUPPLY SECTOR							
Utility-Scale Solar Scale with Battery Storage (4 hr)	Expand electricity production capacity to displace/avoid import of power to support domestic consumption in dry seasons and export renewable energy to displace fossil power generation in neighboring countries in wet seasons through centralized large solar systems connected to the grid (typically greater than 1 mega-watt (MW) in size).	Cumulative MW solar installed / Cumulative MWh storage installed	0 / 0	1,800 / 0	4,000 / 8,000	5,000 / 10,000	7.43 $MMtCO_2e$
Solar Distributed Systems with Storage	Implement programs to increase distributed solar generation (e.g., <1 MW programs; <100 kilowatt (kW) projects), such as rooftop solar PV programs and community-solar projects.	Cumulative MW solar installed	0	75	450	1,200	1.99 $MMtCO_2e$
Solar Mini-grid with Storage	Expand electricity production capacity through small-scale generators and energy storage systems interconnected to a distribution network that supplies electricity to a small, localized group of customers and operates independently from the national transmission grid.	Cumulative MW solar installed / Cumulative MWh storage installed	0 / 0	10 / 120	30 / 160	50 / 600	0.07 $MMtCO_2e$
Agri-voltaic and/or Floating Solar	Expand electricity production capacity by: (i) using the same land for both agriculture and solar photovoltaic energy generation; and/or (ii) using floating on a body of water, such as hydropower reservoirs, for hybrid dispatching with hydropower.	Cumulative MW solar installed	0	1,500	3,500	5,000	7.43 $MMtCO_2e$
On-shore Wind with Pumped Hydro Storage (12 hr.)	Expand electricity production capacity to support domestic consumption and displace power supply currently served by coal-based generation through large, centralized, grid-connected wind systems (typically greater than 1 MW in size).	Cumulative MW wind installed / Cumulative MWh storage installed	0 / 0	750 / 9,000	1,500 / 18,000	2,250 / 27,000	5.22 $MMtCO_2e$

Methane Capture and Utilization at Coal Mines, Storage Facilities	Create a new supply of natural gas inputs for electricity generation through capture and combustion of fugitive methane while reducing emissions by avoiding atmospheric deposition of methane.	Cumulative MW installed capacity	0	3	5	5	0.04 $MMtCO_2e$
Upgrades to Transmission and Distribution Systems	Upgrade transmission and distribution grid (lines and substations) to reduce electricity losses, optimize the grid upon the generation mix and power trade patterns. This efficiency gain will also result in reduced coal combustion for power generation[36] and increase resilience to climate-related shocks.	Percent reduction in electrical losses	0%	10%	15%	25%	1.84 $MMtCO_2e$
RCI SECTOR							
Residential Appliance Upgrades (Cooling, Lighting, Refrigerators)	Increase the efficiency of electricity use in urban and rural households through expanded improvements in cooling, lighting, and refrigerators (e.g., implement standards, codes, or incentives to replace old appliances with new ones).	Units replaced with higher efficiency models:					0.51 $MMtCO_2e$
		Air conditioning	2,000	20,000	75,000	150,000	
		Lights	10,000	300,000	500,000	1,000,000	
		Refrigerators	10,000	150,000	400,000	750,000	
Residential Wood Cook Stove Upgrades	Reduce fuelwood demand by expanding upgrades to wood cookstoves (e.g., more efficient stoves).	Cookstoves replaced with upgraded ones	10,000	150,000	400,000	750,000	4.95 $MMtCO_2e$

[36] With installation of more renewables, there will be likely need for more transmission, but determining the level of grid expansion was beyond the scope of this project.

LT-LEDS CATEGORY A ACTION	DESCRIPTION	TARGET UNITS	2025 LT- LEDS TARGET	2030 LT- LEDS TARGET	2035 LT- LEDS TARGET	2050 LT- LEDS TARGET	2050 EMISSION REDUCTIONS
Residential Charcoal Cook Stove Upgrades	Reduce fuelwood demand by expanding upgrades to charcoal cookstoves (e.g., more efficient stoves).	Cookstoves replaced with upgraded ones	5,000	50,000	150,000	250,000	0.40 $MMtCO_2e$
Efficiency of Residential Building Shell: Reflective Roofs	Increase building envelope energy efficiency by replacing rooftop surfaces with reflective ones to help keeping households cool	Residential roofs upgraded	2,000	50,000	250,000	500,000	0.42 $MMtCO_2e$
Energy Efficiency in the Commercial /Service Sector	Increase the efficiency of electricity use in commercial buildings through improvements in appliances, fixtures, and building envelopes.	Percent reduction in electricity demand	0%	10%	20%	30%	1.78 $MMtCO_2e$
INDUSTRY SECTOR							
Industrial Energy Efficiency – Electricity	Enhance energy efficiency of industrial processes to reduce the consumption of coal-based electricity (e.g., energy saving motors and transformers).	Percent reduction in electricity demand	0%	10%	20%	20%	3.61 $MMtCO_2e$
Industrial Energy Efficiency - Fuel	Enhance the efficiency of industrial processes to reduce the direct consumption of fossil fuels, mainly petroleum-based products, including gasoline and diesel, (e.g., upgrades to efficient furnace burners, process heaters).	Percent reduction in fuel demand	0%	10%	20%	20%	2.90 $MMtCO_2e$
Waste Heat Recovery Systems - Cement Plants	Install systems to generate on site electricity from waste heat from cement production to and reduce the use of current electricity from coal- based generation.	MW of electricity generated	0	0	15	30	0.14 $MMtCO_2e$
Waste Heat Recovery Systems - Iron & Steel Plants	Install systems to generate on site electricity from waste heat from iron and steel production to and reduce the use of current electricity from coal- based generation.	MW of electricity generated	0	0	6	12	0.08 $MMtCO_2e$

LT-LEDS CATEGORY A ACTION	DESCRIPTION	TARGET UNITS	2025 LT- LEDS TARGET	2030 LT- LEDS TARGET	2035 LT- LEDS TARGET	2050 LT- LEDS TARGET	2050 EMISSION REDUCTIONS
Cement Clinker Substitution	Use of slag, fly ash, and other wastes as input to cement clinker production to reduce the amount of input required by the waste-receiving industry sector and the associated GHG emissions for producing those inputs (for cement clinker, these inputs include limestone which produces CO_2 during production).	Million tons of cement produced with clinker substitutes	0	5	6	8	3.77 $MMtCO_2e$
TRANSPORTATION SECTOR							
Electric vehicles (High-, Medium-, Low-Duty vehicles) Expansion	Replace internal combustion engines (ICE) with electric vehicles (EVs) that have electric engines and battery storage, supported by electric charging infrastructure. The types of EVs involved in this technology shift include Electric Cars, Electric Light-duty Trucks, Electric 2-Wheelers, Electric 3- Wheelers, Electric Heavy Trucks, and Electric Buses.	Cumulative electric vehicles sold by that year:					11.71 $MMtCO_2e$
		Cars	2,000	35,000	150,000	200,000	
		Light-duty trucks	5,000	250,000	500,000	1,200,000	
		2-wheelers	25,000	900,000	2,000,000	4,500,000	
		3-wheelers	1,800	3,500	8,000	18,000	
		Heavy-duty trucks	0	4,000	30,000	140,000	
		Buses	0	200	2,000	13,000	
Ethanol Use in on-road vehicles by Increasing Gas/Ethanol Blend	Expand the use of ethanol through a 15 percent blend for gasoline (e.g., establish blend requirements).	Percent of remaining on-road gasoline blended with 15% ethanol	0%	15%	35%	100%	0.04 $MMtCO_2e$
Use of Biodiesel Use on-road vehicles by Increasing Diesel/Biodiesel Blend	Expand the use of biodiesel through a 10 percent blend (e.g., establish blend requirements).	Percent of remaining on road diesel blended with 10% biodiesel	0%	15%	30%	100%	0.16 $MMtCO_2e$
Bus Rapid Transit (BRT) Expansion	Expand the use of BRT by increasing bus capacity and frequency and expanding transit infrastructure.	Million passenger-kilometers per year	0	5	25	50	0.11 $MMtCO_2e$

LT-LEDS CATEGORY A ACTION	DESCRIPTION	TARGET UNITS	2025 LT- LEDS TARGET	2030 LT- LEDS TARGET	2035 LT- LEDS TARGET	2050 LT- LEDS TARGET	2050 EMISSION REDUCTIONS
Shift Passenger to Electric Rail	Encourage shifts of passengers and freight from gasoline-based road transport systems to electric rail through infrastructure improvements and incentives.	Million passenger-kilometers per year Million ton-kilometers of freight	0 0	0 0	200 500	400 800	2.60 $MMtCO_2e$
AGRICULTURE SECTOR							
Biofertilizers Use (Nitrogen Management)	Inoculate crops with nitrogen fixing microbes to reduce the need for chemical fertilizers, reduce the release of carbon from fertilized production and distribution, and reduce nitrous oxide emissions from field application.	Hectares	0	75,000	250,000	500,000	0.03 $MMtCO_2e$
Adjusted water management practices in lowland rice cultivation	Reduce the flooded period in lowland rice cultivation to reduce methane emissions from the anaerobic decomposition of vegetation.	Hectares	5,000	50,000	75,000	110,000	0.31 $MMtCO_2e$
Agroforestry systems	Plant woody crops along with annual crops to increase carbon sequestration on cropland and produce wood products that can be sold on the market.	Hectares	0	50,000	100,000	200,000	2.20 $MMtCO_2e$
Mitigate Enteric Methane Emissions	Incorporate feed additives to reduce methane emissions from cattle.	Heads of cattle and buffalo	15,000	75,000	250,000	500,000	0.12 $MMtCO_2e$
Manure Digesters	Produce and capture biogas from pig and poultry waste to reduce fugitive methane gas release and then use it for on-farm electricity generation to displace coal-based electricity use.	Percent of animal waste	0%	5%	10%	20%	0.87 $MMtCO_2e$

LT-LEDS CATEGORY A ACTION	DESCRIPTION	TARGET UNITS	2025 LT- LEDS TARGET	2030 LT- LEDS TARGET	2035 LT- LEDS TARGET	2050 LT- LEDS TARGET	2050 EMISSION REDUCTIONS
FORESTRY SECTOR							
Avoided Deforestation Practices	Expand conservation and protection of forestland and the terrestrial carbon that it sequesters.	Cumulative Hectares by that 2050	10,000	100,000	300,000	500,000	3.06 $MMtCO_2e$
Expand Forest Management /Restoration Practices	Expand management of land so that it can naturally regenerate into forest and sequester terrestrial carbon.	Cumulative Hectares by 2050	50,000	750,000	1,500,000	2,600,000	23.83 $MMtCO_2e$
WASTE MANAGEMENT SECTOR							
Solid Waste composting and recycling	Expand composting of organic waste and recycling of solid plastic waste to reduce the level and costs of waste for subsequent treatment and to reduce fugitive emissions of carbon dioxide and methane.[37]	Annual Tons of Waste	0	200,000	350,000	350,000	0.38 $MMtCO_2e$
Refuse Derived Fuel Systems	Expand composting and energy recovery from solid waste to produce fuel and replace coal-based heat inputs to cement production and other industrial coal uses, as well as provide compost for agriculture.	Annual Tons of Waste	0	100,000	300,000	350,000	0.37 $MMtCO_2e$
Landfill Gas Plant	Install plants to recapture methane gas produced through the natural decomposition of waste in landfills and use it as a replacement input to electricity generation through new gas- based power plants, thereby reducing the use of coal (i.e., fugitive gas power production).	Cumulative MW of Installed Generation	0	1	3	4	0.21 $MMtCO_2e$

[37] This does not include biogas from solid waste, but that is something that could be considered for future analysis.

LT-LEDS CATEGORY A ACTION	DESCRIPTION	TARGET UNITS	2025 LT- LEDS TARGET	2030 LT- LEDS TARGET	2035 LT- LEDS TARGET	2050 LT- LEDS TARGET	2050 EMISSION REDUCTIONS
Install Biogas Latrines/biodigesters for households	Install wastewater biogas digesters for latrines to convert fugitive methane emissions from wastewater (whether treated or untreated) through equipment that captures fugitive gas and collects and concentrates it for direct fuel for woodstove cooking.	Households Served	200	10,000	100,000	200,000	1.05 $MMtCO_2e$

Source: Authors' elaboration

TABLE 4-2. LT-LEDS Suggested Category B Actions

LT-LEDS CATEGORY B ACTION	DESCRIPTION	ASSUMED LEVEL OF MITIGATION BY 2050	ASSUMED 2050 EMISSION REDUCTION
INDUSTRY SECTOR			
Industrial Fuel Interventions	Expand electrification, use of biomass and/or green hydrogen, depending on availability and end use needs.	Mitigate related remaining emissions in the industry sector after Category A actions by 95%	11.40 $MMtCO_2e$
Process Emissions Interventions	Introduce emerging low- or zero-emission technologies for cement, iron and steel production.	Mitigate related remaining emissions in the industry sector after Category A actions by 95%	2.93 $MMtCO_2e$
AGRICULTURE SECTOR			
Enteric Fermentation	Introduce emerging feed supplement practices, new low-emission cattle breeds and/or shift to other types of livestock production (poultry, pork).	Mitigate related remaining emissions in the livestock sub-sector after Category A actions by 63%	7.52 $MMtCO_2e$
Advanced Manure Management Practices	Introduce new manure management practices based on detailed assessment of current practices.	Mitigate related remaining emissions in the livestock sub-sector after Category A actions by 63%	1.79 $MMtCO_2e$
Regenerative Agriculture Practices	Introduce new regenerative agriculture practices for crop production based on a detailed assessment of current practices.	Mitigate related remaining in the agriculture sector after Category A actions emissions by 63%	4.88 $MMtCO_2e$

LT-LEDS CATEGORY B ACTION	DESCRIPTION	ASSUMED LEVEL OF MITIGATION BY 2050	ASSUMED 2050 EMISSION REDUCTION
OTHER SECTORS			
Transportation	Take action that reduce vehicle miles traveled (VMT), pursue electrification of marine vessels, use advanced aviation fuels, and consider emissions in urban planning	Mitigate related remaining emissions in the transportation sector after Category A actions by 95%	0.31 $MMtCO_2e$
Residential & Commercial	Electrification of cooking and other end uses.	Mitigate remaining emissions in the RC sector after Category A actions by 95%	3.11 $MMtCO_2e$
Wastewater	Collection and modern treatment practices.	Mitigate related remaining emissions in the waste sector after Category A actions by 63%	0.41 $MMtCO_2e$

Source: authors' elaboration

5. ESTIMATED IMPACTS OF THE LT-LEDS ACTIONS

5.1. Overview

The assessment of the potential impacts of the implementation of the LT-LEDS actions covered during the planning period (2020-2050) *(i)* the estimated climate mitigation potential (either GHG reduction or removal), *(ii)* the estimated direct costs or direct savings, *(iii)* other potential economic implications related to employment and economic growth, and *(iv)* the potential adaptation co-benefits.

A summary of the economy-wide impact assessment results is shown in the following sections. More details can be found in Annexes 4 to 10. **The assessment for LT-LEDS is not meant to be a full in-depth analysis for each sector.** Detailed sector-level assessments can be undertaken separately to support further development and implementation of actions. These may include regional power trade analysis or least-cost optimization modeling to determine the exact mix of renewables/storage for the energy sector; assessment of rail/routes capacity for the transportation sector; or assessment of specific climate-smart agriculture practices.

5.2. Estimated GHG Emission Impacts

5.2.1. Introduction

Each LT-LEDS action was first evaluated on an "independent" or stand-alone basis, meaning that no interactions or overlaps with other actions were considered. When the independent analysis was completed for the actions, an assessment was conducted to determine if there were interactions/overlaps between actions in the same sector (i.e., an “intra-sector” overlap analysis) or between actions in different sectors (i.e., a “cross-sector” overlap analysis). Methods were then developed and applied to correct these interactions/overlaps. Examples of both types of interactions/overlays are shown in Box 1 below.

BOX 1: OVERLAP ANALYSIS - EXAMPLES

Intra-sector overlap – Action focused on transport demand and a vehicle electrification action –

An action such as smart urban planning or a mode shift from cars to public transport will overlap with an action addressing the electrification of light vehicles. This is because through the implementation of the action focused on transport demand there will be a reduced amount of vehicle activity (compared to BAU levels) which will affect the impacts of vehicle electrification. In this case, the overlap can be eliminated by evaluating the electrification action based on already adjusted vehicle activity levels to reflect the implementation of the action focused on transportation demand.

Inter-sector overlap – Renewable electricity generation action and energy efficiency action –

These actions interact because implementing the renewable electricity generation action results in a cleaner electricity grid, and the energy efficiency action will therefore produce lower GHG reductions because it is evaluated against this cleaner grid. In this case, the interaction between actions is addressed by adjusting the GHG reductions from the energy efficiency action, taking into account the new grid carbon intensity that results from the implementation of the renewable electricity generation action.

Data sources and assumptions used for the GHG emission reduction impact assessment vary based on the action and are documented in Annexes 4 to 10. **Key data sources** include:

- UNFCCC Clean Development Mechanism (CDM) project data
- IPCC Guidelines for National Greenhouse Gas Emission Inventories
- Assessment of Electric Vehicle Penetration in the Lao People’s Democratic Republic (eria.org)

5.2.2. Economy-wide Results

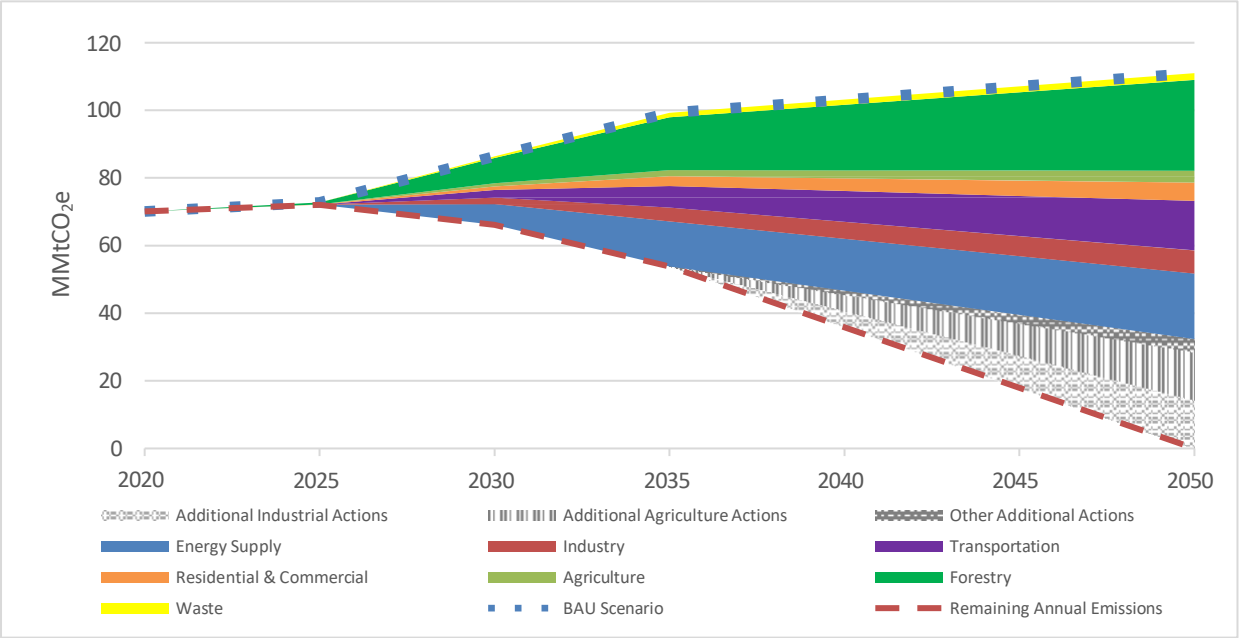
The implementation of the LT-LEDS actions is expected to enable Lao PDR to achieve its net zero target by 2050. The break down details are as follows:

1. A reduction of 78.6 $MMtCO_2e$ (71% reduction from BAU GHG emissions levels) achieved through LT-LEDS Category A actions that results in the following key transformations of the economy (more details on these transformations are provided later in this section):
    - Decarbonize electricity generation for export (i.e., displace coal power with solar and wind power) with required energy storage (pumped storage hydro and battery storage systems) and regional interconnection lines, as well as strengthened transmission and distribution grid. As mentioned earlier, the additional hydropower and geothermal power are not included here because they are part of the NDC Implementation Plan issued by the government and thus are covered in the BAU scenario.
    - Electrify end-uses such as vehicles, industrial kilns, residential and commercial cookstoves.
    - Reduce energy consumption through efficiency measures.
    - Increase forest carbon sequestration.
    - Expand climate-smart agriculture practices.
    - Expand sustainable waste management practices, such as composting and waste-to- energy.
2. A reduction of 32.4 $MMtCO_2e$ (i.e., 29% reduction from BAU GHG emissions levels) through LT- LEDS Category B Areas of Interventions that include fuel switching, enteric fermentation mitigation, regenerative agriculture, and others to be identified in detail.
3. The LT-LEDS actions with the highest GHG emission reduction impacts are estimated to be forest restoration, electric light-duty trucks, and utility-scale solar.

Figure *5-1* below summarizes, by sector, the estimated GHG emissions reductions achieved by the LT-LEDS against the economy-wide BAU scenario. Each wedge in the chart represents the GHG emission reduction generated in a specific sector by the related LT-LEDS actions. The solid-colored wedges refer to GHG emission reductions generated by LT-LEDS Category A actions, while the patterned wedges refer to GHG emission reductions generated by LT-LEDS Category B Areas of Interventions. GHG emission reductions achieved by each LT-LEDS action are described in Annexes 4 to 10. **The LT-LEDS GHG emissions are presented in a net accounting format, which means that both GHG sources and sinks (removals) are included.**

Table 5-1 below indicates for each sector: *(i)* the 2050 BAU GHG emissions levels and related percentage contribution to the economy-wide BAU emission levels; *(ii)* 2050 GHG emissions reductions from LT-LEDS Category A actions and related percentage contribution to the economy-wide GHG emission reduction; *(iii)* 2050 GHG emissions reductions from LT-LEDS Category B Areas of Interventions and the related percentage contribution to the economy-wide GHG emission reduction.

FIGURE 5-1. Economy-wide LT-LEDS Scenario Emissions Reductions



Source: Authors' calculations

TABLE 5-1. Sector Level LT-LEDS Emission Reductions

	2050 BAU Emissions		2050 LT-LEDS Category A Emission Reductions		2050 LT-LEDS Category B Emission Reductions[1]	
Sector	**MMtCO$_2$e**	**%**	**MMtCO$_2$e**	**%**	**MMtCO$_2$e**	**%**
Electricity Supply	20.2	18.2%	18.9	24.6%	0.0	0%
Industry	21.9	19.7%	6.7	8.8%	14.5	45%
Transport	15.0	13.5%	14.6	18.6%	0.3	1%
Residential & Commercial	6.9	6.2%	5.4	6.8%	2.9[2]	9%
Agriculture	23.9	21.5%	3.5	4.5%	14.3	44%
Forestry	21.2	19.1%	24.8	34.2%	0.0	0%
Waste	2.0	1.8%	2.0	2.5%	0.5	1%
Total	111	100%	75.8	100%	32.4	100%

[1] Rough estimates based on estimated remaining emissions after Category A reductions and mitigation difficulty (combustion emissions have higher mitigation potential than non-energy sectors).

[2] Sum of Category A and B reductions are greater than BAU emissions in this sector because some of the reductions from Category A actions (efficiency cook stoves) are from the Forestry sector.

Source: Authors' calculations

The GHG emission reductions include direct emission reductions (e.g., reductions in fuel use; land management changes) and indirect emissions reductions (e.g., reductions in electricity use; or renewable energy production). The emission reductions shown in the graph are adjusted to account for the inclusion in the energy supply sector of emissions reductions from electricity efficiency in the demand sectors (residential, commercial, industrial).

The results show that **most of the GHG emission reductions are expected to come from the Transportation, Forestry and Energy Supply sectors**. Across the sectors, as mentioned, **the achievement of the 2050 net zero target will depend on the following key transformations of the economy**:

1. **Decarbonize electricity generation for export** by:
    - Scaling down operation and phasing-out existing coal power plants (Hongsa and Sepon) assuming that EGAT terminates the power purchase agreement related to the Hongsa coal power plant by 2050.
    - Moratorium of the installation of the three planned coal power plants (Bulapha, Sekong Kaleum and Sekong Lamam) for which construction has not started yet.
    - Meeting all domestic demand and electricity exports with increased renewable electricity generation (solar and wind) supported by adequate energy storage (pumped storage hydro and battery storage systems) and regional interconnection lines, as well as strengthened transmission and distribution grid. As mentioned earlier, the additional hydropower and geothermal power are not included here because they are part of the NDC Implementation Plan issued by the government and thus are covered in the BAU scenario.
2. **Electrify end-uses** through replacement of wood and charcoal cookstoves in residential and commercial buildings and significant expansion of electric vehicles (light-, medium- and heavy- duty).
3. **Reduce energy consumption** through efficiency measures and upgrades for appliances, cookstoves, buildings, and industrial processes.
4. **Expand climate-smart agriculture** through agroforestry systems, fertilizer management, rice cultivation irrigation, and improved manure practices.
5. **Increase carbon sequestration** by avoiding deforestation and expanding forest management and restoration practices.
6. **Expand waste management practices** through composting, recycling, and waste-to-energy systems.

The LT-LEDS scenario recommends the displacement of coal power generation with renewables (solar and wind) and adequate energy storage (pumped storage hydro and battery storage systems) and regional interconnection lines, as well as strengthened transmission and distribution grid – this is the only viable pathway for Lao PDR to achieve the net zero target and benefit from net savings compared to the scenario where coal production continues. As shown in the sections below**, the 2050 annual costs for the scenario with continued coal power generation are much higher than those under the LT-LEDS scenario with displacement of coal-generated electricity. This recommendation suggests that GoL should engage in discussions and advance long-term power sector planning with neighboring countries, particularly Thailand, expand solar and wind energy, install adequate energy storage (pumped storage hydro and battery storage systems) and build regional interconnection lines.** It also assumes that EGAT terminates the power purchase agreement related to the Hongsa coal power plant by 2050. A future in- depth assessment for regional power trade could support this planning effort. More details on the assumptions are provided in section 5.4.1 The Proposed LT-LEDS Scenario for the Energy Sector below.

Section 5.4 below provides more details on alternative scenarios for the displacement of coal power generation based on a sensitivity analysis. As mentioned, GHG emissions are accounted for on a production basis. Thus, since coal power is generated in Lao PDR, the related GHG emissions are accounted to Lao PDR rather than the countries importing power.

5.3. Estimated Costs and Savings

5.3.1. Introduction

Direct financial costs refer to the initial investments (spending) required to implement an action (such as the costs of acquiring equipment or land) and any additional ongoing costs for its continued implementation (such as labor, regulatory fees, energy, materials, operations, and maintenance). The assessment of potential costs was performed in comparison to BAU conditions. Implementing an action can also result in reduced costs over time due to new technologies or practices that create savings in energy, materials, labor, and other costs (common with LEDS actions). Over time, savings will accumulate to levels that will partially or totally offset initial costs, leading to overall savings to implement the action. Actions may also generate new revenues with the same effect.

Due to limited information available on the design and targets of the Category B Areas of Interventions, **costs and savings were estimated only for LT-LEDS Category A actions**. The general approach to cost analysis is to estimate the total investment, annualized initial investment, annual O&M, and other costs, such as fuel savings for the action at full implementation. These full-implementation costs are then scaled to different levels of implementation in each period in the GACMO model. The BAU cost value is subtracted from the LT-LEDS scenario value, and if costs are lower under the LT-LEDS scenario, then the value of the net change will be negative. This negative value represents savings to society, while the positive value represents a cost.

Data sources and assumptions for the estimation of costs and savings vary based on the type of actions and the availability of information. Details on data used and related data sources are indicated for each LT-LEDS Category A action in Annexes 4 to 10. For each action, the analysis table from the GACMO tool is presented, showing all input data used.

As a general note, some cost data used in the analysis are Lao PDR specific and were collected through research. For instance, costs for residential equipment were obtained by contacting local retailers. Where information was not made available, data sources for similar actions in other countries in the region were used in the analysis. For instance, costs for industrial waste heat recovery systems were based on a similar project in India developed under the UNFCCC Clean Development Mechanism (CDM).

5.3.2. Economy-wide Results

Total direct implementation costs of the LT-LEDS Category A actions are expected to result in about $4 billion ($4,139) saved throughout society in 2050 after an upfront investment of about $29 billion ($28,481 million).

Table 5-2 below shows the total investments, the 2030 and 2050 annual net costs and Net Present Value (NPV) at full implementation of all the LT-LEDS Category A actions in each sector, and in addition to the total investment cost needed under the BAU scenario. Total Investment includes only capital costs and does not include secondary impacts such as income, jobs, or social costs of carbon. Annualized net costs include annualized investment, ongoing O&M costs, savings, and private revenues in 2050, assuming full implementation of the actions.[38] Net Present Value (NPV) is the sum of annual costs across all forecast years (2024-2050), discounted using a discount rate of 8%. **Please note that negative values indicate net savings, while positive values indicate net costs**. Total investment and net costs specific to each LT-LEDS Category A action are provided in Annexes 4 to 10.

[38] The way how the GACMO model estimates costs does not produce an NPV value. This could be estimated with further analysis.

TABLE 5-2. LT-LEDS Sector Totals for Total Investment, 2030 and 2050 Annual Net Costs and NPV

LT-LEDS Sector Totals	Total Investment in addition to BAU (2024-2050), Million USD	Annual Net Costs (Annualized investment, O&M, Private Revenue/Savings) in addition to BAU, Million USD		NPV in addition to BAU (2024-2050), Million USD
		2030	2050	
Electricity Supply[39]	13,002	-225	-580	-2,920
Industry	1,075	-51	-118	-623
Transport	9,034	-498	-3,404	-11,619
Residential & Commercial	809	-114	-361	-1,823
Agriculture	137	-3	-14	-55
Forestry	4,030	95	345	1,576
Waste	394	-2	-6.5	-34
Total	28,481	-798	-4,139	-15,498

Source: Authors' calculations

For each LT-LEDS Category A action, the NPV is divided by its total cumulative GHG emission reductions to give a value for cost-effectiveness (CE). The CE value is shown for each action in below to show the cost in USD of reducing a ton of CO_2e (e.g., for Composting, the CE value is -2 and it means that the action will generate $2 of savings for each ton of CO_2e reduced).

[39] Due to data availability, the cost estimates assume agri-voltaics and other technologies instead of floating solar.

TABLE 5-3. Cost Effectiveness and Emission Reductions for LT-LEDS Actions

LT-LEDS Action	Total Emission Reductions in 2050 ($MMtCO_2e$)	Cumulative Reductions, 2024-2050 ($MMtCO_2e$)	NPV, 2024-2050 (Million USD)	Cost Effectiveness ($/$tCO_2e$)
Res. Lighting	0.02	0.27	-131.4	-478.3
Electric Heavy Trucks	0.70	6.96	-1321.2	-189.8
Biofertilizer	0.03	0.44	-67.1	-152.7
Electric Light-duty Trucks	7.14	91.05	-8359.2	-91.8
Electric Cars	0.76	11.99	-781.6	-65.2
Electric 2-Wheelers	3.02	39.48	-2307.1	-58.4
Electric 3-Wheelers	0.04	0.56	-32.4	-57.8
Wood Stove Upgrade	4.95	69.61	-1381.6	-19.8
Agri-Voltaic Solar	7.43	121.11	-1691.4	-14.0
Charcoal Stove Upgrade	0.40	5.99	-62.9	-10.5
Waste Heat - Iron & Steel	0.08	1.02	-9.9	-9.8
Commercial Energy Eff.	1.78	22.96	-217.7	-9.5
Waste Heat - Cement	0.14	1.74	-13.6	-7.8
Clinker Substitution	3.77	54.72	-423.6	-7.7
Utility-Scale Solar + Storage	7.43	131.26	-976.8	-7.4
Electric Buses	0.05	0.45	-3.1	-7.0
Res. Air Conditioning	0.11	1.44	-9.0	-6.3
Res. Refrigerators	0.39	5.44	-25.8	-4.7
Wind Energy + Storage	5.22	84.08	-262.4	-3.1
Ind. Fuel Eff.	2.90	42.53	-93.7	-2.2
Biogas Latrines	0.21	3.44	-7.5	-2.2
Composting	0.38	7.89	-15.4	-2.0
Manure Digesters	0.87	12.07	-21.2	-1.8
Ind. Electricity Eff.	3.61	54.86	-81.6	-1.5
Grid Upgrades	1.84	22.53	-20.2	-0.9
LFG Plant	0.37	6.55	-4.3	-0.7
RDF	1.05	13.58	-7.1	-0.5
Agroforestry	2.20	30.62	-12.1	-0.4
Coal Methane Capture	0.04	0.87	-0.3	-0.4
Reflective Roofs	0.42	5.59	5.0	0.9
Solar Mini-grids + Storage	0.07	1.09	1.4	1.3
Distributed Solar	1.99	22.30	30.1	1.3
Lowland Rice	0.31	5.20	7.8	1.5

LT-LEDS Action	Total Emission Reductions in 2050 ($MMtCO_2e$)	Cumulative Reductions, 2024-2050 ($MMtCO_2e$)	NPV, 2024-2050 (Million USD)	Cost Effectiveness ($/tCO_2e$)
Forest Restoration	23.83	357.19	1331.1	3.7
Avoided Deforestation	3.06	45.20	244.9	5.4
Expand Biodiesel Use	0.16	2.07	39.9	19.3
Enteric Methane	0.12	1.61	37.6	23.3
Shift from Road to Electric Rail	2.60	32.92	1061.8	32.3
Bus Rapid Transit	0.11	1.47	60.1	40.8
Expand Ethanol Use	0.05	0.54	23.9	44.3

Source: Authors' calculation

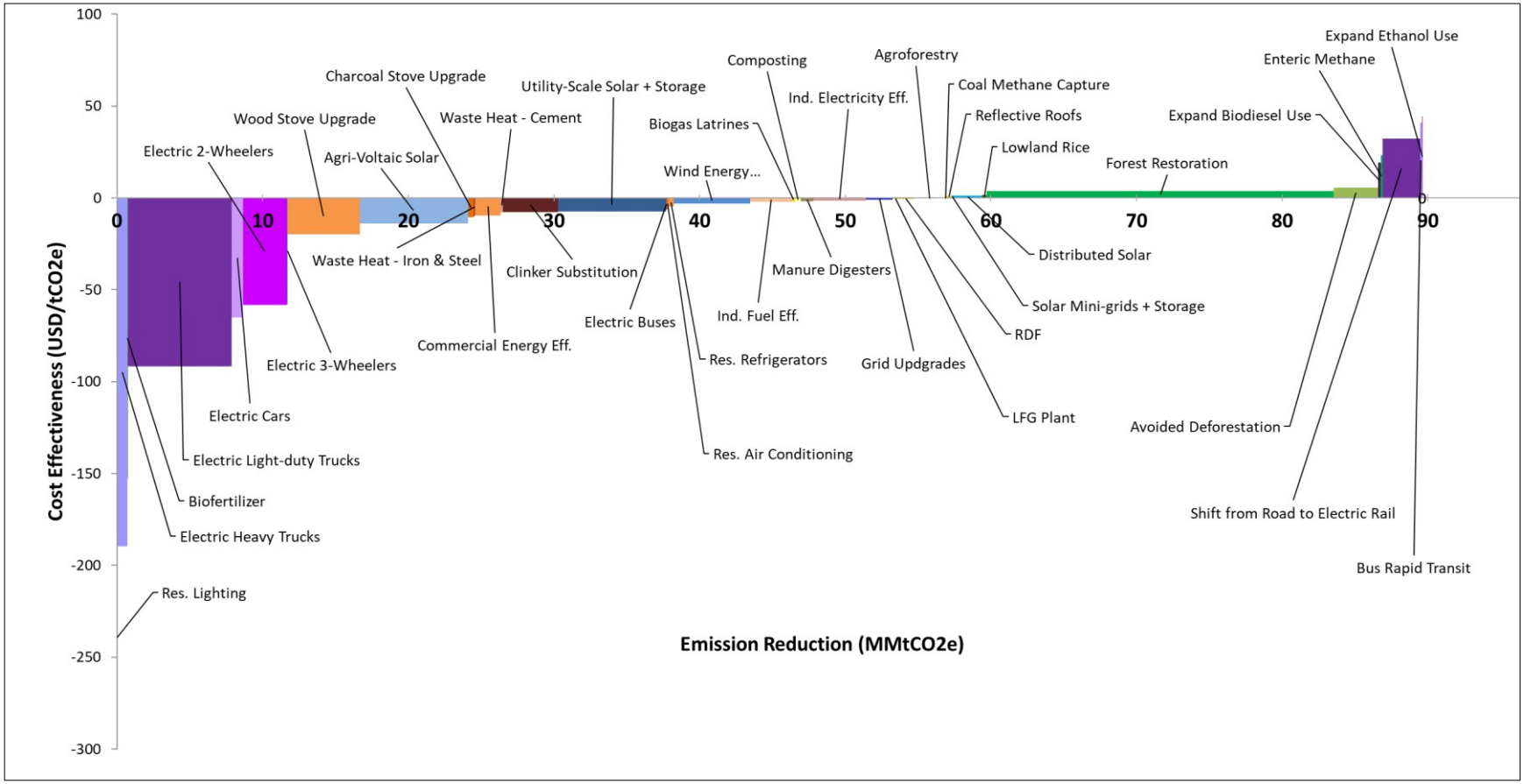
Based on the estimated GHG emission reduction (

Figure 5-1 above) and CE of each LT-LEDS Category A action (Table 5-3 above), the Marginal Abatement Cost Curve (MACC) below was developed. The MACC ranks each action in the order of its CE (from lowest to highest CE). The bars show CE ($/tCO2e) versus GHG emission reduction ($MMtCO_2e$) for each LT-LEDS Category A action. The width of each bar (x-axis) represents the GHG emission reduced for a given action, and the height of each bar (y-axis) represents the CE of a given action. Negative CE indicates savings; positive CE indicates costs. The MACC is based on direct costs and savings (e.g., capital costs for infrastructure, operation, and maintenance), and it does not include income, jobs, and social costs of carbon.

The MACC curve shows that only a few actions are estimated to have net positive financial costs. However, these actions typically generate social and economic benefits (see sections below on other benefits). Among the individual LT-LEDS actions, the Forest Restoration and Electric Rail actions appear to be of the highest in terms of direct costs due to land restoration, infrastructure, and equipment costs. **Most of the actions are estimated to generate savings**; among them, EV actions generate significant savings in later years when EVs are assumed to reach cost parity with internal combustion engine (ICE) vehicles and significant fuel savings are realized.

The most cost-effective actions, in terms of direct costs versus GHG reductions, are estimated to be residential lighting, electric heavy-duty trucks, and biofertilizer. However, it should be noted that this method of cost and benefit assessment is restricted only to financial costs and GHG benefits and does not include other costs and benefits common in socio-economic analysis (such as macroeconomic and adaptation impacts discussed in later sections).

FIGURE 5-2. Marginal Abatement Cost Curve (MACC) for LT-LEDS Actions



Source: Authors' calculation

5.4. The importance of decarbonizing electricity generation to achieve the net zero target and savings

5.4.1. The Proposed LT-LEDS Scenario for the Energy Sector

The proposed LT-LEDS assumes that by 2050 increased renewable-based electricity generation (solar and wind) will gradually displace coal-based electricity, mainly for export since domestic electricity demand is already met mainly by renewables (hydro) and a small portion of coal generated electricity from Sepon in the BAU scenario**. More specifically, compared to the BAU scenario, the LT-LEDS scenario assumes that:**

a) **The Bualapha coal power plant is not installed.** This assumption considers that the construction of the plant has not started yet and thus there won't be additional costs incurred for the phase- out of the plant.

b) Existing coal power production from Hongsa and Sepon will shift gradually to serve only peak load by 2040 and then be phased out by 2050. More specifically, they will be phased down to about 75% of current capacity around 2040, to about 35% of current capacity around 2045, and fully shut down by 2050. This scenario assumes that the power purchase agreement with EGAT related to the Hongsa coal power plant will phase down more quickly than the BAU scenario and eventually phase out by 2050.

c) **Additional solar and wind power production will be gradually installed between 2025 and 2050 to displace coal-based electricity from Hongsa and Sepon. This is in addition to the hydropower and geothermal power plants indicated in the NDC Implementation Plan and included in the BAU scenario**.

Table *5-4* summarizes the different electricity generation sources under the BAU and LT-LEDS scenarios during the planning period based on the assumptions above.

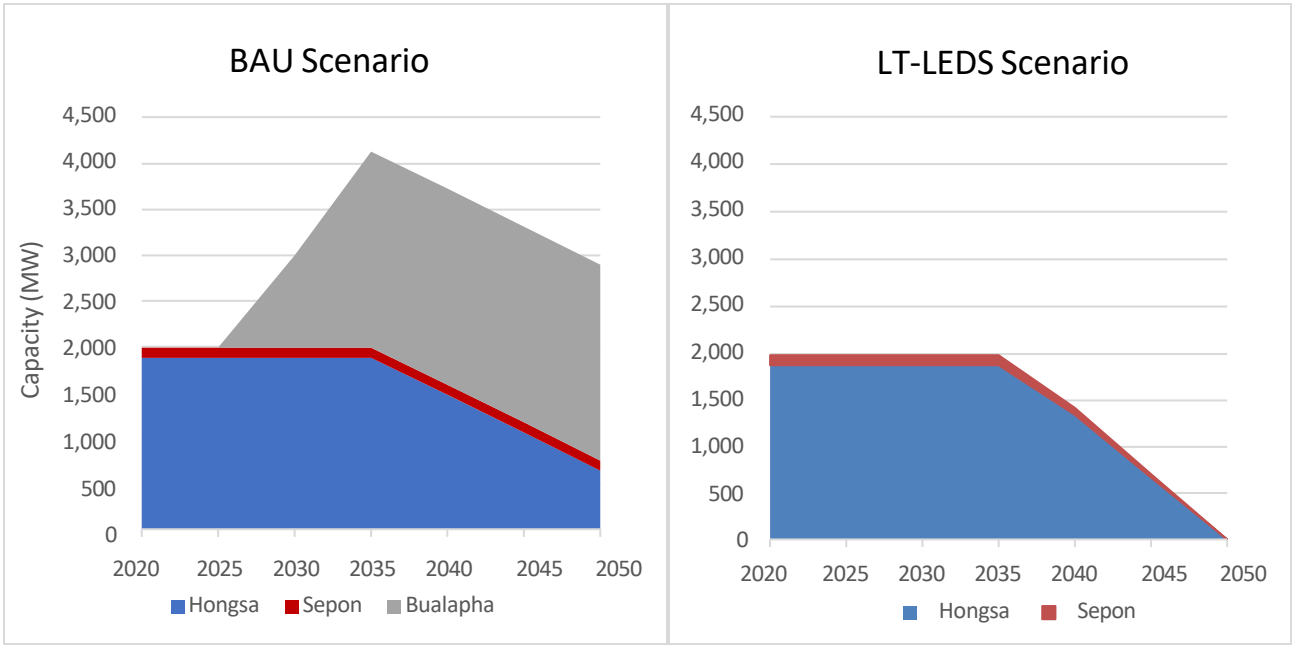
TABLE 5-4. Electricity Generation Sources for BAU and LT-LEDS Forecast Time Periods

Electricity generation source	2025-2035		2035-2040		2040-2050	
	BAU	LT-LEDS	BAU	LT-LEDS	BAU	LT-LEDS
Hongsa Coal Power Plant	Operation continues at current capacity		Operation continues, but decreases to 86% capacity when hydropower and geothermal power come online	Phased down to 75% capacity	Operation continues, but decreases to 42% capacity by 2050 due to existing hydropower and geothermal power	Phased down to 35% capacity by 2045 Shut down by 2050
Sepon Coal Power Plant	Operation continues at current capacity		Operation continues at current capacity	Phased down to 75% capacity	Operation continues at current capacity	Phased down to 35% capacity by 2045 Shut down by 2050
Bualapha Coal Power Plant	Comes online	No installation	Operation continues at the same capacity	No installation	Operation continues at the same capacity	No installation
Sekong Kaleum and Sekong Lamam Coal Power Plants	No installation		No installation		No installation	

Electricity generation source	2025-2035		2035-2040		2040-2050	
	BAU	LT-LEDS	BAU	LT-LEDS	BAU	LT-LEDS
Additional Hydropower and Geothermal Power listed in the NDC Implementation Plan to offset coal-based power	No additional installations to displace coal		Phase in of new installations to displace coal		Phase in of new installations to displace coal	
Solar and Wind Power	No additional installations to displace coal	Phase in of new installations to displace coal	No additional installations to displace coal	Phase in of new installations to displace coal	No additional installations to displace coal	Phase in of new installations to displace coal

Figure 5-3 below shows the coal generation capacity under both the BAU scenario and the LT-LEDS scenario.

FIGURE 5-3. Comparison of Coal Generation Capacity under the BAU and the LT-LEDS Scenarios

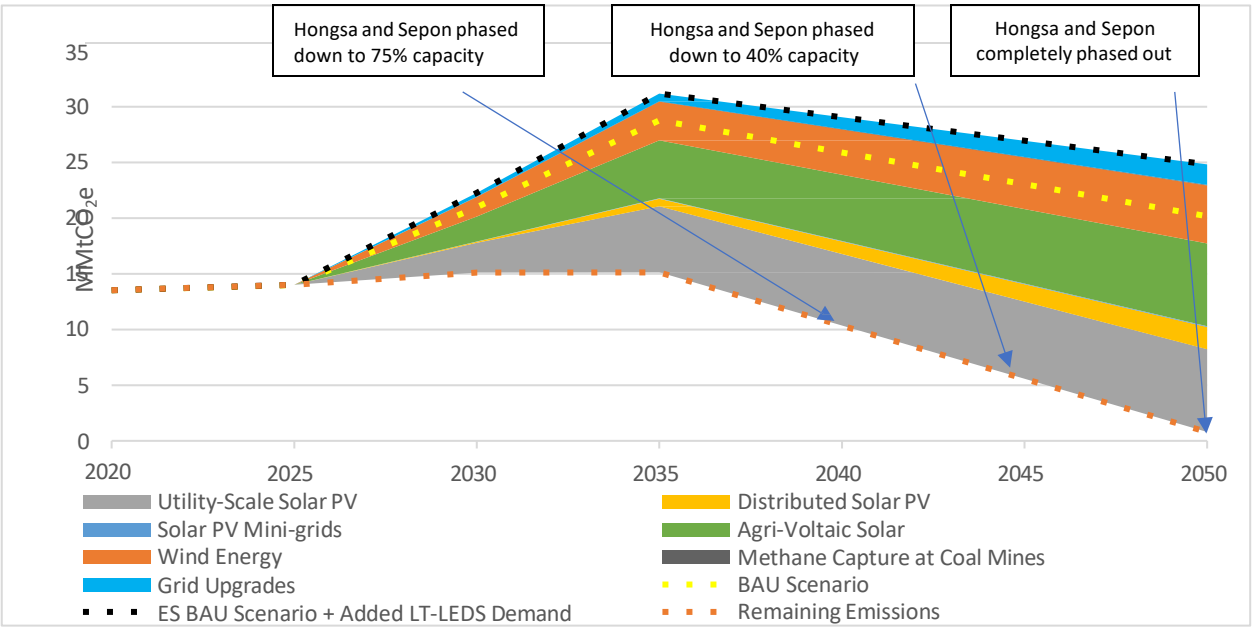


Source: Authors' Calculation

Gradual phase-out of coal power production with renewable expansion (solar and wind) is the only scenario that enables Lao PDR to achieve the net zero target and benefit from net savings, compared to the scenario where coal production continues. As shown in detail below**, the 2050 annual costs for the scenario with coal power generation are much higher than those under the LT-LEDS scenario with displacement of coal-generated electricity.**

Figure 5-4 below shows the impact of the above LT-LEDS scenario on the energy supply sector. Each wedge in the chart represents the GHG emission reduction generated by a specific energy supply LT- LEDS action (e.g., utility solar scale, wind, agri-voltaics, etc). This scenario is additional to the BAU scenario that includes 2 GW of geothermal and additional hydropower installed between 2035 and 2050 consistently with the NDC Implementation Plan (resulting in the downward slope in BAU emissions after 2035). It also includes the increase of GHG emissions in the BAU scenario to meet the additional electricity demand resulting from the increase of electrification in buildings and transportation (shown as "Added LT-LEDS Demand" in the ES BAU scenario). This LT-LEDS energy supply scenario enables the reduction of GHG emissions in the energy supply sector by 97%.

FIGURE 5-4. Energy Supply Sector LT-LEDS Emission Reductions (i.e., renewable electricity generation expansion with displacement of coal-based electricity generation)



Source: Authors' Calculation

The displacement of coal power production with renewables (solar and wind) requires GoL to engage in discussions and advance long-term power sector planning with neighboring countries, particularly Thailand and assumes that EGAT terminates the power purchase agreement related to the Hongsa coal power plant. A future in-depth assessment of the alternative options for regional power trade could support this planning effort. Under the BAU scenario, most of the coal-generated electricity produced in Lao PDR is exported to Thailand through a dedicated line to meet its growing demand needs. Additionally, Lao PDR does not have operational control of the Hongsa coal power plant and without relying on coal would not be able to provide a reliable baseload power supply to Thailand.

However, at the same time, regional power trade should not be seen only as a way for countries to meet their growing electricity demand, but also as a way to access clean energy sources in a cost-effective way to decarbonize their economies by 2050.[40] This will enable them to meet international commitments, align with other countries in the region, and attract funding. **Lao PDR is blessed with abundant renewable resources (hydro, solar and wind) and could become a key source of clean electricity for the region in the long term. This will require advanced planning with its trading partner countries, expansion of solar and wind energy, adequate energy storage capacity (pumped storage hydro and battery storage systems) and interconnection lines, as well as strengthened transmission and distribution grid, as well as effective investments**. Appropriate domestic reforms and international support to enable financing for investments in renewables could change the political economy dynamics that currently force Lao PDR and its neighboring countries to rely on coal power. Once deployed, renewable power operating costs are low.

Additionally, renewables become more attractive from a political and economic standpoint because they allow the country to transition to a sustainable economy and meet its decarbonization and economic growth targets.

[40] World Bank "Concept note - Interconnections and Power Trade Options with Lao PDR (ID:P500502) Lao People's Democratic Republic, Cambodia (EAST ASIA AND PACIFIC)

Box 2 summarizes the assessment measures that are recommended to be undertaken for the energy supply sector.

Box 2: Recommended Assessments for the Energy Supply Sector

- Develop a *least-cost expansion plan* for generation, transmission, and distribution to ensure that demand be met at the lowest cost and adequate levels of reliability.
- Review the *potential of specific solar and wind technologie*s, including floating solar, to operate in combination with the existing and planned hydro, and improve the quality and stability of power supply as well as increase the value of water.
- Assess *clean alternatives to replace the coal power plant* capacity planned to meet export commitments.
- Review the development of storage capacity, such as pumped storage hydro and battery storage systems that are critical for integration of variable renewable energy such as solar and wind power.
- Assess and improve *sector governance* ensuring that investment decisions follow the least-cost expansion plan; competition in solicitation of investments in power generation assets is introduced to reduce costs; a consistent and comprehensive approach in managing all the existing hydropower assets after the end of their current concession periods is followed to avoid case-by-case negotiations; pricing/tariff reforms are enacted to enable investment in storage capacity, improve the level of cost recovery, and protect the poor with targeted tariff subsidies.

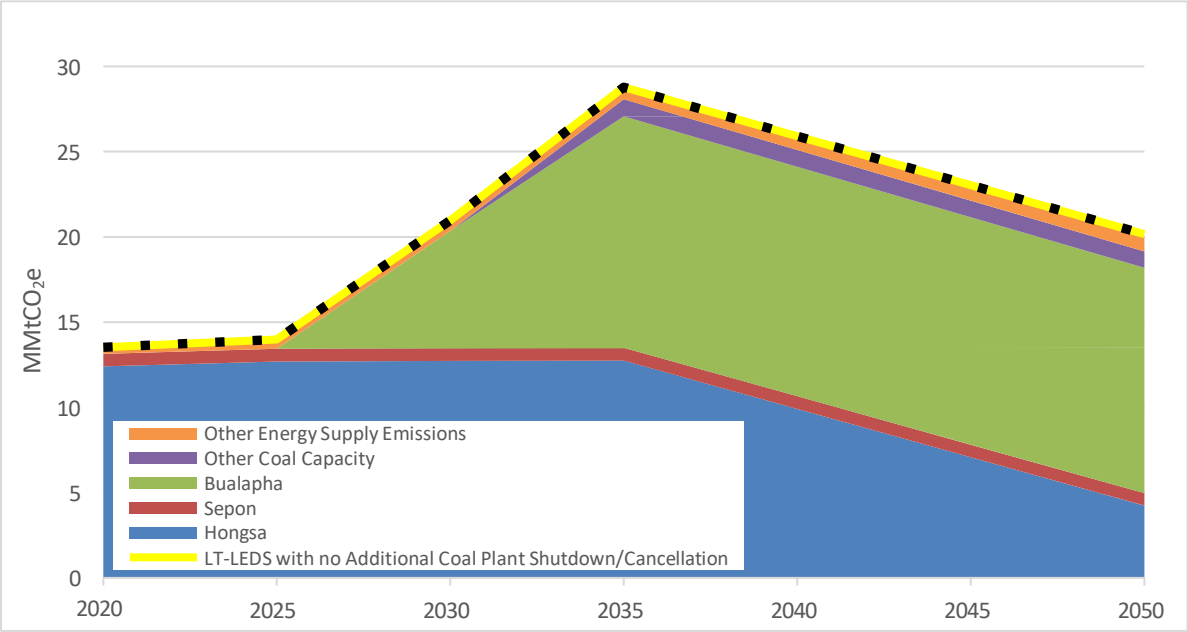
5.4.2. Implications of not replacing coal-generated electricity for export

Sensitivity analysis of scenarios not involving displacement of the coal power generation with renewables (solar and wind) by 2050 was conducted. **It has shown negative implications in terms of achievement of the net zero target by 2050, costs and feasibility**.

"Scenario with coal and renewables". Under this scenario, existing coal power plants are not shut down by 2050, the three new planned coal power plants are installed by the same timeframe, and more renewable-based electricity generation (solar and wind) is still added to the energy mix. The analysis shows that:

- The additional generated renewable power will mainly increase exports without displacing any coal generation (since domestic demand is already met mostly with hydropower in the BAU scenario) or generating any net savings.
- As a result, **the energy supply sector LT-LEDS actions will only generate slight GHG emissions reductions** (from the coal mine methane action) compared to the BAU scenario, and the total GHG emissions for this sector will remain at 20 $MMtCO_2e$ in 2050 under this scenario, as shown in
- Figure *5-5* below. **This means that at the economy-wide level the country cannot achieve net zero GHG emissions by 2050, since the energy sector GHG emissions remain almost at the same level as the BAU GHG emissions.**

FIGURE 5-5. Energy Supply Scenario Without Shutdown of Coal Plants and with More Renewable



Source: Authors' Calculations

"Scenario of coal with CCS and no renewables". To reduce GHG emissions without displacing coal, Lao PDR would need to install carbon capture and storage (CCS) on existing and new coal power plants. This scenario for the energy supply sector considers *(i)* a total of 3,800 MW of coal with CCS in 2050, and *(ii)* no new renewable energy beyond what is already planned in the BAU scenario to avoid the additional investment costs associated with more renewables. Since coal generation remains in this scenario, no additional renewable is needed to meet electricity demand, unless Lao PDR intends to increase export.

The implications and considerations of this scenario are the following:

1. **The 2050 annual costs under this scenario with CCS are much higher than under the LT-LEDS scenario with displacement of coal-generated electricity.** Under this scenario, the 2050 annual costs associated with CCS exceed the net annual costs (revenue) for the coal plants. This is due to the significant decline in costs of renewable energy in recent years, with this trend expected to continue through 2050. Comparative costs of renewable energy are already lower than or competitive with fossil-based generation, including coal, gas, and diesel-based generation. At the same time, market scaling of renewable energy technology adoption is increasingly accelerating due to advances in small scale technology aggregation and grid integration that enables high volume generation, transmission, and distribution of solar, hydropower, and wind power. **CCS technology costs, on the other hand, are quite variable depending on process, distance of transport, and storage site, and may not decline much in the future.** A 2017 study predicts only modest reductions in costs for carbon capture; transport and storage costs are not likely to decline since they are based on basic, established processes such as pipelines, gas pumps, and shipping.[41]
2. Table *5-5* below shows the total fixed investment costs and the annual net costs in 2050 for this "Scenario with coal + CCS, no renewables". These costs include *(i)* the costs of installing new coal generation; *(ii)* the annual costs of continuing to operate existing plants; *(iii)* investment and annual costs for CCS systems for all new and existing coal plants; and *(iv)* estimated costs for additional forestry actions to sequester remaining emissions. It is followed by Calculations

[41] Assessing the relative costs of high-CCS and low-CCS pathways to 1.5 degrees, 2023.

3. Table 5-6 which shows the total investment and annual net costs for the proposed LT-LEDS scenario with no coal. As shown, the overall investment is estimated to be similar for the two scenarios, but annual costs are higher for the scenario with coal and CCS. This scenario assumes an electricity sales price of $0.10/kWh, the same price used for sales of renewable electricity in the LT-LEDS scenario. More details on assumptions for this scenario are provided in Annex 4.

TABLE 5-5. "Scenario Coal + CCS, No Renewables" Total Investment and 2050 Annual Net Costs

LT-LEDS Sector Totals	Total Investment (2024-2050), Million USD	2050 Annual Net Costs (Annualized investment, O&M, Private Revenue/Savings), Million USD	NPV (2024-2050), Million USD (Discount rate of 8%)
Coal Plant Installation (New Plants)	4,148	-490	-3,280
Continued Operation of Existing Plants	-	-415	-8,605
CCS on New and Existing Coal Plants	7,056	1,923	10,043
Methane Capture at Coal Mines	1.2	-0.05	-0.3
Grid Upgrades	1,666	-4.1	-20
Additional Forestry Actions*	206	5.5	13
Total	**13,077**	**1,020**	**-1,851**

*Additional forestry actions to sequester carbon are assumed to be needed, since ccs will not fully mitigate emissions from coal plants. Costs are estimated based on the costs of avoided deforestation action in the forestry sector.

Source: Authors' Calculations

TABLE 5-6. LT-LEDS Energy Supply Scenario without Coal Total Investment and 2050 Annual Net Costs

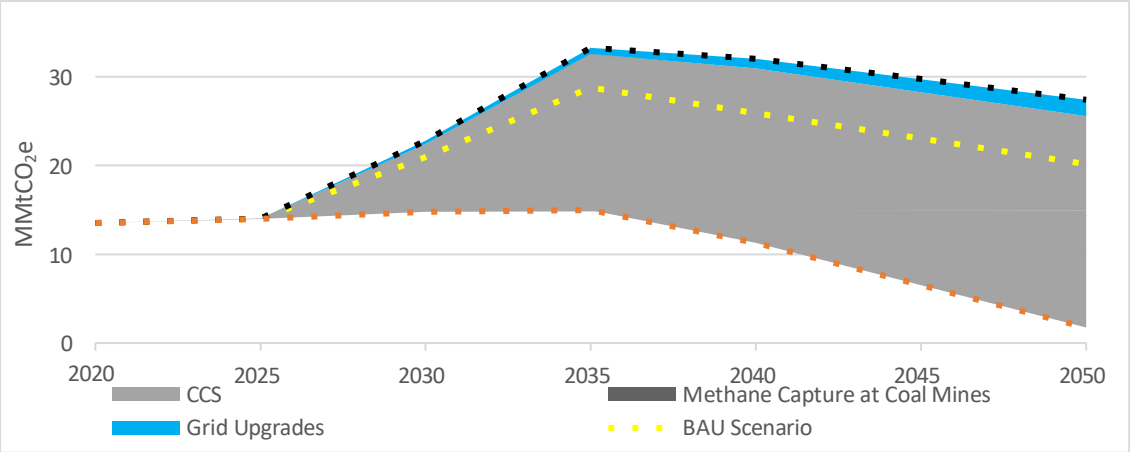
LT-LEDS Sector Totals	Total Investment (2024-2050), Million USD	2050 Annual Net Costs (Annualized investment, O&M, Private Revenue/Savings), Million USD	NPV (2024-2050), Million USD (Discount rate of 8%)
Utility-Scale Solar PV + Battery Storage (4 hr)	4,383	-153	-977
Distributed Solar PV + Storage	746	-3.0	-30
Solar PV Mini grids	74	1.4	1.4
Agri-Voltaic Solar	2,786	-355	-1,691
Wind Energy + Pumped Hydro Storage (12 hr)	3,346	-66	-262
Methane Capture at Coal Mines	1.2	-0.05	-0.3

Grid Upgrades	1,666	-4.1	-20
Total	**13,002**	**- 580**	**-2,920**

Source: Authors' Calculations.

4. **CCS could reduce emissions by 90% in theory,** as shown inFigure *5-6*. Energy Supply Scenario with Coal + CCS, No RenewablesFigure 5-6**.** However, **there are a lot of uncertainties.** A 2022 survey of 13 facilities found that only two CCS facilities performed at or close to 90% emissions reductions, with more than half of the facilities capturing significantly less. [42] In addition, even under the assumption that CCS reduces 90% of GHG emissions, **the net zero target cannot be achieved unless carbon sequestration is further increased in the forestry and/or agriculture sectors (beyond current estimation in the LT-LEDS scenario). This increase is very unlikely** since the LT-LEDS targets in these sectors are already ambitious.

FIGURE 5-6. Energy Supply Scenario with Coal + CCS, No Renewables



Note: The "BAU Scenario + Added LT-LEDS Demand" emission estimates include the additional net demand from electrification and energy efficiency actions in other sectors, as well as the additional electricity demand from the CCS systems.

Source: Authors' Calculations

5. There would also be feasibility issues in identifying carbon storage sites. Carbon storage sites are typically in depleted oil and gas fields, abandoned or un-mineable underground coal seams, or other geologic sites, such as saline aquifers or basaltic formations.[43] It is unclear if any such sites can be identified in Lao PDR. If the CO_2 needs to be transported to storage sites in neighboring countries, this increases the costs further.

6. There might be safety risks associated with CO_2 pipeline transport. While studies show that these pipelines do not pose a higher risk of accident than for fossil fuels, most of them currently in use run through sparsely populated areas. Deployment of pipelines from existing power plants in more densely populated areas could pose greater risks. Leakage of CO2 from pipelines could lead to elevated concentrations of CO2 in ecosystems, human settlements, and in groundwater. There are also risks around storage sites, such as induced seismicity and displacement of saline or hydrocarbons (depending on the type of storage site) into aquifers or surface waters.[44]

7. Coal based power generation produces local air pollution that impairs public health, including the labor force for coal mining. Zero emissions renewable energy technologies not only avoid these health effects but create equal or greater employment opportunities due to significant labor needs of new supply chains and production activities.

[42] The Carbon Capture Crux: Lessons Learned; Institute for Energy Economics and Financial Analysis, 2022. https://ieefa.org/resources/carbon-capture-crux-lessons-learned.
[43] Carbon Storage FAQs, National Energy Technology Laboratory
[44] Carbon Dioxide Capture and Storage: Issues and Prospects, 2014.

8. Coal based power generation produces local air pollution that impairs public health, including the labor force for coal mining. Zero emissions renewable energy technologies not only avoid these health effects but create equal or greater employment opportunities due to significant labor needs of new supply chains and production activities.

9. Access to capital for expansion of renewable energy is becoming more secure in comparison to coal and other fossil industry financing needs, due to the shift by policy sensitive energy investment sources to low carbon sustainable sources. This is particularly true for foreign institutional investments that are policy sensitive, highly capacitated, and hold the potential to reduce pressure on domestic capital markets that are critical to growth. If Lao PDR does not capture the interest of foreign sustainable investment sources, they may look to other locations and reduce the competitive fiscal advantage for Laos.

10. As mentioned earlier in the report, coal facilities could become stranded investments while renewable energy capacity expansion meets long term policy and investment needs. This can happen if the investment shift towards renewables does not occur at the early stages of energy investment decisions, and instead Lao PDR focuses on long term coal plant capacity expansion and locks in long term high carbon capital commitments. In this case, the country risks having long term expenditures fail to match long term policy and investment preferences.

11. Laos has already faced significant loss and damage from climate change across many local populations and sectors, such as rural villages and agriculture zones. Shifts to renewable energy expansion are critical to addressing growing risks and vulnerabilities to climate change. The adoption of net zero technologies and practices for energy generation and distribution can also institute shifts to improve infrastructure resilience that reduces exposure to climate risks; some examples of shifts are grid hardening and other updates to the electricity system.

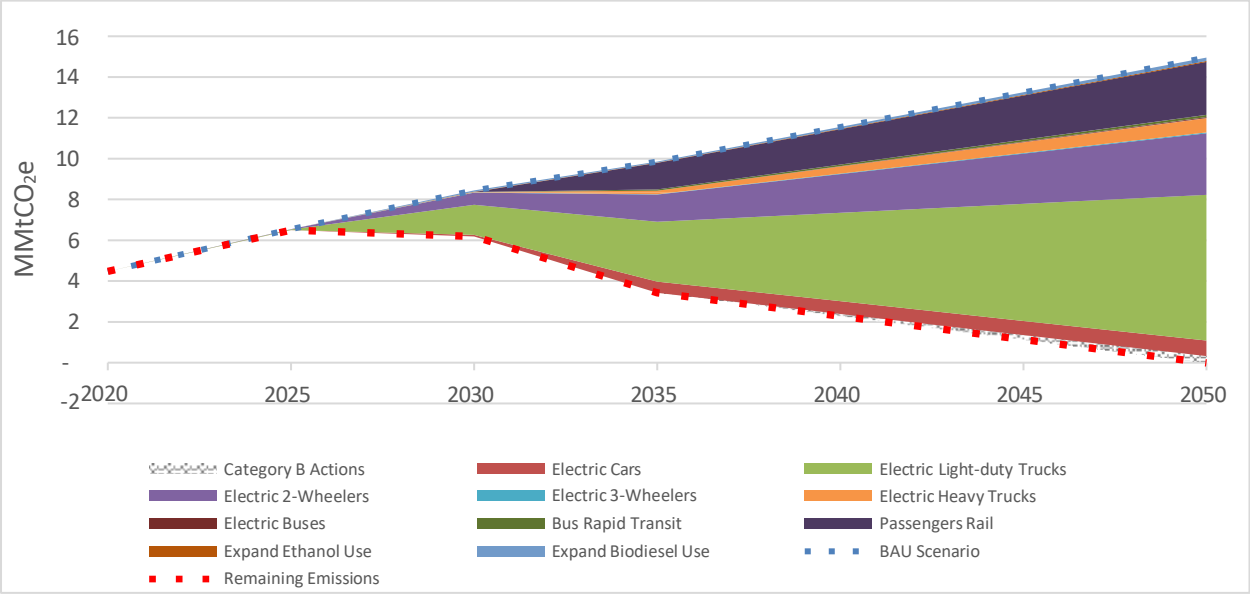
In summary, the "Scenario of coal with CCS and no renewables" is not a viable option to achieve the net- zero emissions target, given its significant uncertainty in emission reduction effects and reliable storage sites, and higher costs. The same uncertainties and challenges would apply to the "Scenario of partial coal, partial renewables, and CCS", just at a different degree.

5.5. The contribution of the transportation sector to achieve the net zero target

In addition to the decarbonization of electricity generation, the Lao PDR 2050 net zero pathway requires significant transformations in the transportation sector that together with energy and forest is the other main sector expected to drive GHG emission reduction by 2050.

The most impactful LT-LEDS action in the transportation sector is expected to be the shift to electric vehicles. This will include electric cars, electric light-duty trucks, electric 2-wheelers, electric 3-wheelers, electric heavy trucks, and electric buses. More specifically, it is estimated that this shift will reduce GHG emissions by 15 $MMtCO_2e$, 18.6% of the total LT-LEDS GHG emissions reduction. Each wedge in Figure 5-7 below represents the GHG emission reduction generated by a specific LT-LEDS action in the Transportation sector. More details on each of these actions, including targets, costs, data, and assumptions, are provided in the related sector-level Annex.

FIGURE 5-7. Transportation Sector LT-LEDS Emissions Reductions (Direct Emissions Only)



Source: Authors' Calculations

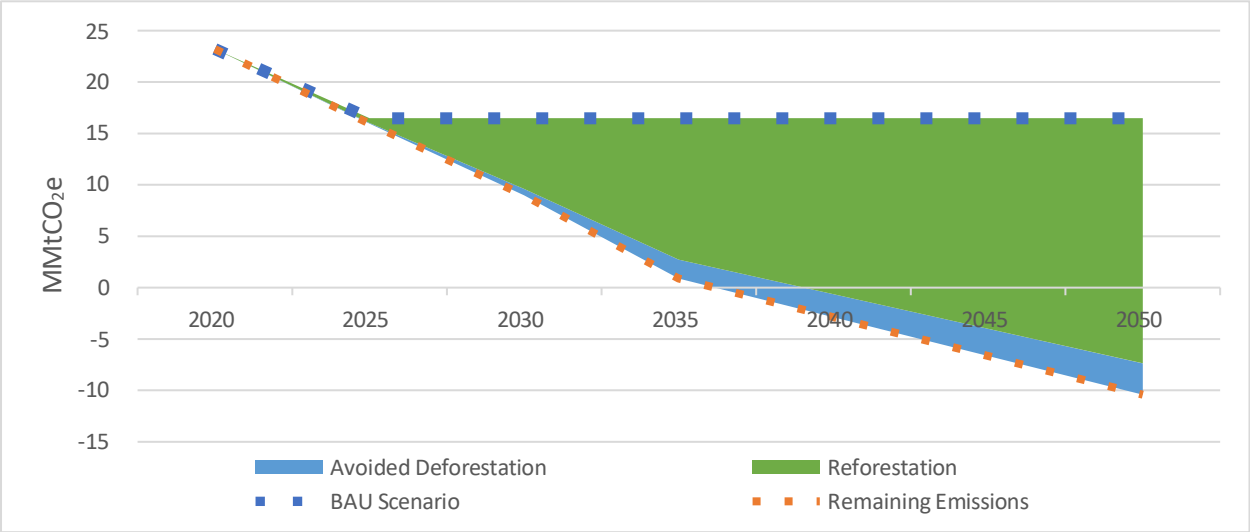
The targets for EV actions were established based on the forecasted number of vehicles for each vehicle type, and the assumption that approximately 30% of light-duty vehicles will be replaced by 2030 and nearly 100% of all vehicles will be replaced by 2050. These targets are consistent with GoL's plans and the shift will begin immediately for light-duty vehicles and between 2025 and 2030 for heavy-duty vehicles.

The assessment of these actions assumes that new electricity generation to meet demand for EVs will come from the existing locally derived grid energy mix with the required investments in transmission and distribution and expanded use of locally derived renewable energy (solar and wind). This assumes that the country's renewable energy capacity can support the increased demand of electricity estimated from the implementation of EV actions. The assessment also assumes that adequate charging infrastructure is in place in urban, suburban, and rural areas (the costs for chargers are accounted for in the analysis). Initially, EV costs are estimated to be higher compared to ICE vehicles; however, they are expected to decrease over time. The implementation of EV actions requires that **the fiscal implications of EV implementation be examined and dealt with and that mechanisms to incentivize users to shift to EVs are established. These might include purchase incentives, leasing programs, and public awareness campaigns to accelerate the shift.**

5.6. The contribution of the forestry sector to achieve the net zero target

The forest sector plays a critical role in the achievement of the 2050 net zero target under the LT-LEDS scenario. GHG emission reductions in the forestry sector are expected to come from avoided deforestation through the expanded conservation and protection of forestland and the terrestrial carbon that it sequesters and **expanded forest management/restoration** to allow land to naturally regenerate into forest and sequester terrestrial carbon. It is estimated that these actions will reduce emissions by 27 $MMtCO_2e$, equal to 34.2% of the total LT-LEDS GHG emissions reduction. Each wedge in Figure 5-8 represents the GHG emission reduction generated by these LT-LEDS actions in the forestry sector. More details on each of these actions, including targets, data and assumptions are provided in the related sector-level Annex.

FIGURE 5-8. Forestry Sector LT-LEDS Emissions Reductions



Source: Authors' Calculations

The targets for the two LT-LEDS actions in the forestry sector were established based on historical deforestation rates and the area of land needed to be converted to forest to reach Lao PDR's goal of 70% forest cover. **Implementation is assumed to be phased in gradually starting in 2025.**

Avoided deforestation is a critical action to enable the achievement of the net zero target by 2050. Forest loss is a critical issue in Lao PDR due mainly to infrastructure development, such as hydropower, mining, roads, illegal logging, and conversion of forests to agricultural land, attributable to population increase and expansion of commercial crop production. As indicated earlier in this report, **slow progress in structural transformation** of moving workers from relatively low-productivity agricultural sectors to higher-productivity non-agricultural sectors **has led to an overreliance on agriculture.** Weak private sector development has hindered diversification away from agriculture toward sectors like manufacturing or services. This dependency on agriculture, coupled with the acceleration of commercial agriculture in recent years, has driven the expansion of agricultural land into forests, contributing to deforestation. [45]

An in-depth assessment of the forestry sector, including the main drivers of deforestation and challenges, was outside the scope of this assessment. The implementation of the LT-LEDS actions in the forestry sector will require a careful assessment of the causes, challenges, and trade-offs, including the economic drivers and adequate policy reforms to address them. In addition, a lack of detailed inputs and available information on the proposed LT-LEDS forestry actions did not allow to identify the practices that would need to be implemented under each of these actions. For instance, in order to reduce deforestation, site-specific practices could include fire prevention measures, control measures for invasive plants, satellite and remote sensing technologies for forest monitoring, and the use of conservation easements and partnerships with local communities, techniques and practices to increase agricultural yields, reducing the need to expand agricultural land. For reforestation and restorations, specific practices could include replanting of damaged or degraded forests, monitoring and treatment of pests and diseases, thinning and density management, and expansion or new establishment of forests on non-forested lands. Inputs and data needed to identify these practices include detailed geographic analysis of forest types, causes of deforestation, agricultural practices, and local communities.

[45] Lao PDR Systematic Country Diagnostic 2021 Update, available at https://www.worldbank.org/en/country/lao/brief/lao-pdr-systematic-country-diagnostic-2021-update-brief

Considerations of costs for the LT-LEDS forest actions are important. Due to limited available information, costs were estimated for the LT-LEDS assessment based on information available for current REDD+ programs; however, **costs may vary for specific programs based on forest type, region of the country, causes of deforestation, and specific implementation mechanisms. Therefore, they should be reassessed as reforestation and management practices are defined**. In addition, mechanisms should also be established to incentivize these actions. These may include payments for ecosystem services schemes to reward landowners for forest conservation and reforestation initiatives.

5.7. Economic Implications

5.7.1. Lao PDR Macroeconomic Context

The Lao PDR current macroeconomic context and outlook are dominated by "unprecedented macroeconomic challenges"[46] that call for significant and concrete reforms to **"**restore macroeconomic stability, enhance revenue mobilization, increase spending efficiency, and tackle fiscal risks."[47] **Restoring macroeconomic stability and fiscal space are necessary conditions to generating positive macroeconomic impacts from the implementation of the LT-LEDS actions.**

Lao PDR is currently in **debt distress** with **limited fiscal space** to support investments and is experiencing slow economic growth, high inflation, and national currency depreciation. Past experience in the country has shown that large-scale investments in capital-intensive sectors, such as mining and hydropower, were mainly "financed by external debt, gradually jeopardizing debt sustainability."[48] **Additionally, these projects attracted significant private finance through public-private partnerships (PPs), but "have likely provided limited value for money,"**[49] creating few jobs and leading to "an increase in fiscal commitments, contingent liabilities, and foregone revenues."[50] **Weak institutional and regulatory governance and limited capacities** in assessing and managing PPPs have been some of the key contributing factors. Lao PDR is currently relying on debt service deferrals and renegotiations to avoid further deterioration of its macroeconomic situation: debt restructuring is needed to restore debt sustainability, and revenue reforms are essential to increase fiscal space. The country should also consider elevating efforts to improve productive capabilities that require also improved education to increase the potential for its workforce to support new local supply chains for LT-LEDS actions. This is a key driver of macroeconomic gain that could result from a more environmentally sustainable economy.

[46] World Bank. 2023 Public Finance Review. Lao People's Democratic Republic. Washington, DC. World Bank. 2023. License: Creative Commons Attribution CC BY 3.0 IGO
[47] *Ibid*
[48] *Ibid*
[49] *Ibid*
[50] *Ibid*

5.7.2. Methodology

The additional economic evaluation of the LT-LEDS Category A actions in this section examines their potential economic implications in terms of economic growth and employment. This assumes that macroeconomic stability and fiscal space are restored, and productive capabilities (e.g., skills, knowledge, and innovation potential) are improved so that assumptions made around the implementation of these actions materialize**. The development and application of a comprehensive, empirical macroeconomic analytical model for Lao PDR is outside the scope of this assessment**. Instead, this evaluation was carried out using an **indicator-based approach for economic growth and employment** to determine the potential direction (positive, negative or neutral) of the impacts driven by the LT-LEDS actions in each sector and the drivers for these effects. It should be noted that the determination of the magnitude or scale of such effects requires sector level GDP or value- added data that was not available for this assessment but would be a helpful additional analysis to be conducted.

This methodology is based on previous regression analysis of several macroeconomic studies of climate change mitigation actions[51] that show that six indicators (or factors) are important drivers of economic growth and employment for specific sector-level climate mitigation actions. Each of these indicators is manifested through the specific structure and function of LT-LEDS actions. **For each LT-LEDS action, this assessment is based on an assumed implementation design structure and function; the results of the quantitative assessment of direct costs and savings**; **restored macroeconomic stability and fiscal space; and improved productive capabilities (e.g., skills, knowledge, and innovation potential) through education and workforce enhancement.[52]**

MACRO-ECONOMIC EVALUATION OVERVIEW

The study cited in the footnote below shows that low-carbon policy actions have the potential to provide significant net macroeconomic benefits given appropriate implementation design and financial performance. This outcome is the result of favorable effects associated with the adoption of new technologies and practices in place of, or in addition to, current approaches.

Comprehensive macroeconomic assessment typically estimates changes in economy-wide, sector-wide, and sector specific policy and program measures with metrics for employment, GDP (or economic growth), personal income, personal consumption and expenditure, changes in price and productivity, and value added. These improvements occur as people and organizations respond to changes in income, costs of living and business costs, and availability of work once a low-carbon action is implemented.

This level of economic analysis typically follows a primary, or direct impact analysis of costs and benefits which provides inputs to macro level comparison of multiplier effects for new versus current activities. Evaluations of the secondary or macroeconomic impacts of actions can be carried out quantitatively and/or qualitatively and with varying degrees of detail and sophistication depending on the need, the level of available detail for the implementation design of the action (particularly as it affects income and expenditures), and the availability of costs/savings and spending/revenue data. Results of this form of impact analysis can guide the planning, implementation, and further analysis and development of low carbon actions to ensure that they meet socio-economic goals and objectives (sometimes referred to as "political economy").

[51] The indicator-based macroeconomic assessment is based on the study titled "Summary of Key Factors Contributing to the Macroeconomic Impacts of GHG Mitigation Options" by Dan Wei, Adam Rose and Noah Dormady of the School of Public Policy Sol Price of USC.

[52] World Bank. 2023 Public Finance Review. Lao People's Democratic Republic. Washington, DC. World Bank. 2023. License: Creative Commons Attribution CC BY 3.0 IGO.

The six indicators are:

1. **Shifts in implementation costs.** Changes in technologies and practices resulting from the LT-LEDS actions can lead to lower overall net implementation costs than in the BAU scenario. When total net implementation costs are less than the expected net cost in the BAU scenario, financial resources can be freed up for re-spending in other sectors to stimulate economic growth. This requires that private revenues and savings generated by the implementation of a LT-LEDS action are retained within the country and result in a domestic reinvestment effect. When such benefits are siphoned away by foreign owners and investors, the responding effect is negated.

2. **Shifts in energy and natural resource spending costs**. Changes in technologies and practices resulting from the LT-LEDS actions can lead to lower energy and natural resource spending costs than in the BAU scenario. Gains in efficiency and energy or resource savings through newly adopted LT-LEDS technologies or practices lead to financial resources becoming freed up to stimulate economic growth. This assumes a net basis incremental increase in spending that expands the multiplier effects of spending. As in changes in overall costs described above, this requires that private revenues and savings generated by the implementation of a LT-LEDS action are retained within the country and result in a domestic reinvestment effect. When such benefits are siphoned away by foreign owners and investors, the responding effect is negated.

3. **Shifts toward sourcing energy supplies from local resources**. Shifts from imported to local energy or resource sources stimulate local multiplier effects and macroeconomic growth rather than nonlocal (outside of the region) effects. In addition, this shift can reduce market volatility from global fossil fuel-based markets and challenges in exchanging foreign currency for fuel purchases and can result in expansionary effects. This requires that the local workforce can expand and absorb higher levels of local production demand and requires adequate workforce preparation and deployment programs, including basic and trade-based education.

4. **Shifts toward sourcing supply chains from local sources**. Shifts from imported to local product inputs from other local sectors or local supply chains stimulate local multiplier effects and macroeconomic growth, rather than nonlocal effects. This also requires that the local workforce can expand and absorb higher levels of local production demand and requires adequate workforce preparation and deployment programs, including basic and trade-based education. Please note, however, that the assessment of specific supply chain shifts is outside the scope of this assessment and could be an area for future analysis.

5. **Shift toward labor-intensive activities.** Shifts in favor of more local labor-intensive LT-LEDS activities compared to the BAU scenario stimulate net increases in the levels and diversity of local employment growth versus nonlocal effects. As with the shifts toward local production of inputs and supply chains mentioned above, this also requires that the local workforce can expand and absorb higher levels of local production demand and requires adequate workforce preparation and deployment programs, including basic and trade-based education.

6. **Shifts toward external sources of investment and income.** Usually, shifts toward external sources of investment, such as from international sources, create newly available funds for local spending to stimulate economic growth without offsetting the effects of competition for a static local pool of funding. This requires a macro investment environment that provides stability and the control of major forms of fiscal and macroeconomic risk such as inflation, debt, currency risk, corruption, and foreign asset control. Lao PDR has received significant foreign investments in the past 20 years that did not generate positive benefits on the local economy as indicated earlier in this report. Thus, foreign direct investment in the future needs to be supported by macroeconomic reforms in order to be more impactful on the local economy. Note that this assessment did not conduct a financing analysis of LT-LEDS actions that would have entailed a level of effort and expanded scope. Future studies could refine the evaluation of the investment indicator by expanding the direct economic impact analysis to include a more detailed financial analysis of end uses of funds and matching sources for each of the LT-LEDS actions, as well as identification of efficient mechanisms and partnerships for deployment. This would enable a much more specific evaluation of investment barriers and macroeconomic effects.

Based on macroeconomic enabling conditions and implementation design structure, the implementation of an LT-LEDS action can positively or negatively affect each of the indicators related to GDP growth and/or employment, and the overall net effect of all six indicators combined for any given action may be positive or negative. These impacts may also change over time, such as when new supply chains initially require the importation of technologies but are later replaced by domestic production capacity that reduces import dependence (e.g., photovoltaic panels). Results are summarized at the economy-wide level in the section that follows and in the matrix for each Category A action or group of similar actions in Annexes 4 to 10.

This approach is not intended to substitute for a quantitative assessment that can provide higher levels of detail and aggregate systems-level evaluations. In addition, it does not evaluate the role of key exogenous variables such as fiscal effects (e.g., national debt, inflation, currency risk) or climate-based loss and damage. In particular, the Social Cost of Carbon (SCC) has not been included in economic impact assessments The inclusion of SCC could have a material effect on the estimated macroeconomic performance of LT-LEDS actions that do not presently appear entirely positive and could reverse neutral and negative impact findings. Implementation of design enhancements to specific LT-LEDS actions could have the same effect.

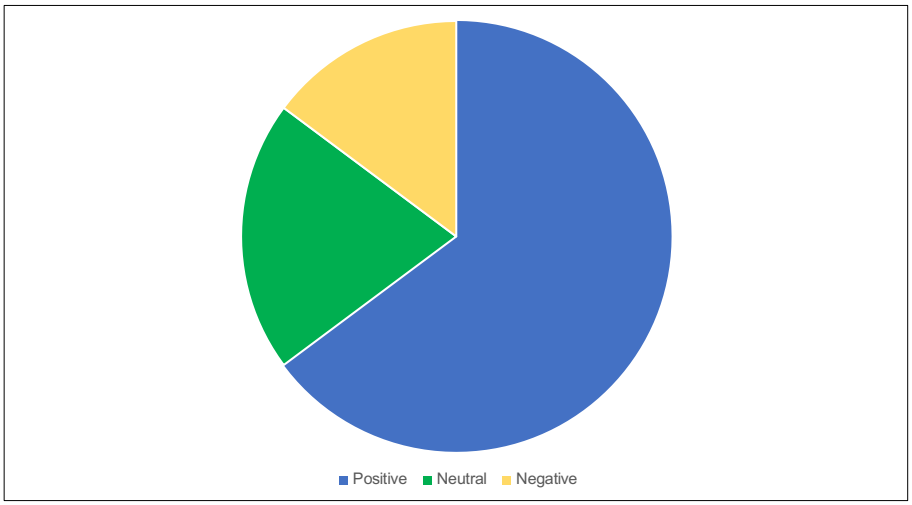
The evaluation of other social impacts was beyond the scope of the assessment, such as analysis of **disproportionate effects on** populations and equity indicators, or changes in public health and workforce productivity. These would be helpful expansions of analysis in future renditions of this report and would enable to identify targeted compensatory interventions since the net zero transition may burden some sectors or population groups and create additional opportunities for others. The study also was not able to provide a sensitivity analysis of key variables on macroeconomic indicators. This would be helpful in the future not only for each of the indicators, but also for each of the major areas of the macro enabling environment such as debt, inflation, corruption, currency risk, and national education.

5.7.3. Economy-wide Key Findings

All LT-LEDS Category A actions can generate net positive economic impacts if macroeconomic stability and fiscal space are restored and productive capabilities are improved within the country through significant, concrete, and measurable reforms as outlined in the 2023 World Bank Public Finance Review. Based on these conditions and assumptions, this section provides economy-wide results while the assessment of each LT-LEDS Category A action (or group of similar actions) is provided in Annexes 4 to 10.

Figure 5-9 below represents the economy-wide results as the sum of the positive, negative, or neutral impacts of LT-LEDS Category A actions (or group of similar actions, such as renewables) against the indicators. The pie chart represents the number of times a positive, negative, or neutral indicator appears but not its scale (such as in relation to sector-level GDP or value added). Based on the assumptions highlighted above, the LT-LEDS actions are expected to generate mostly positive impacts on the indicators across all sectors.

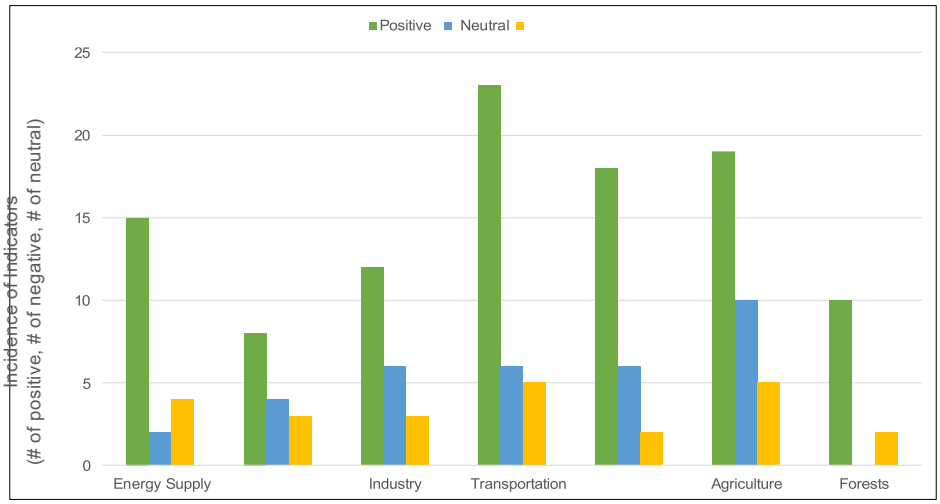
FIGURE 5-9. Sum of Impacts of LT-LEDS Actions Against Indicators



Source: Authors' Evaluation

Figure *5-10* below provides a breakdown by sector showing the sum of the positive, negative, or neutral impacts of LT-LEDS Category A actions (or group of similar actions, such as renewables) in each sector against the indicators. This figure also shows the number of times such indicators appear within sectors but not their relative scale. Results again show a preponderance of positive effects in each sector.

FIGURE 5-10. Direction of Indicators by Sector



Source: Authors' Evaluation

Positive macroeconomic impacts are estimated to be driven mainly by:

1. Reduction of costs. As indicated in previous sections and shown in the MACC, most of LT-LEDS Category A actions will generate net savings compared to the BAU scenario, assuming some significant investments are made upfront, and that savings are retained in the country. Additionally, as shown in the detailed cost analysis of specific LT-LEDS actions in Annexes 4 to 10, most of the actions will reduce overall energy and resource system costs and costs of energy to producers and consumers. Assuming that revenues and savings are retained domestically**,** both reductions in cost will free up capital in the economy that can be re-spent elsewhere within Laos. For instance:
    - The direct economic cost and savings analysis shows that the overall net cost of power generation from solar and wind is lower than coal-based generation with carbon capture and storage due to a decrease in technology acquisition and maintenance costs over time.
    - New energy-efficient wood and charcoal cookstove technologies result in significant energy cost savings to consumers associated with reduced fuel demand.
2. Creation of local supply chains and local energy/resource inputs for LT-LEDS actions. The implementation of most of the LT-LEDS Category A actions can expand domestic resource conversion, production, and distribution chains. This would spur local economic activity and, in some cases, create a shift from imports that occur in the BAU scenario. For instance,
    - The current use of local conventional fertilizers is assumed to be reduced at a 1:1 ratio and replaced with locally derived nitrogen-fixing microbe fertilizer. Shifts from imports to product inputs from local supply chains would stimulate local multiplier effects and macroeconomic growth rather than nonlocal effects.
3. Introduction of labor-intense technologies and activities. Most of the LT-LEDS actions will require the development, installation, operation and maintenance of technologies, equipment and practices that are expected to be more labor-intense than activities and technologies under the BAU scenario. For instance, new renewable energy systems typically involve a higher ratio of human to capital inputs in comparison to mature, fossil-based systems, while also bringing lower overall costs. Additionally, the implementation of these practices or use and operation of these technologies will need to be supported by targeted training, education, and workforce development. It also will require that improved macroeconomic stability, fiscal space and national education occur. For instance,
    - The labor intensity associated with waste recapture equipment is expected to be higher than the business-as-usual scenario. This is due to new product development intensities that result

in higher levels of employment associated with early stage product and market development in comparison to mature products and markets.

- Workforce needs to meet new EV infrastructure will require training and capacity building that are more likely to attract new labor segments, including diverse categories.

4. The attraction of foreign investments into the country could create new opportunities to foster economic activities. In the past, PPPs in hydropower in Lao PDR failed to create tangible benefits to the local economy. These capital-intensive investments have benefited from generous tax exemptions, channeling limited investment into the country, and with limited linkages to the rest of the economy. Assuming that PPP practices within the country are reformed, the LT-LEDS actions could attract foreign investments to the extent that they generate new and higher levels of global benefits, such as equitable and sustainable energy and resource production. For instance,
    - BRT expansion requires significant investment from both the public and private sectors in comparison to the BAU scenario. EV bus transit expansion has the potential to provide global benefits of interest to international funding sources in comparison to traditional vehicle infrastructure, which carries negative social externalities.

However, for new investments in wind and solar power, a different investment approach is recommended. Given the nature of these investments (e.g., capital intensity and resource exploitation for export), a critical element to consider could be adequate taxation – which increases the fiscal resources available to finance public investments (e.g., education and infrastructure) and increases the supply of foreign exchange in the country.[53]

However, **negative circumstances can reduce the overall scale of these positive impacts.** This might include the following types of implementation conditions for the LT-LEDS actions:

a) **Actions require initial imports of technologies and equipment rather than domestic products.** This is the case for renewable generation, methane capture, grid upgrades, energy efficiency, efficient cookstoves, BRT, shift to electric rail, manure digesters, mitigation of enteric methane emissions, solid waste composting, and refuse derived fuel. An increase in imports won't benefit the local economy and will require the direction of local capital to recipients outside the country. Additionally, initial imports will also place pressure on the already weak exchange rate. **However, this negative macroeconomic impact could potentially be mitigated over time by creating local supply chains that replace imports** (assuming improved national education and workforce development)**.** This is the case for instance, for the BRT, where the initial shift to EV buses will require imported technology, but the longer-term effect will be stimulus for local production and installation. This gain would require restored macroeconomic stability and fiscal space, as well as improved national education.

b) **Actions reduce energy demand and thus local economic activities associated with local energy production (not imported energy).** This is the case for efficient cookstoves, waste heat recovery for cement and iron/steel plants, clinker substitution. In all these cases, **however, the negative macroeconomic impact can be mitigated by reinvestment of savings (resulting from the reduction of energy demand) to new areas of targeted investment, including local supply chains, more labor-intensive activities, and external investment sources.** For instance, for efficient cookstove actions, a reduction in demand for energy inputs for cooking reduces associated local economic activity. In addition, total demand for supply chain inputs to wood and charcoal cookstove production and distribution is reduced and reduces associated local economic activity. However, the introduction of new technologies that are more labor-intensive, especially if locally supplied, will create more opportunities for employment. This gain would also require restored macroeconomic stability and fiscal space, as well as improved national education.

Several potential key beneficiaries of the LT-LEDS Category A actions were identified across the economy. These include producers, installers, and operators of technologies and equipment; suppliers and distributors; consumers, farmers, landowners, households (including in rural communities); industries; and workers involved in production and distribution, and governments, especially local governments who provide services.

[53] World Bank. 2023 Public Finance Review. Lao People's Democratic Republic. Washington, DC. World Bank. 2023. License: Creative Commons Attribution CC BY 3.0 IGO.

5.8. Adaptation Co-benefits

5.8.1. Introduction

This assessment examines the potential likely exposure of LT-LEDS Category A sectors and activities to climate change risk and vulnerability, as well as potential adaptation co-benefits of the LT-LEDS Category A actions for Lao PDR.

The evaluation of the LT-LEDS Category A actions involved a review of the implementation approach (or design) for each sector level action based on its structure and function to gauge its potential exposure and sensitivity to a composite of applicable Climate Impact Drivers (CIDs), including temperature, precipitation, and wind -- but not sea level rise (for geographic reasons) or ground level smog and ozone (for research and data availability reasons). This was followed by an evaluation of the likely potential for each LT-LEDS action to address elevated CIDs in whole or part. Due to limited information on LT-LEDS action implementation designs, expert judgement and assumptions were required for the assessment of the structure and function of each action (as with the macroeconomic assessment). Key activities that were beyond the scope of this assessment include: a review of the separate impacts of individual CIDs and related sub-metrics for each; empirical estimates of vulnerability gaps due to the absence of adaptive capacity; detailed geographic (placed based) review of subnational location impacts in Lao PDR; and analysis of subsegment impacts for human populations and plant and animal populations. Nonetheless, the evaluation conducted provides a full sector level framework of the causes and effects of climate change on LT- LEDS actions and the potential for these actions to provide adaptation benefits. It can be used as a broad platform for more detailed assessments of climate risks and vulnerabilities, along with adaptation response actions and their interactions with non climate vulnerabilities.

ADAPTIVE CAPACITY AND MITIGATION ACTIONS OVERVIEW

Climate vulnerabilities (impacts) are the result of climate change and can interact with a range of non-climate vulnerabilities related to economic, social, political, geographic, environmental, and other conditions. Climate Impact Drivers (CIDs) include changes in heat, precipitation, and wind events as well as sea level rise and ground level smog and ozone (which can be both a cause and effect of climate change). These are the result of global warming (radiative forcing of GHGs on Earth). Changes in these impact drivers may result in elevated risk if they result in i*ncreased exposure to sensitive populations, activities, and places*. These increases in risk (also known as threats or hazards) may result in elevated levels of vulnerability (gaps) if they are not met by adequate levels of adaptive capacity. Where vulnerability gaps exist, they can be closed or reduced through expansion or enhancement of existing adaptive capacity, or the introduction of new or innovative capacities.

Such adaptive capacities often exist coincidentally through climate mitigation technologies and practices, but not always. Where they are lacking, climate mitigation action designs can often be modified to incorporate new vulnerability reduction functions through enhancement or innovation. For instance, buildings upgrades may incorporate climate proofing technologies at the same time as energy efficiency, such as through use of stronger materials or product design to adjust to extreme climate events and damage risk. Care must be taken to ensure that the opposite does not occur and result in a tradeoff between adaptation and mitigation, for instance when backup power systems rely on liquid fuels with distribution systems (roads and pipelines) that are sensitive to climate disruption, or when distributed renewable energy capacity is sited in the pathway of risk, such as flood or fire prone areas. Careful review is required to determine potential tradeoffs and corrective measures.

The following steps in the evaluation were followed:

1. Key potential threats (climate risks) were identified from a composite of CIDs for each LT-LEDS sector action based on the structure and function of each LT-LEDS action. This included the potential for exposure-based impacts on people involved in relevant production and consumption-based activities. For instance, the expansion of renewable electricity generation, transmission, and distribution could be affected by increased storm frequency and intensity. This in turn could affect the construction and operation of such facilities by workers and businesses (production activities) as well as the use of new energy by households, businesses, and other organizations (consumption activities).
2. Then the likely potential for each LT-LEDS Category A action to address elevated CIDs in whole or part was assessed based on the review of the structure and function of each of the LT-LEDS actions. This supported the determination of their potential to enable affected populations to become more resilient by *(i)* reducing elevated levels of exposure to sensitive production and consumption activities (risk avoidance), and/or *(ii)* increasing the ability of populations to absorb climate threats (risk tolerance) during these activities. The potential for these forms of resilience depends on the levels and kinds of adaptive capacities provided by the LT-LEDS actions, which is directly tied to its structure and function. For instance, actions to increase renewable energy generation and access may reduce exposure to grid-based climate risks where they involve expansion of off-grid (distributed generation), and they may increase risk tolerance when the construction and operation of off-grid systems is climate proofed. The opposite effect from LT- LEDS actions can also occur when resilience is degraded.
3. Finally, key primary beneficiaries (populations) in terms of livelihood effects were also identified for the specified LT-LEDS activities in each sector, including likely effects on rural and urban areas based on activities.

Based on the steps above, it was estimated that LT-LEDS actions can have significant or insignificant exposure to CIDs as well as positive, neutral, or negative impacts on climate change *adaptive capacity*. Actions with positive effects *reduce exposure or increase tolerance to risk*. Negative actions do the opposite. Actions can affect both *production and consumption activities* within sectors and subsectors.

5.8.2. Economy-wide Key Findings

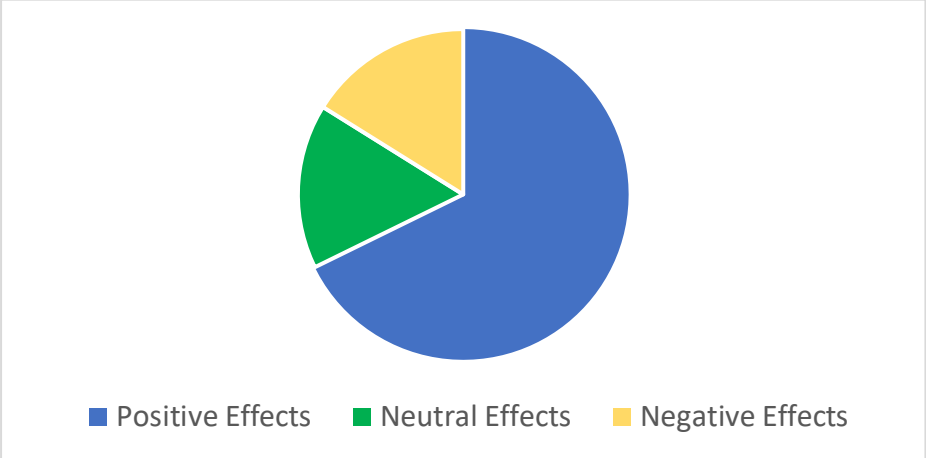
The structure and function of LT-LEDS Category A actions are predominantly expected to generate net positive adaptation co-benefits (resilience) through a combination of risk avoidance and absorption. This section provides economy-wide results while the adaptation co-benefits evaluation of each LT-LEDS Category A action (or group of similar actions) is provided in Annexes 4 to 10. It should be noted that Information to enable scaling of the adaptation co-benefits of the LT-LEDS actions in each sector to gauge their magnitude was not available and the related assessment was outside the scope of this assessment. This area of analysis should be considered in the future to understand the relative and absolute magnitude of the benefits.

Figure 5-11 shows aggregate effects across all sectors. The results represent the sum of positive, negative, or neutral adaptation impacts for all LT-LEDS actions.

Figure 5-12 shows the presence of impacts on adaptive capacity by sub-sectors. Results in sectors and subsectors represent the sum of positive, negative, or neutral impacts of LT-LEDS actions on climate change adaptive capacity in that sector or sub-sector. Potential negative impacts on transportation are the result of two shifts due to LT-LEDS actions:

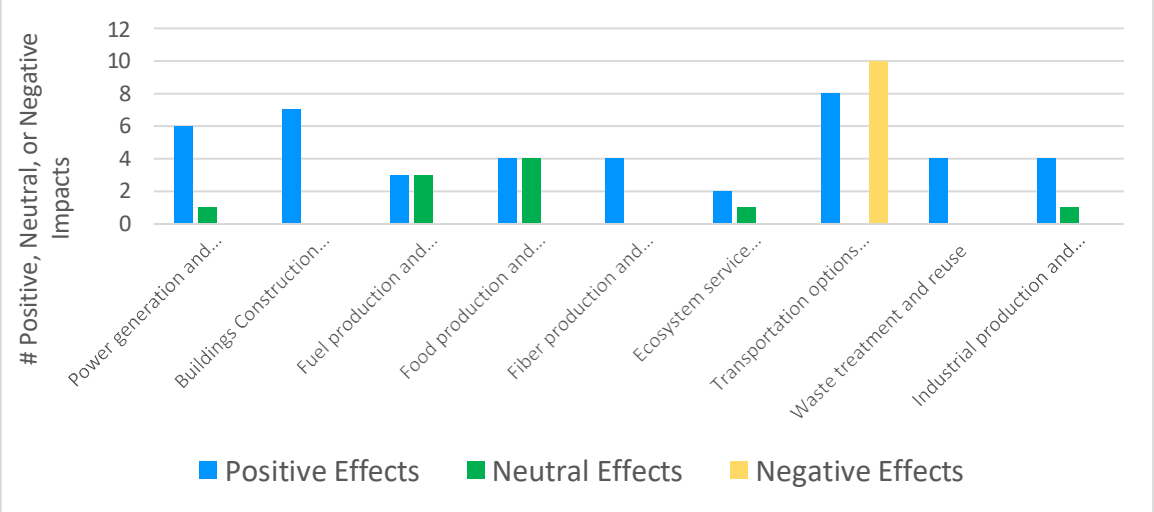
- Vehicle electrification and increased dependence on power transmission and distribution systems may be exposed to increased climate risk. This can be addressed through climate proofing of power systems and management of demand.
- Increased use of biofuels results in increased exposure to climate sensitive agricultural production. This can be addressed by climate proofing agricultural production of ethanol feedstocks and management of transportation demand.

FIGURE 5-11. Presence of Impacts of Adaptive Capacity at Economy-wide Level



Source: Authors' Evaluation

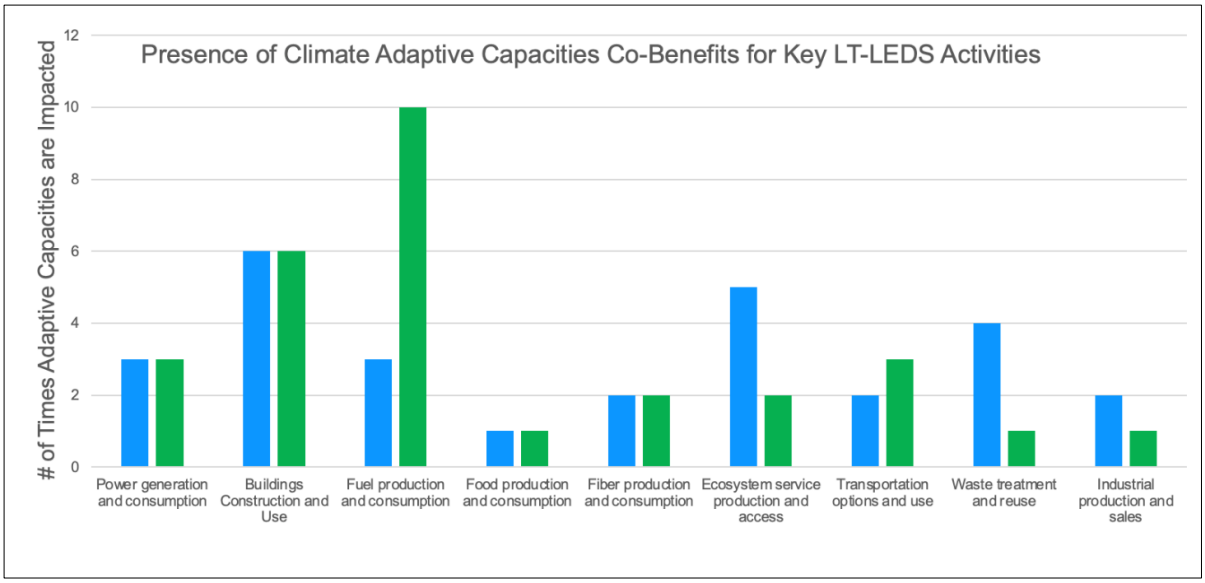
FIGURE 5-12. Presence of Impacts on Adaptive Capacity by Subsector



Source: Authors' Evaluation

Figure 5-13 shows the frequency of each type of positive impact on adaptive capacity (i.e., number of times there are improvements in risk avoidance and risk tolerance in each of the sectors, subsectors, and activities due to a LT-LEDS action. Results in sectors and subsectors represent the sum of positive, negative, or neutral impacts of LT-LEDS actions on climate change adaptive capacity in that sector or sub-sector.

FIGURE 5-13. Presence of Positive Impacts on Adaptive Capacities by Type



Source: Authors' Evaluation

Sector-level key findings are summarized below:

Energy Supply, RCI and Industry sectors

The following potential climate threats to the energy supply, RCI and Industry sectors were identified:

- Power generation, connections, transmission, and distribution to end uses may experience disruption or incapacitation due to chronic and acute changes in heat, precipitation, and wind events.
- Grid based energy is vulnerable to system wide transmission and distribution effects. Grid based energy consumption may be sensitive to interruptions without adequate backup systems and infrastructure resilience.
- Climate risk exposure to clinker substitution itself is not significant. However, direct fuel (coal) distribution can be exposed and sensitive to climate threats.

It is expected that:

- LT-LEDS Category A actions in the energy supply sector can create new generation connections and distribution systems with potentially higher levels of resilience to climate risks when climate proofing technologies are put in place for instance to face storm events (these technologies may include modular designs, redundancy, and smart grid technologies). Additionally, new renewable energy installations located at a shorter distance to the grid can reduce transmission related risks and vulnerabilities and system wide disturbances and failures caused by extreme climate events. However, at the same time, it is recognized that some renewable forms of electricity such as wind may result in longer distances to the grid due to the remote nature of these facilities. Some renewable energy technologies, such as wind and solar, do not require significant water consumption for operation and thus they reduce exposure to drought or changes in precipitation caused by climate change events.
- LT-LEDS Category A actions in the RCI and Industry sectors can create positive adaptation effects by reducing overall grid-based electricity use and exposure of end users to disruptions in power transmission and distribution caused by climate risks.
- Risks are also reduced when efficiency upgrades to the transmission and distribution grid include climate resilient technologies and practices (climate proofing).
- LT-LEDS Category A actions in the RCI sector can also create positive adaptation effects by reducing overall biomass fuel use and the exposure of biomass growth and distribution to climate risks.
- LT-LEDS Category A actions in the industry sector can also create positive adaptation effects by reducing exposure of direct fuel use and distribution to climate risks.

Key beneficiaries of adaptation benefits include energy producers, distributors, and consumers of electricity, including off-grid and remote access communities at risk.

Transportation

The following potential climate threats to the transportation sector were identified:

- Fuel distribution to transportation (vehicles and storage) uses can be exposed and sensitive to climate threats without adequate distribution and storage system infrastructure resilience or backup systems.
- The shift toward electrification could have the same impact if grid-based power is used versus distributed generation or if the grid is not upgraded.

It is expected that:

- LT-LEDS Category A actions in the transportation sector can create positive effects by reducing overall fuel use and thus exposure of fuel distribution to climate risks.
- If actions involve a shift to electrification, grid transmission and distribution upgrades that include climate resilient technologies and practices build additional resilience.

Key beneficiaries of adaptation benefits include users of vehicles and consumers of direct fuel, including communities with remote access to fuels.

Agriculture

The following potential climate threats to the agriculture sector were identified:

- Feedstock generation and distribution can be exposed and sensitive to climate threats without adequate food systems and livestock management resilience.
- Wood products, food and fiber generation, and distribution can be exposed and sensitive to climate threats.
- Food production systems requiring fertilizer inputs may be highly sensitive to climate risks. It is expected that:
- Actions that upgrade feedstocks to reduce enteric fermentation will not alter climate threat exposure. However, if new feedstocks are more efficient at weight gain or milk production, less overall feedstock is needed, and less production and distribution are exposed to climate risks.
- Integrated agroforestry management systems may reduce climate threat exposure or sensitivity by adding technologies and practices that are more climate resilient to risks such as storms and drought.
- Reduced water use will reduce climate risk exposure and sensitivity through reduced water dependences. At the same time, Laos is experiencing heavier storms and more intense rainfall as a result of climate change – so rice paddies are having to contend with increased variation of precipitation, such as more flooding, which may increase the need for water management.

Forestry

Forest ecosystem services, as well as fiber generation, access, and distribution, can be exposed and sensitive to climate threats such as extreme events and gradual shifts in climate over time without adequate forest system management for climate resilience.

It is expected that expanded forest systems will reduce climate threats if newly protected forest systems are managed to be resilient (such as through forest health protection and enhanced soil protection from erosion).

Key beneficiaries of adaptation benefits include producers and consumers of forest goods and services.

Waste Management

The following potential climate threats to the waste management sector were identified:

- Solid waste collection, landfilling, and treatment may experience disruption or incapacitation due to their energy and transportation dependence and related exposure to climate threats.
- On-site use of coal for cement production requires distribution through a transportation network that can be exposed to climate threats.

It is expected that:

- Actions that expand composting and recycling reduce demand for waste collection and treatment activities and thus reduce exposure to related energy and transportation disruptions. In addition, the development of new infrastructure such as landfills (e.g., Vang Vieng Landfill) are incorporating a range of engineering design measures to ensure resilience and that services will not be disrupted as a result of climate change (e.g., leachate collection systems that can cope with intense periods of rain, stormwater drains, buildings that can withstand high wind velocity and storms, roads build above flood levels, and the provision of welfare facilities for operational staff to provide comfort during extreme weather).
- Actions that expand the use of on-site refuse-derived fuel reduces climate exposure to disruptions in coal distribution and supplies.

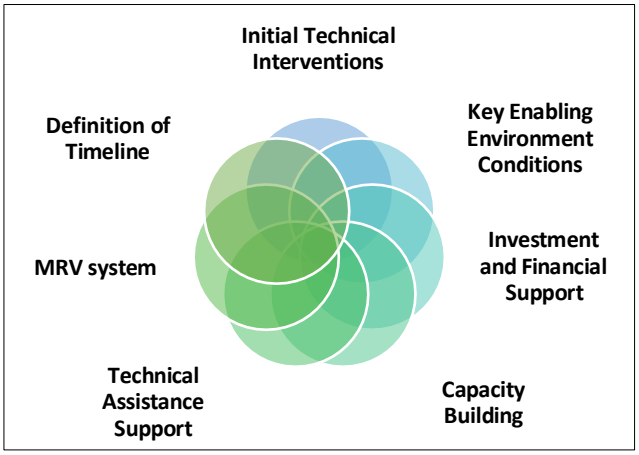
Key beneficiaries of adaptation benefits include households and business, especially in rural areas, industries.

6. CONSIDERATIONS FOR IMPLEMENTATION

This section provides preliminary considerations for the implementation of the LT-LEDS actions, and it was developed based on current understanding of their design and implementation. **It should be intended as a living document that will change as the implementation design of the LT-LEDS is refined**. Indeed, translation of these considerations to detailed steps for the implementation of each action and associated timeline should follow once the design of the actions is further defined and an assessment of implementation gaps (institutional, regulatory, capacity, financial) is conducted.

The successful implementation of the LT-LEDS for Lao PDR will require a combination of technical, institutional, regulatory, and financial capacities, as well as technical interventions and assistance (the "Building Blocks"). These Building Blocks are listed in Figure 6.1**Error! Reference source not found.** below and each entails a series of activities that can be based on the economic sector or the specific action or be applicable across sectors for the LT-LEDS implementation.

FIGURE 6-1. Building Blocks for Successful LT-LEDS Implementation



Source: Authors' Elaboration

Based on the specific LT-LEDS action, some activities within the Building Blocks will be conducted in parallel, while in other cases, they will be sequential.

Table *6-1* below provides an overview of key cross- cutting and action-based activities required for the implementation of the LT-LEDS Actions. **It is not meant to be a detailed implementation plan or roadmap**, but rather an initial framework of key areas to guide GoL in the next steps. It will require refinement and revisions as the implementation details of the LT-LEDS actions are defined by the GoL. In the current analysis, all LT-LEDS Category A actions are expected to **phase in gradually between 2025 and 2050**. **The activities listed in the table assume that:**

- All the macroeconomic and fiscal conditions indicated in this report materialize.
- Coal power generation is phased out at the conditions indicated in this report.
- The required financing for the LT-LEDS implementation is secured in the short- and medium-term.
- The implementation of less challenging actions (e.g., energy efficiency measures, waste recycling and composting, reforestation) starts soon, while it is likely that the implementation of other actions (e.g., BTR, heavy-duty electric vehicles) will start later with a quick ramp up to ensure their targets are met by 2050.
- Some of the activities in the table below will need to be aligned with the forthcoming revisions of the NDC and the related investment plan.

Identification of specific financing mechanisms for LT- LEDS Actions requires an in-depth financial analysis and development of a financing strategy, which is not covered by this project and is recommended as one of the implementation steps.

TABLE 6-1. Key Steps and Timelines for LTS Implementation

LT-LEDS Actions	2025-2030	2030-2035	2035-2040	2040-2050
Cross-cutting	• Establish a *governance structure*: lead governmental agency and other supporting agencies (roles and responsibilities)[54] • Engage s*takeholders*: developers; utilities; plant and grid operators, construction workers, operators, maintenance providers; local users (households, businesses, industries, farmers); local communities. • Conduct *financial analysis* and develop *financing strategy.* • Identify *financing mechanisms* (e.g., carbon market, blended finance, taxation); secure financing.	• Establish an appropriate *MRV system* for data collection, reporting and verification. • Carrying out an *assessment of capacity building* and training needs. • Conduct *training for highly skilled domestic labor* to operate and maintain renewable power plants and new technologies and systems. • Conducting *training on contracts management.* • Design and conduct an *awareness and information campaign* (households, business and industry communities, farmers).	• Define *Category B Actions,* conduct full assessment. • Start implementation of *Category B Actions* • *Monitor* progress. • Continue *capacity building.*	• *Monitor* progress. • Continue *capacity building*
ENERGY SECTOR				
Solar and Wind Power Expansion and Grid Upgrades	• Develop a *least-cost power expansion plan.* • Assess *interconnection line and grid upgrades* needed for coal power displacement with renewable based power. • Conduct *mapping of locations of new power plants* and full economic and technical feasibility studies. • Assess *storage* capacity needs and locations. • *Map electricity transmission and distribution assets* to be upgraded	• Start *construction and operation* of power plants, interconnection lines and storage (pumped storage hydro and battery storage systems). • Start *upgrades* to the transmission and distribution grid.	• *Complete construction* of power plants. • Continue *operation and maintenance* of power plants and grid.	• Continue *operation and maintenance* of power plants and grid.

[54] Governmental agencies specific for each LT-LEDS actions are listed in the sector-level annexes.

	• Define *competition procedures and contractual arrangements* for new investment and the construction of new power plants (Design – Bid – Build (DBB), Build Operate transfer (BOT), Engineering-Procurement- Construction (EPC)). • Define *power trade agreements* with Thailand and Cambodia and other neighborhood countries. • Define *regulatory mechanisms* (e.g., FiTs or PPAs), net mering policies and tariff reforms for cost recovery, especially storage. • Streamline *permitting and approval processes*			
Methane Capture at Coal Mines	• Identify *state-of-the-art methane capture and recovery technologies* (ventilation air methane abatement, pre-drainage systems, etc.). • Develop and enforce *regulations* that require to implement methane capture systems. • Mandate *reporting of methane emissions.* • Start *installation and operation* of recovery technologies.	• Continue *operation and maintenance*	• Continue *operation and maintenance*.	• Continue *operation and maintenance* until Hongsa and Sepon phase-out.
RCI SECTOR				
Energy Efficiency and Wood/Charcoal Cookstove Upgrades	• Conduct detailed *assessment of energy consumption* end-uses and levels. Identify *specific energy efficiency interventions* (e.g., types of appliances, buildings retrofit practices, energy saving motor systems and transformers in industries). • Identify *clean cooking technologies*. • Set up a long-term *program to collect and dispose* of old appliances. • Establish/update minimum *energy efficiency standards and mandatory disclosure requirements*. • Establish/update *cookstove standards* and requirements. • Provide *incentives* for homeowners, businesses and industries.	• Continue *market expansion* of energy efficiency measures and cookstoves upgrades.	• Continue *market expansion* of energy efficiency measures and cookstoves upgrades.	• Continue *market expansion* of energy efficiency measures and cookstoves upgrades.

INDUSTRY SECTOR				
Cement/Iron & Steel Waste Heat Recovery Systems	• Identify the *most appropriate waste heat recovery technology* for cement, iron and steel plants. • Ensure *grid interconnection* for the electricity produced. • *Mandate* waste heat recovery systems in all new cement, iron and steel production plants. • Enact *regulations to enable and enforce grid operators* to incorporate electricity output from the waste heat recovery system into the grid. • Establish *incentives* for industries to acquire and install new waste heat recovery systems.	• Start *installation and operation* of recovery systems.	• *Scale up market penetration* of recovery systems. • Continue *operation and maintenance*.	• Continue *operation and maintenance*.
TRANSPORTATION				
Electric Vehicles	• Map the *locations of EV charging stations* and build a comprehensive network in urban, suburban, and rural areas. • *Reform* current fuel tax policy. • Establish and enforce *zero-emissions standards* for vehicles. • Establish and enforce *congestion pricing or emission fee* to discourage the use of ICE vehicles. • Establish *preferential/prohibited circulation or access schemes* such as low- and zero-emission zones or differentiated circulation fees. • Offer *purchase incentives* (tax credits, rebates, etc.). • Promote *leasing programs* that make EVs more accessible to consumer. (Links to the circular economy here – ride share platforms etc). • Provide *incentives f*or homeowners, businesses and parking facilities to install charging infrastructure.	• Identify *recycling and disposal programs* for used EV batteries to minimize environmental impact. • Streamline *regulatory processes* to facilitate the approval and installation of charging. • Start *installation of charging infrastructure*. • Start implement l*ight-duty vehicle* • electrification	• Start implement *heavy-duty vehicle* electrification • Maintain new infrastructures and EVs. • Continue *market* • *expansion*.	• Maintain new infrastructures and EVs. • Continue *market expansion*.

Bus Rapid Transit (BRT) and Expansion of Electric Rail for Passengers and Freight	• Develop comprehensive *urban plans that prioritize BRT corridors* and integrate land use policies to support transit-oriented development.	• Establish/expand *infrastructures for bus service* (e.g., bus turnouts, bus boarding islands, curb realignments, reserved lane, traffic signal). • Offer *incentives* to promote shift to BRT services. • Procure modern, *zero emission electric buses*. • Establish/expand and maintain infrastructures need for a reliable, fast, safe, and efficient electric rail lines.	• Start *operation of BRT* • *Maintain* new infrastructures and buses. • Continue *market expansion*.	• *Maintain* new infrastructures and buses. • Continue *market expansion*.
Expand Biodiesel and Bioethanol Use	• Enact and enforce *policies* to promote the use of a variety of feedstocks for biofuel sustainable production. • Establish *tax incentives, credits, and subsidies* to biofuel producers.	• Establish/expand biofuel infrastructure for the production, storage, and distribution of biofuels, (e.g., pipelines, storage tanks, and transportation networks. • Establish and enforce *quality control standards* for ethanol and biodiesel to ensure consistency and prevent engine damage.	• *Maintain* new infrastructures while EVs are being phased-in.	• Complete EV phase-in.
AGRICULTURE SECTOR				
Agroforestry	• Develop *agroforestry plans* that are site specific to account for local ecological conditions, climate, and soil types. • Define and secure *land tenure and user rights* for landowner to ensure that enough land is allocated for the integration of forestry area and natural resource uses. • Establish *partnerships* between tree plantation companies and landowners. • Facilitate access to *credit for farmers* to introduce new farming systems and technologies • Provide *incentives* such as access to land or tax incentives for companies that employ agroforestry models that support local	• Implement *strategies to manage pests and diseases* in agroforestry systems, agriculture lands and forestry. • Support *mechanization of agriculture activities* to optimize labor (e.g., hand-jab seeder, direct sowing machine for hand tractors). • Create *markets and value chains for agroforestry products*, such as timber, non-timber forest products, or fruits, to ensure income generation for farmers	• *Scale up market penetration* of agroforestry systems. • Continue *operation.*	• *Scale up market penetration* of agroforestry systems. • Continue *operation.*

	communities. • Design and implement mechanisms such as production of low-cost tree seedlings directly by farmers to *reduce investment costs* (e.g., community nurseries). • Establish *cooperatives* that provide production services, including inputs for farm households, fertilizers, feed ingredients. • Start *establishment of agroforestry* • *systems*.	• Provide extension services to farmers and smallholder that include technical knowledge on specific agroforest systems that address climate change impacts based on *specific* site conditions and on land preparation. • Provide access to technical information and data such as accurate weather forecasts		
Adjusted water management practices in lowland rice cultivation and Nitrogen Management	• Identify *water management practices* and modernize irrigation schemes to proper engineered standards. • Identify *practices to improve the efficiency* of irrigation (e.g., drip irrigation). • Conduct impact *assessments to evaluate potential nitrogen impacts* and mitigate them. • Identify specific *practices to manage nitrogen use* such as use of nitrogen inhibitors, nitrogen-fixing crops, application of organic amendments, including compost, biochar, and biosolids. • Develop a *comprehensive nutrient management plan* that includes best management practices for nitrogen use efficiency. • Establish and enforce *regulatory limits on nitrogen emissions*, concentrations, and loads in water bodies and air. • Establish requirements for *environmental impact assessments* to evaluate potential nitrogen • impacts and mitigate them.	• Provide *Incentives* for farmers to introduce new systems and technologies. • Start *adoption of water management practice*s. • Start *adoption of nitrogen management practices.* • Expand the *use of precision fertilizer application* systems.	• *Scale up market penetration* of new practices.	• *Scale up market penetration* of new practices.

Mitigate enteric methane emission and manure management	• Identify *specific practices* to mitigate enteric methane emissions.[55] • Provide *incentives* to farmers to install manure digesters. • Ensure that manure digesters can be *connected to the electrical grid* to sell excess electricity. • Conduct *training for farmers* on best practices for methane reduction. • Start i*nstallation* of digesters.	• *Scale up market penetration.* • *Continue operation and maintenance.*	• *Scale up market penetration.* • *Continue operation and maintenance.*	• *Scale up market penetration.* • *Continue operation and maintenance.*
FORESTRY SECTOR				
Avoided deforestation and Forest Management and Restoration	• Identify specific *practices to reduce deforestation* that are site- specific.[56] • Identify specific *practices for reforestation and restoration*.[57] • Establish and enforce *land use planning and zoning regulations* that protect forests. • Expand *protected areas* and enforce related regulations. • Enact and enforce regulation to *prevent illegal logging* and limit timber exports. • Identify *measure to protect the rights of local communities and indigenous peoples* in forest management practices. • Establish *payments for ecosystem services* (PES) schemes to reward landowners forest conservation and • reforestation initiatives.	• Consider *forest certification instruments* to demonstrate responsible and sustainable forest management practices. • Promote *higher density development i*n urban centers. • Start *implementation* of deforestation and reforestation practices.	• *Scale up market penetration.*	• *Continue* implementation and enforcement.

[55] Examples include implement feed additives and supplements that can reduce methane production; implement livestock production systems that minimize the number of animals needed for meat and dairy production; introducing cattle breeds with lower enteric fermentation rates; shifting to different types of livestock production with lower emission rates (such as poultry or pork); implement rotational grazing practices; consider methane inhibitors to be added to livestock feed.

[56] These might include fire prevention measures, control measure for invasive plants, satellite and remote sensing technologies for forest monitoring, the use of conservation easements, techniques and practices to increase agricultural yields reducing the need to expand agricultural land.

[57] These might include replanting of damaged or degraded forests, monitoring and treatment of pests and disease, thinning and density management, expansion or new establishment of forests on non-forested lands.

WASTE MANAGEMENT				
Solid waste composting and recycling	• Establish/expand *waste collection* from households and businesses. • Establish/ expand and maintain *composting and recycling facilities* with efficient equipment and technologies • Provide/increase *collection containers for organic waste* to facilitate composting, collection contains for recycle material and/or transfer stations. • Establish/expand and maintain *waste segregation and sorting facilities* to separate compostable and recyclable materials. • Enact and enforce *regulations that require the separation and diversion* of organic waste and recycling materials for businesses, institutions, and residents. • Develop *regulatory frameworks that govern the operation of composting and recycling facilities*, including permitting, odor control, and environmental impact assessments. • Simplify *permitting processes* for construction and` operation of solid waste composting recycling facilities while ensuring environmental compliance. • Develop *protocols and standards* for monitoring and controlling the quality of compost.	• Incentivize *the use of waste collection services and facilities in rural villages* imposing collection fees or establishing micro, community driven waste collection schemes at village levels • Develop *markets for compost and recycled products*. • Establish PPP arrangements for waste management services. • *Scale up market penetration.*	• *Scale up market penetration of practices.* • *Scale up market penetration compost and recycled products..*	• *Continue* implementation,
Landfill gas (LFG) plant with power production and	• Enact and enforce *sanitation standards* for biogas latrines	• *Scale up market penetration* of RDF facilities . • *Continue* operation and maintenance of RDF facilities.	• *Scale up market penetration* of LFG systems.	• *Continue* operation and maintenance of RDF facilities.
Refuse Derived Fuel (RDF) Energy	• Establish *FiTs or PPAs* that guarantee a fixed price for electricity generated from RDF. • Establish/expand *RDF production facilities* to sort waste into combustible fractions. • Provide *incentives, tax credits, or subsidies* to households and businesses to cover the cost of installation of biogas latrines/biodigesters.	• Establish/expand and maintain efficient *gas collection systems* to capture gases emitted from landfills, as well as gas treatment technologies and flare systems. • Ensure *proper connection to the national electrical grid* to	• *Continue* operation and maintenance of LFG systems. • *Continue* operation and maintenance of RDF facilities.	• *Continue* operation and maintenance of LFG systems.

	• Assess *operational challenges* (e.g., the ability to create vacuums in landfills with adequate liners and capping to allow for gas extraction) and solutions. • Simplify *permitting processes* for construction and operation of RDF energy facilities while ensuring environmental compliance.	sell excess electricity generated through captured methane gas in landfills. • Enact and enforce environmental regulations to ensure LFG plants meet *emissions and air quality standards*. • Provide *incentives, tax credits, or subsidies* to LFG energy producers to support capital investments and operations.		

Source: Authors' Elaboration

7. CONCLUSIONS AND RECOMMENDATIONS

To summarize, the Lao PDR LT-LEDS technical recommendations present an effective low-emission development pathway for Lao PDR to achieve its net zero emissions target by 2050. Implementation of the recommended actions is expected to spur macroeconomic growth and employment and increase climate resilience, provided that upfront investments are made, macroeconomic stability and fiscal space are restored, and productive capabilities (e.g., skills, knowledge, and innovation potential) are improved.

Under the BAU conditions, Lao PDR's GHG emissions in 2050 are projected to grow to 111 $MMtCO_2$. Key drivers of future emissions are the following sections: agriculture, forestry, energy supply, transportation, and industry.

Achievement of the 2030 NDC and other national plans puts Lao PDR on track to low emissions development, but more needs to be done to step up towards mid-century decarbonization. The LT-LEDS portrays a recommended pathway for Lao PDR to achieve the net zero GHG emissions by 2050. This net zero pathway entails the following **key transformations**:

- **Decarbonize electricity generation** by meeting all domestic demand and electricity exports with increased renewable electricity generation (solar and wind), adequate energy storage (pumped storage hydro and battery storage systems) and regional interconnection lines, as well as and strengthened transmission and distribution grid. This will require gradually phasing out existing coal power plants (Hongsa and Sepon) and not installing the three currently planned coal power plants (Bualapha, Sekong-Kaleum, and Sekong-Lamam). As mentioned earlier in the report, the additional hydropower and geothermal power are not indicated in this LT-LEDS scenario because they are part of the NDC Implementation Plan issued by the government and thus are covered in the BAU scenario.
- **Electrify end-uses** through replacement of wood and charcoal cookstoves in residential and commercial buildings, significant expansion of electric vehicles (light- medium- and heavy-duty) and charging infrastructures, and electrification of industrial end-uses.
- **Reduce energy consumption** through efficiency measures and upgrades for appliances, cookstoves, buildings, and industrial processes to reduce overall demand, lower peak load, and improve affordability.
- **Expand climate-smart agriculture** through agroforestry systems, fertilizer management, rice cultivation irrigation, improved manure practices, and regenerative agricultural practices.
- **Increase carbon sequestration** by avoiding deforestation and expanding forest management and restoration to strengthen ecosystem protection. Specific measures and practices within this area will need to be identified and assessed.
- **Expand sustainable waste management** through composting, recycling, and waste-to-energy systems.

The implementation of the above transformations requires GoL to enhance its long-term planning, implement policy reforms and close institutional, regulatory, financial, and capacity gaps. Of particular relevance is the need for Laos PDR to *(i)* restore macroeconomic stability and fiscal space to enable the needed investments across sectors and a successful implementation of the LT-LEDS actions; *(ii)* engage in long-term power sector planning with Thailand and other neighboring countries to enable the phase-out of the coal power plants by 2050 and the transition to export of renewable generated electricity (with adequate energy storage such as pumped storage hydro and battery storage systems, regional interconnection lines and strengthened transmission and distribution grid); *(iii)* access sustainable and impactful forms of financing and engage with the private sector to incentivize the transition to new practices and technologies; *(iv)* balance competing demands of multiple land uses and address economic drivers of deforestation while generating sufficient revenues and socio-economic opportunities; and *(v)* improve productive capabilities (e.g., skills, knowledge, and innovation potential) that will require investment in workforce development and education to support new local supply chains and create new job opportunities.

It is recommended that the GoL start the implementation of the LT-LEDS while working on the above conditions. Some LT-LEDS actions, such as increased reforestation, expanded forest management and energy efficiency measures can be carried out right away as they are not dependent on significant upfront investments or changes in the enabling environment, such as new policies or regulations.

It is estimated that the above recommended LT-LEDS transformations will not only decarbonize Lao PDR's economy, but will also:

- Generate $4 billion net savings throughout society in 2050 after an upfront investment of about $29 billion.
- Spur economic growth and employment, assuming that macroeconomic stability and fiscal space are restored, and productive capabilities (e.g., skills, knowledge, and innovation potential) are improved as outlined in the 2023 World Bank Public Finance Review.
- Increase climate change resilience through a combination of climate risk avoidance and climate risk absorption.

In order to implement the LT-LEDS, adequate institutional and regulatory frameworks should be established; local capacities should be created; preliminary technical assessments should be conducted; required financing should be mobilized (e.g., incentive schemes); and a monitoring and evaluation system should be established.

To ensure the LT-LEDS technical recommendations stay current and suit the evolving needs, the key LT- LEDS actions should be reviewed, updated, and refined periodically, taking into account the emerging circumstances and the new data and information that becomes available.

8. LIST OF ANNEXES

Annex 1	List of Stakeholders and TWG Members
Annex 2	Summary of Stakeholders' Engagement Activities
Annex 3	Community Consultation Report
Annex 4	Energy Supply Sector (BAU scenario, LT-LEDS actions, impact assessment)
Annex 5	Residential & Commercial Sector (BAU scenario, LT-LEDS actions, impact assessment)
Annex 6	Industry Sector (BAU scenario, LT-LEDS actions, impact assessment)
Annex 7	Transportation Sector (BAU scenario, LT-LEDS actions, impact assessment)
Annex 8	Agriculture Supply Sector (BAU scenario, LT-LEDS actions, impact assessment)
Annex 9	Forestry Sector (BAU scenario, LT-LEDS actions, impact assessment)
Annex 10	Waste Management Sector (BAU scenario, LT-LEDS actions, impact assessment)



THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP
East Asia & Pacific

The World Bank Group Lao PDR Country Office,
East Asia and Pacific Region

Xieng Ngeun Village, Chao Fa Ngum Road,
Chanthabouly District, Vientiane, Lao PDR

worldbank.org/lao