Environmental Challenges for Green Growth and Poverty Reduction: A Country Environmental Analysis for the Lao People's Democratic Republic

Ernesto Sánchez-Triana, Editor

WORLD BANK GROUP

Korea Green Growth Trust Fund

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

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List of Acronyms

AAP	outdoor ambient air pollution
AGFA	Aqueduct Global Flood Analyzer
ALRI	acute lower respiratory infection
ANS	adjusted net savings
AQG	air quality guideline
ARI	acute respiratory infection
BCC	behavioral change communication
BCR	benefit-cost ratio
BLL	blood lead level
BOD	biological oxygen demand
C	charcoal
CES	constant elasticity of substitution
CGE	computable general equilibrium
COD	chemical oxygen demand
CoNRD	costs of natural resource degradation
COPD	chronic obstructive pulmonary disease
CWP	ceramic water purifier
DHUP	Department of Housing and Urban Planning
DNEP	Department of Natural Resources and Environmental Policy
DNREM	Department of Natural Resources and Environmental Monitoring
DOCs	diesel oxidation catalysts
DPFs	diesel particulate filters
DW	disability weight
EC	environmental certificate
ECC	environmental compliance certificate
EIA	environmental impact assessment
EPA	United States Environmental Protection Agency
EPF	Environmental Protection Fund
EPL	Environmental Protection Law
ES	electric stove
ESI	Economics of Sanitation Initiative
ESIA	environmental and social impact assessment
ESMMP	Environmental and Social Management and Monitoring Plan
EU	European Union
FAO	Food and Agriculture Organization
FLEGT	Forest Law Enforcement, Governance, and Trade program
GDP	gross domestic product
GGDPO	Green Growth Development Policy Operation
GGGI	Global Green Growth Institute
GNI	gross national income
GNSS	global navigation satellite system
GoL	government of Lao PDR
GoS	government of Sindh
GS	gasifier stoves

HAP	household air pollution
HDVs	heavy-duty vehicles
ICS	improved biomass cookstoves
ICS-C	improved charcoal cookstoves
ICS-W	improved fuelwood cookstoves
IFI	international financial institution
IGES	Institute for Global Environmental Strategies
IHD	ischemic heart disease
IODB	International Organizations and Development Banks
IPCC	International Panel on Climate Change
IPPS	Industrial pollution projection system
ISIC	International Standard Industrial Classification of All Economic Activities
LAK	official national currency of Lao PDR
LC	lung cancer
LDC	least-developed country
LDVs	light-duty vehicles
LECS	Lao expenditure and consumption surveys
LENS	World Bank Lao Environment and Social Project
LMB	Lower Mekong Basin
LPG	liquified petroleum gas
LSIS	Lao Social Indicator Survey
LWWR	2017 Law on Water and Water Resources
MAF	Ministry of Agriculture and Forestry
MDGs	Millennium Development Goals
MEM	Ministry of Energy and Mines
MoF	Ministry of Finance
MoH	Ministry of Health
MoIC	Ministry of Industry and Commerce
MoJ	Ministry of Justice
MoNRE	Ministry of Natural Resources and Environment
MPI	Ministry of Planning and Investment
MPWT	Ministry of Public Works and Transport
MRC	Mekong River Commission
MSW	municipal solid waste
NA	National Assembly
NEPA	National Environmental Policy Act
NEQS	National Environmental Quality Standards
NGGS	National Green Growth Strategy
NGO	nongovernmental organization
NHTSA	United States National Highway Traffic Safety Administration
NLTA	non-lending technical assistance
NPAs	National Protected Areas
NRESP	Natural Resources and Environment Sector Five-Year Action Plan
NRESV	Resources and Environment Sector Vision
NSEDP	National Socio-Economic Development Plan
NSEDS	National Socio-Economic Development Strategy

List of Acronyms

NTFP	non-timber forest products
OD	open defecation
ODA	official development assistance
OECD	Organisation for Economic Co-operation and Development
O&M	operations and maintenance
PA	protected areas
Pb	lead
PDR	People's Democratic Republic
PEN	poverty-environment nexus
PFA	production forest areas
PIF	potential impact fraction
POU	point of use
POUT	point-of-use treatment
PPP	polluter pays principle
PSFM	participatory sustainable forest management
PV	present value
RA	risk adjusted
RRs	relative risks
SAM	social accounting matrix
SBP	systolic blood pressure
SEA	strategic environmental assessment
SEPSA	strategic environmental, poverty, and social assessment
SESO	standard environmental and social obligations
SSWG	subsector working group
SWG	sector working group
SWM	solid waste management
TEG	technical expert group
ToR	terms of reference
TSS	total suspended solids
TWG	technical working group
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UXO	unexploded ordnance
VC	village committee
VCOMS	Vientiane City Office for Management and Service
VSL	value of statistical life
VUDAA	Vientiane Urban Development Administration Authority
W	fuelwood
WASH	water, sanitation, and hygiene
WHO	World Health Organization
WRI	World Resources Institute
YLD	years lost to disease
YLDs	years lived with disability

Foreword

The Lao People's Democratic Republic was one of the fastest-growing economies in the world until the COVID-19 pandemic hit in early 2020. The economy was growing at an average annual rate of 8 percent since the beginning of the century and poverty was steadily declining. However, even before COVID-19 emerged, the Lao PDR government recognized that this strong economic growth was largely fueled by natural resource-based activities, including mining, logging, hydropower, and agriculture. It was clear that Lao PDR needed to shift to a new economic model based on the sustainable use of natural resources. This new approach would need to continue helping people out of poverty and guarantee more equitable income sharing, but it would also have to preserve the environment and improve resilience to natural disasters and economic shocks. These aspirations shaped the country's National Green Growth Strategy, adopted in early 2019.

While Lao PDR has already started taking steps to implement this new approach, this report helps to identify the environmental priorities that are most closely interwoven with poverty reduction and shared prosperity in the country. The report offers evidence-based recommendations, including specific actions that address these priorities. It also suggests institutional and governance reform that would provide government organizations with the mandate, incentives, and resources to support the transition toward green growth.

This report presents compelling evidence of the need to act swiftly and decisively. Around 10,000 Lao die every year from preventable causes due to pollution. Lead exposure robs thousands of children of the opportunity to develop to their full potential. Even under conservative estimates, the environmental health risks generated by pollution and the depletion of natural resources result in costs equivalent to more than 19 percent of Lao PDR's gross domestic product. There are solutions. This report examines how solutions have been applied in other countries and explains how Lao PDR can apply them to systematically address its challenges.

The sudden onset of the novel coronavirus has dramatically underscored the need for a transition toward green growth, given the need to urgently improve the health and economic prospects of all Lao. As such, this report's findings and recommendations can inform efforts to promote a cleaner, more resilient, and sustainable recovery from the pandemic and its economic impacts. We hope this work generates awareness about the severity of environmental challenges and strengthens support from across the spectrum of Lao society to support their country's transition to green growth.

Mariam J. Sherman

Country Director for Myanmar, Cambodia, and Lao PDR

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EXECUTIVE SUMMARY

The Environmental Challenges for Green Growth and Poverty Reduction in the Lao People's Democratic Republic report reveals strong linkages among environmental quality, economic growth, and social well-being of the nation's 7 million inhabitants. This report is a comprehensive presentation prepared after two years of targeted diagnostic research and analysis of issues and conditions within Lao PDR. The analysis was conducted by an international team of World Bank researchers in cooperation with counterparts in lead government agencies in Lao PDR. Information from the Ministry of Health, the Ministry of Natural Resources and Environment—and others—provided an initial basis for the assessments, and this was complemented by other international information. The results can be regarded as a state-of-the-art contribution of information to decision makers in Lao PDR having an interest in achieving sustainable growth consistent with the 2019 National Green Growth Strategy.

Management of connections between environment and human health is an urgent priority

The report's scope includes consideration of impacts on key economic sectors and on risk factors influencing the health of the population. The assessments encompassed the economic costs of degradation in the forestry, agriculture, fisheries, mining, and hydropower sectors. The report identifies solid waste management and plastics as an important priority to which the Government of Lao PDR has already pledged its support in regional and global initiatives. Within the context of the Mekong River and its watershed, this report addresses climate-change impacts including increased risks of flooding.

Among the most urgent priorities, however, are the impacts of pollution on human health. The assessments attribute some 10,000 deaths annually to four environmental health risk factors—household air pollution alone represents 44 percent. The 10,000 deaths were 21.6 percent of all deaths in the country. The risk factors also caused nearly 100 million days of illness annually. Illness from these factors in turn decreases enjoyment of life, increases costs of treatment, and lowers economic productivity. All told, the costs of such deaths and illnesses was equivalent to 15 percent of national gross domestic product (GDP) in 2017.

The urgent message of this report is that all the identified issues must be—and can be—systematically addressed. The scope of recommendations is informed by benefit-cost analyses to help identify efficient interventions ranging from simple solutions already successfully adopted in other countries to more complex approaches targeted at improving air quality. Innovative financial mechanisms associated with environmental taxes or fees are also considered.

All recommendations are considered carefully within the scope of the effectiveness of existing laws (including the *Environmental Protection Law*), the division of authority within the current institutional framework, and the role of environmental and social impact assessments (ESIA) in environmental planning. A number of reforms should be pursued—all are realistically achievable if there is political will. All can contribute meaningfully to improved environmental quality, green economic growth that is more sustainable, and alleviated poverty.

Context

Lao PDR has achieved rapid growth and poverty reduction since 2000. GDP has grown at an average annual rate of 8 percent since the beginning of the century. Lao PDR has been the second-fastest growing economy in ASEAN and among the world's 15 fastest-growing economies. Rapid economic development was associated with a fall in the national poverty line, from 46 percent in 1993 to 18 percent in 2019.

In recent years, income disparities have widened. The Gini index increased from 31 in 1993 to 39 in 2019, according to Lao poverty assessments. Most of the wealth is concentrated in the Vientiane area, where only about 10 percent of the population lives. The top fifth of the population controls 44 percent of the country's wealth while the bottom fifth controls only 8 percent.

Key economic activities underpinning Lao PDR's economic dynamism included uncontrolled mining, unregulated and illegal logging, hydropower-sector expansion, and inefficient agriculture. While these activities provided important economic gains, they have also resulted in significantly high rates of natural resource depletion and environmental degradation. The annual cost of environmental degradation is estimated at 19.3 percent of GDP in 2017.

Unsustainable use of natural resources and environmental assets has artificially driven economic growth

Highlights of Diagnostic Analyses

The most important environmental problems are associated with environmental health, representing an annual cost equivalent to 14.6 percent of GDP in 2017. The highest cost is due to household air pollution. Inadequate water supply, sanitation, and hygiene; outdoor ambient air pollution; and lead exposure also represent pressing challenges. Problems associated with degradation of natural resources and losses from natural disasters have an annual cost equivalent to 4.7 percent of GDP in 2017.

Waste generation in Lao PDR stands at 0.15 kilograms daily per person, making it among the lowest in Asia. Nonetheless, the quantities generated are poorly managed and present risks to human health and the Mekong River watershed. Open dumps constitute 60 percent of wastes. Plastics are currently recognized as a global issue and find their way into the Mekong watershed destined for global oceans. In Vientiane, plastics constitute 12 percent of the total waste stream.

Annual cost of environment degradation in Lao PDR (%GDP) in 2017.

Household air pollution	5.68%
Ambient air pollution	3.50%
Water, sanitation, and hygiene	2.89%
Microbiological pollution	2.62%
Arsenic in groundwater	0.27%
Lead (Pb) exposure	2.52%
Lead (Pb) exposure – children	1.87%
Lead (Pb) exposure – adults	0.65%
Subtotal for environmental health	**14.6%**
Cost of deforetation	1.6%
Cost of forest degradation	1.1%
Cost of natural disasters	0.9%
Soil degradation cost	0.6%
Cost of hydropower development and fish-habitat destruction	0.5%
Cost of AGM exposure to mercury	<0.1%
Substotal for natrual resource degradation and natural disasters	**4.7%**
Total	**19.3%**

As elsewhere in the world, the distribution of pollution impacts falls primarily on the vulnerable. Children bear the largest burden of lead pollution, suffering an estimated annual loss of 340,000 IQ points. The impairment of learning capacity from lead pollution has long-term implications such as lower incomes and compromised quality of life. Women suffer disproportionately from household air pollution, as they traditionally prepare the meals. The degradation of natural landscapes and soils undermines livelihoods of rural dwellers and pollution exposes them to diseases and heavy metals in regions where health services are unavailable or inadequate.

Climate-change hazards will exacerbate current human health issues and degradation of natural resources. The International Panel on Climate Change models suggest that maximum monthly flows in the Mekong Basin will increase by 35–41 percent, while minimum monthly flows will drop by 17–24 percent by 2100, further exacerbating flood and drought risks. Rice production is also at risk to higher temperatures and shifts in rainfall.

Key Findings Informing Environmental Health Intervention Options

Benefit-cost analysis is used to help identify appropriate interventions for addressing environmental health and natural resource degradation issues.

One overriding priority is to achieve 50 percent clean energy use for cooking over the next 10 years by households increasing the use of gas (LPG) and electric stoves.

Four priorities emerge in the drinking-water and sanitation sector: (i) further investigation into the quality of household drinking water, (ii) a pilot promotion program for household point-of-use treatment of drinking water focusing on ceramic filtering and solar disinfection, (iii) addressing arsenic contamination of drinking water in the center and south of Lao PDR, and (iv) rural sanitation to end open defecation.

Three priorities are evident for combatting ambient air pollution: (i) implement ambient air quality monitoring first and foremost in Vientiane Capital; (ii) undertake $PM_{2.5}$ source-apportionment studies in Vientiane Capital to identify priority sectors for air pollution control, and design cost-effective interventions; and (iii) implement no-regret interventions including control of $PM_{2.5}$ emissions from household cooking and diesel vehicles, halting of household burning of waste/debris, and combatting street dust.

Two priorities are crucial regarding assessing the status of lead (Pb) exposure: (i) undertake a study to measure children's blood lead levels to determine exposure levels; and (ii) undertake a study to identify lead sources, including in the household environment, outdoor community environment, school environment, and specific sources such as lead-based paint, toys, ornaments and jewelry, traditional medicines, cosmetics, and utensils.

Key Findings Informing Natural Resource Degradation Options

Economically viable means can be developed to address diverse issues, ranging from flood mitigation to adoption of new seed varieties. Agroforestry is an important potential intervention that mitigates degradation of forest quality and agricultural lands.

Scale also plays a role in determining viability. Large-scale aquaculture provides opportunity for maintaining fishery productivity; family-scale aquaculture is not economic using standard criteria, but it would nonetheless provide a secure supply of nutrition to vulnerable populations in the event of emergencies.

For natural hazard mitigation, it may also be noted that investments in early warning systems are generally warranted. This would include development of improved flood forecasts and education programs on how people should respond to warnings.

Range of Benefit-Cost Ratios of Interventions to Address Natural Resource Degradation and Natural Disasters

Forestry: Rubber planations	0.8-2.2
Forestry: Reforestation	1.7-2.3
Forestry: Agroforestry	1.2-4.9
Soil erosion: Terraced production	2.6-3.1
Soil erosion: Improved seed varieties	2.1-2.2
Soil erosion: Agroforestry	1.2-4.9
Fishery management: Fish passages	0.9-3.8
Fishery management: Family aquaculture	0.3
Fishery management: Large aquaculture	1.0-1.1
Flood management: Infrastructure	0.4-1.7
Flood management: Early warning systems	2.2-2.6
Mining mitigation: Artificial wetlands	1.2-3.1

Institutional Findings and Selected Policy Options

In June 2011, the National Assembly of Lao PDR endorsed the establishment of the Ministry of Natural Resources and Environment (MoNRE). MoNRE was established by combining departments and divisions related to natural resources and environment such as land, forest, geology-minerals, water resources, and environment from different ministries and agencies. The creation of MoNRE was based on the need to improve coordination, collaboration, and integration of natural resources and environmental management. MoNRE has a mandate as a secretariat and key regulator for direct management of land, forest, water, air, and biodiversity and minerals. Its mandate also includes management of climate change, disaster, meteorology, and hydrology throughout the country.

Budget allocations for environmental protection in Lao PDR are insufficient to address severe pollution problems. Currently, there are no formal mechanisms in place that use analytical work to identify priorities or to incorporate priorities into multi-year planning processes. Problems with ESIA in Lao PDR include inadequate screening, overly narrow scope for assessments that are conducted, poor quality of reports, inadequate capacity to evaluate ESIA documents, insufficient public participation, and a general lack of monitoring of the project's compliance with the ESIA's approval conditions. A better solution would be to create an environmental management system in which EIA is not the only conduit through which the productive sectors are required to deal with environmental considerations. Draft reforms are underway, and these can be effective if competing pressures of quick processing and adequate public participation can be acknowledged and achieved.

Environmental taxes provide an opportunity for applying the polluter pays principle to change behavior and raise revenues. The 2012 Tax Law provides the legal framework to establish environmental taxes on individuals and organizations generating pollution and environmental degradation. The same law specifies that tax revenues will be used to treat, rehabilitate, or clean pollution. This report considers (i) fuel taxes and (ii) water-effluent charges as two realistic tax mechanisms that have proven successful in other jurisdictions and could be similarly applied in Lao PDR. These mechanisms complement a green growth agenda that respects competitiveness of domestic industry and achieves other social goals such as reduced congestion and reduced traffic fatalities.

Outlook

World Bank support—through the Green Growth Development Policy Operations (GGDPO)—has contributed to the adoption of policy reforms that already represent important steps in confronting Lao PDR's priority environmental challenges. Reforms adopted to date are aligned with key challenges identified in this report.

1

INTRODUCTION[1]

Chapter Overview

This report on Environmental Challenges for Green Growth and Poverty Reduction in the Lao People's Democratic Republic consists of four main sections: Background and Context, Diagnostic of Current Issues, Socioeconomic and Efficiency Analyses of Current Issues, and Selected Policy Options and Recommendations. Economic analyses were used to quantify and prioritize the costs of environmental degradation, natural resource degradation, and natural disasters, and to represent the flows of transactions within the country's economy.

Lao PDR has achieved rapid growth and poverty reduction since 2000, with its GDP growing on average 8 percent annually. However, Lao PDR's economic growth has been largely driven by the unsustainable use of natural resources and environmental assets. Such unsustainable use has severe implications for development, with resulting costs disproportionately affecting the poor and other vulnerable groups.

The government of Lao PDR has initiated the transition towards a green economy. Its National Green Growth Strategy was adopted in early 2019 after having been developed with international assistance including that from the World Bank. This report provides analytical underpinnings to inform further policy reforms and investments needed to consolidate Lao PDR's transition towards a green economy.

The report focuses on (i) analyzing the policy and institutional adjustments required to address all dimensions of green growth, (ii) identifying the environmental priorities most closely linked to poverty reduction and shared prosperity, (iii) identifying cost-effective interventions to tackle identified priorities and overcome key obstacles for green growth, and (iv) making recommendations to strengthen governance and institutional capacity to manage the transition towards green growth.

1.1 Objective

The Lao People's Democratic Republic has achieved rapid growth and poverty reduction since 2000. Gross Domestic Product (GDP) has grown at an average annual rate of 8 percent since the beginning of the century. Rapid economic development was associated with a decline in the percentage of the population living in poverty, from 34 percent in 2002/03 to 18 percent in 2018/19. However, inequality widened during this period, with the Gini index increasing from 33 to 39, reflecting lower gains for the bottom 40 percent than for the rest of the population. GDP stood in 2017 at approximately US$2,500 per capita for the country's 7 million population. At recent growth rates, Lao PDR is well on the path to catching up to its richer neighbors within a single generation—Thailand's GDP per capita of US$6,600 would be attained in 13 years and China's GDP per capita of US$8,800 would be overtaken in 17 years.

Unsustainable use of natural resources and environmental assets has largely driven Lao PDR's economic growth. However, achieving 8 percent continued growth over the next generation should not be taken for granted. Key economic activities underpinning Lao PDR's economic dynamism included uncontrolled mining, unregulated and illegal logging, hydropower-sector expansion, and inefficient agriculture. While these activities provided important economic gains, they have also resulted in significantly high rates of natural resource depletion and environmental degradation. The annual cost of environmental degradation (reduced natural capital from depletion and reduced human capital from pollution) is estimated at 19.3 percent of GDP in 2017[2]. These figures point to the limitations of Lao PDR's growth pattern[3].

Natural resource depletion and environmental degradation have severe development implications. Their costs disproportionately affect the poor and other vulnerable groups, thereby limiting the contributions of economic growth to reduce poverty. In addition, environmental stress undermines the ability of the natural resource base to provide livelihoods and buffers to natural hazards such as floods. The consequences are particularly severe because more than 70 percent of Lao PDR's population depends on forest resources, soil, wetlands, and fish for income and nutrition. Many of the poorest live in and among degrading and disappearing forests. Poor people are also often highly exposed due to their reliance on wood and charcoal for cooking, limited access to safe drinking water, and inadequate sanitation. The poor also live closer to contaminated soil, to contaminated surface water, and to flood-prone areas. The poor often have limited means to cope and adapt, as was seen in the 2018 flooding.

Faced with growing evidence of the limits of past development patterns, government leaders increasingly recognize that a green economy can be a catalyst for sustainable development goals and poverty eradication. A green economy can be thought of as one that is low carbon, resource efficient, resilient, and socially inclusive. It is driven by public and private investments that reduce carbon emissions and pollution, enhance resource efficiency, prevent the loss of biodiversity and ecosystem services, and reduce environmental and climate risks.

The Government of Lao PDR (GoL) has initiated the transition towards a green economy. The National Green Growth Strategy (NGGS) was adopted in early 2019 after having been developed with international assistance including that from the World Bank. The strategy stresses the need to benefit from the nation's ample natural resources more sustainably and efficiently, while taking a development path that is more resilient to risks such as climate change. The strategy also underlines the need to protect people's health.

The World Bank is supporting this transition through the programmatic Green Growth Development Policy Operations (GGDPO). The World Bank's support has targeted three interlinked pillars: (i) economic management actions to address key macroeconomic risks; (ii) improved strategic planning and policies to make growth greener; and (iii) sectoral actions to improve the sustainability and climate resilience of river basins and hydropower, roads, forestry, protected areas and tourism, and agriculture. The World Bank also supports actions to reduce pollution and improve environmental and human health. All three pillars interact to improve the country's growth prospects.

This report provides analytical underpinnings to inform further policy reforms and investments needed to consolidate Lao PDR's transition towards a green economy. In particular, the report focuses on (i) analyzing the policy and institutional adjustments required to address all dimensions of green growth, (ii) identifying the environmental priorities most closely linked to poverty reduction and shared prosperity in Lao PDR, (iii) identifying cost-effective interventions to tackle identified priorities and overcome key obstacles for green growth, and (iv) making robust recommendations to strengthen governance and agencies' institutional capacity to manage the transition towards green growth[4].

Comments provided by government officials have been addressed in this revised version and are included as footnotes trhough the different chapters.

1.2 Methodology

The analytical work presented in this report was conducted by an interdisciplinary team. Economic analyses were used to quantify and prioritize the costs of environmental degradation, natural resource degradation, and natural disasters. A different type of economic analysis was used to develop a Social Accounting Matrix (SAM) representing the flows of all economic transactions that take place within the economy of Lao PDR. The SAM helped to provide quantitative estimates on the environmental sustainability, economic contributions, and social implications of alternative development scenarios in Lao PDR. Benefit-cost analyses were conducted to compare—and assess the economic feasibility of—alternative interventions that are readily available to reduce the significant costs that environmental degradation imposes on Lao PDR's population.[5] Policy and institutional analysis, and the preparation of case studies, helped to identify opportunities to align environmental management and planning tools with GoL efforts to transition towards a green economy.

1.3 Content of Report

This report comprises the following chapters organized in four sections.

Background and Context: This section provides relevant context for the macroeconomic and institutional situation in Lao PDR, while also providing the background of the overall study process.

> Chapter 1 introduces the report, including its methodology and aims.

> Chapter 2 describes the institutional framework for green growth in Lao PDR.

Diagnostic of Current Issues: This section presents a diagnostic descriptive analysis of Lao PDR's main environmental issues and how they link to the nation's economy[6]. The section commences with a diagnostic of linkages between environmental pollution and human health in terms of mortality and morbidity impacts and the associated consequences on economic productivity. The section then broadens the diagnostic discussion to include a wider range of natural resource degradation issues, including those associated with natural disasters. The section then provides a diagnostic of environmental planning instruments. The section concludes with a look at a high-profile issue associated with solid-waste disposal and associated impacts of mismanagement of solid wastes—plastics in particular.

> Chapter 3 examines the priority environmental health issues faced by Lao PDR.

> Chapter 4 discusses biodiversity values and priority natural resource degradation and natural disaster challenges in Lao PDR.

- Chapter 5 focuses on environmental planning instruments in Lao PDR, particularly Environmental and Social Impact Assessment (ESIA).

- Chapter 6 examines priority issues related to the management of solid waste and plastic waste in both urban and rural settings.

Socioeconomic and Efficiency Analyses of Current Issues: This section reports a series of in-depth analyses to evaluate further the linkages between environmental degradation and other dimensions of economic development. The section commences with an examination of the linkages between poverty and environment in Lao PDR. The section then assesses so-called backward and forward multipliers through the economic production process, described using a Social Accounting Matrix. The remaining two chapters in this section provide standard benefit-cost analyses to calculate BCRs for interventions associated with (i) mitigating environmental health-risk factors, and (ii) reducing impacts of environmental degradation from anthropogenic sources and natural disasters.

- Chapter 7 assesses the linkages between poverty and environment in the country.

- Chapter 8 models economic growth in Lao PDR and its linkages with green growth.

- Chapter 9 assesses and compares alternative interventions to address priority environmental health risks.

- Chapter 10 assesses interventions to tackle natural resource degradation and natural disasters.

Selected Policy Options and Recommendations: This short section provides additional insights into policy options not previously evaluated and summarizes a number of institutional interventions consistent with promoting green growth[7].

- Chapter 11 identifies and reviews examples of potential specific policy options relating to environmental taxes and fees.

- Chapter 12 presents policy recommendations to strengthen governance and institutional capacity to support the transition towards a green economy.

1.4 Notes

1 This chapter was written by Ernesto Sánchez-Triana.

2 World Bank estimates. Household air pollution accounts for 38 percent, followed by water pollution, sanitation, and hygiene at 22 percent; outdoor $PM_{2.5}$ ambient air pollution at 21 percent; and lead (Pb) exposure at 19 percent.

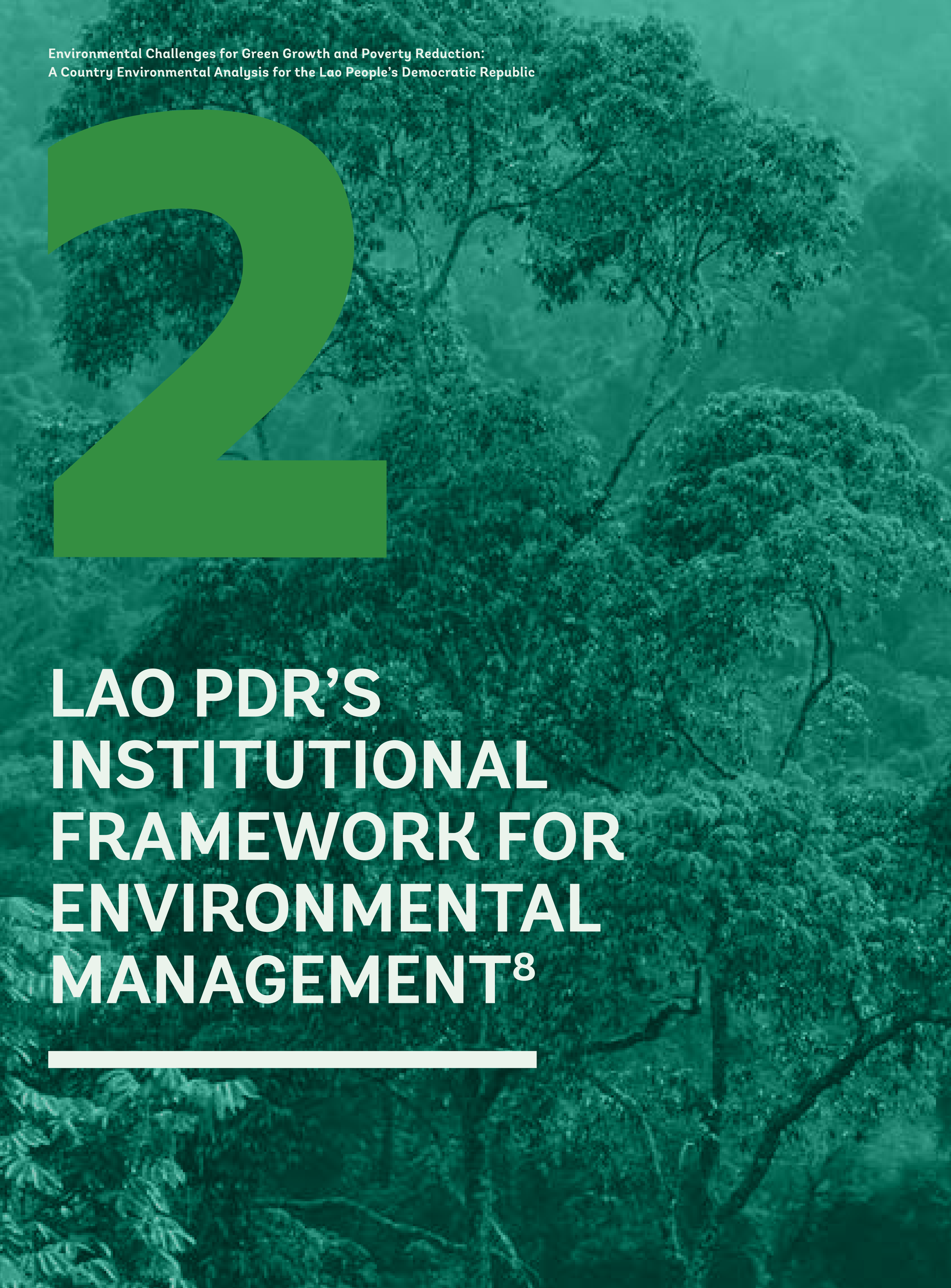
3 The Vice Minister of Planning and Investment, H.E. Dr. Kikeo Chanthabouly, indicated that “It is important to identify and reassess issues that might have impacts on natural resources and environment so that they can be mitigated immediately, and we must come up with measures to address the issues accordingly within the next 5 years (2021–2025).”

4 The Vice Minister to the Prime Minister’s Office, H.E. Mme. Dr. Viengsavanh Douangsavanh, mentioned that the Government of Lao PDR published the State of Environment Report (SOER) many years ago, which according to the law, must be published every three years. She also explained that government officials must follow Decree 177 regarding coordination between ministries and local authorities about information exchange. The Government of Lao PDR will be publishing the State of Environment Report in late 2020.

5 Benefit-cost analyses were conducted using a Benefit-Cost Ratio (BCR) as an indicator for comparing policy interventions to address specific issues. BCR is the ratio of the present value (PV) stream of benefits to the PV stream of costs, calculated using an annual discount rate. The discount rates used in this study are appropriate for the analyses being undertaken, but these discount rates may not be applicable for other purposes. That is, BCR calculations for interventions relating to one issue should not necessarily be compared to BCR calculations for another issue. Specifically, the environmental health BCR calculations in this study use a discount rate of 3%/yr. This discount rate permits comparison to other countries’ similar options relating to human health. For natural resource damages, various studies’ BCR calculations report a range of discount rates of 3%/yr, 5%/yr, and 10%/yr to compare options. Ranking results within a given set of options tend to remain robust for a wide range of discount rates, but comparative rankings between environmental health results and natural resource management results cannot necessarily be made based on the BCR indicator.

6 The Vice Minister of Planning and Investment highlighted the need to focus on priority issues that have the most-severe impacts on the environment.

7 The Vice Minister of Planning and Investment emphasized the need to highlight the report’s main recommendations on Lao PDR’s green growth priorities.



2

LAO PDR'S INSTITUTIONAL FRAMEWORK FOR ENVIRONMENTAL MANAGEMENT[8]

Chapter Overview

This chapter focuses on the crucial role of institutions in addressing environmental challenges in the Lao People's Democratic Republic. Institutions are essential in identifying the most urgent challenges, engaging stakeholders to develop solutions to such challenges, and ensuring that solutions are implemented. Although Lao PDR's legal and regulatory framework has evolved rapidly over the last decade, the country's institutions need further strengthening to perform these functions. Key recommendations to bolster environmental institutions in Lao PDR include the following:

> *Establishing a formal mechanism to define environmental priorities, align environmental expenditures with priorities, and continuously assess progress in achieving environmental goals.*

> *Strengthening the monitoring of priority sites related to environmental quality and using collected data to design evidence-based interventions to reduce pollution and to publicly disseminate information that can help strengthen environmental constituencies.*

> *Establishing systematic procedures to evaluate progress in responding to environmental priorities, incorporate lessons learned, and identify opportunities for continuous improvement.*

> *Strengthening interagency coordination to address environmental priorities through the adoption of goals that are based on environmental-performance indicators and through public dissemination of information that presents and discusses progress in achieving such goals.*

> *Improving public information and promoting transparency, accountability, and awareness through the publication of data, wider use of public forums, and a more detailed review and discussion on environmental-management tools.*

> *Ensuring adequate funding and using result-based agreements to improve effectiveness and efficiency in the use of public resources in all sectors, including the environment.*

> *Strengthening the capacity of environmental agencies to fulfill their mandate, including systematic monitoring and enforcement of environmental regulations, as well as creating specialized technical units to address priority challenges.*

> *Continuing to develop the regulatory and policy framework using a comprehensive set of instruments such as (i) as command-and-control measures; (ii) economic and market-based instruments; and (iii) other means, including public disclosure, legal actions, and formal negotiation.*

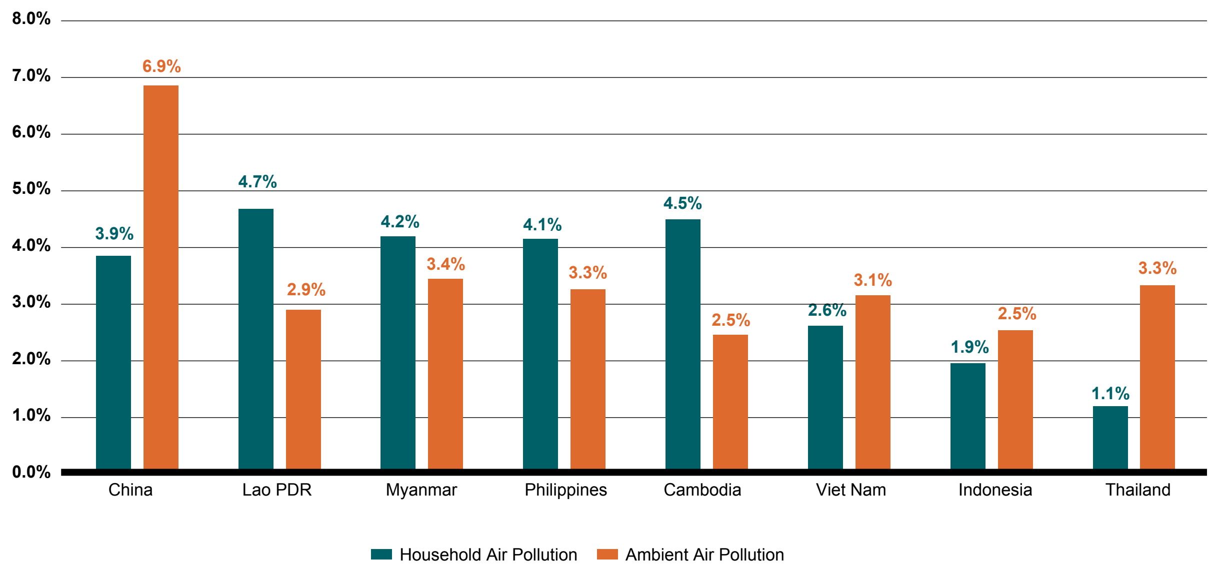
2.1 Introduction

Environmental degradation poses significant development challenges for the Lao People's Democratic Republic (Lao PDR). The negative effects of pollution include a significant loss of lives, health, and economic opportunities for advancement. In 2017, environmental risk factors were responsible for 10,000 deaths in the country, or 21.6 percent of all deaths for that year. The costs of the health effects of key categories of environmental degradation were equivalent to around 14.6 percent of Lao PDR's Gross Domestic Product (GDP) for that year (see chapter 3). Depletion of natural resources and natural disasters result in additional costs that represented 4.7 percent of GDP in 2017 (see chapter 4).

The health effects of air pollution in Lao PDR are more severe than in most countries in South East Asia and in other regions. The World Bank has applied similar methodologies to estimate the costs of environmental degradation in several countries, including estimates of the cost of air pollution in several Asian countries. As shown in Figure 2.1, the costs of household air pollution, measured as a share of GDP, are significantly higher in Lao PDR than in most other Asian countries. Although the cost of ambient air pollution is lower than in neighboring countries, it still represents a very high share of GDP.

Tackling pollution and reducing its severe health effects is fundamental to achieve Lao PDR's broader development goals. Pollution causes illnesses that mainly affect low-income people, children, the elderly, and other vulnerable groups. These illnesses reduce the productivity of adults and, in the case of children, affect their ability to attend school and learn, which subsequently limits their opportunities for professional and human development. Thus, efforts to reduce pollution are an investment in human capital, leading to higher productivity and economic growth.

Figure 2.1 Cost (share of GDP) of Outdoor and Household Air Pollution in Selected Countries in 2017



Source: Based on GBD 2017 health risk functions.
Note: Cost is for mortality only. Cost of mortality accounts for approximately 80–85 percent of total health cost in ASEAN and China.

The Government of Lao PDR (GoL) has increasingly recognized the need to integrate environmental and sustainability criteria into its development model, but significant challenges remain. The institutional framework for environmental management has been strengthened over the last few years, including through the creation of the Ministry of Natural Resources and Environment (MoNRE) in 2011 and the amendment of several laws. In addition, environmental protection goals have been included in a number of high-level, strategic documents, particularly since 2016. However, Lao PDR's legal, policy, and organizational framework has yet to set environmental health and pollution management challenges as a priority, particularly in terms of specifically addressing the pollution challenges that result in the highest social and economic impacts.

This chapter provides an analysis of institutions and organizations in Lao PDR, focusing on those that are relevant to address environmental health and pollution management priority challenges. The analysis understands institutions as humanly devised constraints that structure political, economic, and social interactions. They include formal constraints, such as laws, policies, or property rights, as well as informal constraints such as customs, traditions, and codes of conduct. Institutions define the incentives that largely determine the choices individuals make, which in turn shape the performance of societies and economies over time (North 1991). In turn, organizations are groups of individuals engaged in purposive activity. Whereas institutions are the rules of the game, organizations are the players (North 1990).

Environmental degradation arises largely because individuals and public and private organizations do not consider the effects of their individual actions on the environment. Institutions perform three fundamental functions that support the coordinated actions needed to address environmental degradation (World Bank 2003):

1. Picking up signals, or collecting information, based on scientific measurements or stakeholders' feedback that help to identify and prioritize environmental degradation.
2. Balancing interests, recognizing that solutions to environmental problems generally require measures that can affect individuals or groups. This also calls for ensuring that those who are most significantly affected by environmental degradation can participate in the development of solutions, even if they belong to groups that are generally excluded from such decision-making processes.
3. Executing decisions or implementing the solutions to priority problems that have been agreed to by involved stakeholders.

The rest of this chapter focuses on assessing the capacity of environmental institutions in Lao PDR to conduct these three functions. The approach used to develop this chapter consisted of a desktop review of official documents, as well as assessments from recently completed donor-supported projects describing their results and lessons learned. Consultations with public officials helped to complement this information. A preliminary version of the chapter was shared with public officials of the GoL and discussed in meetings and workshops held in June 2019. The feedback received during those events was incorporated into the final version of the chapter.

2.2 Institutional Framework for Environmental Regulation

2.2.1 Strategies and Policies

Since the country's foundation in 1975, the GoL has relied on different planning instruments to implement the Party's guidelines, manage the economy, and achieve development goals. Long-term plans define national priorities and strategies over periods of 10 years or longer. Medium-term plans have a duration of five years and are implemented through annual plans (Somphanith n.d.). In 2016, Lao PDR's National Assembly approved three medium- and long-term instruments: the 8th National Socio-Economic

Development Plan (NSEDP), the 10-Year Socio-Economic Development Strategy (2016–2025), and the 2030 Vision[9].

Vision 2030 aims for the nation to reach the status of an upper-middle-income country with a green growth orientation by 2030. Sustainable agriculture and forestry, effective environmental protection and natural resource use, and green and environmentally friendly industrialization and modernization are envisioned as the key drivers of this new growth pathway (GoL 2016a). This vision is complemented by the National Socio-Economic Development Strategy (NSEDS) 2016–2025, which describes how Lao PDR will graduate from Least Developed Country (LCD) status by 2020 by balancing economic and sociocultural development with environmental protection (GoL 2016a).

The 8th NSEDP 2016–2020 constitutes Lao PDR's strategic document to guide efforts over the medium term and advance towards the long-term objectives articulated in Vision 2030. The NSEDP includes priority targets and outcomes to be achieved within its five-year period, and these constitute fundamental directions for all governmental policies and programs. The formulation of the 8th NSEDP was informed by an evaluation of the 7th NSEDP (2011–2015). One of the key lessons learned from the 7th NSEDP was the importance of promoting sustainable development to maximize balanced development and environmental protection (GoL 2016b). The NSEDP's environmental quality and pollution-control targets include (a) establishing a system to manage and reduce wastes and the use of chemicals, and toxic and hazardous substances; (b) collecting basic data on air and water pollution from industries and services; (c) monitoring and controlling pollution in 10 priority basins; and (d) developing a full environmental database to support the monitoring and analysis of waste, chemicals, toxic and hazardous substances, air pollution, noise pollution, and wastewater (GoL 2016b).

2.2.1.1 Natural Resources and Environmental Strategies

The Natural Resources and Environment Sector Vision (NRESV) towards 2030 and the Ten-Year Strategy (2016–2025) provide more detail about the GoL approach to achieve the environmental protection goals of Vision 2030 and the NSEDS. Following is the sectoral vision for 2030 (MoNRE 2015a, 21):

> *Keeping Lao PDR Green, Clean, and Beautiful based on green economic growth, to achieve sustainable development and industrialized country and to ensure the resilience to climate change impacts and disaster risks.*

The NRESV is expected to guide the operations of different units under MoNRE at the central, provincial, and district levels, as well as to provide a framework that other sectors can use to build synergies with the natural resources and environment sector.

The NRESV provides an overview of the sector, describing environmental conditions, improvements, and challenges at the time of the strategy's formulation. The overview (MoNRE 2015a, 10) states that

> *[i]n general, Lao PDR has a good environmental quality and rich natural resources compared to other countries in the Asian region that stimulated rapid growth in national socio-economic development.*

It also describes urban environmental quality as follows (MoNRE 2015a, 15–16):

> *In general, the urban environment is in good condition, with peace and safety. However, urban cities are in rapid growth and tend to cause some environmental concerns such as […] lack of public utilities to meet the demands of many forms of pollutants in the air, water, soil and nuisances (smoke, odor, noise), persistent chemical wastes […].*

NRESV has multiple goals, including several that explicitly focus on pollution challenges. Key goals include (a) control of land, water, and air pollution, and of noise from agricultural and industrial practices and services to meet environmental standards along the No 13 national road and the Mekong River; (b) protect water quantity and quality in 10 river basins to satisfy water-quality and quantity standards and to ensure people's livelihood, effective wetland management, strict implementation of RAMSAR and the 1995 Mekong River Conventions, and minimum negative impact on ecosystem; (c) reduce the use of chemical substances in the development of industrial and agricultural sectors by 15 percent across the country to meet the chemicals and waste-reduction target in 2020; and (d) reduce waste generation in the 18 municipal areas across the country by 15 percent through directed use of the 3Rs—reduce, reuse, recycle—to satisfy waste reduction targets in 2030.

The Natural Resources and Environment Sector Five Year Action Plan (NRESP) includes several pollution-control and management-specific goals and focused actions. These include collecting data on emissions and water pollution from industrial and services sectors, as well as from vegetation burning, pollution monitoring and management in 10 priority basins; implementing mechanisms for pollution control and reduction; promoting the reduction of chemical use in agricultural sectors; and developing a centralized pollution database covering solid waste, hazardous materials, emission of air and noise pollution, and wastewater disposal along Road Nº 13 across the country. The plan also included important capacity-development goals, including developing MoNRE's institutional organization and human resources, developing a sustainable financial mechanism to ensure effective and efficient implementation of MoNRE activities, and conducting staff-performance monitoring and evaluation to fulfil human-resources allocation for designated positions to effectively implement MoNRE activities at the central and local levels (provincial and district) (MoNRE 2015b).

2.2.1.2 The National Green Growth Strategy

The GoL is taking additional steps for the integration of green growth principles into the country's strategic and development framework. It established the Green Growth National Steering Committee (GGNSC) mandated with overseeing green growth planning; implementation of programs, policies, and projects; and monitoring. The GGNSC is developing Lao PDR's National Green Growth Strategy (NGGS), which defines green growth as

> *[t]he economic growth, poverty reduction, raising of living standards of the people in an inclusive and equitable manner in conjunction with the increase of efficiency and sustainability of the utilization of natural resources which exist in limited quantity, the decrease of pollution, wastes and greenhouse gas emissions and the mitigation of risks and vulnerability to natural disasters and global economic crisis.*

The NGGS presents an agenda through 2030 for implementing the transition to greener growth. Key elements include priority actions including some cross-sector interactions such as tourism/conservation, the water/energy nexus, and climate-risk management, indicators to measure progress, and financing opportunities. Based on the NGGS, priorities can then be reflected in planning and budgeting instructions for national and sector annual development and investment plans.

The NGGS does not aim to replace existing and local strategies in place, but to supplement them with the aim of mainstreaming a green growth agenda into them, and to promote sector and local authorities in the implementation of programs, projects, activities, or components related to green growth. In addition, recognizing limited resources, the NGSS prioritizes seven sectors: (i) natural resources and environment; (ii) agriculture and forestry; (iii) industry and commerce; (iv) public works and transportation; (v) energy and mines; (vi) information, culture, and tourism; and (vii) science and technology.

2.2.2 Legal Framework

Lao PDR's legal framework has evolved rapidly since the adoption of the first legal instruments for environmental management in the 1990s. Lao PDR's Constitution of 1991 (amended in 2013) established in Article 19 that (GoL 2003)

> *…all organizations and citizens must protect the environment and the natural resources: land, underground [resources], forests, animals, water sources, and the atmosphere.*

The first legal instruments emerging from this constitutional provision included the *1994 Regulation on Industrial Waste Discharge and the 1996 Law on Water and Water Resources.* Table 2.1 summarizes Lao PDR's evolving legal framework. This section summarizes the provisions in key laws.

Table 2.1 Key Elements of Lao PDR's Legal Framework for Environmental Management

Law on Water and Water Resources (1996; amended in 2017)
Law on Electricity (1997)
Law on Mining (1997)
Law on Road Transportation (1997)
Environmental Protection Law (1999; amended in 2012)
Law on Agriculture (1999)
Law on Urban Planning (1999)
Law on Roads (1999)
Law on Industrial Manufacturing (1999)
Law on Hygiene, Disease Prevention and Health Promotion (2001; amended in 2011)
Land Law (2003)
Law on Chemicals (2017)

Source: Updated from JICA 2013.

The *1999 Environmental Protection Law (EPL)*, with its most recent amendments in 2012, constitutes the backbone of the country's legal framework for environmental management (JICA 2013). The EPL includes several provisions focusing on environmental health risks. The law's purpose is to balance the social and natural environment, sustain and protect natural resources and public health, and contribute to socioeconomic development and climate-change mitigation. The 2012 amendments introduced the concepts of *environmental health and impact on social environment,* recognizing the importance of protecting humans from the potential impacts of environmental degradation. Other provisions throughout the law explicitly refer to the protection of human health as a key goal of environmental protection and pollution control (GoL 2012).

The *EPL* recognizes four main types of pollution: air, soil, water, and disturbance (noise, light, odor, vibration, and heat). National Environmental Quality Standards (NEQS) and National Pollution Control Standards (NPCS) control these pollution types. NEQS establish the concentrations of key pollutants as parameters of environmental quality for air, water, and soil, while NPCS set the limits for pollutant emissions from those holding a permit from the authority. The *EPL* also establishes workers' rights to operate in an environment free of toxic chemicals at their workplace and its surroundings (GoL 2012).

In February 2017, the GoL updated its NEQS for national air quality and water quality, and the NPCS for vehicle emissions, through Decree No 81/PM and Ministerial Decision N° 0485/MoNRE. The updated NEQS set the annual final particulate matter ($PM_{2.5}$) concentration at 10 µg/m^3, the same value recommended by the World Health Organization (WHO) Air Quality Guidelines (AQG), which were developed based on the results of studies on the health effects of long-term exposure to $PM_{2.5}$ (WHO 2006). The NEQS for air quality also set a one-year air quality standard for lead (Pb) of 0.15 µg/m^3. This value aims to maintain children's blood lead levels at less than 5 µg/dL, which is the level recommended by other established organizations, including the United States Centers for Disease Control and Prevention.

The GoL, under the leadership of MoNRE, has taken steps to monitor and enforce compliance with environmental standards. Ministerial Instructions N° 5688/MoNRE and N° 6439/MoNRE, adopted in late 2018, regulate standard procedures and parameters of methods for sampling and analyzing key air and water pollutants.

The *2011 Law on Hygiene, Disease Prevention, and Health Promotion* refers to environmental health as an element of hygiene. It also includes provisions on the protection of human health from pollution stemming from key economic activities. Based on the law, health authorities have a mandate to prevent noncommunicable diseases, as well as to enforce compliance with technical standards for production, waste disposal management techniques, and principles of hygiene to avoid potential health impacts. The law also requires health authorities to conduct organized inspections and control to ensure that food products and consumer goods are free from toxic chemical substances, parasites, and microbes. Article 18 on labor hygiene establishes employers' obligations to provide safety equipment and working conditions that protect workers from diseases, toxic chemicals, and radioactive materials. Article 19 includes specific provisions on hygiene in production to avoid the spread of germs and toxic chemicals, particularly in goods for daily consumption, children's toys and cosmetics (GoL 2011). The latter is particularly relevant, given that toys and cosmetics are a main source of lead exposure in Lao PDR (see chapter 3).

MoNRE's Ministerial Instruction on Hazardous Waste Management (2015) established the procedures for classifying, identifying, and labeling hazardous wastes and chemicals. These procedures were later incorporated into the *2017 Law on Chemicals,* which describes the obligations of companies, users, and authorities on the management, monitoring, transport, and disposal of chemical wastes. It also classifies chemicals into four categories based on their potential harm to humans and the environment. The law's provisions cover the management, monitoring, inspection, implementation, and application of activities involving chemicals with the purpose of encouraging and promoting a safe work environment and ensuring healthy living conditions, properties, and a healthy environment. The Ministry of Industry and Commerce (MoIC) is responsible for the implementation and supervision of most of the law's provisions, including the approval of standards, regulations, and technical manuals to ensure safe use of chemicals. Industry and commerce divisions and offices at the provincial and district levels, respectively, are responsible for implementing and enforcing the law's provisions within their jurisdictions. The law established the National Committee for Chemicals, whose membership includes representatives from line ministries associated with industry and commerce, agriculture and forestry, health, environment and natural resources, and science and technology, as well as from the National Chamber of Commerce and Industry. This committee provides a formal mechanism to promote coordination and build consensus on policies, plans, and regulations pertaining to chemical use (GoL 2016c).

The Decree on Pesticide Management (2017) outlines the parameters on how to conform to technical guidelines regarding the procurement, use, and disposal of pesticides. The decree lists the procedures for manufacturing, import, export, transport, use, and monitoring of pesticides. It prohibits the use of pesticides that are not registered in Lao PDR. Sound pesticides management is needed to protect workers' health (and prevent associated labor-productivity reductions) and can help boost trade in foods that are safe and do not pose a risk to consumers' health. It is also useful for the emergence of organics exports, as Lao PDR identifies niche markets for expanding agricultural exports. Labeling is an important factor, since Lao PDR does not produce any pesticides and farmers buy chemicals from traders with labeling in languages other than Lao, especially in border areas. Pesticides are also mislabeled to cover up banned substances and often sold by unlicensed businesses. The decree provides the Ministry of Agriculture and Forestry with a legal mandate to control businesses involved in the import, formulation, sale, and distribution of pesticides.

The *2017 Law on Water and Water Resources* (LWWR) includes several provisions addressing the linkages between environment, health, and development. This includes the obligation to maintain a minimum water flow in watercourses to ensure that communities and ecosystems can meet their needs and the establishment of reserved areas to protect water for drinking and consumption. The law also creates a system of underground and superficial water rights to manage the allocation of water to small, medium-scale, and large-scale uses, including electricity generation, irrigation, mining, and industry. Medium- and large-scale users are required to pay charges that are funneled into the Environmental Protection Fund (EPF), along with charges for wastewater discharges and fees for the restoration of water resources from investment projects and other activities. The law also assigns rights and duties to health-sector authorities in areas such as inspection and surveillance of water quality used for drinking and consumption, and the supply of clean water to people living in rural areas. The law's provisions also give responsibilities to line ministries to manage water use in the sectors they lead, including agriculture and forestry, energy and mines, public works and transportation, industry and commerce, tourism, and education and sports (GoL 2017).

The LWWR is a cornerstone of the country's green growth program, with implications on environmental fiscal instruments, water pollution and waste, energy, agriculture, forest, watersheds, wetlands, flood and drought risk, climate change, groundwater, information and data management, nutrition, and tourism. The LWWR also has implications for managing trade-offs and harnessing mutual opportunities among these themes and sectors. This new legal framework is based on international best practice and assigns implementation responsibilities to MoNRE while recognizing cross-sectoral imperatives.

2.2.3 Financial Instruments

The *2012 Tax Law* provides the legal framework to establish environmental taxes on individuals and organizations generating pollution and environmental degradation. The same law specifies that tax revenues will be used to treat, rehabilitate, or clean pollution. Separate regulations establish taxable activities, exempt activities, taxable targets, taxable amounts, and rates of environmental tax (Global Green Growth Institute [GGGI] 2017).

Article 63 and Article 34 of the *2017 Water Law* also establish sources that will be used to fund the Environmental Protection Fund (EPF). These include (i) fees for the restoration of water resources from investment projects and other activities, and (ii) service charges for water and water-resource use and for wastewater discharges. Fund resources must be used to (i) draft and amend policies, strategies, plans, and legislation relating to water and water-resource management; (ii) support scientific and technological research for the protection of water and water sources; (iii) support prevention, control, and elimination of water pollution and disasters through establishment of training centers, information centers, and laboratories for water-quality analysis; (iv) support training, capacity building, and awareness raising; (v) manage priority issues; and (vi) promote development of local knowledge.

Since 2012, the government has made several attempts to explore the possibilities of introducing various fiscal measures for environmental management to develop the main contents of the Environmental Tax procedure. Since then, different units in MoNRE and the Ministry of Finance (MoF) have assumed the responsibility for developing the regulations on environmental taxes. While continuing to work on the development of such regulations, the GoL has taken preliminary steps to develop green fiscal policies that can strengthen its ability to finance the transition toward green growth. Under the first GGDPO (GGDPO 1), the GoL instituted a reform to allow some revenues of the EPF to be channeled through the national treasury. The GoL eliminated tariff exemptions for fuel imports for investment projects in 2016.

Efforts to increase financing for green growth priorities will be complemented with increased transparency and effectiveness in use of funds, including by enhancing EPF management. With the support of GGDPO 1, the GoL strengthened the EPF, set up as one of the financing vehicles for environmental protection and rehabilitation, through streamlining its operations in line with the *Environmental Protection Law*. In 2018, and supported by GGDPO 2, the EPF Board approved updated bylaws that establish priority investment windows for a range of implementers and environmental themes, including climate change. The GoL also set up a transparency mechanism to disclose publicly, on a regular basis, the EPF resources collected through each revenue source and the selection and justification for resource allocation to environmental priorities. Future reforms would support increased and diversified financing available to a better-managed and more transparent EPF.

2.3 Organizational Framework

On June 24, 2011, the National Assembly of Lao PDR endorsed the establishment of the Ministry of Natural Resources and Environment (MoNRE). MoNRE was established by combining departments and divisions related to natural resources and environment—such as land, forest (conservation and protected areas), geology-minerals, water resources and environment—from different ministries and agencies. The creation of MoNRE was based on the need to improve coordination, collaboration, and integration of natural resources and environment management (MoNRE 2015a). The Ministry of Natural Resources and Environment has a mandate as a secretariat and key regulator for direct management of land, forest, water, air, and biodiversity and minerals. Its mandate also includes management of climate change, disaster, meteorology, and hydrology throughout the country.

The institutional structure for environmental management in Lao PDR consists of (i) national committees that guide inter-sectoral coordination among agencies, (ii) national-level ministries and agencies that play a core role in protecting and conserving the environment, (iii) provincial and district entities that implement local-level environmental management, and (iv) mass organizations that support the government's efforts to promote public participation and awareness. In 2015, 18 provincial offices with 148 offices in districts supported environmental management. The environmental sector had 4,479 government officers, 727 working at the central level and 3,752 at the local level. Around 1,200 of these officers had a vocational education degree, 1,608 a technical diploma, 1,350 a bachelor's degree, 241 a master's degree, and 10 officers had doctoral degrees (MoNRE 2015a).

The Department of Environmental Quality Promotion is responsible for the Environmental Protection and Climate Change Programme, in coordination with Department of Pollution Control, Department of Disaster Management and Climate Change, Department of Environmental and Social Impact Assessment, Natural Resources and Environment Institutes, and other relevant sectors. The Department of Environmental Quality Promotion is obliged to report to Department of Planning and Cooperation on routine basis (MoNRE 2015b).

MoNRE has the main responsibility for implementing the LWWR at the national level, including the issuance and management of licenses for the use of water and water resources. Provincial, district, municipal, city, and village authorities have similar responsibilities within their jurisdictions. The LWWR gives other agencies key responsibilities regarding water resource management:

- The Ministry of Agriculture and Forestry (MAF) is responsible for managing water resources for irrigation, fishing, agricultural, and forestry production.
- The Ministry of Energy and Mines (MEM) is responsible for managing water resources for hydropower and mineral exploitation processes.

> The Ministry of Public Works and Transportation (MPWT) has responsibilities related to water supply, navigation and waterway transportation, bank-erosion protection, and wastewater collection and treatment.

> The Ministry of Industry and Commerce (MoIC) has a mandate on the use of water resources in industrial processing.

> Responsibilities of the Ministry of Health (MoH) include the inspection of water sources used for drinking and clean water supply for people living in rural areas, and surveillance of water quality for drinking and consumption.

> Local Administrations are responsible for the approval of river basin management plans, for determination of water and water reserved areas in their localities, and for combating and dealing with damage from water.

2.3.1 Inter-Sectoral Coordination

Coordination of sectors with environmental authorities includes both formal and informal mechanisms. The formal forums include sector working groups (SWGs) and sub-sector working groups (SSWGs) on environment, health, and the agriculture and forestry sectors. Informal information sharing, cooperation, and decision making are important in Lao PDR. These exchanges occur often after working hours such as in sports and social events—for example, when playing petanque.

For very specific topics in trade negotiations such as in the case of the Forest Law Enforcement, Governance, and Trade (FLEGT) program, there are also Technical Working Groups (TWGs) and Technical Expert Groups (TEGs) where MoNRE and MAF work together. During focused TWGs, stakeholders across ministries cooperate well with each other, following the Popular Decree PM15. TWGs would also be needed in the environmental health and pollution-control sector. TWGs could be a key forum to strengthen evidence-based policy making and to close policy gaps as well as implementation gaps.

Each governmental entity, including environmental departments and divisions, has its own Terms of Reference (ToRs). The ToRs are one of the main instruments that shape the direction of departments. The ToRs relate to the NSEDP with its MDG-related indicators and targets. Sometimes, if one department is considered to be overloaded, projects may be assigned to another department if it has key staff with experience in that area. Besides ToRs, Ministerial and Prime Ministerial decrees and orders provide adjustments to the authorities' direction of work.

2.3.2 Oversight and Accountability

Like all line ministries, MoNRE reports to and works closely with the Prime Minister's Office. Article 19 of the *Law on the Government of Lao PDR* states that one of the rights and duties of the Prime Minister's Office is "to study and analyze issues and submit reports to the Government and Prime Minister [PM] to assist in the development of policy on protecting natural resources and the environment," as well as to "manage the career areas which are not under the Ministries and Ministry-equivalent organizations." Hence, the PM's Office is key in providing oversight to environmental authorities and in identifying gaps in the implementation of legislation.

The National Assembly (NA) holds regular sessions where all sectors, including the environmental and health sectors are discussed. In addition, citizens can report their observations directly to their local NA representatives (personal communication with WBG Lao PDR office staff and consultants, March–April 2018). The Ministry of Justice (MoJ) is the authority through which all laws are reviewed before laws such as those on environment and health are sent to the NA. MoJ mostly ensures consistency with other laws and the Constitution of Lao PDR. The MoJ can sometimes raise questions on specific points to MoNRE in case aspects of the policies would not be aligned with other laws or overarching laws such as the Constitution, PM Decrees, Presidential Decrees, or the National Socio-Economic Development Plan.

Public reviews occur in the form of live broadcasting of NA sessions on the internet or on television. Environmental health issues are also discussed in the media, such as newspapers, the radio, and TV. These tend to be the views of citizens, international organizations, and specific line authorities. In a recent case in Vientiane Capital, environmental authorities intervened in a case of ambient air pollution. This was a case where a company was disposing plastic waste by open burning next to an international company, which is a subcontractor in the steel and pipe industry for the energy and mining sector. The company invited environmental authorities to investigate the case. Subsequently, MoNRE authorities were able to enforce the *EPL.*

Formal and informal feedback mechanisms help to identify areas of need relevant to the improvement of environmental policies. Formal feedback is provided in the SWGs and SSWGs, as well as in specific technical working groups and committees. The NA hotline is also a formal feedback mechanism (Slater and Keoka 2012). More-informal feedback mechanisms include social media and website discussion forums, although these tend to be more information-sharing mechanisms amongst citizens, where the public and private sectors usually do not comment. However, these are good informal mechanisms for authorities to find out what their citizens are discussing and, based on that information, authorities will often raise those citizen concerns and points in internal and public meetings.

A good example is the development of stricter decrees on pollution control, such as PM Decision 81. Sharing of pictures by citizens of children who had accidentally eaten pesticides may have been a contributing factor in the application of stricter limits on accepted levels on pollution, as seen in the case of Decision 81 (personal communication with environmental authorities; *Hindustan Times* 2017; Reuters 2017). Regarding the tackling of pollution-management and environmental protection priorities, the default counterpart to solve the issues at the national level is MoNRE. However, each instance is handled on a case-by-case basis in the field. For example, if there have been human health effects suspected to be caused by agrochemicals, local authorities representing MAF and MoH are the focal points. Especially in rural areas, the first point of contact for citizens is usually their Village Chief *(Naiban).* The Naiban presents grievances to the Village Committee (VC) for joint analysis of the main impacts. Depending on the personal relationships, the VC will include representatives of district or provincial authorities at an early stage, or only present the informal complaint to them. The VC usually consists of nonprofessionals as well as representatives of the police, the Lao Women's Union, and the Lao Front for National Construction.

If the source of pollution is a factory, the VC (and/or district authorities) will often also approach the factory to resolve any issues, especially in emergencies. The presence of leadership such as village chiefs, village-management organizations, and Lao Women's Union representatives—and having a Village Health Committee—have been noted as key factors for success (personal communication with Pollution Control Department staff, System Science Consultants Inc. 2016). The leadership group may also approach provincial authorities if the company is not locally represented or if its representatives are not easily approachable.

Most pollution cases are solved informally and locally with compensation paid by the company. However, cases sometimes end up in provincial courts. One issue of concern in monitoring investments is the high level of discretion written in the concession agreements. While in some cases this provides important flexibility to apply regulations in different local circumstances, it can also lead to uncertainty (UNEP 2018). In some cases, citizens publish their grievances on social media. There is also an emergency telephone line at the National Assembly for urgent cases, as well as a telephone hotline directly to the Prime Minister's Office. NA members are also active in touring villages in their constituency. Hence, it is common for citizens to approach their representatives and provide feedback and suggestions when they visit in their villages.

Representatives of farmer organizations are invited to provincial consultations, and they have an opportunity to consult their National Assembly representatives to bring up their issues at the national level. Poor and vulnerable groups—such as farmers on poor soils—do not influence policy making to a considerable extent, unless their farmer representatives, farmer producer groups active in collecting their views, or they themselves are active in reporting issues to their NA representatives and authorities. There are provincial consultations when policies and laws are developed, but very few poor have the time to participate from their farm work and collection of natural resources. If they are aware of the importance of environmental health concerns, their best way of participating is to contact local farmer producer groups, National Assembly representatives, or local authorities, or to call the hotlines.

2.3.3 Resource Allocation

Budget allocations for environmental protection in Lao PDR are insufficient to address severe pollution problems. The Natural Resources and Environment Sector Plan 2011–2015 had a total budget of US$199.6 million, including the GoL development budget, Overseas Development Assistance (ODA), and private-sector investments (Table 2.2). The amount allocated to environmental programs during this period represented 10 percent of the plan's budget (Figure 2.2). However, it represented less than 1 percent of the development budget provided by the GoL to the plan and, as a result, the environmental protection program was highly dependent on donor support (Figure 2.3). Private contributions were almost four times larger than that of the GoL. The comparatively large contributions from the private sector can potentially create a conflict of interest, since environmental authorities might be reluctant to sanction a private firm that does not comply with environmental standards if the environmental authority is financially dependent on that firm's payments.

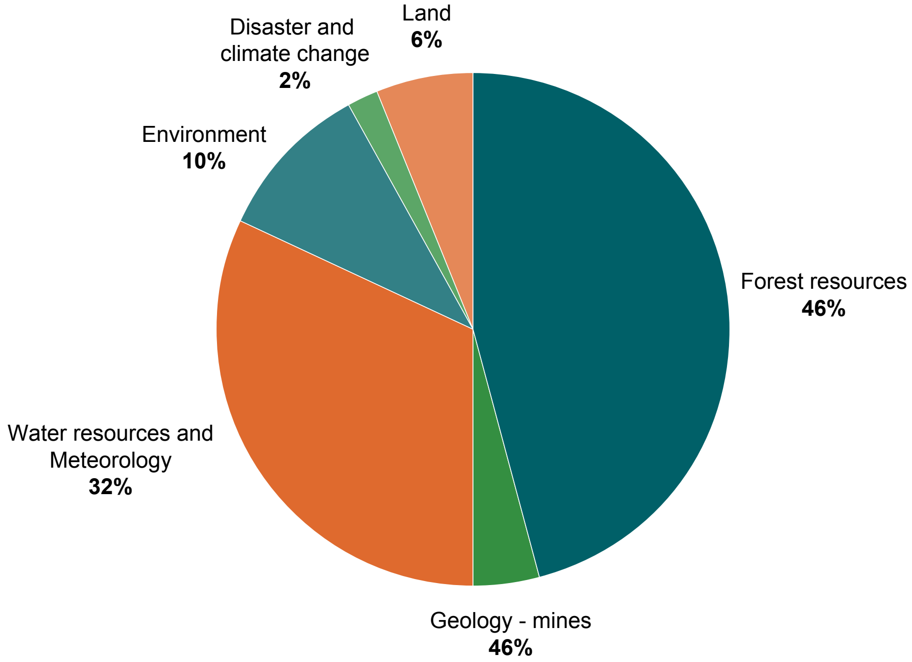
Based on available information, environmental protection budgets have not been used to address priority environmental health risks. The main achievements of the environmental protection program between 2011 and 2015 included development of environment-quality and pollution-monitoring systems for household and investment projects; setting up the national laboratory in Vientiane Capital, Luang Prabang, Xiengkhouang, and Champasak; and the pilot implementation of 3Rs practices in six pilot cities (Vientiane Capital, Kaisone Phomvihanh, Luang Prabang, Paksan, Sayaboury, and Vanvieng) (MoNRE 2015b).

Table 2.2 Budget Sources for the Natural Resource and Environment Sector Plan, 2011–2015 (US$)

Programs	ODA	Private	GoL	Total
Land	–	–	12,026,003	12,026,003
Forest resources	–	–	91,800,000	91,800,000
Geology—mines	7,268,600	–	218,750	7,487,350
Water resources and Meteorology—Hydrology	43,430,776	–	21,484,678	64,915,454
Environment	17,180,000	2,000,000	570,000	19,750,000
Disaster and climate change	3,500,000	–	100,000	3,600,000
Total	**71,379,376**	**2,000,000**	**126,199,431**	**199,578,807**

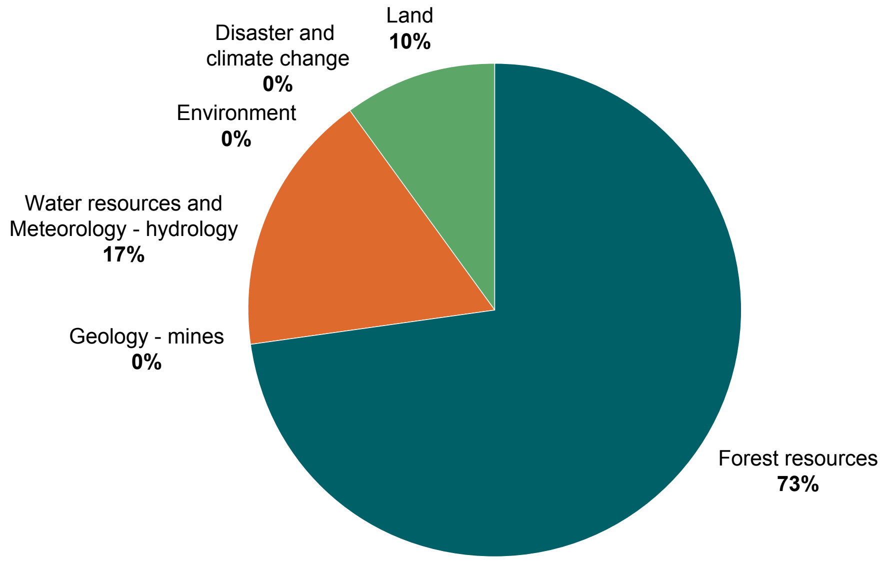
Source: MoNRE 2015b.

Figure 2.2 Total Budget Distribution per Environmental Program, 2011–2015 (US$)



Source: MoNRE 2015b.

Figure 2.3 Distribution of GoL Development Budget per Environmental Program, 2011–2015 (US$)



Source: MoNRE 2015b.

MoNRE's own assessment is that the budget is insufficient to implement its programs. The requested budget for the implementation of the 2016–2020 Natural Resources and Environment Sector Plan was LAK 4,595.68 billion, while the actual budget was LAK 2,553.45 billion, including LAK 126.25 billion from the public investment budget and LAK 2,647.2 billion from ODA. Thus, at the time of the plan's preparation, MoNRE faced a financing gap of LAK 2,042.23 billion, or approximately 45 percent of the resources needed for the plan's implementation (MoNRE 2015b).

In recent years, budget allocations to the water resources and environment sector have fallen. The sector's total budget for 2014–2015, including expenditures by central and local governments, was LAK 257,712 million. This amount was reduced to LAK 127,939 million in the planned budget for 2017 (Table 2.3). This reduction of about 50 percent of the allocations to the water resources and environment sector happened at a time when the total budget expenditure increased by about 5 percent. Whereas the sector's budget represented 0.83 percent of the total

Table 2.3 Budget Allocations for the Water Resources and Environment Sector in Selected Years (LAK, millions)

	2014–15			2017		
	Total (Central + Local)	**Central**	**Local**	**Total (Central + Local)**	**Central**	**Local**
Total expenditure (all sectors)	**30,926,577**	**22,963,645**	**7,962,931**	**32,402,000**	**23,302,989**	**9,099,011**
Water Resources and Environment	**257,712**	**168,660**	**89,052**	**127,939**	**49,456**	**78,483**
Salary and allowances	83,310	16,597	66,714	79,342	20,805	58,537
Compensation and policy allowances	6,520	3,061	3,459	6,733	2,979	3,754
Operational expenditure	23,639	14,927	8,712	24,943	15,809	9,134
Technical activities, subsidies	10,663	8,078	2,585	9,638	6,733	2,905
Other expenditures	1,585		1,585	3,362	3,130	232
New purchase for operation	9,365	9,099	266			
Capital expenditure	122,630	116,898	5,732	3,921		3,921

Source: Based on MoF 2015; 2017.
Note: Data for 2014–2015 are from budget implementation and those for 2017 are from the State Budget Plan.

Table 2.4 Changes in Budget Allocations between 2014–15 and 2017

All sectors	Total (Central + Local)	4.77%
	Central Expenditure	1.5%
	Local Expenditure	14.3%
Water Resources and Environment	Total (Central + Local)	–50%
	Central	–71%
	Local	–12%

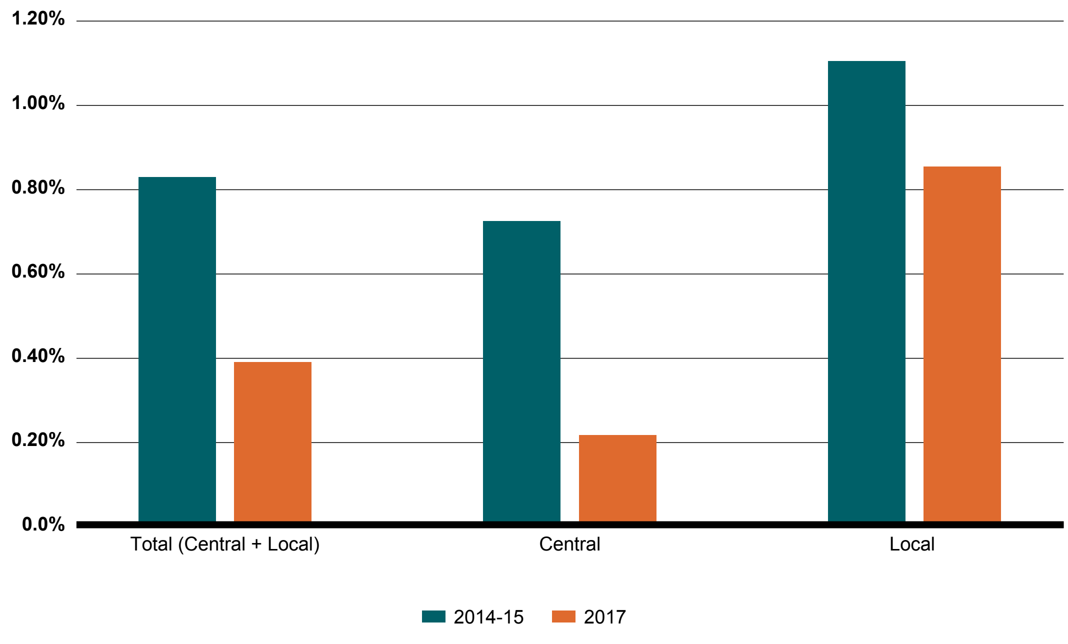
Source: Based on MoF 2015; 2017.

budget for 2014–15, it fell to less than 0.39 percent of the total budget in 2017. Sectoral allocations for the central government fell the most during this period, shrinking from 0.73 percent to 0.21 percent of the central government's expenditure in all sectors (Table 2.4 and Figure 2.4).

The composition of budget expenditure within the Water Resources and Environment sector has also changed significantly in recent years, particularly in the central government. Salaries, allowances, and compensation represented around 79 percent of sector expenditure in local governments in 2014–2015 and 2017. However, at the central level, this grew from 12 percent to 48 percent during this period. Furthermore, while capital expenditure at the central level was the largest expenditure item in 2014–2015, representing more than 69 percent of the sectoral budget, it fell to 0 in 2017 (Figure 2.5 Expenditure Items in the Water Resources and Environment Sector in Selected Years).

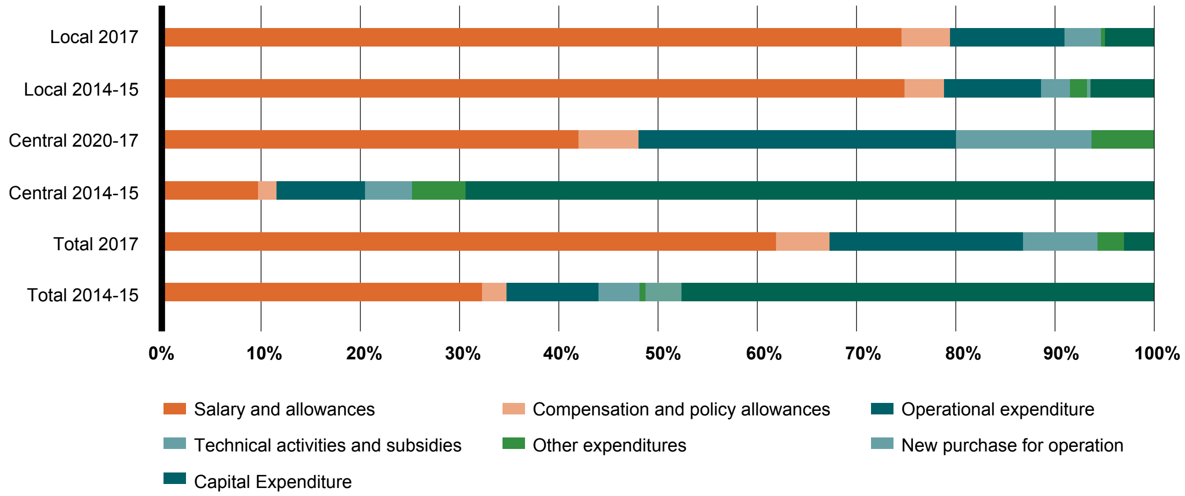
Available data suggest that industrial pollution emissions are highly concentrated in terms of sectors, numbers of facilities, and geographic locations. A 2015 study estimated that discharges of air pollutants from industrial sources were mainly concentrated in Vientiane Capital and Khammouane and Vientiane Provinces. Similarly, the majority of the toxic metal pollutants were primarily emitted in Vientiane Capital and Khammouane and Savannakhet provinces (ADB 2015). The report could not use actual emission data, which are largely missing in Lao PDR, and did not include pollution-dispersion models to assess the actual damages caused by industrial pollution. Yet, the report suggests that these provinces might receive priority attention from environmental authorities to better understand the severity of industrial pollution. However, available budget data do not show greater allocations to these potential hotspots. On average, the 18 provinces' allocation for the water resources and environment sector represents 0.9 percent of the resources allocated to all sectors. This share is significantly lower in Khammouane and Savannakhet provinces (Table 2.5).

Figure 2.4 Allocations to the Water Resources and Environment Sector (% of total budget)



Source: Based on MoF 2015; 2017.

Figure 2.5 Expenditure Items in the Water Resources and Environment Sector in Selected Years



Source: Based on MoF 2015; 2017.

Table 2.5 Allocations to the Water Resources and Environment Sector in Selected Provinces, 2017 (% of total budget)

	Average for 18 provinces	Vientiane Capital	Vientiane	Khammouane	Savannakhet
Budget for all sectors (LAK, millions)		639,400	625,615	552,096	866,041
Budget of Water Resources and Environment (LAK, millions)		8,906	6,066	3,990	4,886
Water Resources and Environment Budget (% of total expenditure)	0.90%	1.39%	0.97%	0.72%	0.56%

Source: Based on MoF 2017.

2.4 Policy-Based Strategic Environmental Assessments

Lao PDR's institutional framework for environmental management has relied significantly on the use of Environmental and Social Impact Assessments (ESIA) as a regulatory tool for individual projects (see chapter 5). Recently, Lao PDR has taken steps to incorporate the preparation of policy Strategic Environmental Assessments (SEA) to integrate environmental and sustainability considerations at strategic decision-making stages, including the preparation of policies, plans, and programs.

With support from the World Bank's first GGDPO, the GoL adopted the 2016 Prime Minister Order No. 55 and the 2017 Ministerial Decision No. 483/MoNRE, which introduced legal requirements for using SEA to integrate environmental and social sustainability, as well as SDGs, into all policies, programs, and strategic plans. These policies define the roles, responsibilities, and main procedures for establishing a SEA system. The GoL has also established detailed regulations and procedures for conducting SEAs, including information disclosure and public participation. By May 2019, the full set of SEA regulations was ready to be implemented for a variety of policy-level topics, including hydropower, the National Green Growth Strategy, and others priority topics.

The reforms adopted by the GoL are based on international evidence showing that policy SEAs have been more effective than impact-centered SEAs in mainstreaming green growth considerations at the strategic level. Impact-centered SEAs were first introduced as instruments with the potential to overcome many of the limitations of the project-based environmental impact assessment (EIA), including the incorporation of environmental considerations in upstream decision-making stages and identification of cumulative, synergistic, or induced impacts that are difficult to consider at the project level (Thérivel 2004). Still, the methodologies adopted by these ‘first generation’ SEAs were largely based on EIA practice and were mainly used to assess the environmental impacts of groups of investment projects clustered in programs, and of land-use zoning and regional plans (Ahmed and Sánchez-Triana 2008; Dalal-Clayton and Sadler 2004; Partidario 2000). As such, they are based on the assumption that policy making is a rational, linear process that can be strengthened by simply providing better environmental information to policy makers (Kornov and Thissen 2000). Given that EIA-like SEAs use the same procedures and methodologies as EIAs, except for addressing cumulative and large-scale impacts of megaprojects, there are no significant differences between a comprehensive EIA and an EIA-like SEA in terms of methodologies and arguably, also in terms of influencing decision making (Tetlow and Hanusch 2012).

In contrast, policy SEA is defined as “an analytical and participatory approach for incorporating environmental, social, and climate change considerations in sector reforms” (World Bank et al. 2011). Policy SEAs focus on identifying environmental priorities, assessing institutions and governance systems, and assessing alternative policy actions. Policy SEAs are acknowledged to require “a particular focus on the political, institutional, and governance context underlying decision-making processes” (World Bank et al. 2011, 2).[10] The objective of policy SEAs is different from that of EIA-like SEAs, particularly since the objective of policy SEAs includes

- Identifying environmental priorities for poverty alleviation and analysis of the capacity of natural resources and environmental services to support sector-wide economic activities and sector growth;
- Highlighting institutional and governance gaps or constraints affecting environmental and social sustainability;
- Promoting capacity building and institutional, legal, and regulatory adjustments critical for environmental and social sustainability of sector reforms;
- Strengthening accountability on the management of environmental and social risks through increasing transparency and empowering weaker stakeholders; and
- Institutionalizing social learning processes around the design and implementation of public policies (World Bank et al. 2011).

Policy SEAs have been effective in various countries across the world, because they (i) provided decision makers with better information, particularly with respect to identifying environmental priorities and institutional roadblocks to address them; (ii) enabled attitudes to change through participation and involvement, particularly by engaging a broad stakeholder base and enhancing accountability; and (iii) changed established routines, notably through the adoption of social learning processes.

Several policy SEAs developed in Pakistan after 2004 illustrate the potential contributions of this type of assessment to raise public awareness, promote debate nationwide, and lead to the design of environmentally sustainable public policies. Influential policy SEAs include the Sindh Environmental and Climate Change Priorities SEA; the Strategic Environmental, Poverty and Social Assessment of Freight Transport Reforms (SEPSA); and the Mainstreaming Environmental Sustainability into Pakistan’s Industrial Development SEA, which are summarized in the following paragraphs:

- ***Mainstreaming Environmental Sustainability into Pakistan's Industrial Development SEA*** was initiated at the end of 2009 to mainstream sustainability into Pakistan's industrial competitiveness. The SEA was steered by a High-Level Committee set up by the Ministry of Industries, representing the federal government, four provincial governments, academia, NGOs, the private sector, and the World Bank. The SEA promoted a consensus-building process that resulted in the formulation of a coherent and sustainable industrialization strategy. The SEA stresses that industrial structural change, spatial transformation, and improvements in infrastructure in industrial clusters are needed if Pakistan is to realize gains in economic efficiency and competitiveness, especially in export markets. This, in turn, requires a cross-sectoral approach that has been endorsed by the Planning Commission and the Ministry of Industries, which has requested programmatic lending support for the implementation of Pakistan's green industrial growth strategy (Sánchez-Triana, Ortolano, and Afzal 2012; Sánchez-Triana et al. 2014).

- ***Sindh Environmental and Climate Change Priorities SEA.*** At the request of the Government of Sindh (GoS) in 2010, the World Bank initiated a non-lending technical assistance (NLTA) in Sindh Province with the objectives of (i) creating a mechanism for ranking the province's environmental problems; (ii) assessing the efficiency and cost-effectiveness of alternative interventions to address priority environmental problems; and (iii) identifying the policy reforms, technical assistance, and investments needed to strengthen environmental sustainability in Sindh. As in the previous case, this SEA was steered by a High-Level Committee composed of representatives from the provincial government, business associations, environmental NGOs, and other stakeholders. The SEA stressed that there was no priority-setting mechanism in Sindh, and the scarce available resources were not used to address the categories of environmental degradation that were causing the most significant effects. This SEA constituted the first formal assessment of the severity of environmental degradation in the province. It also provided a roadmap for carrying out investments, policy reforms, and institutional strengthening activities that would result in better environmental conditions. The methodologies and approach adopted by the NLTA can be replicated in the future to evaluate progress in improving environmental conditions, identifying policy and intervention improvements, and determining the most efficient use of scarce resources (Sánchez-Triana et al. 2015).

- ***Strategic Environmental, Poverty and Social Assessment of Freight Transport Reforms (SEPSA).*** In order to ensure meaningful discussion among key stakeholders in the identification of specific sustainability criteria that would be incorporated into freight-transport reforms, the GoP and the Bank held a series of workshops during 2009 to scope out the studies that would be completed using methodologies developed for policy SEA and poverty and social impact analysis (PSIA). This gave rise to the Pakistan Strategic Environmental, Poverty and Social Assessment of Freight Transport Reforms (SEPSA). The environmental management component of SEPSA focused on the environmental aspects of investments and reforms in the trade and transport sector, particularly freight. The potential environmental effects of three strategic alternatives were analyzed: (i) the "no reforms" alternative, (ii) policy reform and investment in the road freight sector, and (iii) policy reform and investment in the rail freight sector. Each alternative was evaluated based on the set of priority issues identified jointly with stakeholders (climate change, air quality, transport of hazardous materials, road and railway safety, urban sprawl and accessibility, and environmental management systems) to assess their potential environmental and social implications.

The PSIA was prepared to identify potential social and distributional impacts of transport-sector reforms on stakeholder groups, employing a computable general equilibrium (CGE) model that uses actual economic data to simulate how an economy might react to changes in policy or other external factors. The PSIA identified the main effects of proposed policy reforms and developed a menu of options to mitigate negative impacts, incorporate poverty alleviation measures into the design of transport reforms and projects, enhance positive effects on poverty alleviation, and address environmental and social priorities. Strong governance and institutional capacity in sectoral and environmental agencies were highlighted as indispensable for the adoption of the options identified. Findings from the Pakistan SEPSA include that a modal shift from road-freight to rail-freight transport for long hauls would have significant environmental and social benefits; that environmental issues should not be considered in isolation from social ones, particularly in situations in which policy reforms could increase the risk of social conflict; and that understanding social patterns and conflicts illuminates the feasibility and weaknesses of potential solutions and needed mitigation measures. To stimulate economic growth, employment, and poverty reduction, reforms to promote industrial competitiveness need to be made along with significant investments in increasing road density to improve the connectivity of industrial clusters to domestic and international markets. Strengthening the infrastructure of urban centers to receive rural and inter-provincial migrants is also required (Sánchez-Triana et al. 2013).

An analysis of the profiled policy SEAs identifies similar features: robust stakeholder participation, client ownership, and temporal coordination with the county's development priorities and processes. They also tend to be done in ways that are collaborative, evolving, and ongoing rather than as a safeguard-clearance requirement, which may receive more attention during project preparation than during project implementation (Slunge and Loayza 2012).

Several SEA practitioners have pointed out that the duration of the SEA itself is often too short to achieve results and that its main contributions are long-term, often indirect, outcomes (Axelsson et al. 2012; Jha-Thakur 2012; Slunge and Loayza 2012). Therefore, a key contribution of policy SEAs to mainstream green growth principles into policies and programs is to use the assessments to initiate a dialogue with a broad stakeholder base and set the foundations for a policy learning process through which responses to identified environmental priorities can be progressively addressed.

The SEA regulations adopted by the GoL provide key elements to guide public servants and practitioners on the best practices for designing and implementing SEAs, developing institutional capacity over time, and supporting better decision making. By ensuring meaningful participation from relevant stakeholders, including vulnerable groups often excluded from decision making, policy SEA can contribute to make growth green, inclusive, and climate informed. The GoL plans to use SEA to inform the preparation of the NGGS. This first experience using SEA will be an important step in building GoL capacity to lead the preparation of SEAs. Continuing to build such institutional capacity remains the main challenge to realize the full potential of policy SEAs.

2.5 Conclusions and Recommendations

Lao PDR's institutional framework for environmental management has evolved rapidly, as discussed throughout this chapter. There are, however, opportunities to further strengthen the framework and ensure it performs the three fundamental functions that support the coordinated actions needed to address environmental degradation. These three fundamental functions—picking up signals, balancing interests, and executing decisions—are discussed below.

2.5.1 Picking up signals

Official documents suggest that the institutional framework has not picked up the signals indicating that Lao PDR faces significant environmental challenges. The assessment of the costs of environmental degradation presented in chapter 3 indicates that the health and economic effects of such degradation have a cost equivalent to 14.6 percent of GPD, a higher share than in any of the other countries in which the

Bank has conducted similar analyses. These findings contrast starkly with the way in which the high-level policy documents summarized in this chapter describe environmental conditions. For instance, the NRESV characterizes Lao PDR's environmental quality as good and comparing favorably with other countries in the Asian region.

Chapter 3 also finds that the environmental health problems that require attention most urgently are household air pollution; ambient air pollution; water, sanitation, and hygiene; and lead exposure. However, these issues have received minimal attention in the high-level policies, instruments, and budget allocations discussed in this chapter. This misalignment between environmental priorities, institutional efforts, and resource allocation is largely due to (a) the absence of an integrated system of reliable data to provide analytical support to the decision-making process; (b) the lack of representation of vulnerable groups that are mainly affected by environmental degradation; and (c) the absence of a formal mechanism for allocating financial and human resources according to clearly defined environmental priories that are linked to poverty alleviation and social priorities.

Monitoring capacity is constrained by a lack of reliable time-series data on the state of the environment and natural resources, the nonexistence of a system of results-focused indicators of environmental quality, and insufficient resources to ensure an adequate institutional presence in the field.[11] The World Bank-supported Green Growth Development Policy Operations (GGDPOs) have contributed to establish the mechanisms that will allow for the regular monitoring of environmental data. For instance, with support from the second operation, MoNRE regulated standard procedures and parameters of methods for sampling and analyzing particulate matter ($PM_{2.5}$ and PM_{10}) in air, as well as arsenic, cyanide, lead, manganese, mercury, fecal coliform, and total coliform (as part of pathogens) in water. These actions will help to monitor air and water pollution in priority sites, which will be key to both design data-driven interventions to reduce pollution and to publicly disseminate information. Continued support and commitment will be key to ensure that monitoring systems are well resourced and maintained over time.

Another important step to strengthen environmental planning would be to ensure that data collected through monitoring are used to inform a data-driven approach to identify environmental priorities, assess alternatives to address them, and evaluate progress in achieving environmental goals. The Cost of Environmental Degradation presented in chapter 3 of this report is an example of a methodological approach to identify environmental priorities, while the cost-benefit analyses presented in chapter 9 illustrate an approach to select the priority interventions that are likely to benefit individuals and society the most. The GoL could also consider creating a group within MoNRE and in coordination with other sectors to conduct analytical work that would provide robust foundations for setting environmental priorities across sectors and budget allocation in response to those priorities.

The GoL might similarly conduct analytical work to assess progress in responding to environmental priorities, incorporate lessons learned, and identify opportunities for continuous improvement. The systematic establishment of baselines and the evaluation of governmental interventions constitute an appropriate tool to gauge progress, incorporate the lessons from past experience, and adjust policies based on new developments in science and technology. The information collected with this tool is crucial for building performance-based indicators, which allow organizations to set measurable goals, evaluate their achievements, and engage in a process of reforming and improving their practices. Performance-based indicators also have the potential to strengthen the environmental sector by enhancing transparency and accountability, as well as by demonstrating the social benefits of investing public resources in environmental protection.

2.5.2. Balancing interests

Lao PDR has good examples of interagency coordination that has been instrumental to balance the interests of various sectors, such as the establishment of working groups in the context of trade negotiations. However, major environmental issues still lack the minimum coordination structure for defining priorities and action plans, as evidenced by environmental problems such as indoor air pollution, ambient air pollution, and lead exposure[12]. Efforts to foster closer interagency coordination could be based on quantifiable goals. The process of developing environmental performance could be closely tied to efforts requiring units from different organizations to set specific quantifiable goals in their action plans, and to systematically monitor their progress toward those goals. Ideally, this performance evaluation system would measure direct impacts on environmental quality, such as reduction in waterborne diseases or in outdoor and indoor concentrations of $PM_{2.5}$. Disseminating such data and publicly disclosing them can create strong incentives for compliance with coordinated plans and for improved institutional performance.

Responding to priority environmental challenges in Lao PDR calls for a more systematic effort to raise awareness of environmental issues. Ways to improve public information and promote transparency, accountability, and awareness include the publication of data in support of key environmental indicators (including health statistics or pollution loads); wider use of public forums to air development initiatives; and broader and more detailed review and discussion of environmental management tools. In Colombia and Indonesia, among other countries, the publication of key environmental performance indicators has been instrumental in raising environmental awareness and placing environmental issues on the national agenda. Mechanisms to disseminate information in a manner that is easily interpretable can allow communities to serve as informal regulators; such mechanisms also promote accountability on the part of those being regulated (World Bank 2005)[13].

MoNRE has taken important steps recently to improve the dissemination of environmental information. Key efforts include posting environmental compliance reports on its website and developing a color-coded air quality index that can inform a wide audience about air quality and the types of actions that are recommended for different air quality levels. These efforts can help to both raise awareness about the severity of air pollution and catalyze action to control pollution. They can also contribute to increased accountability. Currently, a key accountability and oversight mechanism consists of citizens reporting their observations directly to their local National Assembly representative. Having publicly available data would provide a more systematic and evidence-based approach to complement citizens' observations.

Also missing in the current institutional framework are mechanisms to incorporate the concerns of groups most severely affected by environmental degradation into Lao PDR's planning processes, as well as clear criteria to efficiently allocate scarce financial and human resources for environmental management in the provinces[14]. The GoL might consider including criteria linked to poverty reduction and shared prosperity in its budget allocation procedures.

2.5.3. Executing decisions

Gaps in environmental policies, weak enforcement, and deficient technical capacity have rendered Lao PDR's environmental management framework ineffective to reduce environmental degradation in the country. Current environmental regulations only apply to (or are only enforced for) a limited subset of activities or in response to a public complaint, and environmental regulation systematically neglects some of the most polluting activities. Government regulators lack resources to enforce the regulatory framework. Because of this, enforcement is selective and compliance with regulations is extremely low.

Weaknesses in executing decisions are associated with inadequate funding for the environmental sector and decreases in the national government's total environmental expenditure. According to MoNRE's own assessment, its budget was insufficient to implement the 2016–2020 Natural Resources and Environment Sector Plan. The limited data that are publicly available indicate that environmental protection activities have been highly dependent on donor funding and that allocations to the sector have fallen even as total government expenditure has risen.

The GoL might consider adopting results-based agreements to improve effectiveness and efficiency in the use of public resources in all sectors, including environment. This approach consists of the signing of results-based agreements between the Ministry of Finance and national agencies and subnational governments. MoF and the leading sectoral agencies (for example, MoNRE) monitor compliance of the agreement based on a small, clear set of critical standards indicators and milestones, which are part of the agreement. Budgetary disbursements are subject to a given degree of compliance, and allocations in the following budget cycle are decided according to the previous cycle's results.

There is also an urgent need to strengthen the capacity of environmental organizations to execute decisions. MoNRE was established in 2011 and is still in the process of consolidation. Even though the sector had a staff of more than 4,000 in 2015, environmental authorities are largely unable to conduct essential functions such as monitoring and enforcing the NEQS. The GoL might consider creating specialized technical units to respond to identified environmental priorities and ensuring that they have the necessary human, technical, and financial resources to fulfill their mandate[15].

As Lao PDR continues to develop its institutional framework for environmental management, it should consider developing a wider range of environmental instruments. Currently, ESIA is the main tool used for environmental management, as discussed in more detail in chapter 5. In many countries, ESIA has become the main environmental management tool and is often the only instrument used to address complex environmental problems, serving as a "de facto" substitute for regulations in key areas, such as pollution control, biodiversity conservation, and effective land-use planning (Acerbi et al. 2014). Lao PDR could mitigate the risk of placing an undue burden on its ESIA system by developing a comprehensive set of environmental policy and management instruments, including (i) direct government regulation through what are referred to as command-and-control measures; (ii) economic and market-based instruments; and (iii) other means, including public disclosure, legal actions, and formal negotiation. These instruments could initially focus on identified environmental priorities and gradually expand to cover additional areas.

Table 2.6 Recommendations for the Strengthening of Environmental Institutions in Lao PDR summarizes this chapter's recommendations and their suggested timeframe.

Table 2.6 Recommendations for the Strengthening of Environmental Institutions in Lao PDR

Objective	Policy Recommendation	Timeframe*
Setting environmental priorities	Establish a small group in MoNRE for analytical work and environmental policy design	Short term
	Design and implement a policy (through laws and regulations) to set environmental priorities at the national and subnational levels, based on learning mechanisms to periodically review and learn from the experiences of implementation of environmental policies	Short term
	Strengthen monitoring systems to comprehensively assess environmental quality in priority sites and use collected data to inform decision making	Medium term
	Install and implement systems to monitor and evaluate environmental management and the extent to which the objectives of environmental priorities are efficiently met	Medium term
	Periodically evaluate progress on the implementation of policies to tackle environmental priorities with the support of the accumulation of data, results, and experiences achieved through interinstitutional coordination and learning	Medium term
Strengthening inter-institutional coordination	Set coordination incentives and quantifiable goals	Medium term
Increasing public awareness and accountability	Establish and strengthen public disclosure mechanisms for environmental information	Short term
	Support the technical and financial capacity of accountability agencies, including the PM's Office and the National Assembly, to oversee environmental performance, and create an enabling environment for public participation and social accountability	Medium term
Aligning environmental expenditure with priorities	Establish the leadership and institutional arrangements and capacities to set priorities in environmental policy design and implementation	Short term
	Align environmental expenditure with priorities and use results-based agreements to improve effectiveness and efficiency in the use of public resources	Medium term
Strengthen the capacity of environmental agencies	Establish specialized technical units to respond to identified environmental priorities and ensure that they have the necessary human, technical, and financial resources to fulfill their mandate	Medium term
	Develop a comprehensive set of environmental policy and management instruments, including (i) direct government regulation; (ii) economic and market-based instruments; and (iii) other means, including public disclosure, legal actions, and formal negotiation.	Medium term

Note: * = Short term: 1–3 years; Medium term: 3–7 years; Long term: 7 years and longer.

2.5 Notes

8 This chapter was prepared by Santiago Enriquez.

9 The Vice Minister of Planning indicated that this report will be used to prepare the 9th NSEDP.

10 A succinct presentation of insights and guidance on Policy SEA can be found in World Bank et al. (2011).

11 The former Vice Minister of Natural Resources and Environment, H.E. Mme. Monemany Gnoibouakong, underlined the importance of achieving the Sustainable Development Goals and of monitoring environmental data over time to gauge progress in achieving goals.

12 The former Vice Minister of Natural Resources and Environment pointed out the importance of promoting coordination for the design and implementation of green growth policies among different ministries and departments.

13 The Vice Minister to the Prime Minister's Office recommended working with the Ministry of Information to raise awareness of environmental issues. She also suggested integrating environmental issues into Lao PDR's education system to raise young people's awareness.

14 The Vice Minister of Public Works and Transport, H.E. Mme. Vilaykham Phosarath, highlighted the importance of working with provincial and district public works and transportation offices to address key issues highlighted in the report.

15 The Vice Minister to the Prime Minister's Office indicated that "We should build our human capacity continuously so that we can actually solve environmental problems."

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3

COST OF ENVIRONMENTAL DEGRADATION: ENVIRONMENTAL HEALTH ISSUES[16]

Photo credit: Wildlife Conservation Society

Chapter Overview

As many as 7.6 million people died worldwide (14 percent of all global deaths) from the four largest environmental health-risk factors in 2017 according to the Global Burden of Disease 2017 (Stanaway et al. 2018).[17] About 7 million (92 percent) of these deaths were in low- and middle-income countries. The four risk factors are outdoor ambient air pollution (AAP); household air pollution (HAP) from the use of solid fuels for cooking and other household purposes; inadequate drinking water, sanitation, and handwashing; and exposure to lead (Pb).

Air pollution accounted for 4.9 million deaths globally, or two-thirds of the deaths from the major environmental risk factors. Air pollution is the fifth-leading risk factor for mortality worldwide and causes more deaths than malnutrition, malaria, unimproved sanitation, or unimproved water sources, according to the Global Burden of Disease 2017. Air pollution not only causes pain, suffering, and reduced quality of life, but also loss of income of affected people from illness, premature death, and loss of productivity.

Nine out of ten people globally breathe outdoor air containing levels of pollutants ($PM_{2.5}$) exceeding the World Health Organization's (WHO's) annual air quality guideline (AQG), and 40 percent of the world population uses solid fuels as primary cooking fuels with household air pollution levels exceeding the WHO's AQG by 10–20 times. In the Lao People's Democratic Republic, most of the population is exposed to elevated pollution associated with at least two of the four environmental health-risk factors assessed in this chapter.

Household air pollution: Over 93 percent of Lao PDR's population relied on solid fuels (wood, charcoal) for cooking in 2017. In contrast, in Vietnam, a country whose per capita income is similar to Lao PDR's, 33 percent of the population used solid fuels. The use of solid fuels for cooking and other household purposes causes severe household air pollution and health effects in Lao PDR. A recent study in Savannakhet province found that household cooks were exposed to 24-hour average $PM_{2.5}$ concentration levels that are 12 times higher than WHO's AQG for annual average outdoor $PM_{2.5}$ of 10 μg/m^3. Personal exposures of other adult household members and children are also very high. Average outdoor ambient $PM_{2.5}$ in the villages was as high as 52 μg/m^3, mainly due to the smoke from solid fuels used for cooking.

Ambient air pollution: There is a severe lack of ground-level monitoring of outdoor ambient $PM_{2.5}$ in Lao PDR, even in major population centers including Vientiane Capital. The limited available monitoring data suggest that the majority of Lao PDR's population are exposed to $PM_{2.5}$ outdoor concentrations exceeding WHO's annual AQG, and that ambient $PM_{2.5}$ in Vientiane Capital may exceed the annual WHO AQG by a multiple of 3–4, and possibly more in some sections of the city. Rising pollution from a rapidly increasing vehicle fleet—especially diesel vehicles—and continued air pollution from household burning of waste/debris, high level of dust from streets and other sources especially during the dry season, and cooking with solid fuels (that is, wood, charcoal) are likely some of the main sources of air pollution. Air quality monitoring and $PM_{2.5}$ source-apportionment studies are much needed to confirm the situation, identify priority sectors for air pollution control, and design cost-effective interventions.

Drinking water and sanitation: An estimated 84 percent of Lao PDR's population used an improved drinking-water source in 2017, according to the Lao Social Indicator Survey II. Nearly 40 percent of the population reported that they treat (mainly by boiling) their water prior to drinking, and 48 percent of the population purchased bottled drinking water. Nevertheless, nationwide testing of drinking water revealed that as many as 86 percent of the household population had E. coli in their drinking water. The situation was not much better for households using bottled water, with 85 percent of users having E. coli in their bottled water. Over 70 percent of the population had access to improved, nonshared sanitation in 2017. However, 24 percent of the population continued to practice open defecation, predominantly in rural areas.

Arsenic in drinking water from tubewells is a concern in central and southern Lao PDR. However, arsenic-measurement studies are very limited. One available study suggests that as many as 400 thousand people in these provinces may be exposed to arsenic in drinking water exceeding WHO's guideline of 10 µg/liter.

Lead (Pb) exposure: Lead is toxic to humans and has many known health effects. Although exposure to lead has globally declined substantially with the phaseout of leaded gasoline, multiple other sources of lead exposure remain. These sources include, among others, industry and mining; occupational exposure; contaminated drinking water, food, dust, soil, paint, cosmetics, utensils, several herbal medicines, children's toys, ornaments, and jewelry. No measurement study of blood lead levels (BLL) in Lao PDR's population is available. If BLLs are similar to the levels in neighboring countries, then over 90 percent of children and adults in Lao PDR may have BLLs that are detrimental to children's neuropsychological development and adults' cardiovascular health, according to recent research evidence.

The impacts of environmental pollution in Lao PDR have profound short-term and long-term implications for the well-being of the Lao people, as well as profound implications for the country's economic development and poverty alleviation. The analytical work presented in this chapter clearly shows that the impacts of pollution on human health are among the most urgent issues confronting Lao PDR.

Quantitative assessments of the health impacts of pollution, both in physical and monetary terms, can be widely understood throughout government and the general public. Such assessments can therefore serve as an instrument for identifying environmental priorities, for mobilizing support for their implementation, and, more broadly, for moving forward towards realizing environmental goals and objectives.

Developing the capacity within MoNRE to conduct such analytical work would support analytically sound foundations for setting environmental priorities across sectors and budget allocation in response to those priorities. The budgetary allocation for environment should be informed by a priority-setting mechanism such as analysis of the cost of environmental degradation—including analysis of the health-related costs of environmental degradation, as well as benefit-cost analysis of potential interventions, as presented in chapter 9.

3.1 Introduction

International research during the last decade has evidenced and confirmed that health effects associated with major environmental risk factors are often more severe and/or occur at much lower pollution concentrations or exposure levels than previously documented. This is the case especially for household air pollution (HAP) from the use of solid fuels for which a health assessment now includes cardiovascular health effects. It is also the case for lead (Pb) exposure among young children, for which neuropsychological effects are now understood to occur at much lower levels of exposure than previously thought.

This chapter provides estimates of health effects in Lao PDR from household air pollution (HAP); outdoor ambient air pollution (AAP)[18]; inadequate water supply (including arsenic in groundwater), sanitation, and hygiene (WASH); and lead (Pb) exposure among children and adults. The social and economic costs of these health effects are monetized in Lao Kip (LAK) and as a percentage of Lao PDR's GDP in 2017. This chapter also presents some perspectives on the current status of indicators related to environmental health. The report does not cover other environmental health issues such as air, soil, and water pollution from mining, industry, and pesticides, and occupational health risks from pesticide application.

The report finds that the four environmental health-risk factors are estimated to have caused 10,000 deaths in Lao PDR in 2017. This was 21.6 percent of all deaths in the country. The risk factors also caused nearly 100 million days of illness and a loss of over 340 thousand IQ points in children in 2017. The annual cost of these health effects is estimated at LAK 17.6–23.6 trillion in 2017, with a central estimate of LAK 20.6 trillion. This is equivalent to 12.4-16.7 percent of GDP, with a central estimate of 14.6 percent (Figure 3.1).

3.2 Household Air Pollution

The use of solid fuels for cooking causes serious household air pollution (HAP). Over 1.6 million people died globally in 2017 from harmful exposure to $PM_{2.5}$ emissions from cooking with solid fuels, according to the Global Burden of Disease 2017 (Stanaway et al. 2018).[19] This makes HAP one of the leading health-risk factors in developing countries. About 40 percent of the world population and 48 percent of the population in low- and middle-income countries relied on solid fuels as primary cooking fuels in 2016 (World Bank 2019). The prevalence of solid-fuel use is especially high in Sub-Saharan Africa and in several countries in South and South East Asia, including Lao PDR (Figure 3.2).

Figure 3.1 Central Estimate of Annual Cost of Environmental Health Risks in Lao PDR, 2017 (LAK, billions, and % equivalent of GDP)

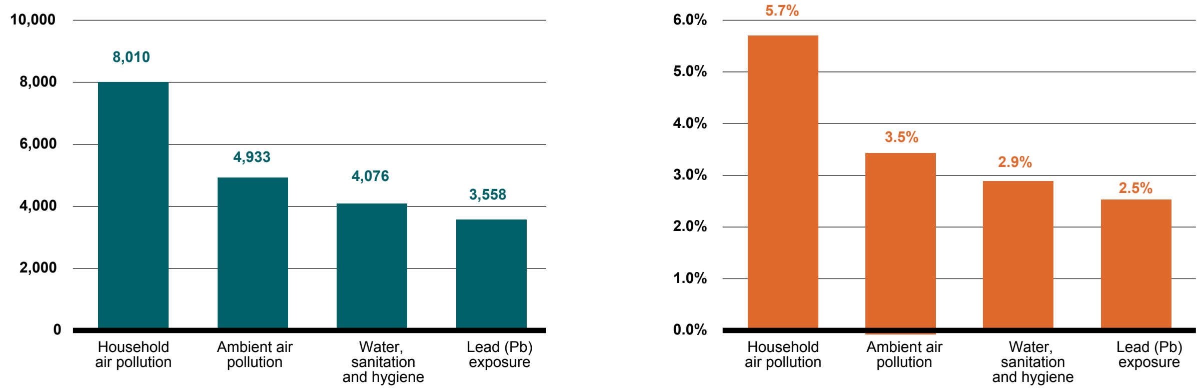
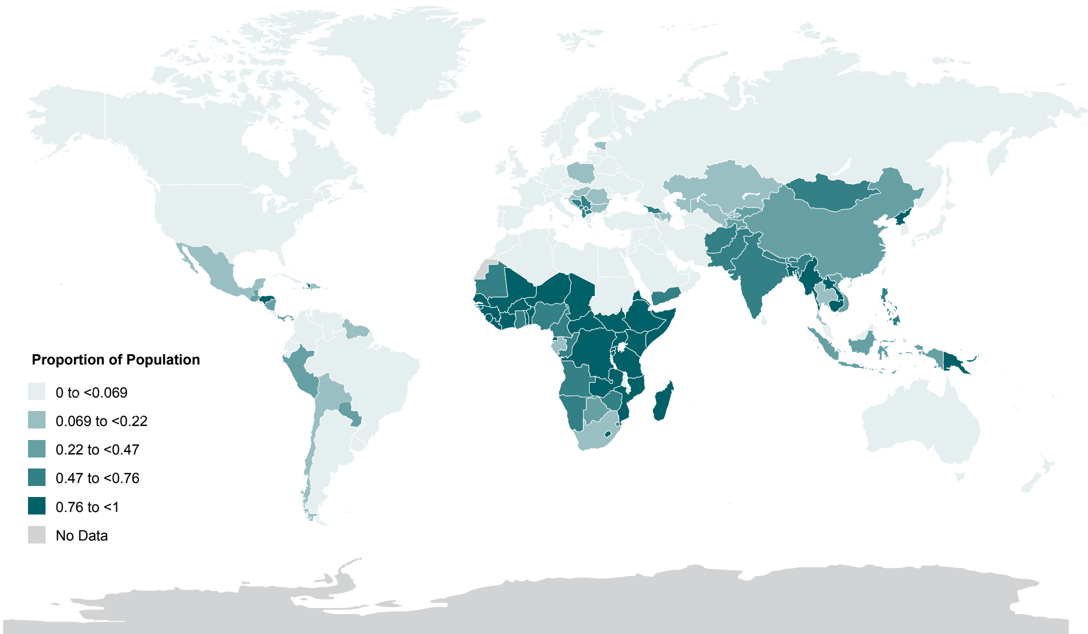


Figure 3.2 Population Prevalence of Solid-Fuel Use, 2017



Sources: Health Effects Institute 2019; State of Global Air 2019. Data source: Global Burden of Disease Study 2017 (IHME 2018).

Less than 6 percent of the population in Lao PDR used clean energies (for example, LPG, electricity, and gas/biogas) as primary cooking energies in 2016. This compares to 39-44 percent in other lower-middle-income countries, India, and South Asia. While the use of clean energies increased by nearly 20 percentage points from 2000 to 2016 in these groups of countries and India, the increase in Lao PDR was less than 2 percentage points (Figure 3.3).

Within ASEAN, the use of clean energies for cooking is by far the lowest in Lao PDR. Rates of clean energy use in countries with comparable GDP per capita (that is, the Philippines and Vietnam) are 43-67 percent. In Cambodia--whose GDP per capita is about half of Lao PDR's—the use of clean energies for cooking is about three times as high as in Lao PDR (Figure 3.4).

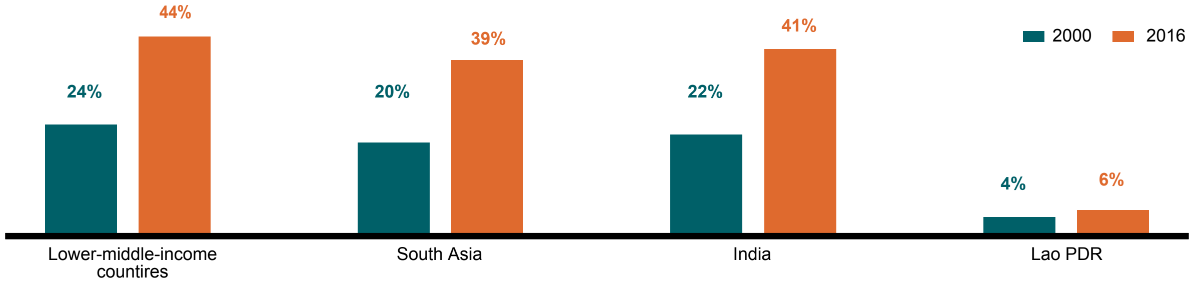
An analysis of countries' energy use in relation to income level indicates that 33-50 percent of the population in Lao PDR would be expected to use clean energies as primary cooking energies in 2016 based on the country's per capita income level, rather than the actual level of less than 6 percent. This can be inferred from the dotted lines in Figure 3.5 and Figure 3.6, which show the expected use of clean energies in relation to GDP per capita. There seems to be substantial scope for promoting clean-cooking solutions in Lao PDR even at the current income level.

The analysis also indicates that the use of clean energies across countries accelerates with higher GDP per capita. The use of clean energies is 1.5-1.75 percent higher for every 1 percent increase in GDP per capita (or PPP GDP per capita).

3.2.1 Use of Solid Fuels

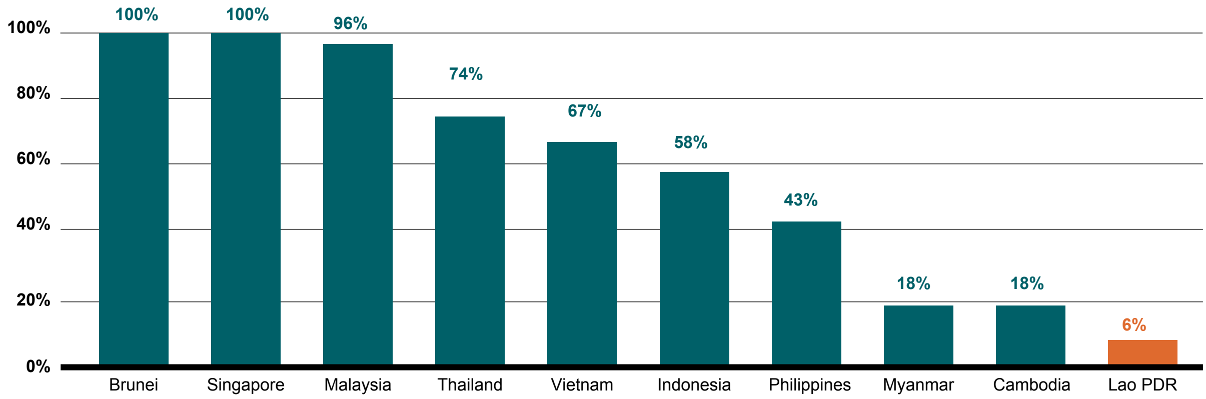
Over 93 percent of Lao PDR's population used solid fuels as their primary cooking fuel in 2017, with 67 percent of the population relying on wood and over 26 percent on charcoal, according to the Lao Social Indicator Survey 2017 (LSB 2018). Cooking with clean energies (for example, electricity, LPG, and gas/biogas) was practiced by less than 7 percent of the population nationwide. In contrast, 67 percent of the population in Vietnam and 75 percent of the population in Thailand cooked with clean energies in 2016 (World Bank 2019).

Figure 3.3 Use of Clean Energies for Cooking in 2000 and 2016 (% of population)



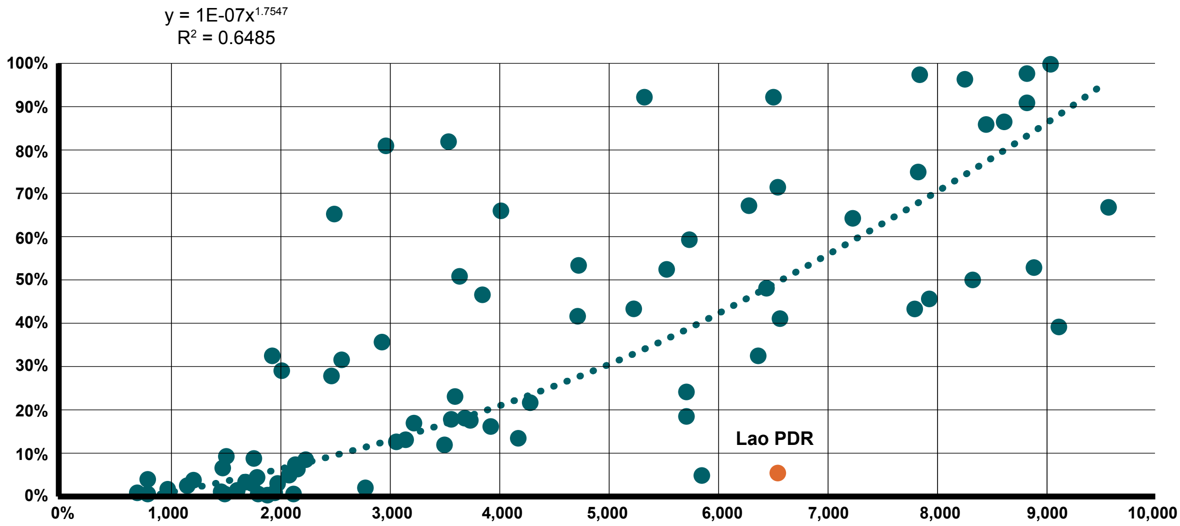
Source: Produced from World Development Indicator data in World Bank 2019.

Figure 3.4 Use of Clean Energies for Cooking in ASEAN Countries, 2016 (% of population)



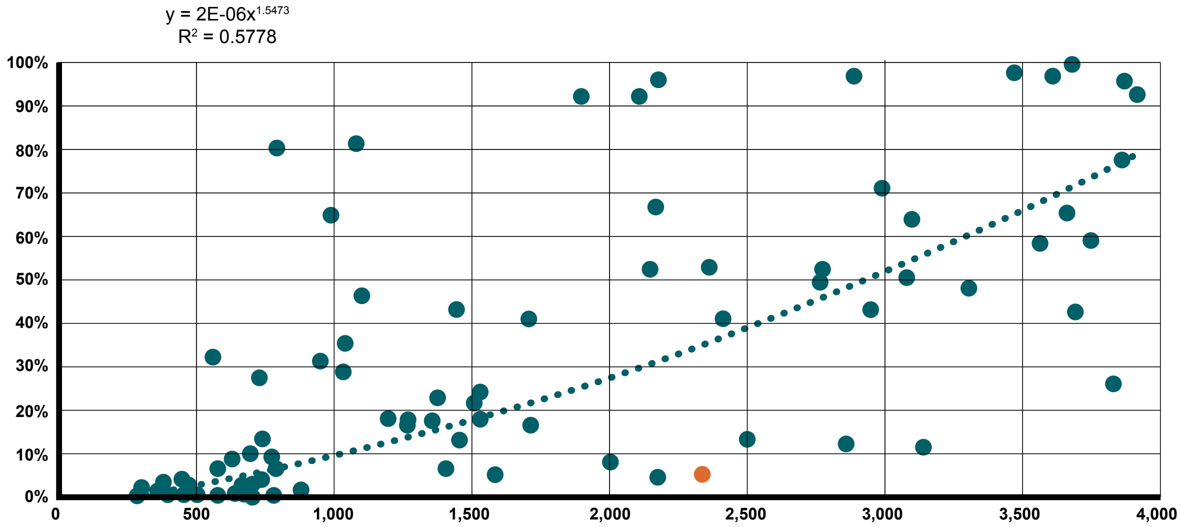
Source: Produced from World Development Indicator data in World Bank 2019.

Figure 3.5 Population Use of Clean Energies for Cooking in Relation to GDP per Capita ($ PPP), 2016



Source: Produced from World Development Indicator data in World Bank 2019.

Figure 3.6 Population Use of Clean Energies for Cooking in Relation to GDP per Capita (current US$), 2016

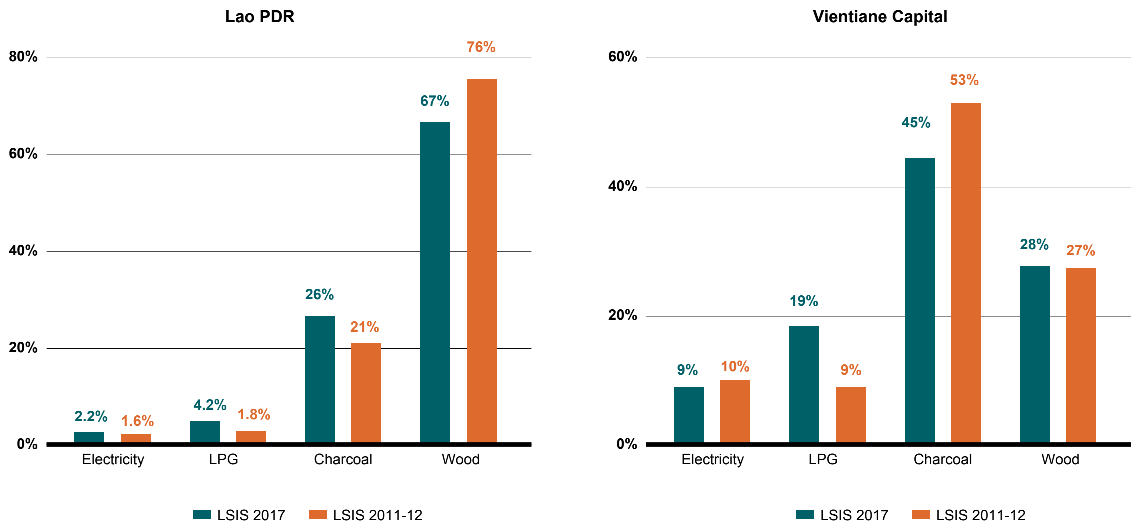


Source: Produced from World Development Indicator data in World Bank 2019.

Nationally, the use of LPG increased marginally in most parts of Lao PDR from 2011-12 to 2017. The use of charcoal increased substantially in rural areas, particularly in the south where nearly half of households used charcoal in 2017, compared to 32 percent in the central region and 3 percent in the north.

The transition to clean energies for cooking has advanced the most in Vientiane Capital where 27 percent of the population used electricity or LPG in 2017. The use of LPG doubled from 2011–2012 to 2017, the use of charcoal declined, and the use of electricity and wood remained constant (Figure 3.7).

Figure 3.7 Household Primary Cooking Fuel in Lao PDR and Vientiane Capital (% of population), 2011–2012 and 2017



Source: Produced from LSIS 2011–2012 (MoH/LSB 2012) and LSIS 2017 (LSB 2018).

The use of clean energies is noticeably higher among richer and better-educated households. Among the population from the richest wealth quintile in 2017, over 26 percent cooked with clean energies, up from 15 percent in 2011–2012. Similarly, among households with household heads having higher education in 2017, over 26 percent cooked with clean energies, up marginally from 22 percent in 2011–2012.

About 94 percent of Lao PDR's population had access to electricity in 2017, according to the LSIS II 2017 (LSB 2018); this is a commendable achievement at the income level of Lao PDR, with its mountainous terrain, low population density, and many remote populations. However, only 2.2 percent of the nationwide population, 5.3 percent of the urban population, and 9 percent of the population in Vientiane Capital used electricity as primary energy for cooking in 2017 (LSB 2018). This is practically the same as in 2011–2012 but represents a marked decline from 1995 when over 10 percent of the urban population and 22 percent of the population in Vientiane Capital used electricity for cooking (World Bank 2016a). The decline is attributed to the rise in residential electricity tariffs for cost recovery and financial viability of the national utility company.

As to household-cooking location, 54 percent of Lao PDR's population cooked in the house, 34 percent cooked in a separate building, and 12 percent cooked outdoors in 2017 (Figure 3.8). This pattern does not vary much by region or by urban–rural location in Lao PDR, except for a very low rate of outdoor cooking in the north.

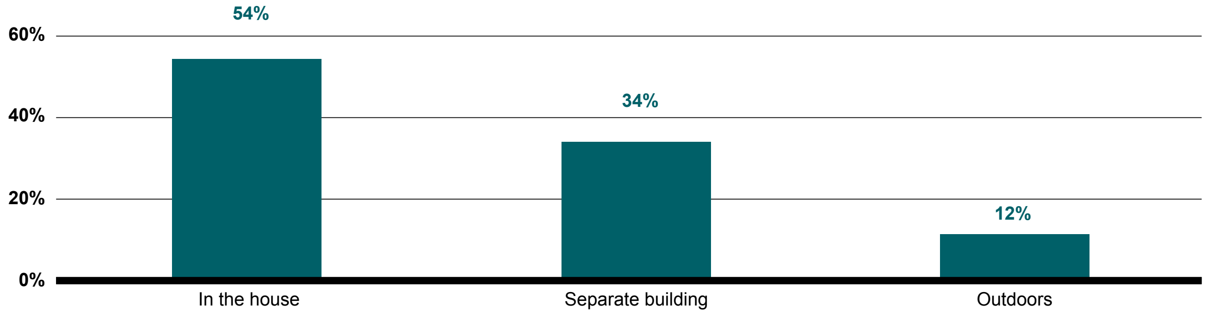
3.2.2 Household $PM_{2.5}$ Exposure

$PM_{2.5}$ concentrations in the household environment vary substantially in relation to type of solid fuel, cooking location, type of stove and ventilation practices, cooking duration, and structure of dwelling. Household members' personal exposure to $PM_{2.5}$ from the combustion of solid fuels depends additionally on their activity patterns inside and outside the household environment.

Nearly 49 percent of households in Lao PDR use a manufactured solid-fuel stove, 21 percent use a traditional solid-fuel stove, and 22 percent use a three stone stove/open fire, according to the LSIS II 2017. The survey contains no information on the extent to which any of these stoves are *improved* stoves. However, less than 1 percent of households have a chimney or exhaust fan (LSB 2018).

A recent study in three villages in Savannakhet found average 48-hour $PM_{2.5}$ kitchen concentrations of 439 µg/m3 in a sample of 72 households cooking with solid fuels (UC Berkeley and Berkeley Air Monitoring Group 2015). The average 48-hour personal exposure to the main cook was 119 µg/m^3, which is 12 times the WHO annual outdoor air quality guideline (AQG) of 10 µg/m^3. The average outdoor ambient $PM_{2.5}$ in the villages was as high as 52 µg/m^3, mainly due to the smoke from solid fuels used for cooking.

Figure 3.8 Household Cooking Location in Lao PDR (% of population), 2017



Source: Produced from LSIS 2017 (LSB 2018).

In estimating the health effects of household air pollution, the exposure of the main cook is used as a reference point for personal exposure of adult women. This is because the person cooking in the household is most often a woman, and the exposure-measurement study discussed above is in reference to the person cooking. Exposures of adult men and young children are set at 60 to 85 percent of adult women's exposure, since adult men and young children generally spend less time in the household environment and the kitchen than adult women spend there (Smith et al. 2014). Regarding the cooking location, cooking in the house is used as a reference location. Personal exposures from cooking outdoors or in a separate building are set at 60 to 80 percent of exposure from cooking in the house (Table 3.1). The exposure levels reflect that a portion of biomass smoke from outdoor cooking or cooking in a separate building enters the indoor living and sleeping areas.

An average exposure level of 120 μg/m^3 is applied to adult women cooking in the house with wood over an open fire or a traditional cookstove. Average exposure levels of adult men and children under five years of age and in various cooking locations are calculated in relation to the exposure level of adult women cooking in the house. This calculation is made by applying the relative exposure factors in Table 3.1. For instance, the exposure level of adult men in a household cooking outdoors is 120 μg/m^3 * H2 * L3 = 120 μg/m^3 * 60% * 60% = 43 μg/m^3 (Table 3.2).

Very few measurements and studies have been conducted of personal exposure from cooking with *charcoal*. This is mainly because charcoal is a primary cooking fuel in only a small minority of countries. Cooking with charcoal is generally associated with lower personal exposure levels of $PM_{2.5}$ than cooking with fuelwood. Personal exposures from cooking with *charcoal* are set at 60 percent, 65 percent, and 75 percent of personal exposures from cooking with fuelwood in the house, in a separate building, and outdoors, respectively (Table 3.2).

Table 3.1 Relative Exposure Levels by Household Member and Cooking Location

		Household member (H)		Location (L)
1	Adult women	100%	In house	100%
2	Adult men	60%	Separate building	80%
3	Children <5 years	85%	Outdoors	60%

Table 3.2 Long-Term Personal $PM_{2.5}$ Exposure by Cooking Location in Households Using Traditional Cookstoves with Fuelwood or Charcoal (μg/m^3)

	Fuelwood Traditional stove/open fire			Charcoal Traditional stove		
	Adult women	Adult men	Children <5 years	Adult women	Adult men	Children <5 years
In house	120	72	102	72	43	61
Separate building	96	58	82	62	37	53
Outdoors	72	43	61	54	32	46

3.2.3 Health Effects

Health effects of long-term exposure to $PM_{2.5}$ in the household environment from the burning of solid fuels include (i) ischemic heart disease (IHD), (ii) cerebrovascular disease (stroke), (iii) lung cancer (LC), (iv) chronic obstructive pulmonary disease (COPD), (v) diabetes Type II among adult women and men, and (vi) acute lower respiratory infections (ALRI) among children and adult women and men. These are all major health effects evidenced by the Global Burden of Disease Project 2017 (GBD 2017) (Stanaway et al. 2018).

Figure 3.9 shows how the risk of these six health effects in terms of mortality increases with increasing levels of $PM_{2.5}$ exposure. At the average exposure level of adult women cooking with fuelwood in the house (that is, 120 μg/m^3 of $PM_{2.5}$), the risk of these six health outcomes is 20–83 percent higher than if the exposure level were below a theoretical minimum risk exposure level of 2.4–5.9 μg/m^3,[20]. Even at the average exposure level of adult men in households cooking with fuelwood outdoors (that is, 43 μg/m^3), the risk is 15–40 percent higher.

The prevalence rates of solid-fuel use and cooking locations in Figure 3.7 and Figure 3.8, $PM_{2.5}$ exposure levels in Table 3.2, and the relative risks of health effects in Figure 3.9 are combined to estimate the health effects of household $PM_{2.5}$ air pollution from the use of solid fuels. Annual deaths from household air pollution are estimated at 3,962–4,663 with a central estimate of 4,313. Household air pollution from solid fuels also causes over 44–52 million days of illness (Table 3.3).[21]

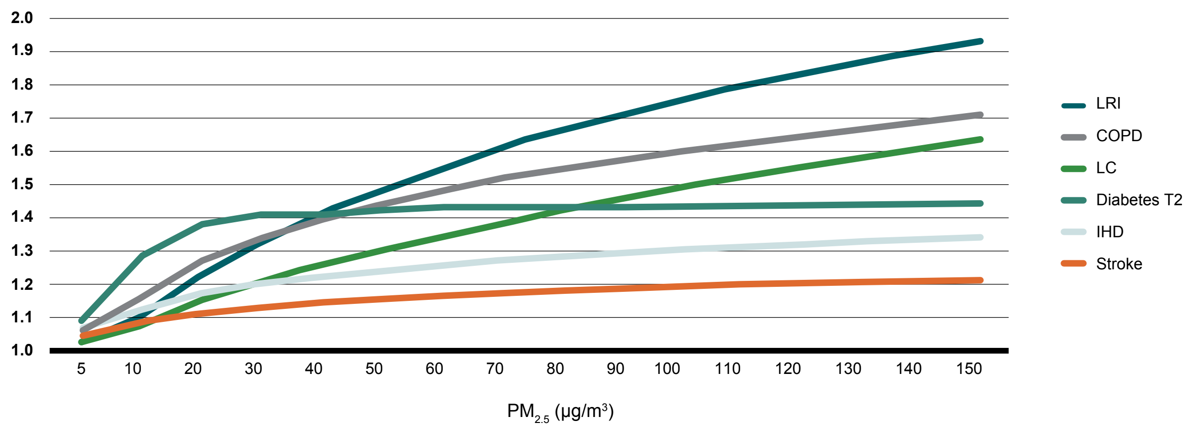
Table 3.3 Annual Health Effects of Household $PM_{2.5}$ Air Pollution from Solid Fuels, 2017

	Low	Central	High
Deaths	3,962	4,313	4,663
Days of illness (million)	44	48	52

3.2.4 Cost of Health Effects

The health effects of household air pollution are monetized as a cost to society by using economic valuation methods. The annual cost of the health effects is estimated at LAK 7,359–8,661 billion in 2017, with a central estimate of LAK 8,010 billion. This is equivalent to 5.2-6.1 percent of GDP in 2017, with a central estimate of 5.7 percent (Table 3.4).

Figure 3.9 Relative Risk of Mortality from Long-Term $PM_{2.5}$ Exposure, GBD 2017



Source: Produced from Stanaway et al. 2018 Supplement Appendix 1.
Note: Age-weighted relative risks.

Table 3.4 Cost of Health Effects of Household Air Pollution from Solid Fuels (LAK, billions), 2017

	Low	Midpoint	High
Cost of mortality	6,042	6,576	7,111
Cost of morbidity	1,317	1,434	1,550
Total cost	7,359	8,010	8,661
% equivalent of GDP, 2017	5.2%	5.7%	6.1%

The cost of mortality is estimated using a *value of statistical life* (VSL) of LAK 1.52 billion in 2017 (74 times GDP per capita), calculated using the methodology in World Bank (2016b). The cost of morbidity is estimated at 50 percent of wage rates per day of illness.

3.3 Ambient Air Pollution

The health effects of ambient air pollution (AAP) have been studied across different countries and regions. Particulate matter (PM) and especially $PM_{2.5}$ is the outdoor ambient air pollutant that globally is associated with the largest health effects. A decade ago, WHO reduced its Air Quality Guideline (AQG) limits to an annual average ambient concentration of 10 $\mu g/m^3$ of $PM_{2.5}$ and 20 $\mu g/m^3$ of PM_{10} in response to increased evidence of health effects at very low concentrations of PM (WHO 2006). Since then, evidence shows that serious health effects occur even at levels as low as 5 $\mu g/m^3$, and WHO is now in the process of updating and revising the AQGs (WHO 2016). Globally, over 2.9 million people died from outdoor $PM_{2.5}$ in 2017, according to the Global Burden of Disease 2017 (Stanaway et al. 2018).[22]

3.3.1 Ambient $PM_{2.5}$ Concentrations

Monitoring data of ambient PM in Lao PDR are scarce. Table 3.5 summarizes two studies from 2002–2004 and 2008.

The first study involved a total of 30 measurements of ambient PM10 at seven sites in Vientiane Capital from September 2002 to April 2004 and showed an average of 87 $\mu g/m^3$. Measurements were taken at the end of the rainy season and during the dry season, generally showing substantially higher PM_{10} concentrations during the dry season.[23]

The second study involved measurements of PM10 at seven sites in Vientiane Capital in 2008. Average 24-hour concentrations varied from 23 $\mu g/m^3$ to 88 $\mu g/m^3$, with an average of 55 $\mu g/m^3$ across all seven sites. These measurements were taken during July in the middle of the rainy season, during which time air pollution concentrations are generally substantially lower than during the dry season.[24]

Table 3.5 Monitoring Studies of Ambient PM10 Concentrations in Vientiane Capital, 2002–2008

Pollutant	$\mu g/m^3$	Season	Monitoring study
PM_{10}	87	Dry (September–April)	30 measurements at 7 locations in 2002–2004
PM_{10}	55	Wet (July)	24-hour measurements at 7 locations in 2008

Combining the data from the dry seasons of 2002 to 2004 and from the rainy season of 2008 gives an annual average of 75 µg/m^3 of PM_{10}. This may be about 40 µg/m^3 of $PM_{2.5}$, given that the $PM_{2.5}$ fraction of PM_{10} is characteristically around 0.5–0.6. An annual average of this magnitude is four times as high as the WHO AQG.

Ambient PM_{10} and $PM_{2.5}$ are likely to be lower in other urban areas of Lao PDR. However, seasonal burning of waste and agricultural fields, and area-wide dust, may cause high concentrations during certain periods during the dry season both in urban and rural areas. Household use of solid fuels for cooking is also contributing to elevated levels of $PM_{2.5}$ in rural villages as well as in urban areas. A study in three villages in Savannakhet found outdoor ambient $PM_{2.5}$ of 52 µg/m^3, according to a recent report (UC Berkeley and Berkeley Air Monitoring Group 2015). Air pollution in hot spots may also be high.

3.3.2 Population Exposure

A nationwide population-weighted exposure to outdoor ambient $PM_{2.5}$ concentrations of 20 µg/m^3 is applied for estimating health effects in Lao PDR. This exposure level is based on the level in Vientiane Capital discussed above, and on assuming half of this level in other urban areas and 15 µg/m^3 in rural areas (Table 3.6). The assumed level in rural areas may, however, not reflect outdoor ambient air pollution from household use of solid fuels. It is recognized that actual exposure levels are highly uncertain due to the scarcity of ground-level monitoring.

3.3.3 Health Effects

Health effects of long-term exposure to outdoor ambient $PM_{2.5}$ air pollution include (i) ischemic heart disease (IHD), (ii) cerebrovascular disease (stroke), (iii) lung cancer (LC), (iv) chronic obstructive pulmonary disease (COPD), (v) diabetes Type II among adult women and men, and (vi) acute lower respiratory infections (ALRI) among children and adult women and men. These are all major health effects evidenced by the Global Burden of Disease (GBD) Project 2017 (Stanaway et al. 2018).

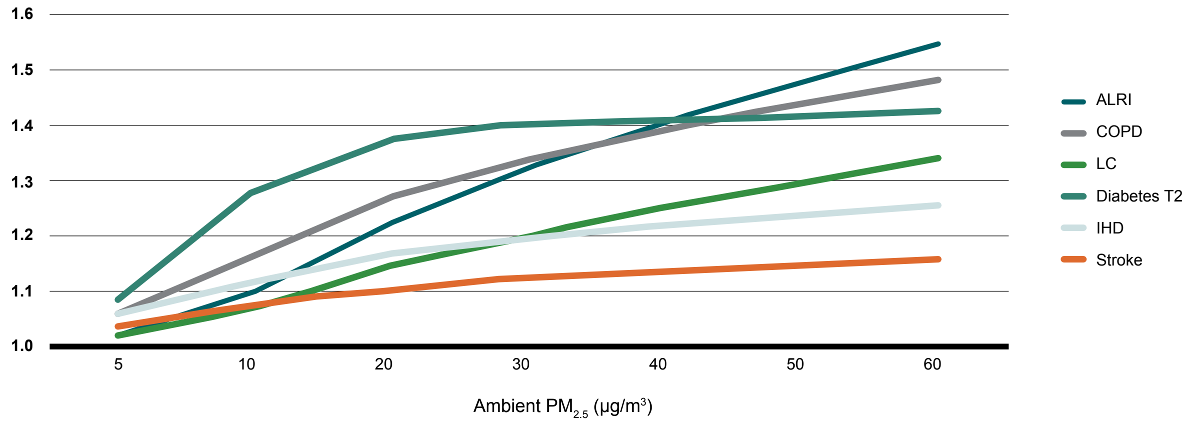
At the average pollution level that may prevail in Vientiane Capital (that is, 40 µg/m^3 of $PM_{2.5}$), the risk of these six health outcomes is nearly 20-40 percent higher than if the pollution level were below a theoretical minimum risk-exposure level of 2.4–5.9 µg/m^3 (Figure 3.10).[25] At the average pollution level that may prevail in other urban areas of Lao PDR (that is, 20 µg/m^3), the risk is 14-23 percent higher. Even at a level of 15 µg/m^3, which may be the average in rural areas, the risk of the health outcomes is 12-18 percent higher.

A population-weighted exposure level of 20 µg/m^3 is estimated to cause 2,693 deaths per year and 28 million days of illness per year.[26] This is estimated by applying the $PM_{2.5}$ population-exposure distribution in Table 3.6 and the risk functions in Figure 3.10.

Table 3.6 Applied Population Exposure to Outdoor Ambient $PM_{2.5}$ Air Pollution, 2017

	Population (millions)	Population exposure (µg/m^3)
Vientiane Capital	1.1	40
Other urban areas	1.7	20
Rural areas	4.1	15
National (population-weighted average)	6.9	20

Figure 3.10 Relative Risks of Major Health Outcomes Associated with $PM_{2.5}$ Exposure



Source: Produced from Stanaway et al. 2018 Supplement Appendix.
Note: Age-weighted relative risks.

However, the population-weighed exposure level in Lao PDR is highly uncertain, because of the lack of ground-level monitoring of $PM_{2.5}$. *Low and High* estimates of health effects are therefore presented in Table 3.7 reflecting exposure levels of 15 μg/m³ and 25 μg/m³ of $PM_{2.5}$. Even at 15 μg/m³ of $PM_{2.5}$, annual deaths are as many as 2,371 and days of illness are nearly 24 million.

Table 3.7 Annual Health Effects of Outdoor Ambient $PM_{2.5}$ Exposure, 2017

	Low	Central	High
Deaths	2,371	2,693	3,041
Days of illness (million)	24	28	31

3.3.4 Cost of Health Effects

The annual cost of the health effects of ambient $PM_{2.5}$ air pollution is estimated at LAK 4,344–5,571 billion in 2017, with a central estimate of LAK 4,933 billion. This is equivalent to 3.1-4.0 percen of GDP in 2017, with a central estimate of 3.5 percent (Table 3.8).

The cost of mortality is estimated using a "value of statistical life" (VSL) of LAK 1.52 billion in 2017 (74 times GDP per capita), calculated using the methodology in World Bank (2016b).[27] The cost of morbidity is estimated at 50 percent of wage rates per day of illness.

Table 3.8 Cost of Health Effects of Outdoor Ambient $PM_{2.5}$ Air Pollution (LAK, billions), 2017

	Low	Central	High
Cost of mortality	3,616	4,107	4,638
Cost of morbidity	727	826	933
Total cost	4,344	4,933	5,571
% equivalent of GDP, 2017	3.1%	3.5%	4.0%

3.3.5 Sources of Ambient $PM_{2.5}$

There are many sources of ambient $PM_{2.5}$ in Vientiane Capital and other urban areas of Lao PDR. An apportionment study of $PM_{2.5}$ would provide useful perspectives on the share of $PM_{2.5}$ from main sources. Key sources in Vientiane Capital, as well as other urban areas, are likely to include

- Motor vehicles
- Waste burning
- Road dust
- Burning of wood and charcoal for cooking
- Industry
- Construction activities

Urban areas may also be affected by long-range $PM_{2.5}$ from seasonal agricultural burning. Main sources of ambient $PM_{2.5}$ in rural areas include

- Burning of wood and charcoal for cooking
- Agricultural burning
- Brick kilns in some areas

A major source of motor-vehicle pollution is highly polluting diesel vehicles. Most diesel vehicles in Lao PDR have no PM emission-control devices and use diesel of variable quality. Highly polluting diesel vehicles include old, secondhand imported minivans, commercial trucks, and buses, as well as private pickup trucks and SUVs.

Attention is also needed to point-source pollution such as cement plants and metallurgical plants (smelters, metal recycling, and E-waste), as well as proactive prevention in relation to future coal-fired power plants and aluminum smelters using local bauxite. It is also an opportune time to address issues related to mining pollution.

3.4 Water, Sanitation, and Hygiene

Health effects from inadequate drinking water, sanitation, and hygiene (WASH) assessed in this report arise from two principal sources. First, health effects are estimated from fecal contamination or microbiological pollution in relation to drinking water, sanitation, and hygiene. Second, health effects are estimated from exposure to arsenic in groundwater tubewells used for drinking.

3.4.1 Microbiological Pollution

Inadequate drinking water, sanitation, and hygiene cause diarrhea and other infectious diseases (Prüss-Ustün et al. 2014; Wolf et al. 2014). Poor sanitation and hygiene increase the risk of parasite infestation. Repeated diarrheal infections in early childhood contribute to poor nutritional status (for example, underweight), as evidenced by research studies in communities with a wide range of diarrheal infection rates in a diverse group of countries (World Bank 2008).

Good hygiene practices—especially handwashing with soap at critical times—are also essential for preventing infectious disease. These practices have globally been found to reduce diarrheal illness substantially (Cairncross et al. 2010; Curtis and Cairncross 2003; Ejemot et al. 2009; Fewtrell et al. 2005; Freeman et al. 2014; Waddington et al. 2009). Poor handwashing practices are a major contributor to respiratory infections in children (Rabie and Curtis 2006).

Estimates of some of the health effects of inadequate water supply, sanitation, and hygiene in Lao PDR are provided in this report. The estimates include diarrheal mortality and morbidity in children and adults, and child mortality from poor nutritional status caused by inadequate water supply, sanitation, and hygiene.

Access to Improved Drinking Water and Sanitation

An estimated 84 percent of Lao PDR's population used an improved water source for drinking in 2017, according to the nationally representative Lao Social Indicator Survey II 2017 (LSB 2018), up from 74 percent in 2011–2012 (MoH/LSB 2012). The most prevalent source was bottled water. As many as 48 percent of the household population used this source of drinking water in 2017, up from 26 percent in 2011–2012 (Figure 3.11).

While the overall access to improved water sources in the country is important, there is almost a 20 percentage point gap between the urban and the rural population[28]. Nearly 97 percent of people living in urban areas use improved sources of drinking water versus 78 percent in the rural areas (LSB 2018).

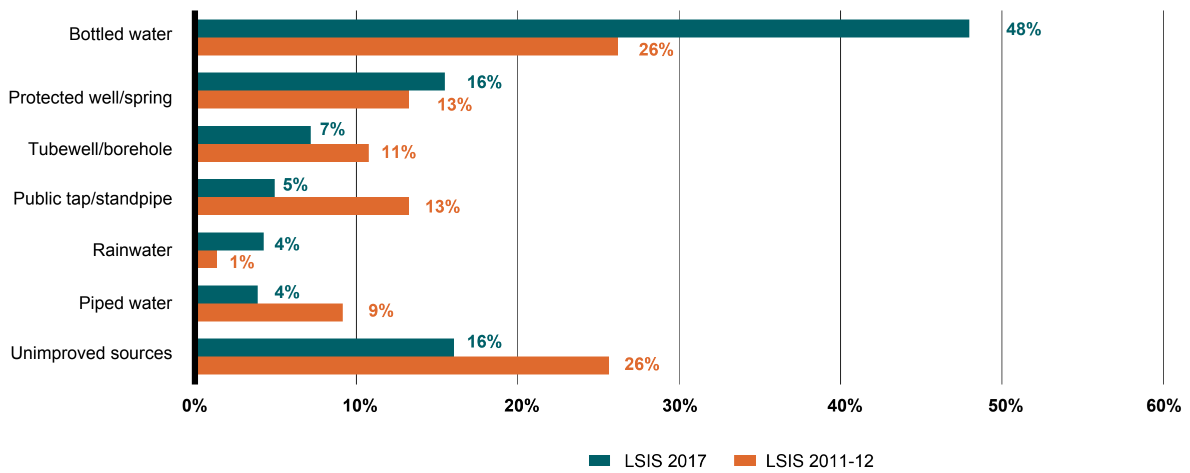
The use of bottled water for drinking is particularly prevalent among the two richest quintiles of households. The use of bottled drinking water more than doubled among the second-richest quintile in a matter of five years from 2011–2012 to 2017 and quadrupled among the middle quintile. The use of bottled water is minimal among the two poorest quintiles (Figure 3.12).

About 37 percent of the household population reported treating their water by an appropriate method prior to drinking in 2017.[29] The main methods of treatment were boiling of water (33 percent) and filtering of water (4 percent). This represents a dramatic decline from 2011–2012 when 57 percent reporting treating their water prior to drinking.

The prevalence of drinking-water treatment is particularly low among the two richest quintiles of households, coinciding with these households mainly using bottled water for drinking. Drinking-water treatment also declined among the two poorest quintiles from 2011–2012 to 2017 (Figure 3.13).

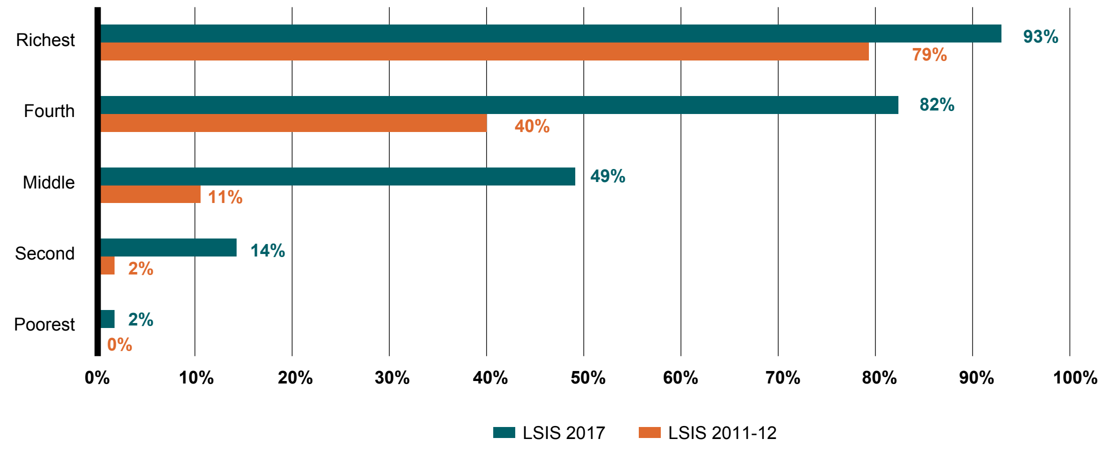
The LSIS II 2017 included testing for *E. coli* bacteria—an indicator of fecal contamination—in the drinking water of over 3,000 households throughout Lao PDR[30]. As many as 86 percent of the household population had *E. coli* in their drinking water, and as many as 38 percent had *very high* concentrations (>100 *E. coli* per 100 ml). The prevalence of *E. coli* was not very different for households using improved versus households using unimproved sources of drinking water (Figure 3.14).[31]

Figure 3.11 Sources of Household Drinking Water in Lao PDR (% of population), 2011–2012 and 2017



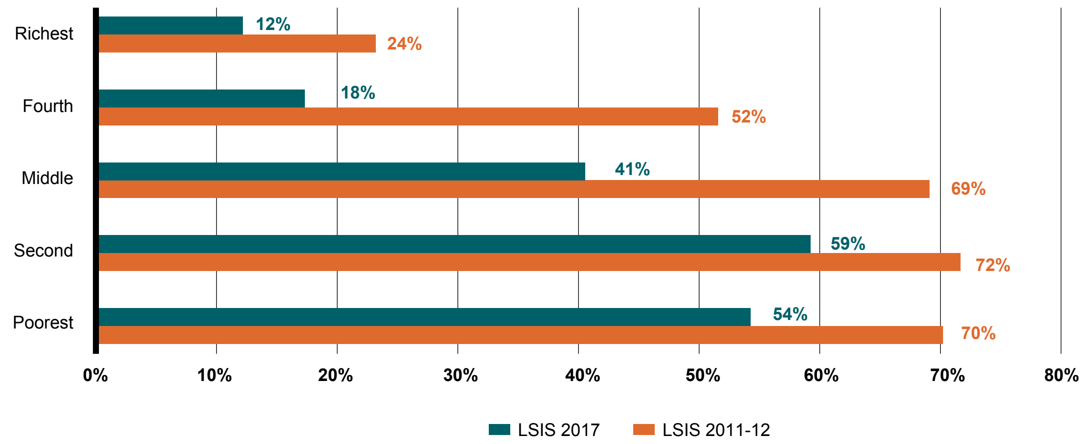
Sources: Produced from LSB 2018 and MoH/LSB 2012.

Figure 3.12 Use of Bottled Water for Drinking in Lao PDR (% of population), 2011–2012 and 2017



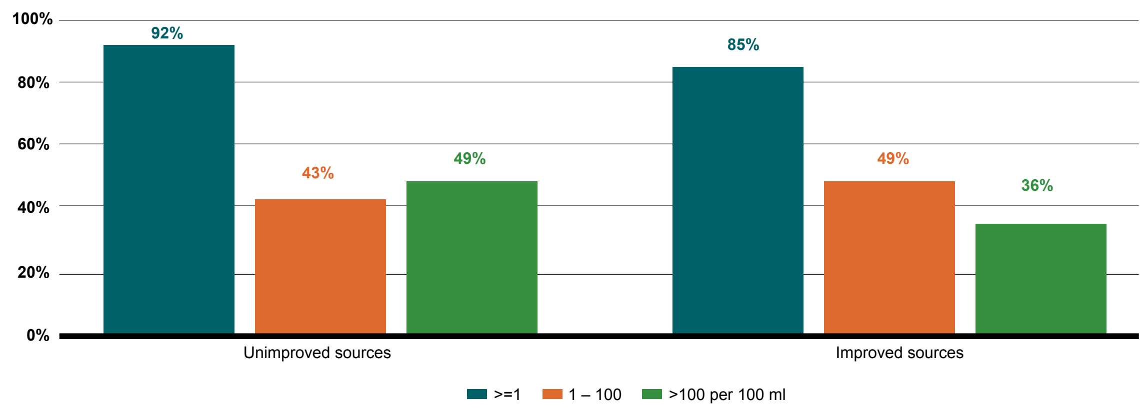
Sources: Produced from LSB 2018 and MoH/LSB 2012.

Figure 3.13 Household Treatment of Drinking Water in Lao PDR (% of population), 2011–2012 and 2017



Sources: Produced from LSB 2018 and MoH/LSB 2012.

Figure 3.14 Household Drinking Water with E. coli in Lao PDR (% of population), 2017

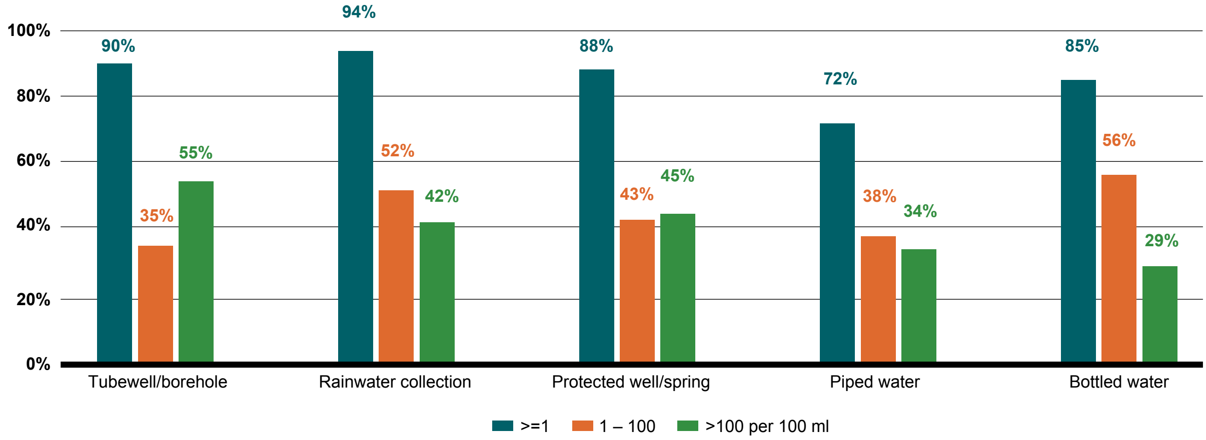


Source: Produced from LSB 2018.

The prevalence of *E. coli* across main sources of drinking water is also quite similar, with a somewhat lower prevalence among households using piped water and bottled water for drinking. However, the situation for bottled water—expected to have been treated with reverse osmosis—was not substantially better than the other types of drinking water, with 85 percent of users having *E. coli* in their bottled drinking water and 29 percent of users having very high concentrations (Figure 3.15).

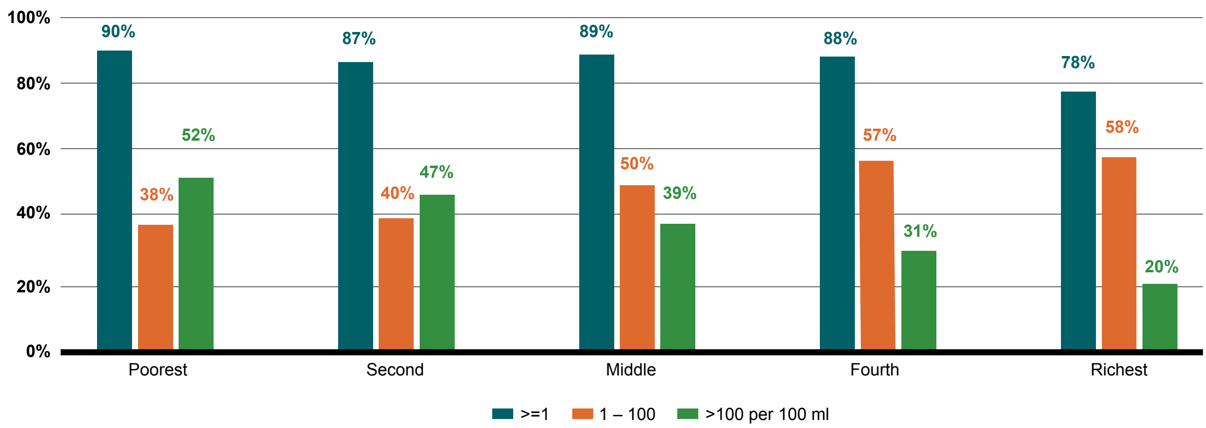
The household prevalence of one or more *E. coli* per 100 ml of drinking water is very similar across household living standards. Only among the richest quintile of households is the prevalence somewhat lower at 78 percent compared to 87–90 percent. However, the prevalence of more than 100 *E. coli* per 100 ml of drinking water gradually declines from 52 percent among the poorest households to 20 percent among the richest households (Figure 3.16).

Figure 3.15 Household Drinking Water with E. coli by Main Type of Drinking Water (% of population), 2017



Source: Produced from LSB 2018.
Note: Piped water here includes public tap/standpipe.

Figure 3.16 Household Drinking Water with E. coli by Quintile of Household Living Standard, 2017

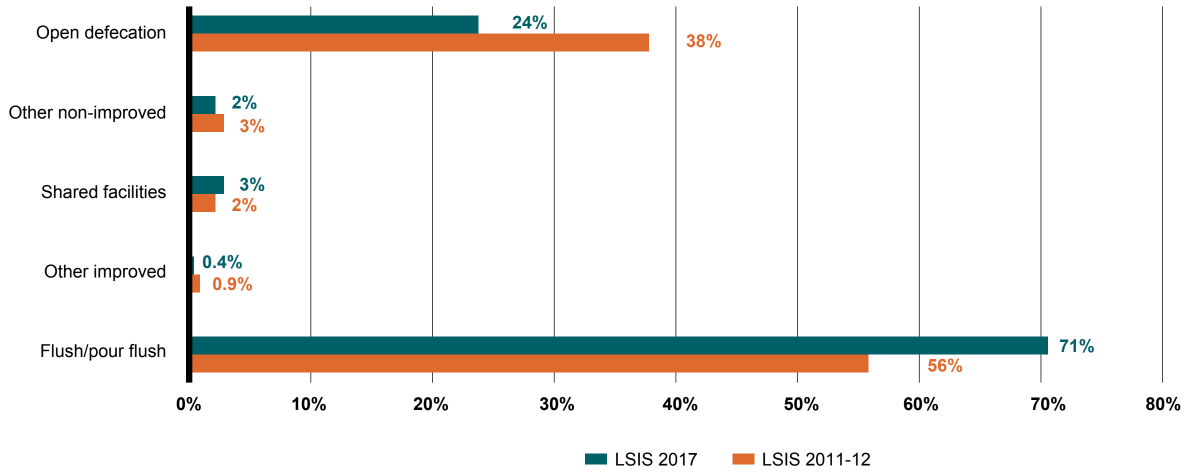


Source: Produced from LSB 2018.
Note: Graph shows the percent of population from each quintile of household living standard with E. coli in their household drinking water.

It is noteworthy that 29 percent of all households using bottled drinking water had *E. coli* of more than 100 per 100 ml, while only 20 percent of the richest quintile of households had this concentration of *E. coli*, although the richest quintile almost exclusively used bottled water for drinking. This suggests that the richest quintile of households is obtaining bottled water of better quality than other households, either by their location in the country or by the companies from which they are purchasing bottled water.

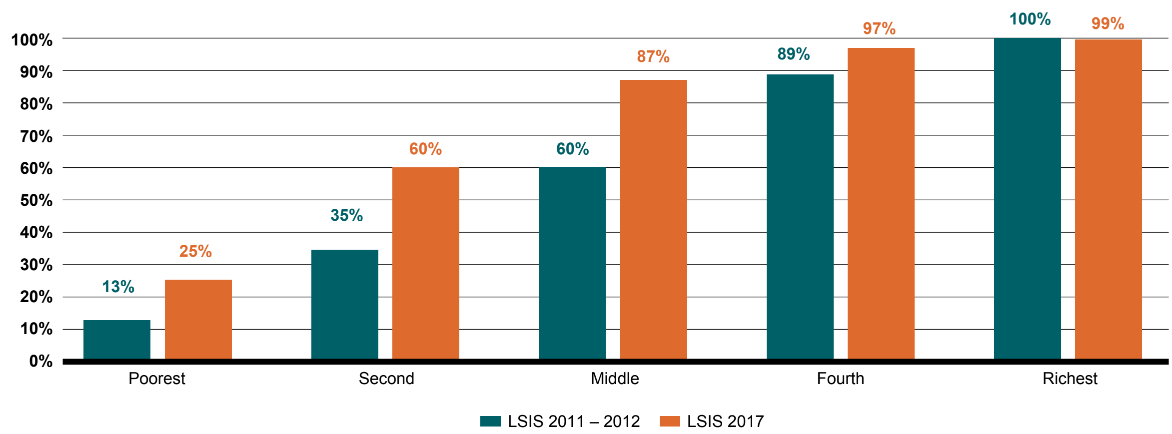
About 71 percent of the population had access to improved, non-shared sanitation in 2017, up from 57 percent in 2011–2012. The predominant type of sanitation facility is flush or pour-flush toilet connected to a septic tank or pit. Less than 3 percent uses other types of sanitation facilities such a dry pit, VIP, composting toilet, or bucket/hanging toilet. As many as 24 percent practiced open defecation (OD) in 2017, albeit down from 38 percent in 2011–2012 (Figure 3.17).

Figure 3.17 Access to Sanitation in Lao PDR (% of population), 2017



Sources: Produced from LSB 2018 and MoH/LSB 2012.

Figure 3.18 Access to Improved Sanitation in Lao PDR by Quintile of Household Living Standard, 2011–2012 and 2017



Sources: Produced from LSB 2018 and MoH/LSB 2012.
Note: Graph shows the percent of population from each quintile of household living standard having such access.

Access to improved sanitation varies greatly by household living standard. Just about 100 percent of the richest quintile of households have improved sanitation, while only 25 percent of the poorest quintile of households have improved sanitation (Figure 3.18).

3.4.2 Health Effects

An estimated 46-95 percent of diarrheal disease mortality and morbidity is due to inadequate drinking water, sanitation, and hand hygiene in Lao PDR (Table 3.9). The lower bound is based on risks of diarrheal disease reported in a global review by Prüss-Ustün et al. (2014). The upper bound is based on risks applied by the Global Burden of Disease Project 2015 (see also Larsen [2019: annex 4]). Individually, inadequate drinking water is associated with the largest attributable fraction of diarrheal disease (Table 3.9).

The attributable fraction of diarrheal disease based on Prüss-Ustün et al. (2014) may be a conservative estimate. This is because Prüss-Ustün et al. (2014) do not include the share of diarrheal disease that may be due to lack of a sewerage network and wastewater treatment. Pruss-Ustun et al. (2014) may also be underestimating the share of diarrheal disease from drinking water (see also Larsen [2019: annex 4]).

Annual deaths from WASH are estimated at 1,379–2,754 per year, with a central estimate of 2,074 (Table 3.10). The main source of death is diarrheal disease including typhoid and paratyphoid. The second-largest source is infectious disease mortality from underweight caused by repeated diarrheal infections in early childhood, followed by mortality from acute lower respiratory infections (ALRI) from inadequate handwashing (see also Larsen [2019: annex 4]). Inadequate WASH is also responsible for an estimated 12–24 million days of diarrheal illness.

Cost of Health Effects

Inadequate drinking water, sanitation, and hygiene is estimated to cost in the range of LAK 2,449–4,923 billion per year, with a central estimate of LAK 3,698 billion. This

Table 3.9 Attributable Fractions (AFs) of Diarrheal Disease from Inadequate WASH in Lao PDR, 2017

	Prüss-Ustün et al. (2014)	GBD2015
Inadequate drinking water	25%	86%
Inadequate sanitation	10%	57%
Inadequate handwashing with soap	19%	35%
Inadequate drinking water, sanitation, and hand hygiene (WASH)	46%	96%

Source: Estimated values. Note: The joint AF of WASH is less than the sum of the individual AFs.

Table 3.10 Annual Deaths from Inadequate WASH in Lao PDR, 2017

	Low	Central	High
Diarrheal disease	727	1,123	1,518
Typhoid/paratyphoid	93	143	194
ALRI from inadequate handwashing	272	376	477
Infectious diseases from underweight	287	432	565
Total*	**1,379**	**2,074**	**2,754**

Note: * Adjusted for multiple risk factors.

is equivalent to 1.7-3.5 percent of GDP in 2017, with a central estimate of 2.6 percent (Table 3.11).

The cost of mortality is estimated using a *value of statistical life* (VSL) of LAK 1.52 billion in 2017 (74 times GDP per capita), calculated using the methodology in World Bank (2016b). The cost of morbidity is estimated at 50 percent of wage rates per day of illness.

3.4.3 Arsenic

Arsenic Exposure

Arsenic in drinking water from tubewells is a concern in central and southern Lao PDR. A study in six central and southern provinces of the country measured arsenic concentrations in 61 tubewells in 2008. All tubewells were of cement equipped with a lid and handpump. Their depth varied from 4 meters to 55 meters (Chanpiwat et al. 2011).

Arsenic concentrations ranged from less than 0.05 μg/liter to as high as 278 μg/liter. Concentrations exceeded the WHO guideline of 10 μg/liter (WHO 2011) in 56 percent of the tubewells and exceeded 50 μg/liter in 15 percent of the tubewells. Average concentrations of arsenic ranged from 0.4 μg/liter in Vientiane Province to 40 μg/liter in Champasack. Four percent to 41 percent of the population in the six provinces used tubewells for drinking in 2011–2012, according to the Lao Social Indicator Survey I (LSIS). This declined to 1–29 percent of the population in 2017, according to LSIS (Table 3.12).[32]

If the study by Chanpiwat et al. (2011) is representative of arsenic contamination, then an estimated 400 thousand people in the central and southern provinces were using tubewells for drinking in 2011–2012 with arsenic concentrations above the WHO guideline of 10 μg/liter. This figure declined to 300 thousand in 2017 as fewer people used tubewells for drinking in 2017 than in 2011–2012.[33]

Table 3.11 Cost of Health Effects of Inadequate WASH (LAK, billions), 2017

	Low	Central	High
Cost of mortality	2,103	3,163	4,200
Cost of morbidity	346	534	723
Total cost	2,449	3,698	4,923
% equivalent of GDP, 2017	1.7%	2.6%	3.5%

Table 3.12 Arsenic in Drinking Water and Use of Tubewells for Drinking in Central and Southern Lao PDR

	Number of tubewells tested	Arsenic concentrations (μg/liter)				Population using tubewells for drinking in 2011–2012 (%)	Population using tubewells for drinking in 2017 (%)
		Mean	Median	Low	High		
Champasack	26	40.0	19.4	0.8	277.8	41	21
Saravane	11	18.5	14.2	0.5	65.2	37	29
Savannakhet	4	23.4	19.0	13.2	42.3	10	11
Borikhamxay	7	14.7	4.2	0.1	58.4	7	4
Attapeu	10	11.0	6.8	0.1	37.4	34	7
Vientiane province	3	0.4	0.4	0.1	0.8	4	1

Sources: Arsenic concentrations are from Chanpiwat et al. 2011. Use of tubewells for drinking is from the Lao Social Indicator Survey 2011–2012 (MoH/LSB 2012) and 2017 (LSB 2018).

Over one-third of the exposed population resides in Champasack, a quarter resides in Saravane, and 38 percent in Savannakhet (Table 3.13). The LSIS II 2017 reports that the use of tubewells for drinking water declined markedly in some of the provinces from 2011–2012 to 2017 as the population increasingly changed to bottled water and rainwater harvesting for drinking water.

Research Evidence

Exposure to arsenic in drinking water has been found to be associated with various health effects. Health effects include skin lesions (Argos et al. 2011; Karagas et al. 2015) and various forms of cancer, kidney and liver failure, and ulcer (FAO et al. 2010). Increased risks of lung and bladder cancer and of arsenic-associated skin lesions have been found from ingestion of drinking water with arsenic concentrations below 50 µg/liter (WHO 2011). There is also increasing evidence that prenatal arsenic exposure is associated with morbidity and mortality later in life (FAO et al. 2010).

Various neurological impairments—such as poor cognitive performance; reduced intellectual function, learning deficits, mood disorders; and visual, speech, attention and memory disturbances—from arsenic exposure have also been documented in many studies (Brinkel et al. 2009; Tyler and Allan 2014).

Several studies have also documented the effect of arsenic in drinking water on mortality: All-cause and chronic-disease mortality (Argos et al. 2010); nonaccidental mortality, cancers, cardiovascular-disease mortality, and infectious-disease mortality (Sohel et al. 2009); heart-disease mortality (Chen et al. 2011); lung-disease mortality (Argos et al. 2014); mortality in children (Rahman et al. 2013); and stroke mortality (Rahman et al. 2014).

Mortality from Arsenic Exposure

Argos et al. (2010) assessed the association between arsenic exposure and all-cause mortality among adults 18+ years of age, and Sohel et al. (2009) assessed the association between arsenic exposure and all-cause nonaccidental mortality among people 15+ years of age. Nearly 12,000 participants were recruited during October 2000 to May 2002 with an average follow-up of 6.5–6.6 years in the study by Argos et al. Sohel et al. studied a population of 115,903 persons from 1991 to 2000. Both studies were conducted in Bangladesh, a country with widespread arsenic contamination of tubewells.

Table 3.13 Estimated Population Exposure to Arsenic (As) in Drinking Water in Central and Southern Lao PDR

	Population 2015	Use of tubewell for drinking	Use of tubewell for drinking	Tubewells with As >10 µg/liter	Tubewells with As 10–50 µg/liter	Tubewells with As > 50 µg/liter	Population exposed to As > 10 µg/liter
Champasack	694,000	21%	145,740	65%	38%	27%	95,292
Saravane	397,000	29%	115,130	64%	55%	9%	73,265
Savannakhet	969,700	11%	106,667	100%	100%	0%	106,667
Borikhamxay	273,700	4%	10,948	43%	29%	14%	4,692
Attapeu	139,600	7%	9,772	30%	30%	0%	2,932
Population	2,474,000	16%	388,257	282,847	231,579	51,268	282,847

Sources: Estimates based on Chanpiwat et al. 2011 and LSB 2018.

Estimated hazard ratios from the two studies for all-cause and nonaccidental all-cause mortality are presented in Table 3.14 in relation to arsenic concentrations in the participants' drinking water. Both studies found an increased risk of mortality from exposure to arsenic at concentration levels above 10 μg/liter.

Health Effects and Costs

Based on the arsenic-exposure estimate and mortality risks presented above, arsenic in tubewell drinking water in Lao PDR's central and southern provinces is estimated to cause 169–248 deaths and 1.2–2.8 million days of illness per year.[34] The health effects had a cost equivalent to 0.21-0.33 percent of GDP in 2017, with a central estimate of 0.27 percent (Table 3.15).

The cost of mortality is estimated using a value of statistical life (VSL) of LAK 1.52 billion in 2017 (74 times GDP per capita), calculated using the methodology in World Bank (2016b). The cost of morbidity is estimated at 50 percent of wage rates per day of illness.

3.5 Lead (Pb) Exposure

Lead (Pb) is toxic to the human body and was considered a major global health issue until a decade ago. A major source of lead pollution was leaded gasoline. This source of exposure was first phased out in high-income countries and then in low- and middle-income countries. A substantial decline in population blood lead levels (BLLs) was subsequently observed, and the phaseout of leaded gasoline is an example of a global environmental achievement. Since then, lead pollution has received less attention.

There are, however, reasons why lead continues to be a substantial health problem in many countries. An increasing number of studies find that even very low levels of lead exposure have much larger impacts on children's neuropsychological development than previously understood. Low exposure levels also have cardiovascular effects in adults, with 540 thousand deaths globally per year according to the GBD 2016.[35] There are multiple sources of lead exposure contributing to elevated BLLs in many countries.

Table 3.14 Risk of Mortality from Arsenic in Drinking Water

Arsenic (μg/liter)	Hazard ratio (95% CI)	
	All-cause mortality*	Nonaccidental all-cause mortality**
≤10	1.00	1.00
10–50	1.34 (0.99–1.82)	1.16 (1.06–1.26)
50–150	1.09 (0.81–1.47)	1.26 (1.18–1.36)
>150	1.68 (1.26–2.23)	1.36 (1.27–1.47)

Sources: *Argos et al. 2010; **Sohel et al. 2009. **Note:** CI=Confidence Interval.

Table 3.15 Cost of Health Effects of Arsenic in Drinking Water in Central and Southern Provinces (LAK, billions), 2017

	Low	Central	High
Cost of mortality	258	318	378
Cost of morbidity	37	61	84
Total cost	**296**	**379**	**462**
% equivalent of GDP, 2017	0.21%	0.27%	0.33%

Lead in the human body can originate from exposure to lead in air, drinking water, food, dust, soil, paint, cosmetics, utensils, several herbal medicines, children's toys, ornaments, and jewelry, and other sources.

Known health effects of lead exposure include neuropsychological impacts such as impaired intelligence in children (Fewtrell et al. 2003; Hong et al. 2015; Jusko et al. 2008; Lanphear et al. 2005; Liu et al. 2013; Mazumdar et al. 2011; Rothenberg and Rothenberg 2005; Roy et al. 2011; Surkan et al. 2007); increased blood pressure and cardiovascular disease among adults (Fewtrell et al. 2003; Lim et al. 2012; Nawrot et al. 2002); and chronic kidney disease, anemia, and gastrointestinal symptoms (Fewtrell et al. 2003). Lead exposure in early childhood has also been associated with antisocial, criminal, and violent behavior in adult life (Dietrich et al. 2001; Mielke and Zahran 2012; Needleman et al. 2002; Nevin 2007; Reyes 2007; Wright et al. 2008).

Anemia and gastrointestinal symptoms generally occur at high blood lead levels (BLL), for example, greater than 60 micrograms of lead per deciliter of blood (μg/dL). These health effects of lead exposure are therefore of minimal relevance today, since blood lead levels in the general population have declined substantially in the last decades. However, there is no known lower BLL threshold below which there are no neuropsychological impacts in children, impacts on blood pressure and cardiovascular disease among adults, and impacts on renal functioning (that is, kidney disease). This report therefore provides estimates of impacts of lead exposure on these latter health outcomes.

No systematic measurement studies of population exposure to lead (Pb) have been conducted in Lao PDR. Blood lead levels (BLL) in neighboring countries may provide an indication of such exposure in Lao PDR. The median BLL in children in China is 4.5–5 μg/dL (Li et al. 2014). The average BLL in Ho Chi Minh City is 4.4 μg/dL (Havens 2012). The average BLL a decade ago in the population of Phnom Penh and Hanoi was about 5 μg/dL (Agusa et al. 2006).

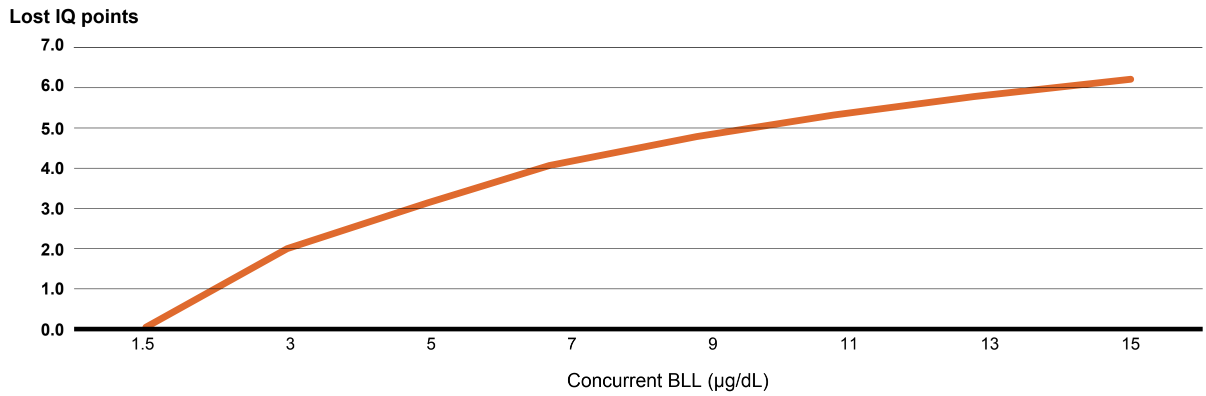
Examples of lead (Pb) exposure in neighboring countries, which may also be the case in Lao PDR, include (i) high lead content in some traditional medicines in northern Vietnam in 2011–2012 (Nguyen et al. 2012), (ii) lead-acid batteries in Solar Home Systems in some rural villages in Thailand have been found to be associated with elevated blood lead levels (BLLs) in children (Swaddiwudhipong et al. 2013), and (iii) several brands of Asian tongue powder applied to infants in Thailand were found to have very high lead content (Woolf et al. 2008).

3.5.1 Neuropsychological Effects in Children

A well-established effect of lead exposure is neuropsychological impairment in children, measured as IQ losses.[36] The effect is found to occur even at very low BLLs (Jusko et al. 2008; Lanphear et al. 2005; Surkan et al. 2007). In fact, no BLL threshold below which there are no impacts on children's IQ has been identified in the international research literature. Gilbert and Weiss (2006) argue for a BLL action level of 2 μg/dL, Carlisle et al. (2009) for a benchmark of 1.0 μg/dL, and the European Food Safety Authority uses a benchmark dose level of 1.2 μg/dL for neurotoxicity in children (EFSA 2013).

Lanphear et al. (2005), based on a pooling of seven international longitudinal cohort studies, specified a log-linear function that best describes the relationship between children's IQ and their BLL. This relationship is confirmed by Rothenberg and Rothenberg (2005) using the same pooled data as in Lanphear et al. (2005). Thus, children 5–7 years of age with concurrent BLL of 5 μg/dL to 15 μg/dL have lost 3.25 to 6.2 IQ points (Figure 3.19). These estimates are based on a concurrent BLL lower-threshold value of 1.5 μg/dL as applied in this report and approximately corresponding to a lifetime BLL lower-threshold value of 2.0 μg/dL (see also Larsen [2019: annex 2]).[37]

Figure 3.19 Loss of IQ Points in Early Childhood



Source: Produced from results reported in Lanphear et al. 2005.

If the average BLL in children in Lao PDR is 4–5 μg/dL—as appears to be the case in neighboring countries—then 50-60 percent of children in Lao PDR may have BLL in the range of 1.5–5 μg/dL, 30-40 percent may have 5–10 μg/dL, and 5-10 percent may have BLL exceeding 10 μg/dL.[38]

Total annual losses of IQ points among children under five years of age in Lao PDR are estimated at 298–382 thousand, with a central estimate of 342 thousand IQ points in 2017 (Table 3.16).[39] About 60 percent of these IQ points are lost among children with a BLL of <5 μg/dL, and 35 percent are lost among children with BLL of 5–10 μg/dL.

3.5.2 Cardiovascular Health Effects in Adults

The main health effect of lead exposure among adults included in the Global Burden of Disease (GBD) Project 2017 is the effect on systolic blood pressure (SBP) and consequent risk of cardiovascular disease (Stanaway et al. 2018). The analysis in this report is therefore limited to cardiovascular disease (see also Larsen [2019: annex 3]).

The risk of cardiovascular disease from a change in SBP varies by age; estimating the cardiovascular-disease burden among adults from lead exposure requires BLLs by age groups. An estimate of mean BLLs by age group in Lao PDR is based on a mean BLL of 4–5 μg/dL among adults (as applied to children) and the observed BLL patterns across age groups in the United States.[40] A BLL lower-threshold

Table 3.16 Estimated Annual Losses of IQ Points ('000) among Children <5 Years in Lao PDR, 2017

Concurrent BLL groups	Low	Central	High
0–5 μg/dL	196	202	202
5–10 μg/dL	90	120	151
10–15 μg/dL	10	16	24
>15 μg/dL	2	3	6
Total	**298**	**342**	**382**

value of 2.0 μg/dL is applied to estimate the cardiovascular disease burden. If the mean BLL is 4–5 μg/dL, then an estimated 496–620 deaths and 2.0–2.5 million days of nonfatal cardiovascular disease per year are caused by lead exposure among adults (Table 3.17).[41]

Table 3.17 Estimated Health Effects among Adults from Lead Exposure in Lao PDR, 2017

	Low	Central	High
Deaths	496	562	620
Days of illness (million)	2.0	2.2	2.5

3.5.3 Cost of Lead Exposure

An individual's income is associated with the individual's IQ score. This has long been empirically established by Schwartz (1994) and Salkever (1995). These two studies found that a decline of one IQ point is associated with a 1.3-2.0 percent decline in lifetime income. Studies of the cost of lead (Pb) exposure, or of the benefit of lowering BLL in children, have applied the findings by Schwartz and Salkever in France and the United States (Gould 2009; Grosse et al. 2002; Muennig 2009; Pichery et al. 2011).

The present value of future lifetime income of a child under five years is estimated at LAK 566 million based on an estimated average annual labor income in Lao PDR in 2017 of LAK 15.8 million.[42] The cost of one lost IQ point is estimated at LAK 7.7 million. This is estimated as the product of loss of income per lost IQ point (midpoint estimate in Schwartz [1994] and Salkever [1995]) and the percentage of children that may be expected to participate in the labor force. Expected labor-force participation is assumed to be the same as the current rate of participation. With an estimated annual loss of 298–382 thousand IQ points among children under five in Lao PDR, the estimated annual cost is LAK 2,297-2,948 billion in 2017, with a central estimate of LAK 2,635 billion. This is equivalent to 1.6-2.1 percent of Lao PDR GDP that year, with a central estimate equivalent to 1.9 percent of GDP (Table 3.18).

Among adults, the health effects had a cost equivalent of 0.6-0.7 percent of GDP in 2017, with a central estimate of 0.65 percent (Table 3.19). The cost of mortality is estimated using a *value of statistical life* (VSL) of LAK 1.52 billion in 2017 (74 times GDP per capita), calculated using the methodology in World Bank (2016b). The cost of morbidity is estimated at 50 percent of wage rates per day of illness.

This brings the total estimated cost of lead exposure among children and adults to an equivalent of 2.2-2.8 percent of GDP in 2017, with a central estimate of 2.5 percent.

Table 3.18 Estimated Annual Cost of IQ Losses among Children under Five Years of Age in Lao PDR, 2017

	Low	Central	High
Present value of future lifetime income (15–64 years) (LAK)	566,389,353	566,389,353	566,389,353
Lifetime income loss per IQ point lost (% of lifetime income)	1.69%	1.69%	1.69%
Labor force participation rate (15–64 years)	81%	81%	81%
Cost per lost IQ point (LAK)	7,714,358	7,714,358	7,714,358
IQ points lost per year	297,789	341,615	382,088
Total cost (LAK, billions)	2,297	2,635	2,948
Cost % equivalent of GDP, 2017	1.6%	1.9%	2.1%

Source: Estimated values.

Table 3.19 Estimated Annual Cost of Health Effects of Adult Lead Exposure in Lao PDR (LAK, billions), 2017

	Low	Central	High
Cost of mortality	756	856	946
Cost of morbidity	59	66	73
Total cost of health effects	814	923	1,019
Cost % equivalent of GDP, 2017	0.58%	0.65%	0.72%

Source: Estimated values.

3.6 Conclusions

The environmental health-risk factors assessed in this report are estimated to have caused 10,000 deaths in Lao PDR in 2017. This was 21.6 percent of all deaths in the country. The risk factors also caused nearly 100 million days of illness in 2017. Household air pollution (HAP) from the use of solid fuels caused 44 percent of the deaths, while 23 percent was from drinking-water pollution and inadequate sanitation and hygiene (WASH), and 27 percent from outdoor $PM_{2.5}$ ambient air pollution (AAP). Exposure to lead among adults caused the remaining 6 percent of deaths, and lead exposure among children caused the loss of 340,000 IQ points per year (Table 3.20).

The health effects from the environmental risk factors can be monetized by using standard valuation techniques to provide an economic perspective on the magnitude of these effects. The annual cost of the health effects is estimated at LAK 17.6–23.6 trillion in 2017. This is equivalent to 12.5-16.7 percent of GDP, with a central estimate of 14.6 percent.

Household air pollution (HAP) accounts for 39 percent of these costs, followed by outdoor $PM_{2.5}$ ambient air pollution (AAP) at 24 percent, water pollution and inadequate sanitation and hygiene (WASH) at 20 percent, and lead (Pb) exposure at 17 percent of total cost (Table 3.21).

Table 3.20 Annual Deaths and Days of Illness from Environmental Risk Factors in Lao PDR, 2017

	Deaths			Days of illness (million)		
	Low	Central	High	Low	Central	High
Household air pollution	3,962	4,313	4,663	44.1	48.0	51.9
Ambient air pollution	2,371	2,693	3,041	24.4	27.7	31.2
Water, sanitation, and hygiene	1,549	2,283	3,002	12.8	19.9	27.0
Microbiological pollution	1,379	2,074	2,754	11.6	17.9	24.2
Arsenic in groundwater	169	209	248	1.3	2.0	2.8
Lead (Pb) exposure—children (IQ points)				0.3	0.3	0.4
Lead (Pb) exposure—adults	496	562	620	2.0	2.2	2.5
Total	**8,378**	**9,851**	**11,327**	**84**	**98**	**113**

Table 3.21 Estimated Annual Cost of Environmental Health Effects in Lao PDR, 2017

	Cost (LAK, billions)			Cost (% equivalent of GDP)		
	Low	Central	High	Low	Central	High
Household air pollution	7,359	8,010	8,661	5.22	5.68	6.14
Ambient air pollution	4,344	4,933	5,571	3.08	3.50	3.95
Water, sanitation, and hygiene	2,745	4,076	5,384	1.95	2.80	3.82
Microbiological pollution	2,449	3,698	4,923	1.74	2.62	3.49
Arsenic in groundwater	296	379	462	0.21	0.27	0.33
Lead (Pb) exposure	3,112	3,558	3,967	2.21	2.52	2.81
Lead (Pb) exposure—children	2,297	2,635	2,948	1.63	1.87	2.09
Lead (Pb) exposure—adults	814	923	1,019	0.58	0.65	0.72
Total	**17,559**	**20,577**	**23,583**	**12.45**	**14.60**	**16.73**

3.7 Notes

16 This chapter was prepared by Bjorn Larsen and draws upon additional material by the same author presented in a background report (Larsen 2019) containing a series of annexes in support of the estimates.

17 www.healthdata.org

18 The Vice Minister of Planning and Investment referred to the important linkages between air pollution and health. Air pollution is the fifth leading risk factor for mortality worldwide and causes more deaths than malnutrition, malaria, unimproved sanitation, or unimproved water sources. The World Health Organization estimates that over 7 million people died in 2016 worldwide as a consequence of household and ambient air pollution.

19 http://www.healthdata.org/

20 The theoretical minimum risk exposure level applied in the Global Burden of Disease Project 2017 is a uniform distribution between 2.4 $\mu g/m^3$ and 5.9 $\mu g/m^3$ (Stanaway et al. 2018).

21 The Global Burden of Disease 2017 reports a central estimate of 3,807 deaths from HAP in Lao PDR in 2017 but has not reported the $PM_{2.5}$ exposure levels applied.

22 www.healthdata.org

23 GiZ 2010. *Clean Air for Smaller Cities in the ASEAN Region: Road Map towards a Clean Air Plan for Vientiane, Lao PDR.* http://www.citiesforcleanair.org/

24 *LAO: Vientiane Sustainable Urban Transport Project. Initial Environmental Examination.* 2014. Prepared by the Ministry of Public Works and Transport for the Asian Development Bank (August). https://www.adb.org/sites/default/files/linked-documents/45041-002-ieeab.pdf

25 The theoretical minimum risk exposure level applied in the Global Burden of Disease Project 2017 is a uniform distribution between 2.4 µg/m3 and 5.9 µg/m3 (Stanaway et al. 2018).

26 The GBD Project 2017 reports a central estimate of 1,115 deaths from outdoor ambient $PM_{2.5}$ in Lao PDR in 2017 based on a $PM_{2.5}$ exposure level of 25 $\mu g/m^3$. This estimate of deaths reflects adjustments to estimation of health effects of ambient $PM_{2.5}$ that the GBD 2017 undertakes for the population exposed to both household air pollution from solid fuels and $PM_{2.5}$ ambient air pollution. This is described in Stanaway et al. (2018) Supplementary Appendix 1 (pp. 74–75).

27 The value of statistical life (VSL) is a welfare measure derived from individuals' willingness to pay (WTP) for a reduction in the risk of death.

28 The Vice Minister of Public Works and Transport highlighted that the rural population has significantly lower access to water supply than the urban population.

29 Appropriate methods include boiling, bleaching/chlorination, filtering, and solar disinfection.

30 30The Vice Minister of Public Works and Transport mentioned that rivers are an important source of water supply. She also noted the potential impacts on human health when water sources are polluted.

31 The LSIS II 2017 reports the prevalence of *E. coli* both in the drinking-water source as well as in the actual drinking water. The latter is reported in this section.

32 No tubewells were tested in the province of Khammuane in central Lao PDR. The province has a population of about 400,000, and 11 percent used tubewells for drinking in 2017, according to LSB (2018).

33 This assumes that bottled drinking water is not sourced from tubewells that may be contaminated with arsenic.

34 Days of illness *(D)* is calculated from data on "years lived with disability" (YLDs) reported by the Global Burden of Disease Project for major causes of death associated with arsenic exposure—that is, in the range of 3.7–4.0 YLDs per death in Lao PDR. A disability weight *(w)* of 0.15 is applied to convert YLDs to days of illness. The calculation is *D* = YLDs per death * M * 365 / *w* where M is deaths from arsenic exposure.

35 http://ghdx.healthdata.org/gbd-results-tool

36 Intelligence quotient (IQ) is a score on standardized tests designed to assess intelligence.

37 Concurrent BLL is the BLL of a child at the time of IQ testing. Lifetime BLL is the mean BLL over the life of the child prior to IQ testing.

38 A log-normal distribution of BLL in the child population is applied as in Fewtrell et al. (2003). The standard deviation is 1.75.

39 Annual loss of IQ points is calculated as ΔIQ/5 by assuming that the children's IQ points are lost in the first five years of life.

40 A standard deviation of 1.5 for males and females is applied to a log-normal distribution function for a BLL distribution within each age group that patterns the distribution in the United States.

41 Days of disease are calculated from years lost to disease (YLD) per cardiovascular death from the GBD 2016 and an average disability weight of 0.15.

42 The present value is estimated based on a discount rate of 3%/yr and a real annual future income growth of 2%/yr, assuming that real income in the long run grows at a rate close to the growth rate of GDP per capita.

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4

COST OF ENVIRONMENTAL DEGRADATION: NATURAL RESOURCE DEGRADATION AND NATURAL DISASTERS[43]

Chapter Overview

The Lao People's Democratic Republic is one of the most resource-rich countries in Asia with respect to natural resources. This chapter addresses the costs of unsustainable uses of Lao PDR's natural resources and provides estimates of the cost of natural resource degradation in Lao PDR. Many of the country's people are poor, its human development ranking is 138th, and the poor in Lao PDR are very dependent upon the country's natural resources. Economic development that depletes its natural resource base cannot be sustainable even when the total wealth of the country is increasing.

Adjusted net savings (ANS) is an indicator that aims to assess an economy's sustainability. ANS is based on the concepts of extended national accounts, which include natural and human capital accounts. Lao PDR's ANS has been low and volatile over time. Despite a recent increase in adjusted net savings, natural capital depletion continues. Natural resource losses—mainly forest and mineral depletion as well as pollution damages—are substantial.

Estimates of the impacts and costs of natural resource degradation in Lao PDR are shown in this chapter. These impacts and costs were estimated for the following sectors: deforestation, forest degradation, natural disasters, soil degradation, hydropower development and fish-habitat destruction, and exposure to mercury from mining practices. The costs of environmental degradation are calculated as economic damages of US$822 million annually, or 4.7 percent of GDP in 2017 US$.

This chapter provides a suite of recommendations, with an emphasis on improving the quality of data on the country's natural resources, to better inform decision-makers' priorities regarding interventions to reduce the costs of natural resource degradation. Such data include more-accurate maps of forests, and improved estimates of soil erosion, agricultural land uses, productivity, and yield. Analyses would benefit from better information about the use of agricultural chemical pesticides and fertilizers. A comprehensive, transparent, and accessible system for monitoring water quality; a system for forecasting hydrological and habitat changes from hydropower development; and regionalized models for managing the risks of natural disasters would be very beneficial. All estimates of costs are limited by data quality, which accounts for the use of a range of estimates throughout these analyses.

4.1 Introduction

4.1.1 Objective and Context

The objective of this chapter is to present estimates of the cost of natural resource degradation in the Lao PDR. Such estimates can guide decisions to mitigate damages in the sectors that are critical for the Lao PDR's economy and that are drivers of its economic growth.

Lao PDR (population of 7.14 million) is one of five countries of the Lower Mekong Basin (LMB); many in these countries are poor and traditionally dependent upon agriculture (World Bank 2019). However, development is reducing the contribution of agriculture to economic growth, as the contribution of the industrial and service sectors is rapidly increasing. All LMB countries are expected to have reached middle-income status by 2030. The Mekong contributes significantly to this growth through the opportunities it provides, including water and wastewater services, energy, agriculture, fisheries, transport and trade, and ecosystems services (MRC 2016).

The Lao PDR is situated in the center of the Indo-Burmese Hotspot, one of the world's biologically richest and most endangered terrestrial eco-regions and one of the 10 most important global biodiversity hotspots. Biodiversity is crucial to the Lao PDR economy for reducing poverty and securing livelihoods due to the basic goods and ecosystem services that biodiversity provides. Consequently, biodiversity must be protected and sustainably used for achieving poverty reduction and greener, more-resilient economic growth that can deliver sustainable development outcomes. Biodiversity is also critical for reducing climate risks and greenhouse gas emissions. The careful management of biodiversity and ecosystem services helps people to adapt to the adverse effects of climate change and reduces the risks of floods and drought (World Bank 2019).

Furthermore, biodiversity conservation can be a profitable endeavor, with potentially higher revenues than those from extractive industries. Nature-based tourism is one of the most efficient ways to achieve this goal. Tourism is only 4 per cent of the Lao PDR economy, so there is room for the Lao PDR's green economy to grow, given that much of the demand for tourism in Lao PDR is for experiences with landscapes, wildlife, and the cultures dependent on them. Lao PDR conservation forests possess globally significant biodiversity and habitat integrity, which is a comparative advantage for tourism. Other sources of revenue directly from biodiversity can include patents for pharmaceutical compounds, payments for ecosystem services, sustainable legal timber, and food (World Bank 2019). Thus, biodiversity should be treated as an asset, just like produced capital and human capital. Biodiversity needs to be managed more sustainably and efficiently to improve the wealth and well-being of Lao PDR's population, and to contribute to the global stability of these assets that depend on ecosystems preservation.

Lao PDR is mountainous and landlocked, surrounded by Cambodia, China, Myanmar, Thailand, and Vietnam. While Lao PDR's population was 78 percent rural in 2000, that number has decreased to about 60 percent currently— indicative of the country's rapid ongoing urbanization (World Bank WDI 2018). The eastern country's eastern part is sparsely populated, and population density there is expected to remain less than 5 inhabitants per km2 up to 2020[44].

With a 2017 per capita GDP of US$2,468, Lao PDR remains among the poorer countries in the East Asia and Pacific Region (World Bank WDI 2018). GDP growth averaged 7.8 percent over the last decade, with the use of the country's natural resources—mostly hydropower potential, minerals, and forests—contributing around one-third of this growth (World Bank Lao PDR Country Overview 2018). The most recent (2015) estimate of life expectancy is 66.3 years at birth (World Bank WDI 2018). The country's human development ranking is 138th (UNDP 2018). With this level of poverty, the country's natural resource base is critically important to poverty alleviation and growth. However, natural resource degradation, combined with inadequate provision of environmental services, is disproportionately affecting the poor in Lao PDR (World Bank LEM 2005). The country's ongoing transformation to a green economy aims to generate economic growth and poverty reduction through sustainable solutions that boost resilience, create jobs and livelihoods, and protect natural capital and human health.

Biodiversity is an important aspect of Lao PDR's green growth ambitions, as articulated in the National Green Growth Strategy, the 8th National Socio-Economic Development Plan (NSEDP), and sector strategy (World Bank 2019). No other region of the world has so high a rate of endemism, or endangerment, among its biota. Conservation forests, also referred to as protected areas (PAs), total 15 percent of the country and are home to some of the poorest households. As a result, nature-based tourism has become a high priority in the country's most recent strategic policy frameworks. Yet, these protected areas face serious challenges including illegal logging, infrastructure expansion into them, and low revenues. As a result, biodiversity is suffering. These potential costs are not accounted for directly in the study. However, all efforts should be made to improve and restore damaged ecosystems to good ecological status to avoid tipping points with catastrophic changes to biodiversity, and the resulting significant reduction of the services to people it underpins, at a regional or global scale. In addition, all these analyses need to be considered within the framework that serious tipping points due to climate change may very well exist (Lenton et al. 2019).

Lao PDR stretches 1,700 km from north to south and 100 km to 400 km from east to west, for a total surface area of 236,800 km^2. Some 80 percent of the country's land area, largely in the north, is mountainous. The remaining 20 percent is low-lying plain along the Mekong River and threatened by annual floods. The altitude ranges from 104 meters above sea level in Attapeu to 2,820 meters in Xiengkhouang, at Phoubia Mountain. More than two-thirds of Lao PDR's population lives in the country's south and central parts.

The Mekong flows 1,898 km from north to south through Lao PDR. Water from many small rivers or tributaries represents a vital natural resource for national social and economic development, particularly for agriculture and hydroelectricity generation. Agriculture is the most important economic sector for the country, while the generation of electricity from hydropower serves as the core of the national strategy to turn Lao PDR into the prime producer of electricity for Southeast Asia.

Protecting the well-being of the Lao PDR economy and people will require environmental policies that protect the productivity and biodiversity of the Mekong Basin. Diversification of the economy will be necessary to achieve a more inclusive growth that generates decent work opportunities. This includes protecting its extremely high biodiversity values, with four physiographic regions having very different agro-climatic characteristics. These region are (i) the Northern Highlands—a rugged mountainous region with a dry subtropical climate; (ii) the Annamites Range—a mountainous topography with high monsoonal rainfall; (iii) the Indo-Chinese karst landscapes of Central Lao PDR; and (iv) the Mekong Plain—an alluvial plain along the Mekong and its larger tributaries with a tropical monsoon climate and variable rainfall. These characteristics combined give Lao PDR high levels of biodiversity and diverse production systems for food, fiber, and medicines.

The sections in this chapter describe the many contributions of the Mekong to Lao PDR's economy and the losses from various current practices.

4.1.2 Outline of Analyses

This chapter provides diagnostic estimates of the impacts and costs of natural resource degradation exacerbated by climate change in Lao PDR. When investment decisions to reduce natural resource degradation are made, it is of interest for society to take the monetary value of losses to natural resources into account and include these monetized losses in the decision process. The tool that allows comparing such interventions is benefit-cost analyses for policies and measures that reduce welfare losses attributed to natural resource degradation. Policies and measures for reducing natural resource degradation generally imply additional costs for agriculture, industry, and consumers. It may thus be important for the acceptance of the measure to show that the benefits—for example, from restored ecosystem services—outweigh the costs.

The benefit can be expressed as avoided cost of natural resource degradation. To calculate the avoided costs, it is necessary to create two scenarios: (i) a baseline scenario describing a development without the implementation of the measure or policy, and (ii) a scenario including implementation of the measure or policy. The impacts occurring for the two scenarios are then calculated. The difference between the impacts is monetized; this gives the avoided welfare losses or benefits (provided that the degradation costs of the scenario with the measure are lower than for the baseline scenario). These benefits can then be compared with the costs of the policies and measures. If benefits are larger than costs and the benefit-cost ratio (BCR) is greater than one, the policy or measure is potentially beneficial for society's welfare. A comparison of BCRs for a given issue can inform the optimum combination of measures to be taken.

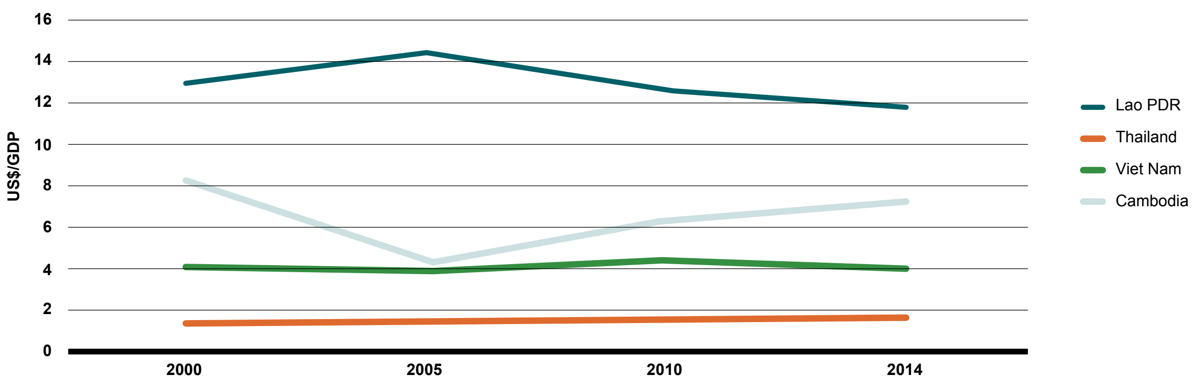
The overall analysis is undertaken in two parts. This chapter provides a diagnostic of the cost of environmental degradation in each sector. Subsequent analyses in chapter 10 outline policies and measures that would reduce the costs of natural resource degradation and prioritizes them through the application of benefit-cost analysis.

4.2 The Mekong Basin and the Natural Capital of Lao PDR

Lao PDR is one of the Asia's most natural resource-rich countries. It has thousands of plant species, many of which are economically valuable (World Bank 2019). Lao PDR has a substantial direct dependence on natural resources for the livelihoods and incomes of its population, and for income for the national treasury. Natural capital is a major source of wealth for the country. Figure 4.1 shows that if GDP is used as a measure, the natural capital of Lao PDR is significantly higher compared to its neighbors[45].

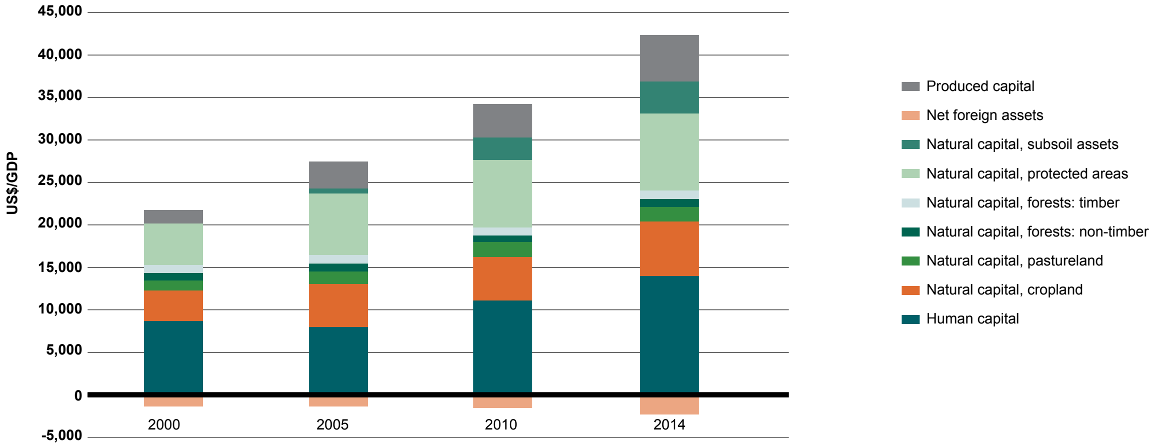
The World Bank Group is using a new indicator—wealth per capita—to measure whether progress toward the two goals of eradicating poverty and promoting shared prosperity is made in a sustainable manner in the country (Lange et al. 2018). At the heart of determining whether development in a country is sustainable is the issue of accumulation of wealth. Wealth is broadly defined to include produced capital and urban land[46], natural capital (including forests)[47], human capital[48], and net foreign assets[49]—all of which underlie the accumulation of wealth (Figure 4.2). Assessments of economic performance need to be based on both measures of annual growth (such as the traditional GDP) and measures of the comprehensive wealth of a country, which indicate whether that growth is sustainable in the long term. Countries should aim to

Figure 4.1 Natural Capital/GDP (in constant 2014 US$)



Source: Estimated using World Bank World Development Indicators 2018.

Figure 4.2 National Wealth, Lao PDR



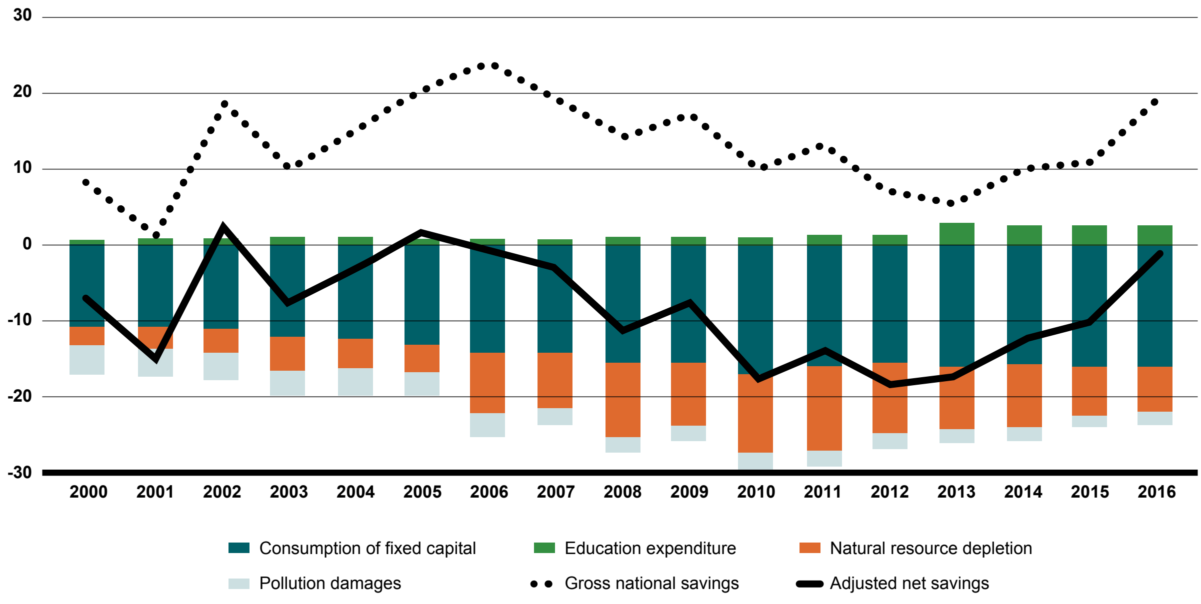
Source: World Bank World Development Indicators 2018.

sustain per capita wealth by saving enough assets to meet the needs of their growing population. Lao PDR's total wealth has been growing over time, with greater contributions from produced and natural capital, but less from human capital. Natural capital has been growing since 1995, from US$42 billion to US$151 billion (constant 2014 US$), representing about a 2.5-fold increase. While human capital has also increased in absolute value in the same period, human capital has decreased as a share of total wealth, relative to natural capital. These numbers indicate that Lao PDR is dependent on natural capital. Protected areas make up the largest share of natural capital, followed by cropland and subsoil assets. Protected areas and other forest resources capital are an important source of income for the poor and the bottom 40 percent of rural farmers and forest-dependent communities that rely on ecosystem services from land and forest resources.

Economic development that depletes a country's natural resource base cannot be sustainable even when that country's total wealth is increasing. Consequently, the new National Green Growth Strategy 2030 of Lao PDR (World Bank 2019) charted a more sustainable development path that prioritizes nature-based tourism, sustainable forestry, and downstream industries as important growth drivers (World Bank 2019). Adjusted net savings (ANS) is an indicator that aims to assess an economy's sustainability based on the concepts of extended national accounts that include natural and human capital accounts. Adjusted net savings measures the true rate of saving in an economy after taking into account investments in human capital, depletion of natural resources, and damages caused by pollution. Positive savings allow wealth to grow over time, thus ensuring that future generations enjoy at least as many opportunities as current generations.

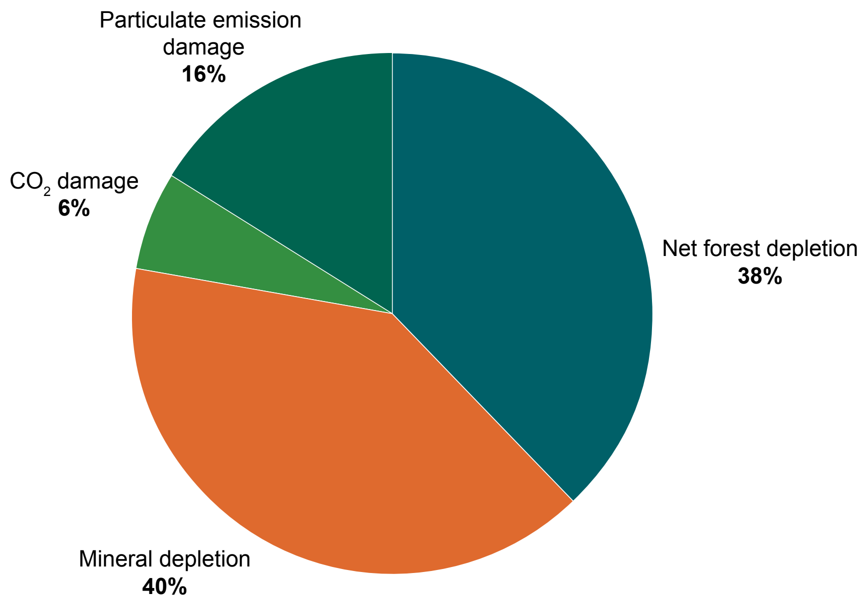
Adjusted net savings are equal to net national savings plus education expenditure, minus energy depletion, mineral depletion, net forest depletion, and carbon dioxide and particulate emissions damage. The adjusted net savings for Lao PDR (Figure 4.3) has been low and volatile over time, reaching about 3 percent of gross national income (GNI) as of 2003 and falling to minus 18 percent of GNI in 2012. It was at minus 1 percent of GNI in 2016. This path is driven partly by volatility in gross savings, which were relatively high for 2006, at 24 percent, compared to 9 percent in 2000 and 19 percent in 2016. Despite a recent increase in adjusted net savings, natural capital depletion is nonetheless persistent. Natural resource (mainly forest) depletion and mineral depletion, as well as pollution damage, are substantial (Figure 4.4). Positive ANS indicates an investment in the future—that a nation is accumulating the assets needed to build up its wealth and ensure its economic growth over the longer term. On the other hand, years of negative savings suggest that a country is running down its capital stock and is on an unsustainable growth trajectory.

Figure 4.3 Adjusted Net Savings: Lao PDR



Source: Adjusted Net Savings Database. Lange et al. 2018.

Figure 4.4 Components of Natural Resource Depletion and Air Pollution Damage in Lao PDR, 2016



Source: Lange et al. 2018.

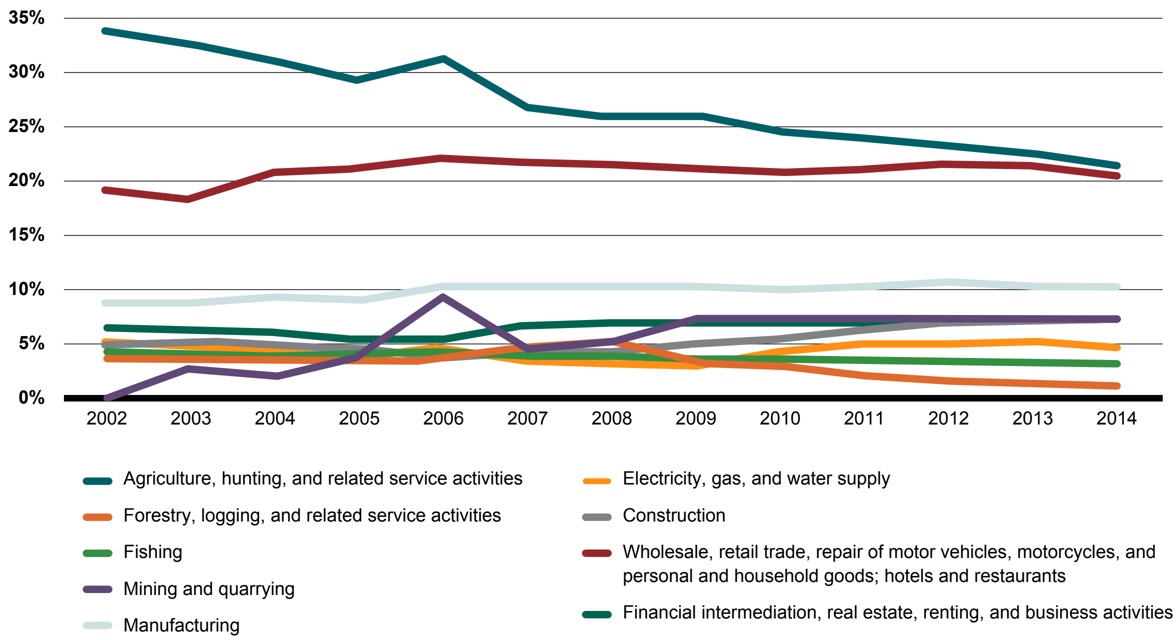
At the same time, value added in the sectors that extract rent from natural resources has been declining over the years (Figure 4.5), suggesting that manufacturing and service sectors are becoming more important for future growth. The mining sector is the only exception. Extraction of subsoil assets is a very important component of the Lao PDR economy and a major export. However, it adds to depletion of other natural resources—notably, deforestation—and puts additional pressure on the Mekong Basin.

Most of Lao PDR is in the Mekong Basin. The livelihoods and food security of most of the rural population are closely linked to the Mekong River system, with over 60 percent of the economically active population having water-related occupations that are vulnerable to water-related shocks and degradation. Most basin inhabitants are rural farmers/fishers and, while they may be resource-rich, they are money-poor.

Often lacking access to basic government services, people in the basin are, on average, less well off than their fellow citizens outside the basin. About half of all villages are inaccessible by all-weather roads. However, what makes life tolerable for these people are the aquatic resources and non-timber forest products (NTFP) provided by the basin's forests, rivers, and wetlands. At the same time, natural resource degradation exacerbated by climate change significantly reduces their welfare (Box 4.1).

While all LMB countries are making good progress towards achieving the Millennium Development Goals (MDGs), about 25 percent to 35 percent of the populations of Cambodia and Lao PDR have incomes below the poverty line, with much higher percentages in many rural areas. Food security and malnutrition exacerbated by unsustainable exploitation practices and climate change pose great challenges (AQUASTAT 2011).

Figure 4.5 Share of Value Added in Lao PDR



Source: Based on National Accounts Official Country Data, United Nations Statistics Division http://data.un.org

Box 4.1 Dependence on Nature of LMB's Rural Communities

Livelihood portfolios are highly diverse. Regardless of principal occupation, all households are engaged in a range of activities. This observed diversity underlines the importance of considering the linkages between sectors. If the productivity of one sector weakens, a household is likely to seek productivity gains or increased production in another sector.

Subsistence-based fishing is a common livelihood activity of most households across rural areas of the LMB. Subsistence-based fishing (and hunting) is a common secondary activity across all occupations. As fisheries are the key source of protein in the basin, households are sensitive to changes in the productivity of fisheries systems. In Lao PDR, fish provides at least 48 percent of protein intake. These trends are apparent throughout the basin, even in upland areas.

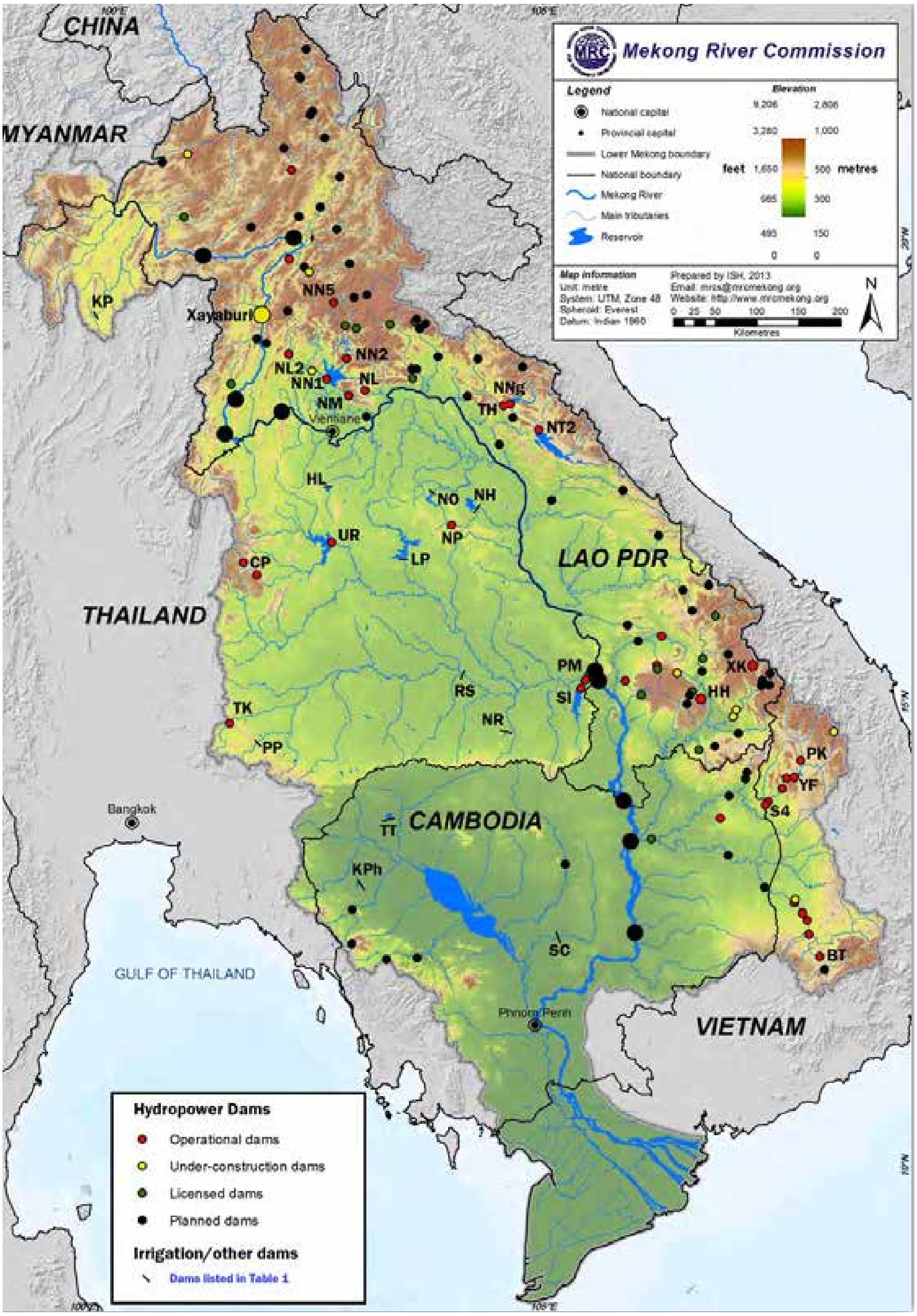
Natural systems are critical to food security. Looking across the different groups, farmers, agro-pastoralists, and other groups are all between 40 percent and 60 percent dependent upon some combination of subsistence farming, fishing/hunting, and gathering. These are all productive sectors that are heavily dependent on healthy ecosystems.

Source: ICEM 2013.

The Mekong is an extremely complex system with high intra-annual and inter-annual flow variability caused by the Southwest Monsoon, bringing both great risks and opportunities. It is also a rapidly changing river not only because of its contribution to the rapid economic development of the basin countries, but also because of this development on the river itself. This includes the impacts of increasing population, urbanization, and industrialization. To protect the resources of the basin and to promote its sustainable development, the Mekong River Commission was established in 1995 (MRC 1995). The basin can be seen in The Mekong is an extremely complex system with high intra-annual and inter-annual flow variability caused by the Southwest Monsoon, bringing both great risks and opportunities. It is also a rapidly changing river not only because of its contribution to the rapid economic development of the basin countries, but also because of this development on the river itself. This includes the impacts of increasing population, urbanization, and industrialization. To protect the resources of the basin and to promote its sustainable development, the Mekong River Commission was established in 1995 (MRC 1995). The basin can be seen in Figure 4.6.

The MRC provides guidance for balanced development and equitable and sustainable use of Mekong River resources. The commission responds to the transboundary and basin-wide impacts of planned developments in the basin. Climate adaptation is one of MRC's regional priorities. The MRC is required to take a whole of basin approach, since cooperation with the upper riparian countries is crucial for the sustainable management of the Mekong River Basin (MRC 2011b). Sustainable development within the Lower Mekong Basin requires mitigating the risks and seizing the opportunities that the Mekong creates for its inhabitants in a manner that conserves the river's functions for future generations (MRC 2016).

Figure 4.6 Mekong River Basin



Source: Hortle and Nam 2017.

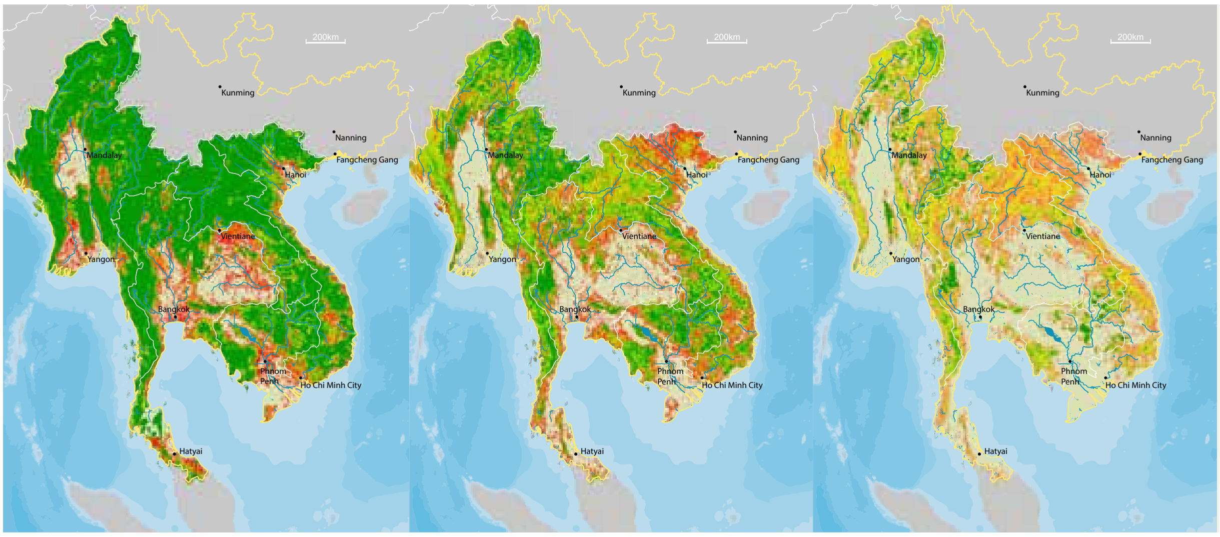
4.3 Cost of Deforestation and Forest Degradation

4.3.1 Process of Deforestation/ Forest Degradation in Lao PDR

Forests cover a substantial part of the Mekong Basin in Lao PDR. They form the foundation of the ecosystem services, since they store carbon, help protect communities and infrastructure from the impacts of drought and flashfloods, supply clean water and food, livelihoods, materials used in construction, trade, and ensure a healthy flow of the Mekong River. Sediment and nutrient transport in the Mekong are critical to ecological health and the distribution of aquatic habitats, and are important for water quality, floodplain processes, and overall basin productivity, particularly in fisheries and agriculture (Piman and Shrestha 2017).

The forests of the Greater Mekong are some of the most biologically diverse places on Earth. However, native forests are becoming increasingly fragmented (Figure 4.7), and contiguous forest areas remain only in northern Myanmar, western Thailand adjacent to the Myanmar border, and northeast Cambodia (near the Cambodia-Lao PDR-Vietnam border). As a result, wildlife can no longer move from one part of the forest to another, and their populations are separated. Sufficiently large breeding populations cannot be maintained, and the danger of extinctions increases. Forest fragmentation also makes it easier for poachers and non-native species to enter, increases the chances of fires, and leads to the accelerating rate of deforestation and loss of biodiversity. Lao PDR has a comparatively high international profile with respect to the illegal wildlife trade. Its neighbors, China and Vietnam, have a heavy demand for illegal wildlife products, including ivory, rhino horns, and tiger and bear parts. Lao PDR is viewed as a soft transit country and is one of Asia's main conduits for illegal trade from Africa. Lao PDR also has rich, unique biodiversity of its own, including high-value tree species, freshwater turtles, orchids, NTFPs, and medicinal plants highly sought after by neighboring countries. Large and medium-sized mammal populations have been severely affected by the illegal wildlife trade. Elephant populations have also undergone major declines throughout the country because of habitat loss, ivory poaching, and human–wildlife conflicts (World Bank 2019).

Figure 4.7 Historical and Projected Forest Fragmentation in Greater Mekong Basin



1973 **2009** **2030**

Forest fragmentation type: Core, Perforation, Transition, Edge, Patch

Source: https://www.wwf.or.jp/eng/activities/2017/10/1388106.html

To counter these trends, the government placed the protected area system under the direct management of the Department of Forestry within the Ministry of Agriculture and Forestry (MAF). The National Protected Area system of Lao PDR has been the cornerstone of the nation's ongoing efforts to protect terrestrial biodiversity over the last 25 years. In 2019, the government redesignated some NPAs, establishing the nation's first two national parks (World Bank 2019). Urban ecosystems are also important in major cities and in smaller provincial and district capitals. Urban centers are opportunities to set up conservation sites such as botanical gardens. Examples of urban parks include Chao Anouvong Park, Chao Fa Ngum Park, Chao Saysetha Park, Natural Cultural Park, Patouxay Park, and That Luang Park in Vientiane Capital. Another outstanding site of nature education potential is Nong Kengsan in Haidsaphong District (World Bank 2019).

The Lao PDR government recognizes the value of forests[50]. The Lao PDR's forestry strategy (MAF 2005) states

> The Lao PDR is particularly endowed with valuable, productive and ecologically unique forests which are not only a vital economic resource but provide essential contributions to the nutrition and income of the rural population and, in particular, the rural poor. Forests also provide a habitat for the nation's rich natural biodiversity and protect its soils, watersheds and water resources. Some eighty percent of the population is heavily reliant on the forest for timber, food, fuel, fibre, shelter, medicines, condiments and spiritual protection. In rural areas, forests provide one of the few available economic activities and non-timber forest products often provide more than half of a family's total income.

The wet evergreen forest in the Annamites has great significance for the global conservation of wet evergreen forest biodiversity. The most important area of wet evergreen forest in Lao PDR lies in the headwaters of the Nam Chat and Nam Pan rivers. The significance of this site for the long-term conservation of wet evergreen forest in Lao PDR makes this site irreplaceable. This forest ecosystem arguably has by far the highest significance and biodiversity importance and priority in Lao PDR of any Lao forest ecosystem. This is so because (i) the wet evergreen forest ecosystems are particularly rich, with high proportions of phylogenetically distinctive taxa; (ii) the wet evergreen forest ecosystem has very minor representation globally with a very small total global area; and (iii) Lao PDR accounts for a highly significant proportion of the global range of wet evergreen forest. The second ecosystem of high global biodiversity importance in Lao PDR includes the massive karst formations of central Lao PDR. The Greater Annamites is montane forests, which has somewhat lower priority because the threats are somewhat lower in general. However, the significance of the Greater Annamites to global biodiversity conservation is high, because they in general have a high representation of species with restricted ranges (World Bank 2019).

Although Lao PDR still has considerable forest resources, significant deforestation and forest degradation have taken place during the past two decades, as reported by a recent USAID study (Thomas 2015). The study cites available official statistics from the MoNRE that, in the 1960s, national forest cover in Lao PDR amounted to around 71.6 percent (17 million hectares). However, due to the prevalence of traditional shifting cultivation—and the presence of vast areas of fallow forest in Lao PDR—it has been challenging to estimate annual average deforestation and forest degradation in Lao PDR. In Lao PDR, a significant area is covered under forest fallow in different stages of shifting cultivation and regeneration through natural vegetative succession. In most cases, these forest fallow lands can regrow and recover into a stocked mixed deciduous forest through natural vegetative succession. The latest document that defines forest and deforestation/forest degradation activities in Lao PDR (MAF 2018a) addresses this issue and comes up with a consistent approach to estimate the extent of forests, deforestation, and forest degradation in Lao PDR. It divides all forestland in the country by strata based on carbon sequestration potential (Table 4.1).

Table 4.1 Forest Classification in Lao PDR

<table>
<tr><th>Level 1</th><th>Level 2</th><th>Area (ha)</th><th>% of total</th><th>Stratum</th></tr>
<tr><td rowspan="6">Current forest</td><td>Evergreen</td><td>2,605,557</td><td>11.3</td><td>1</td></tr>
<tr><td>Mixed deciduous</td><td rowspan="3">9,437,688</td><td rowspan="3">40.9</td><td rowspan="3">2</td></tr>
<tr><td>Coniferous</td></tr>
<tr><td>Mixed coniferous and broadleaved</td></tr>
<tr><td>Dry dipterocarp</td><td>1,188,198</td><td>5.2</td><td>3</td></tr>
<tr><td>Plantation forests</td><td rowspan="3">6,300,445</td><td rowspan="3">27.3</td><td rowspan="3">4</td></tr>
<tr><td rowspan="2">Potential forest</td><td>Bamboo</td></tr>
<tr><td>Regenerating vegetation</td></tr>
<tr><td rowspan="3">Other vegetated areas</td><td>Savannah</td><td rowspan="12">3,522,370</td><td rowspan="12">15.3</td><td rowspan="12">5</td></tr>
<tr><td>Scrub</td></tr>
<tr><td>Grassland</td></tr>
<tr><td rowspan="4">Cropland</td><td>Upland crop</td></tr>
<tr><td>Rice paddy</td></tr>
<tr><td>Other agriculture</td></tr>
<tr><td>Agriculture plantation</td></tr>
<tr><td>Settlement</td><td>Urban area</td></tr>
<tr><td rowspan="2">Other land</td><td>Barren land</td></tr>
<tr><td>Other</td></tr>
<tr><td rowspan="2">Above-ground water source</td><td>Wetland</td></tr>
<tr><td>River</td></tr>
<tr><td>Total</td><td></td><td>23,054,258</td><td>100</td><td></td></tr>
</table>

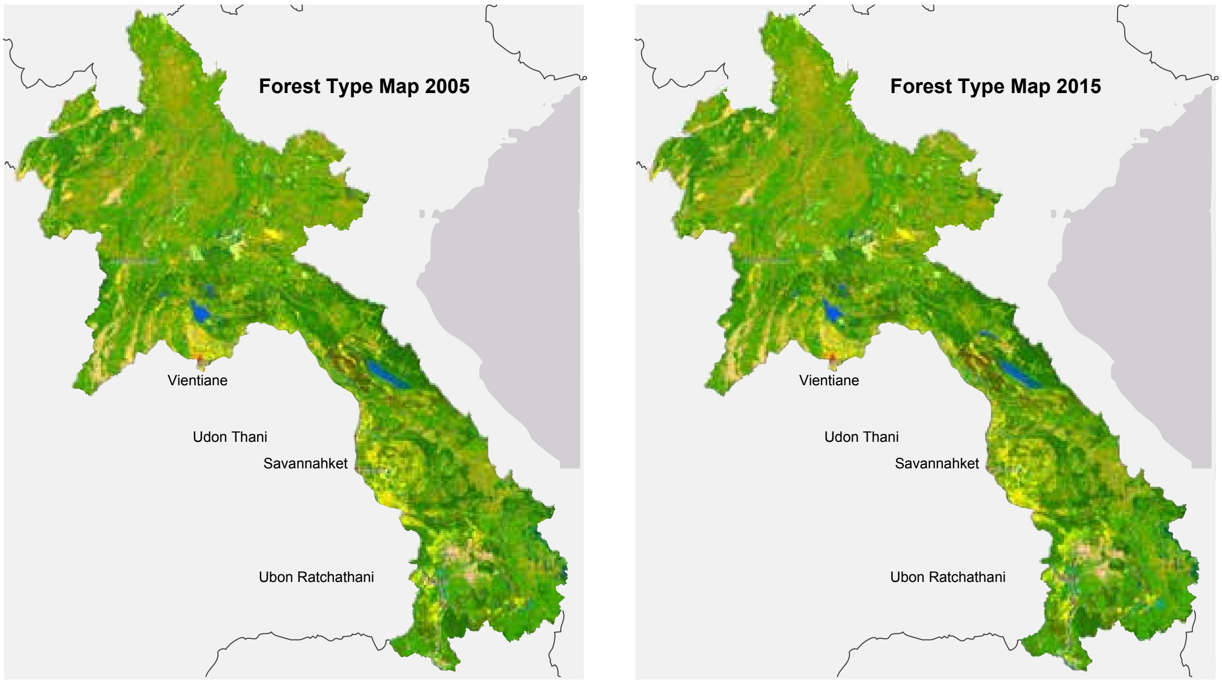
Source: Lao PDR MAF 2018a.

Figure 4.8 shows the forest cover map in Lao PDR (2005–2015) developed with application of the above-mentioned methodology.

Table 4.2 presents a breakdown of Lao PDR forests by forest type. This breakdown is based on a study by the Department of Forestry, 2018 (Lao PDR MAF 2018b).

In Lao PDR, deforestation is caused by many drivers but, in particular, illegal logging, unsustainable timber extraction from commercial logging activities, agricultural expansion, industrial tree plantation development, hydropower development, mining, and other infrastructure development. Pioneering shifting cultivation also contributes depending on the scale of its application, with a lesser impact if carried out on a smaller scale (patches of less than 1 ha). Natural forest fires may also contribute, but in both cases, regrowth of swidden and burnt forest areas can be surprisingly rapid. Wood harvesting by rural households for domestic consumption most likely has a much less significant impact. The first two drivers, illegal logging, which continues in all protected areas (World Bank 2019), and agricultural expansion probably have had the leading impact and are likely to continue to drive high rates of deforestation. Global Forest Watch (2018) estimated that 191,031 hectares of forests were lost in 2014, up from 80,543 lost in 2008. This threat has been

Figure 4.8 Forest Cover Map in Lao PDR (2005–2015)



Source: Lao PDR MAF (2018a).

Table 4.2 Forest Cover Area by Type of Forest in 2015

		Forest cover (forested area)		
Forest categories	**Total area (million ha)**	**Million ha**	**% within category**	**% of total land area**
Protection forest area	7.98	4.62	57.9	20.0
Conservation forest area	4.66	3.47	74.4	15.1
Production forest area	3.10	2.14	69.2	9.3
Areas outside the above three forest categories	7.31	3.14	40.5	13.6
Plantation (included in the forest areas inside and outside the above three forest categories)	–	0.14		0.6
Total, all land types	**23.05**[a]	–		–
Total, forest cover		**13.37**		**58.0**[b]

Source: Lao PDR MAF 2018a.

Note: [a] The total land area lying within Lao PDR's internationally established boundaries is revised to 23.05 million hectares, as provided by the National Geographic Department, based on their remote sensing survey. [b]The forest coverage of 58 percent includes 0.14 million hectares of forest plantation.

greatly curtailed by the introduction of PM Decree No. 15 to ban unprocessed timber exports, although illegal logging still occurs at lower intensities at all sites (World Bank 2019).

Although there are strict rules that stipulate the use of each forest type (Table 4.3), there are no mapping and corresponding forest management plans for all forests in the country. The EU study that addressed forest exploitation in Lao PDR (Grace et al. 2012) revealed that the areas mapped on the national level as protection forest were often used for agricultural production, and even included major town areas. In one case, an entire district was mapped as protection and production forests, but in reality, contained the district's capital, large lowland agricultural areas, and a coal mining concession. Thus, the information can be lacking, low quality, or unreliable regarding the deforestation of the different forest categories.

Due to shifting agricultural cultivation in Lao PDR, the Global Forest Watch (https://www.globalforestwatch.org/country/LAO[51]) database cannot be applied by itself. The identification of annual deforested/degraded areas (Lao PDR MAF 2018a) was based on a survey of the number of fallow years required for regeneration to meet the forest definition (that is, the threshold year). The survey used the annual vegetation-loss dataset (Hansen et al. 2013) to detect the year of loss on forest loss plots, and then measured the crown cover to find whether it had reached the status of forest. The survey results showed that the threshold number of years for a forest fallow to reach the forest threshold was on average seven years. By adding one year for cropping, it was assumed that land that was subjected to traditional slash and burn would regenerate into forest status in eight years.

The survey (Lao PDR MAF 2018a) provided a conservative estimate of deforestation and land degradation. Deforestation is defined as conversion of a forestland stratum (strata 1–3 in table 2.1) to non-forestland stratum (stratum 5 in table 4.1). Total annual deforestation in Lao PDR is estimated in Table 4.4.

Forest degradation is defined as downward change from a higher classified stratum (by carbon content) to a lower forest stratum (Table 4.5).

Table 4.3 Categories of Forests in Lao PDR

Category	Definition
Protection Forests	Forests and forestland classified for the purpose of protection of watershed areas and prevention of soil erosion. This category also includes areas of forestlands that are significant for national security, areas for protection against natural disasters and the protection of the environment, and other areas. (Forestry Law: Article 10)
Conservation Forests	Forests and forestland classified for the purpose of protecting and conserving animal species, plant species, nature, and various other things that have historical, cultural, tourism, environmental, educational, and other specific research values. (Forestry Law: Article 11)
Production Forests	Forests and forestland classified for the purpose of satisfying the requirements of natural economic and social development, people's livelihoods, and for timber and other forest products on a sustainable basis and without significant negative environmental impacts. (Forestry Law: Article 12)
Regeneration Forests	Young fallow forests classified for the purpose of regeneration and maintenance so that there is an increase in maturity towards a stage of natural equilibrium. (Forestry Law: Article 3)
Degraded Forests	Forests that have been heavily damaged, such as land without forest on it or barren land classified for tree planting and/or allocated to individuals and organizations for tree planting, permanent agriculture, and livestock production, or for other purposes, in accordance with national economic development plans. (Forestry Law: Article 3)

Source: JICA 2013.

Table 4.4 Annual Deforestation in Lao PDR

	Forest strata	Amount (ha) 2005	Amount (ha) 2010	Amount (ha) 2015	Total deforestation area, 2005–2015 (ha)	Annual deforestation (ha)
Evergreen	1	2,618,169	2,613,226	2,605,557	12,612	1,261
Other forest	2	9,961,368	9,721,635	9,437,688	523,680	52,368
Dipterocarp forest	3	1,272,006	1,215,712	1,188,198	83,808	8,381
Total		**13,851,543**	**13,550,573**	**13,231,443**	**620,100**	**62010**

Source: Estimated based on Lao PDR MAF (2018a).

Table 4.5 Annual Forest Degradation in Lao PDR

Forest degradation (shift of forest strata)	Share of carbon content loss	Total degradation area, 2005–2015, ha	Annual degradation area, ha
1→2	0.6	2,182	218
1→3	0.8	13	1
1→4	0.9	1,949	195
2→3	0.5	313	31
2→4	0.8	496,389	49,639
3→4	0.6	39,048	3,905
Total			**53,989**

Source: Estimated based on Lao PDR MAF (2018a).

Forest gain, although significant in Lao PDR[52], is not included in these estimates. Forest area increase, achieved with rubber and teak plantations brings significant private benefits, but they are questionable if other ecosystem services provided by forests are taken into consideration (CRILNR 2009).

4.3.2 Forest Values Quantification

Only some forest values were quantified for this analysis for Lao PDR. These estimates are based on secondary information from a number of recent studies for tropical forests in Lao and specifically in the Mekong Basin. Meta-analysis of the non-timber forest values presented in (Siikamäki et al. 2015) provides an estimated value of non-wood forest ecosystem services (Table 4.6). The paper analyzed 139 studies to derive a function of ecosystem services based on location-specific ecological (for example, ecosystem type) and socioeconomic factors (for example, income per capita or population density). The values of forestland estimated for selected countries in Eastern Asia are presented in table 4.7.

Forests yield five main categories of provisional economic benefits: commercial timber exploitation, household wood consumption, fuelwood use, and non-timber forest products (NTFP) harvested at household and commercial levels. Other mean forest values are adopted and derived from the studies for the tropical forest in Lao PDR (Table 4.8).

Table 4.6 Non-Wood Value of Forest Land in the Lower Mekong Basin Countries (US$/ha)

	Lao PDR	Thailand	Vietnam	Cambodia
Recreation	7.9	25.2	16.2	4.6
Habitat/Species Protection	0.2	4.0	0.3	0.4
NWFPs	1.2	0.6	2.3	1.2
Water Services	4.4	49.0	5.1	1.1
Total	**13.7**	**78.7**	**23.9**	**7.3**

Source: Siikamäki et al. 2015.

Table 4.7 Estimated Mean Values of Forest (US$/ha/yr)

	Type of service	Per hectare	Source
Provisioning services	Sustainable timber harvest	US$4.2/yr	EC FLEGT Facility, Baseline Study 2, LAO PDR: Overview of Forest Governance, Markets and Trade, July 2011; World Bank 2015
	Fuelwood	US$4.7/yr	Rosales et al. 2005; World Bank 2013
	Charcoal	US$1.2/yr	FAOSTAT 2016
	NTFP	US$8.5/yr	Rosales 2005; adjusted by GDP deflator to 2017
	Tourism	US$10.1/yr	Ministry of Information, Culture and Tourism, Lao PDR 2016
Regulating services	Carbon storage	US$1,238–1,454/yr	Lao PDR MAF 2018a
	Watershed protection services	US$183/yr	Emerton 2013
Other services	Other services	US$0.20/yr	Siikamäki et al. 2015

Nonetheless, the economic value of NTFPs is impressive, but undervalued. Collectively these forest products constitute a vital economic resource and provide an essential contribution to the consumption and income of the rural poor, as well as conserving biodiversity, soil, and water values. Additionally, medicinal plants, a type of non-timber forest product, are also of great importance, serving as the backbone of primary health care in the country. A database at the Institute of Traditional Medicine of the Ministry of Health (MIH) of Lao PDR houses between 2,000 and 3,000 species of plants recorded to have been used to treat diseases. New medicinal species are being recorded continuously (World Bank 2019).

4.3.2.1 Sustainable Timber Harvest

Harvesting timber at a low rate can be a sustainable use of forest resources if regeneration and the long-term well-being of the forest are taken into consideration. Production Forest Areas (PFAs) cover 3.1 million hectares in Lao PDR, with 51 legally established PFAs. The plan by the Department of Forestry is to complete national inventories and to develop sustainable management plans for all 51 national PFAs by 2013, but there is little information on progress towards this goal (EC FLEGT 2011). The total volume of sustainable harvesting from the Participatory Sustainable Forest Management (PSFM) areas in Lao PDR for all 51 national PFAs could be maintained at approximately

97,000 m^3 annually, increasing up to about 244,000 m3/yr under the more intensive commercial harvest scenario of 10 m^3/ha per harvest cycle. With 25 percent losses for the intensive commercial harvest scenario, and \$40/m^3 stumpage fee, adjusted to 2016 with a GDP deflator of 1.19 (World Bank 2015; World Bank WDI 2018) total sustainable timber harvesting is estimated at US\$14.5 million, or US\$4.2/ha annually. Note that timber harvesting is prohibited in protection and conservation forest; however, we do not have actual deforestation rates in different forest types. The values are attributed to all forest types in this report.

4.3.2.2 Charcoal and Fuelwood

Timber is an important source of fuel for the Lao population. World Bank (2013) reports that 66.9 percent of population in Lao PDR use solid fuel for cooking. On average, every household (5.3 people) uses about 2.16 t of fuelwood per year. If one cubic meter of firewood converts to 775 kg (Lao PDR MoNRE 2013), then about 2.4 million m^3 of fuelwood is used annually. The fuelwood is priced at the opportunity cost of charcoal, as in Rosales et al. (2005), and adjusted to 2016 at US\$50/t of fuelwood. The total benefits of fuelwood use in Lao PDR are estimated to be US\$90 million. The cost of fuelwood use is estimated with time spent for fuelwood collection by the rural population (6 hours of work per household per week—as in World Bank [2013]) at US\$28 million. Net annual benefits from fuelwood use are then US\$62 million, or US\$4.7/ha of forest.

Charcoal net benefit is estimated at 50 percent (for profit margin) of the revenue from charcoal sales in Lao PDR (US\$29 million—FAOSTAT 2018). Thus, the estimated net benefit is US\$15 million, or US\$1.20/ha of forest.

4.3.2.3 Non-Timber Forest Products

Forests in this country are an important source of income and subsistence for the population (Lao PDR MAF 2005). Lao PDR has an estimated 8,000–11,000 species of flowering plants, many of which are economically valuable. These plants have a range of utilities for people, and include NTFPs and medicinal plants, as well as economically important agricultural species, breeds and varieties. Among the fauna, there are between 150–200 species of reptiles and amphibians, 700 species of birds, 90 species of bats, over 100 species of large animals, and 500 species of fish (World Bank 2019). The ADB (2010) reports that the most important NTFPs currently being collected are (i) rattan, (ii) bamboo, (iii) resin, (iv) malva nut, (v) honey, (vi) palm leaf and grass leaf/broom grass flower, (vii) medicinal plants/herbs, (vii) food (such as vegetables and bamboo shoot), and (ix) fuelwood. Food and fuelwood from the forests are the major consumption goods for local people. Rosales et al. (2005) found the annual value of non-timber forest products collected in the natural forests of Sekong province to be US\$398–US\$525 per household, or US\$17/ha to US\$23/ha. Foppes and Samontry (2010) estimated cash income from NTFPs in production forests to be worth on average US\$204 per rural household, in 2010. The non-cash income—that is, the value of household consumption—was estimated to be US\$489. Together, the total income per household comes to US\$693 per household. We apply a more conservative approach, using the same study and Lao PDR MAF (2005) and (World Bank 2019) to show that an average rural household draws about 40 percent of its income from the forest (71 percent for poor households, and 36 percent for rich households)—every year rural

Table 4.8 Estimated Annual NTFP in Lao PDR (US\$/ha)

NTFP per hectare	Bouttavong 2002b	ADB 2010	Rosales 2005		Average
			Low	High	
At the time of the study	2	7	17	23	
Adjusted to 2017 with GDP deflator	6	10	40	54	7.9

Sources: ADB 2010; Bouttavong et al. 2002; Rosales et al. 2005.

households extract US$182 million from forests. After taking out fuelwood, estimated at the time spent for collection, and applying the same benefit-cost ratio as for fuelwood, we estimate that on average households get US$108 million as NTFP, or US$8.5/ha. This estimate is in the range of estimates that are obtained from other studies.

4.3.2.4 Climate and Carbon

The average carbon stock in Lao PDR forests is reported in Lao PDR MAF (2018a). The total value of the carbon emissions due to deforestation and forest degradation and their cost is estimated in Table 4.9 and Table 4.10. Carbon stock of forest in Stratum 5 is estimated at 4.9 tons of C per hectare (Lao PDR MAF 2018a). US$5 per ton of CO_2 is the price used in the above report. On average, the value of carbon lost due to deforestation/forest degradation is estimated to be US$1,454/ha for deforested areas and US$1,238/ha for degraded forest areas.

4.3.2.5 Tourism and Habitat Protection

The estimates related to use of forest for recreation, option value (bioprospecting when a forest can potentially serve as a provider of new medicines) and existence value associated with preservation (non-use) of forests show a wide variety of values in the literature. With over half of Lao PDR's total wealth found in natural capital, the country's comparative advantage in tourism is its conservation landscapes and the wildlife and people dependent on them. This endowment supports globally significant biodiversity and forest cover is 58 percent of the country's total area. Internationally important biodiversity comprises the outstanding natural ecosystems described above, which are further augmented by world-class caves, rivers, and waterfalls.

Table 4.9 Annual Average Carbon Emissions from Deforestation in 2005–2015

	Carbon t/ha	CO_2 release, t/ha	Carbon loss annual, CO_2 t	Cost of carbon loss, US$, millions
Evergreen	200	715	901,758	5
Current other forest	88	305	15,956,530	80
Dipterocarp forest	43	140	1,173,871	6
Total			**18,032,158**	**90**

Table 4.10 Annual Average Carbon Emissions from Forest Degradation in 2005–2015

Forest degradation: change in strata	% loss of carbon content due to change	Total area of degraded forest in 2005–2015, ha	Annual degradation, ha	CO_2 loss t/ha	Total carbon loss, t of CO_2	Cost of carbon loss, US$, millions
1→2	0.6	2,182	218	410	89,527	0.5
1→3	0.8	13	1	575	747	0.0
1→4	0.9	1,949	195	668	130,135	0.7
2→3	0.5	313	31	165	5,153	0.0
2→4	0.8	496,389	49,639	257	12,777,053	63.9
3→4	0.6	39,048	3,905	93	362,235	1.8
Total			**53,989**		**13,364,851**	**67**

This wealth can be mobilized for green growth with nature-based tourism (World Bank 2019). Tourism forest value was approximated from available information (Lao PDR MICT 2016). About 680 thousand international tourists visited Lao PDR in 2016. Each tourist spent about 7.6 days in the country and spent US$77 per day; 67 percent of tourists expressed interest in visiting nature sites. Assuming 50 percent share of the cost, net annual value of tourism in the forests of Lao PDR is estimated at US$134 million or US$10.1 per hectare. This estimate is close to the conservative recreational forest value estimate at US$7.9 per hectare in (Siikamäki et al. 2015, table 6).

Habitat/Species Protection forest values are estimated at US$0.20/ha in (Siikamäki et al. 2015, table 2.6). This estimate is close to the estimate provided in Rosales et al. (2005).

4.3.2.6 Watershed Protection

The benefits related to watershed protection are particularly important for Lao PDR, given its economic dependence on the Mekong River. As ADB, 2010 describes, forests protect watershed functions through retention of water by the crown, trunk, undergrowth vegetation, forest litter and soil. Forests store and regulate availability of surface water and runoff. The forest is often referred to as a sponge and green reservoir for its critical watershed protection capacity. By regulating runoff, forests can contribute to delays in flood peaks and to reductions in flood volume. During the dry season, forests gradually release absorbed water thereby maintaining river flow and relieving droughts. Rainwater retained by forests can be of drinking water quality. Forests also prevent soil erosion and loss, thus reducing or minimizing sedimentation in reservoirs and rivers. This improves water quality and can extend the life of a reservoir.

Following the introduction of rubber plantations and their subsequent rapid expansion in the mountainous areas across the entire Mekong region, the area devoted to rubber plantations has been steadily increasing. It is predicted that this expansion will lead to drier conditions at the local level and will increase surface erosion and reduce soil quality. It will also increase sedimentation and stream disruption and increase landslide risk (Costenbader et al. 2015). These effects are difficult to quantify. However, Emerton (2013) reviewed the studies that valued indirect ecosystem services of the forest in the Lower Mekong Basin, including Lao PDR. The average estimate of US$183/ha/yr is derived in the study with the range US$3–399 ha/yr. We use a mean value of US$183/ha/yr in this analysis.

4.3.3 Summary Costs of Deforestation and Forest Degradation

Table 4.11 summarizes the estimated annual forest ecosystem values. The cost of deforestation/forest degradation in Lao PDR is estimated as NPV of annual forest values lost on deforested land and reduced on the degraded forestland in the same proportion as carbon release on the degraded land compared to the initial forest strata. Carbon released as a result of deforestation is included as the value of carbon stock released as a result of deforestation/forest degradation at the time of deforestation. Forest values are estimated as NPV of forest services per hectare listed in Table 4.11 (30 years, 5%/year discount rate). Table 4.11 shows the NPV of forest ecosystem value loss per hectare separately for deforestation and forest degradation.

The annual cost of deforestation/forest degradation in Lao PDR is estimated as a product of the total values in table 4.11 and annual deforestation/forest degradation area (Table 4.4, Table 4.5). The estimated annual deforestation/forest degradation cost in Lao PDR is presented in Table 4.12.

Table 4.11 NPV of Forest Ecosystem Value Loss (US$/ha)

	NPV deforestation, US$/ha	NPV degradation, US$/ha
Timber	62	49
NTFP	115	92
Fuelwood	66	53
Charcoal	17	13
Recreation	142	0
Total provisional values	402	207
Habitat preservation	3	2
Watershed protection	2,579	2,055
Carbon one-time value loss	1,454	1,238
Total	**4,438**	**3,502**

Table 4.12 Estimated Annual Deforestation/Forest Degradation Cost in Lao PDR

	US$, millions	% GDP in 2017
Deforestation cost	275	1.6
Forest degradation cost	189	1.1
Total	**464**	**2.7**

4.4 Agricultural Expansion and the Cost of Soil Degradation

4.4.1 Agricultural Production in Lao PDR

Most of the people of Lao PDR rely on agriculture for their livelihood, and the country's households spend the most on agricultural products. The population of Lao PDR has increased 2.5 per cent per annum in recent years, a growth rate that can lead to food insecurity, which in Asia is often equated with rice production. The country has to feed almost 50 per cent more people now than 16 years ago (World Bank 2019). Farming systems in the Lao PDR's part of the Mekong River basin range from traditional, sustainable shifting agriculture systems dominated by upland rice through industrial plantations in the lowlands, including smallholder intensive rice farmers. Rainfed agriculture is the dominant type of agriculture in the Lao PDR. Rainfed rice is the dominant traditional crop. Lao PDR is particularly rich in rice varieties, with at least five wild species and some 3,000 varieties of cultivated varieties. Glutinous rice is the staple rice type favored by the Lao people, and around 85 percent of the samples are of glutinous varieties reflecting a potential impressive diversity. Some of local varieties, previously in decline, are now finding favor in national and international markets. Locally almost 200 species found in aquatic rice fields are consumed, supplying a range of nutrients needed by the villagers. Aquatic animals, including fish, amphibians, crustaceans, mollusks and insects form part of the diet (World Bank 2019). Other commercial crops such as maize, or cassava, which have growing importance in farming systems in the region, are also mostly rainfed. Agriculture is highly dependent on climate and especially on rainfall frequency and distribution. With more than 1,000 mm of rainfall per year in the Lao PDR, water shortage is not the primary constraint for agriculture. Instead, it is the unpredictability and variability of rainfall distribution during the rainy season that can lead to drought, water stress, and low yields (ICEM 2013).

Agriculture is central to growth in the country, and rural landscapes have been transformed over the past decade from land use mosaics of subsistence and small farms to large-scale plantations dominated by a few commercial crops (Wong et al. 2014). However, agricultural performance has lagged, with limited productivity with growth mainly driven by expansion into uncultivated lands (ADB 2017). Despite its potential, household survey data indicate that rice yields trail the rest of developing Asia. Livestock and other crop production growth have remained mixed. (ADB 2017). Agriculture's share of the Lao economy is currently about 20 percent of country's GDP, it was about 60 percent of GDP in the early nineties and still almost 80 percent of the total workforce in 2017 (World Bank WDI 2018).

The country's total agricultural area, as defined by the Ministry of Agriculture and Forestry, covers about 4.5 million ha, of which 3.8 million ha is potentially suitable for cultivation (Lao PDR MAF 2015 – cited in ADB 2017). Under international definitions of arable land, which refer to land already under temporary crops, transient meadows, and fallows of limited duration, about 1.5 million ha is classified as arable. FAOSTAT shows about a similar amount land classified as arable, but currently only about 2.4 million ha of total agricultural lands. Under either definition, available agricultural land per rural inhabitant is greater than in much of Asia. In addition to a generous arable land endowment, the Lao PDR has 650,000 ha of pasture and meadowlands that can benefit livestock. Along with land, water is the most important natural resource for agricultural potential, and this resource faces increasing demand. The Lao PDR is fortunate to have abundant water. Rainfall, which averages 1,600 millimeters (mm), is distributed relatively evenly across the country (FAO 2018). When surface waters are considered, the Lao PDR has far more freshwater available per hectare of arable land than other countries in the region (ADB 2017).

Lao PDR has distinct lowland, upland, plateau, and mixed agricultural systems, of which lowland systems are dominant. Farming systems in the lowlands are predominantly based on rice, along with mixed cropping systems of vegetables, groundnuts, and fruit trees. Major livestock (cattle, buffalo, commercial chickens, and ducks) are also raised in the lowland areas. The highland areas are home to many ethnic minorities—for example, the Lao Sung—whose main agricultural practices largely rely on shifting cultivation and subsistence farming. Upland cropping systems often include maize, cassava, and vegetables. In recent years, cultivation of commercial crops, such as rubber, sugarcane, cassava, and maize, has expanded in the uplands. Cultivation of commercial crops is practiced especially on degraded lands that are fallow. The most common livestock in this area are indigenous pigs and local chickens (ADB 2017). Upland agriculture is the most prone to erosion and degradation problems due to slope, as will be discussed below. Table 4.13—and Figure 4.9, Figure 4.10, and Figure 4.11—show the basic types and amount of agricultural land in Lao PDR.

Table 4.13 Farm Area (ha) by Land Type, 2010–2011

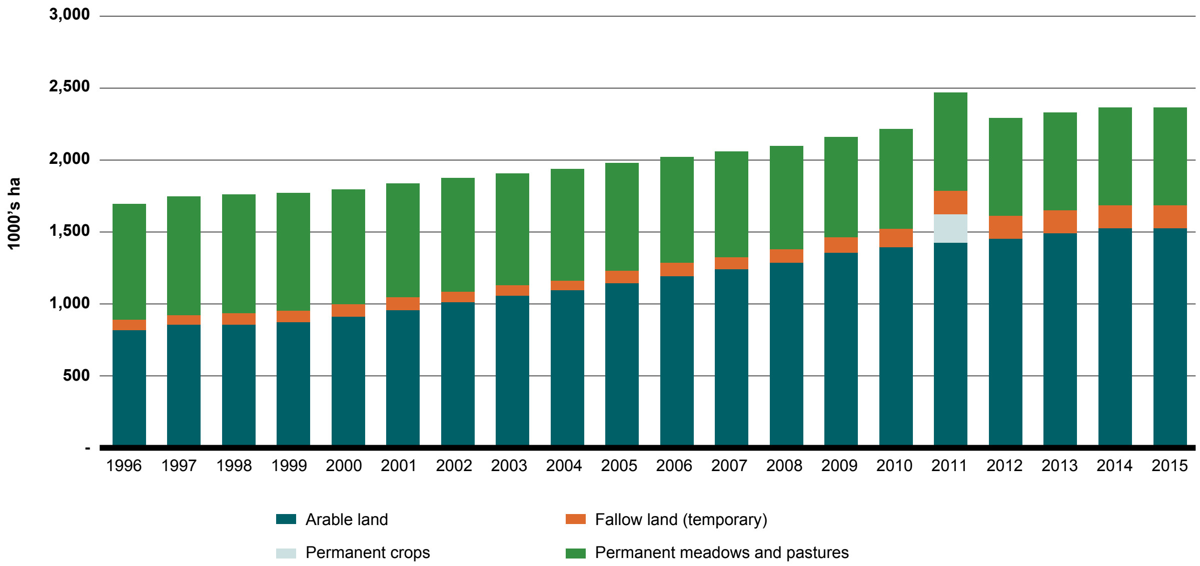
Lowland	Upland	Plateau	Mixed	Total
806,460	402,039	375,870	6,219	1,590,589

Source: ADB 2017.

Major crops include rice, maize (commercial), and pigs. Production of maize has been increasing annually. This is due to both increased area of planting and increased yields. The country plans to increase cash crop production of maize in addition to its use as a domestic food source (Lao PDR MAF 2015) and as fodder for the increasing numbers of pigs. Rice production is also expected to increase both for local food consumption and as a cash crop to be targeted to international markets such as China and neighboring countries (Lao PDR MAF 2015).

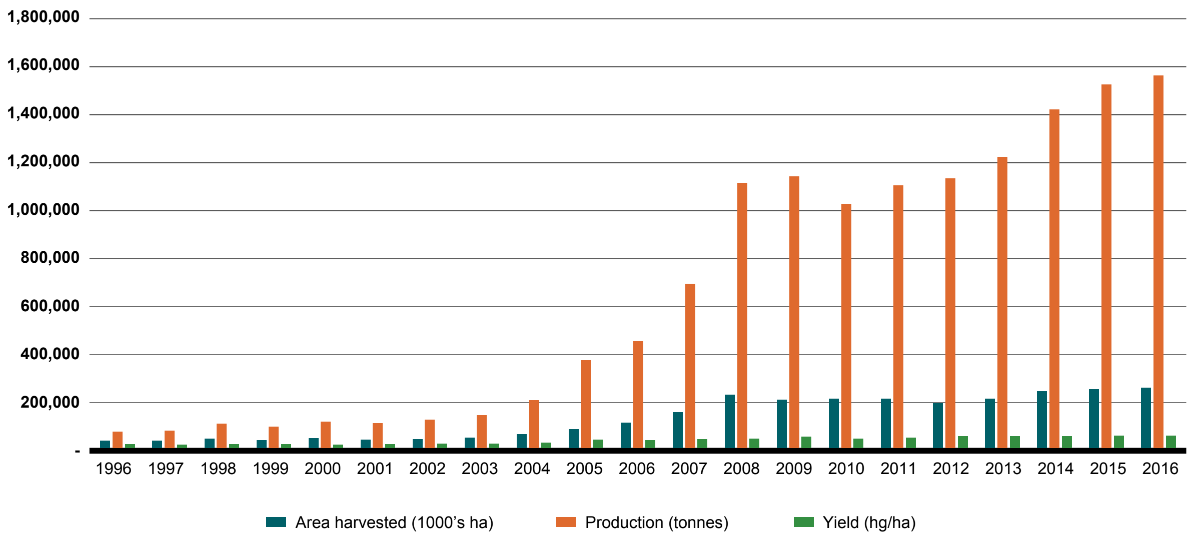
ADB (2017) estimates planted area of maize in 2007 to have been approximately 150,000 ha; and in 2012, it was approximately 200,000 ha.

Figure 4.9 Major Agricultural Land Uses



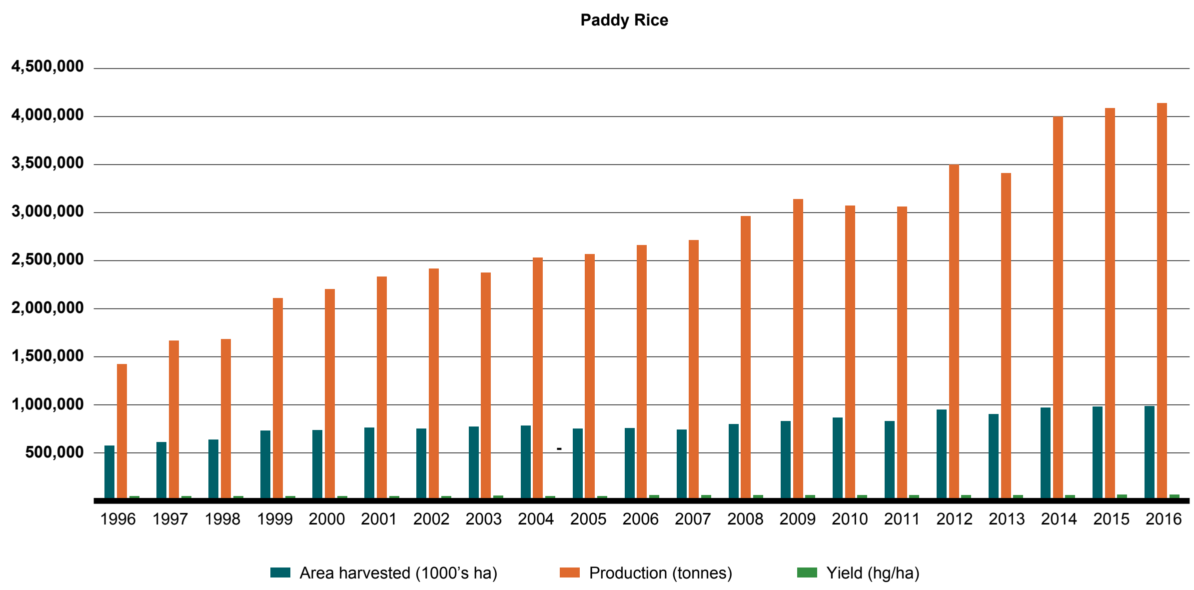
Source: FAOSTAT 2018

Figure 4.10 Maize Production in Lao PDR



Source: FAOSTAT 2018

Figure 4.11 Paddy Rice Production

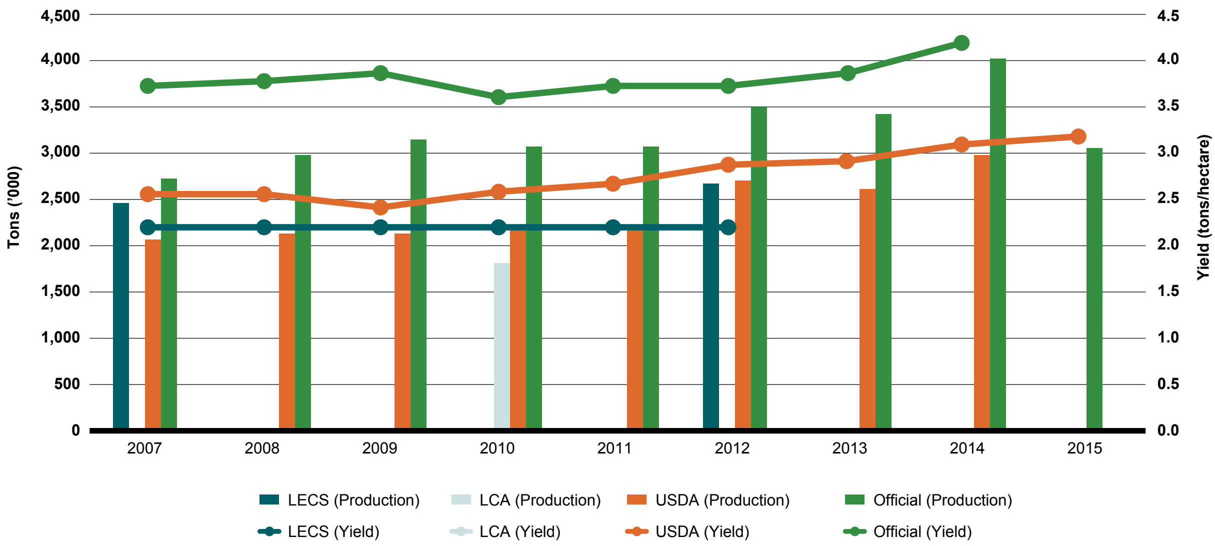


Source: FAOSTAT 2018.

The ADB (2017) analysis suggests that nearly all rice production growth in the Lao PDR is driven by area expansion, which is a trend that is not sustainable, given that land is a finite resource, and the government is actively seeking to expand forest cover. While the ADB survey results reflect no change in rice yields between 2007–2008 and 2012–2013, rice area expanded by nearly 2 percent annually. According to ADB (2017), the planted area of maize in 2007 was approximately 1,100,000 ha; in 2012, it was about 1,250,000 ha (based on data from Lao Statistics Bureau (LSB) 2008. Lao Expenditure and Consumption Survey 2007–2008. Vientiane; and LSB 2013. Lao Expenditure and Consumption Survey 2012–2013. Vientiane). These areas planted numbers are larger than the FAO estimates (~728,000 ha in 2007 and ~928,000 ha in 2012). The FAO analysis (Figure 4.12) shows increases in yield in addition to area expansion, as opposed to the conclusions of the ADB 2017 analysis. The ADB 2017 analysis also differs in analysis of yield (Figure 4.13). This analysis based on a number of sources shows relatively little change in yield, although official numbers show similar production totals. It is not within the scope of this study to explain the reasons for the differences in these numbers.

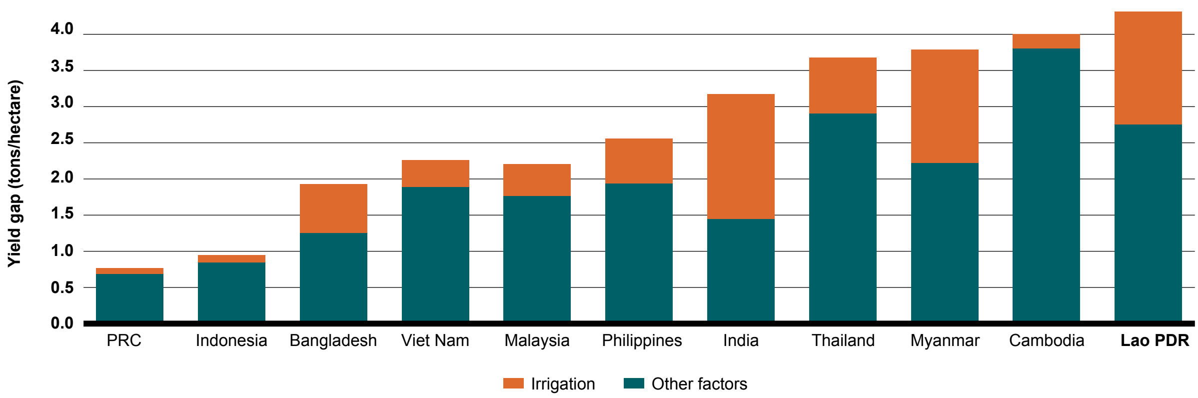
While pioneering shifting cultivation in the uplands appears to have reduced, in its place, growth of commercial agricultural concessions has put new pressure on forests, as noted in the previous section. It has been estimated that commercial agricultural expansion led to 34,200 ha of annual loss, while smallholder expansion drove 14,700 ha of loss each year (Table 4.26). In addition, commercial concessions may drive shifting cultivation and other agriculture into new forested lands when lands under existing uses are allocated to commercial investors, and this may indirectly lead to additional forest clearance. The low level of performance for rice systems according to survey data is explained by the old traditional management practices by farmers, even when biophysical conditions could allow similar yield levels to leading rice producers, such as Vietnam. Even without changing the extent of irrigation, attainable yields can be doubled, and with irrigation in place, it could be tripled relative to survey-based estimates. The gap between actual and attainable rice yield in the Lao PDR is the highest in the region (Figure 4.13).

Figure 4.12 Growth in Paddy Rice Production and Yield, Lao PDR 2007–2015



Sources: Estimated based on the following:
FAOSTAT. Value of Agricultural Production. http://www.fao.org/faostat/en/#data/QV;
Lao Statistics Bureau. Lao Expenditure and Consumption Survey 2007–2008. Vientiane;
Lao Statistics Bureau. Lao Expenditure and Consumption Survey 2012–2013. Vientiane;
Ministry of Agriculture and Forestry. Lao Census of Agriculture 2010/11. Vientiane.
USDA, Foreign Agricultural Service. https://apps.fas.usda.gov/psdonline/app/index.html#/app/downloads;
Note: LCA = Lao Census of Agriculture, LECS = Lao Expenditure and Consumption Survey, USDA = United States Department of Agriculture.

Figure 4.13 Gap Between Attainable and Actual Paddy Rice Yields, 2012



Source: ADB 2017.

4.4.2 Agricultural Inputs

Lao PDR MAF (2015) notes that producers and farmers have improved crop productivity and cultivation through farmer's groups and associations, with improved information access and access to markets. They have been using agricultural techniques and technologies that were promoted by improved agricultural extension services. New and improved irrigation, research centers, seed centers, testing bodies, agriculture and forestry service centers have been very useful.

If the government is to achieve its aims of increasing agricultural production and protect its forests, it will need to increase yields significantly. Manure use has been increasing (Figure 4.14); however, this is not likely to be sufficient. An increase in appropriate use of agricultural chemicals will be required. According to FAOSTAT, there is no measurable chemical fertilizer use in Lao PDR; this is consistent with the analysis within the ADB 2017 report.

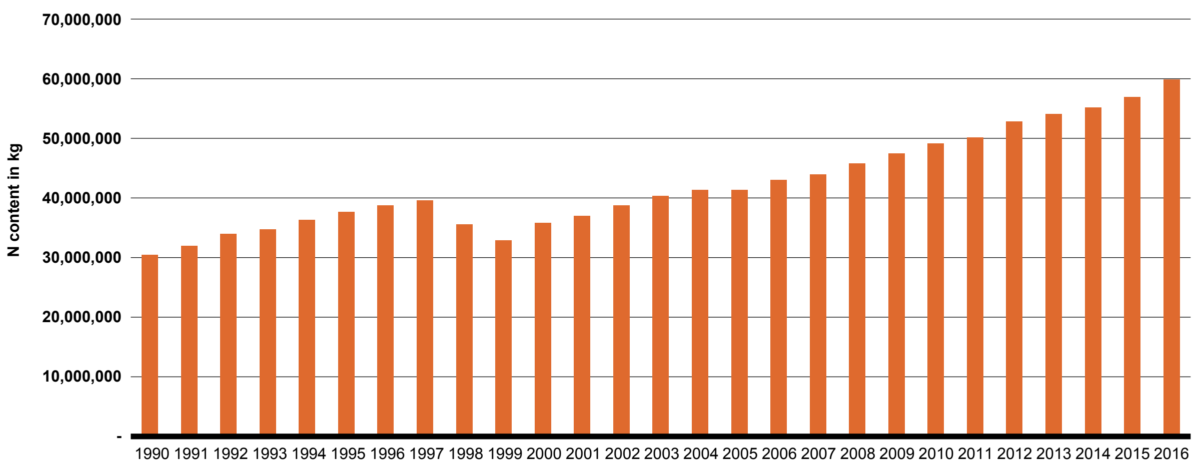
Pesticides (both insecticides and herbicides) are used in Lao PDR, and more than 120 tonnes of active ingredients were used in 2013 (FAOSTAT 2018). In recent years, there has been almost no reported use of pesticides. This year-to-year variation in the pesticide use data is probably far more reflective of data quality, rather than annual differences in actual use. Perhaps the growing use of pesticides accounts for the increase in both maize and rice yield seen in the FAO data in Figure 4.10 and Figure 4.11.

For irrigation use, there are few years with data for Lao PDR (AQUASTAT 2011). Irrigation can be required to smooth out the variability in precipitation in this country. The proposed increases for both food and cash crops by the Lao government signal a need towards more chemical use and better water system management.

4.4.3 Soil Erosion and Land Degradation

Much of the land in Lao PDR is naturally susceptible to soil erosion due to mountainous areas with a high degree of slope, the types of soils and the high rainfall. Soil erosion is compounded by shortened fallow periods, resulting in lower productivity and ever-increasing demand for more land for agriculture. Traditionally, slash and burn agriculture was sustainable. However, changing agricultural practices can be bad for the soils, because of these shortened fallow periods. Villages practicing shifting agriculture report substantial declines in agricultural land productivity (as much as a 50 percent decline) due to shortening of fallow periods from 14–15 years to as little as 3–4 years, causing serious nutrient depletion (World Bank LEM 2005).

Figure 4.14 Manure Applied to Soils



Source: FAOSTAT 2018.

There have been several site-specific small-scale erosion studies in Lao. However, scaling up to country-level estimations of soil loss has been extremely difficult. It is not possible to simply extrapolate the runoff and sediment yield figures from micro-plots to calculate sediment eroded at larger scales, because these processes are scale dependent. Erosion rates measured from micro-plots are generally much higher than at the catchment scale, where sediments may be deposited (Pierret et al. 2011).

Sediment loads in rivers, though, can be significant. Sediment loads in tributaries vary considerably, from 41–345 tonnes/km^2/yr, and sediments are the primary pollutants in Lao PDR's rivers. Tributaries and river reaches with high sedimentation include the upper and lower stretches of the Mekong (AQUASTAT 2011). Tillage erosion results from land preparation and from repeated weeding operations. Erosion in in this context is the movement of soil from higher elevations to, and then deposition at lower portions of the slope. In northern Lao, in a field with a mean slope of 60 percent, soil losses due to tillage erosion were of the same order of magnitude as those due to water erosion. These soil losses affect the most fertile soil layer. Because of the increasing weed pressure, tillage erosion is likely to become very serious, especially on the steepest slopes, which will become more frequently cultivated (Dupin et al. 2002). There are various estimates of soil loss and degradation, several of which can be seen in Table 4.14.

We estimate the annual cost of soil erosion by using data on substitution of maize production for traditional and sustainable shifting agriculture in the uplands. This is one of the major economic changes in agriculture in the Lao PDR. As described in Wong et al. (2014), upland shifting rice production is normally practiced on a rotational basis within the same landscape after a lengthy fallow period. This rotational production requires an extensive land area. As described above, this is the predominant traditional farming system in the northern uplands of Lao PDR. Pressures from national

Table 4.14 Erosion Estimates in Lao PDR Studies Based on Land Use or Slope Gradient

Micro-catchment area (ha)	Land use	Soil loss (t/ha)
1.7	69% rotating land, 31% teak	0.5
29.3	76% rotating land, 6% upland rice	0.6
19.8	80% rotating land, 12% forest	0.0
27.7	61% rotating land, 11% job tear, 10% forest, 7% upland rice	2.1
13.1	53% rotating land, 35% forest, 8% upland rice	2.8
2.5	56% rotating land, 13% forest, 31% teak	2.0
	Slope Gradient %	**Erosion (t/ha/yr)**
	30	2.1
	40	3.1
	50	3.9
	60	4.1
	70	8.7
	80	11.8
	90	14.8
	100	18.6
	110	23.7

Sources: Dupin et al. 2002; Maglinao 2002.

policies that promote expansion of maize and rubber plantations are shortening fallow cycles and affecting the productivity, biodiversity, and ecosystem services from this land use system. Communities in the northern uplands actively cultivate fallow lands and use fallow forests for food and non-timber products. Maize is mostly grown in the mountainous regions and slopes, and this expansion of maize and rubber plantations have come at the expense of old fallow and secondary forests. This is intensifying soil erosion.

Maize plantations have dramatically expanded in Lao PDR over the last 15 years. The average annual increase in area under maize cultivation was about 14,340 ha during the period from 2001 to 2016 (FAOSTAT 2018, figure 3.2). This number is very close to the estimate of the annual agricultural expansion by small landholders (Thompson 2015), who also reports that the annual increase in their agricultural expansion is 14,700 ha. Maize is also a highly soil-depleting crop and farmers commonly report that harvests begin to decline drastically after year 5. Maize farming practice is heavily dependent on chemical herbicides which, if used uncontrollably, leads to soil degradation, water contamination, and environmental health issues in livestock, fisheries and possible to farmers and local communities. In addition, rubber plantations have expanded into uplands and hillslopes, further increasing soil erosion risks.

Wong et al. (2014) estimate the difference in public and private NPV per hectare of planted area under maize and rubber (for two types of land management). Public NPV is reduced by the environmental externalities that are associated with maize and rubber production. For example, public NPV excludes average health costs caused by environmental degradation (for example, herbicide contamination), captured in terms of medical costs and days of lost labor due to illness as reported by farmers in the households' surveys and translated into US$ per hectare. The costs of hospitalization and medicines attributed to herbicide or pesticide related illness varied widely depending on the location and land use, and the average cost is calculated at US$2.80/ha. It is assumed that these costs rise by 5 percent per year after year 5 with rubber and maize plantations when pesticide and herbicide use increase significantly. In addition, public NPV excludes additional inputs associated with soil erosion. The values are adjusted to 2016 and corrected for NPV estimation (30 years, 5%/yr discount rate). Table 4.15 presents the estimated annual cost of agricultural land degradation in Lao PDR.

The potential and now ongoing transition to a modern, production-oriented agricultural system using pesticides, fertilizers and irrigation must be done carefully so as not to create other long-term problems. These problems potentially include other forms of soil degradation and environmental and human health problems.

Table 4.15 Estimated Annual Cost of Agricultural Land Degradation in Lao PDR

	Per hectare, US$	Total, US$, millions	Share of GDP in 2017
Soil degradation associated with maize	6,961	100	0.6%
Soil degradation associated with rubber plantations	25–144	1	0.0%
Total soil degradation cost		**101**	**0.6%**

4.5 Potential Cost of Hydropower Development

4.5.1 The Mekong River Dams: Social and Environmental Costs

The Mekong River dams that are crucial for future water regulation in Lao PDR represent the single largest threat to the local population, wetlands, fisheries, and local livelihoods of the Lower Mekong. Table 4.16 presents major mainstream hydropower plants in Lao PDR planned to be constructed by 2030. The total capacity of the 9 planned mainstream projects is 9,370 MW which would produce about 47,000 GWh—equivalent to about 6 percent of forecast LMB power demand for 2030 (Intralawan et al., 2017). About 90 percent of the electricity from these projects would be exported to Thailand and Vietnam, which accounts for the bulk of LMB power demand. Lao PDR power demand is estimated at 16,000 GWh (Intralawan et al., 2017).

MRC (2015a) presents major social and environmental impacts of large-scale hydropower development in the Mekong River. Social costs for local population are very important. The inundation of lands to create hydropower reservoirs and land lost to project structures (for example, physical plant and transmission lines) may necessitate the relocation of households and villages. It has been shown that, in addition to moving from one place to another, there may be other indirect impacts on resettled peoples such as loss of livelihood, loss of access to traditional food sources, loss of community and culture, negative health impacts from changes in water quality or food availability and increased social stress. Table 4.16 presents the displaced population by each project. In total, about 39 thousand people are estimated to be displaced during 15 years of construction time or about 2600 people annually. In the case of Nam Theun 2, (Laplante 2005) estimated this to be equivalent to an implicit per person one-time resettlement expenditure of US$ 7,400 if adjusted to 2017 with GDP deflator. Annual social cost of hydropower development will then amount to about US$ 19 million in Lao PDR.

Hydropower development will result in impacts to both the distribution and area of LMB wetlands primarily because of changes in flow and flooding. These impacts will affect, in turn, the quantity and quality of ecosystem services provided by those wetlands. The Mekong River and its associated wetlands (forests, marshes, and grasslands that are flooded during the

Table 4.16 Major Mainstream Hydropower Plants in Lao PDR

Location	Capacity (MW)	Capital investment (US$, millions)	Displaced population	Destroyed freshwater wetlands, hectares
Pak Beng	855	2,400	6,700	
Luang Prabang	1,410	2,800	12,966	
Xayaburi	1,285	3,700	2,130	
Pak Lay	1,320	2,400	12,000	
Sanakham	660	1,530	4,000	
Pak Chom	1,080	2,700	535	
Ban Khoum	1,870	4,400	700	
Lat Sua	650	2,100		
Don Sahong	240	720	66	
Total	**9,370**	**22,750**	**39,097**	**5,870**

Sources: Intralawan et al. 2017; MRC 2015.

rainy season) provide a wide range of ecosystem services. These services are essential in sustaining the livelihood and well-being of the local people. The wetlands provide food, medicinal plants, honey, and insects, among other resources, which benefit local people directly and nourish local spiritual and other cultural activities. Lao PDR has two Ramsar "Wetlands of International Importance" comprising 14,760 hectares (World Bank 2019). In total, about 5,870 ha of wetlands are estimated (MRC 2015) to be lost during 15 years of construction time, or about 391 ha annually. The World Wildlife Fund report estimated the average value of ecosystem services in the Lower Mekong Basin countries at US$1,639/ha/year for freshwater wetlands (Emerton 2013). However, a recent report estimated the average value of wetlands ecosystem services in the Lower Mekong Basin countries to be US$12,630/ha/yr (Mekong Region Futures Institute 2015). We estimated NPV (25 years, 6%/year discount rate) of ecosystem services lost for each hectare of wetlands at US$21–162 thousand. The resultant average annual cost of wetlands lost is estimated to be US$8–63 million[53].

4.5.2 Fisheries Abundance, Catch, and Losses

Almost all the territory of Lao PDR is of enormous importance for its fishery resources and for its rich aquatic biodiversity (Phonvisay 2013). The Mekong and Sekong rivers host more than 800 fish species that provide income and food to the people living in the bordering provinces of Stung Treng and Kratie in Cambodia, and Champasak and Attapeu in Lao PDR (MRC 2017). Diversity of fish species in the Mekong is approximately 3 times higher than fish diversity of the Amazon River. The Mekong Fish Database of the Mekong River Commission in 2003 listed 898 indigenous species and 26 exotic species in 2003 (World Bank 2019).

Fisheries play an important role in rural livelihoods in virtually all regions of Lao PDR. Most fishing is carried out as part of a diverse rural livelihood strategy, typically ranked as the second or third most important activity (after rice farming and animal husbandry) and contributing on average about 20 percent to rural household income (FAO 2005). In Southern Lao PDR, up to 80 percent of rural households are involved in the fisheries sector (FAO 2005). Lao PDR's 945,000 ha of rivers, water bodies and other natural and constructed wetlands are found to provide fish and other aquatic animals worth an estimated US$101 million per year for household subsistence, income and small-scale trade, an average of US$106/ha.

Approximately 70 per cent of all farming households, fish on a seasonal basis. Most of this fish catch is consumed within the household, but surpluses may be sold, and this accounts for about a quarter of the total catch. About 48% of all animal protein in Lao diets comes from inland fish and other aquatic animals (World Bank 2019). Few data available on the quantitative extent of fisheries in Lao PDR. Table 4.17 estimates capture fish production in 2007 for the Mekong River Commission. These are the most recent data currently available.

In the Mekong system, all its habitats, its tributaries, shallow lakes, wetlands and floodplains are important for fish production. Additionally, it is thought that deep pools are critical refuges for feeding during the dry season and spawning and/or nursery habitats during the wet season for many migratory species (Box 4.2) (Baran et al. 2007; Halls 2008; Poulsen et al. 2002).

Food security at the household level derives principally from forestry, livestock and fisheries, with freshwater fish being the principal source of animal protein for the rural population. Estimates of an annual per capita consumption vary from 15–57 kg/person/yr with an overall average for most of the provinces at 25 kg/person/yr (an additional 4 kg/person/yr comes from other aquatic animals). Fish consumption is even higher in the Central and Southern Lao PDR (Hortle 2007). Fish and aquatic organisms provide about 48 percent of the total animal protein consumption in Lao PDR (Phonvisay 2013).

Yet, the Mekong River faces threats such as unsustainable fishing practices with illegal fishing gear, accelerated infrastructure development with dam construction, and climate change, which all lead to deterioration in fish habitats.

Table 4.17 Structure of Capture Fish Production in 2007

Types of fisheries	Water resource	Total area (ha)	Production (kg/ha/year)	Production (tonnes)
Capture fisheries	Mekong River and tributaries and five northeast tributary rivers	304,704	70	21,329
	Large Reservoirs (hydropower):	96,030		8,405
	Nam Ngum Reservoir	45,000	133	6,000
	Nam Theun 2 Reservoir	45,000	33	1,500
	Others: Houy Ho: 3,750 ha Nam Leuk: 1,280 ha Nam Mang: 1,000 ha	6,030	150	905
	Shallow lakes, small natural pools, peat swamps, and wetlands	114,800	150	17,220
	Irrigation reservoirs and irrigation weirs	60,000	150	9,000
	Rice fields, small streams, and floodplains:			
	Wet-season rice fields	632,850	50	
	Dry-season irrigated rice fields	153,677	See note	31,643
	Wet-season irrigated rice fields	344,820	See note	1,500
	Flooded area	30,000	50	
Total		**1,238,384**	–	**89,097**

Source: Phonvisay 2013.

Note: It is assumed that irrigated rice fields produce few fish because of pesticide toxicity; more work is needed to test this assumption. Fisheries would benefit greatly from integrated pest management (IPM), which reduces pesticide use in rice fields.

Dams and reservoirs block natural fish migration routes; dams also alter the amount, timing, and speed of flow of rivers; the river's natural patterns of erosion and silt deposition; as well as water temperature and water quality; all of which can have massive impacts on aquatic life (Dudgeon 2011). Dams act as a barrier to fish migrating upstream, and fish migrating downstream generally have to pass through turbines, resulting in many of them being killed. Dams with large storage reservoirs affect river hydrology, including changes in the onset of floods, the extent of the area flooded and the duration of floods. Reduced transport of sediment into the floodplains reduces the nutrients available for aquatic plant growth and therefore fisheries productivity. At the same time, smaller floods of shorter duration reduce the available habitat for fish and reduce the survival rates of eggs and juveniles. Changes in dry season flows, and changes in the timing of the start of the floods, can disrupt the spawning and migration cues that trigger the changes in fish behavior needed for migration, reproduction and ultimately the survival of the species.

The lower Mekong Basin has three main upstream migration systems (see Figure 4.15): a lower zone below the Khone Falls, a zone upstream from the Khone Falls (Don Sahong Dam) to Vientiane, and a zone upstream of Vientiane where the six-dam cascade is planned in Lao PDR (Poulsen et al. 2002).

Figure 4.15 Location of Existing and Planned Dams in the Mekong Basin

Location of existing and planned dams.

1.Gongguoqiao
2. Xiaowan
3. Manwan
4. Dachaoshan
5. Nuozhadu
6. Jinghon
7. Ganlaba
8. Mansong
9. Pak Beng
10. LuangPrabang
11. Xayaburi
12. PakLay
13. Sanakham
14. PakChim
15. BanKoum
16. LatSua
17. Don Sahong (at KhoneFalls)
18. StungTren
19. Sambor.Dams

Estimates of total annual catch aggregated across all fish specie

- 60 000 t
- 0.9–1.2 Mt
- 1.0–1.3 Mt

Source: http://www.mrcmekong.org/topics/sustainable-hydropower/ (accessed April 9, 2019).
Note: Note that other estimates of catch (Barlow et al., 2008; MRCS, 2011a) differ slightly from these figures.

A substantial number of commercially valuable whitefish species migrate longer distances, as do all five of the globally endangered Mekong fishes. There is a considerable degree of interspecific variation in the timing of up and downstream migration (or larval drift). However, individual species migrations appear to be triggered by particular components of the annual flood cycle, such as rising water levels, with much of the upstream migration in the early wet season and least activity in the middle of the dry season (MRC 2011a; Poulsen et al. 2002). Maintenance of the natural flood cycle and connectivity that allow unobstructed passage along the river is essential for fish reproduction and hence a productive fishery (Barlow et al. 2008; Dugan 2008).

Dams cause two main kinds of impacts requiring mitigation: (i) a barrier impact, where a dam blocks a river or stream, and (ii) alterations to flow patterns, which then lead to other changes. Barriers to migrating fish can sometimes be reduced with artificial fish passages. Only a few fish passes have been built in the LMB, so there is a significant need to retrofit many dams as well as to design passage for new dams. Dams also drastically alter flow patterns, and of course, upstream of a dam, water is impounded in a reservoir. This is an artificial environment but may support fisheries, which can indirectly mitigate losses from the river fishery. Maintaining these reservoir fisheries also requires environmental management, such as artificial propagation and stocking of fish from nurseries. The impacts of large dams on fisheries are difficult to mitigate, so may require offsetting the impacts at other sites (Hortle and So Nam 2017).

At least 23 and probably >100 migratory fish species could be affected by the six Lao dams. Much of the effect would be associated with construction of the first dam at Xayaburi, and the associated transition from prevailing fast and seasonally diverse flow regimes to the limited water movement in a large reservoir. The six-dam cascade would convert about 40 percent of the mainstream riverine habitat in the LMB into a series of above dam lakes, representing a loss of 90 percent of the upper migration system (MRC 2011a). The predicted fisheries loss to the basin-wide capture fishery due to the reduction in the area accessible to fishes migrating upstream would be about 66,000 t or an overall, basin-wide reduction of 6 percent of the annual 2.5 Mt fishery yield (MRC 2011a). This conclusion is supported by the recent (MRC 2015) report on the water development scenarios for Lao PDR, where fish production is expected to be reduced by 38–52 thousand tonnes annually under different scenarios. We will use this latter number to estimate the cost of fish habitat destruction in Lao PDR.

Based on this fish catch reduction and the average first-hand sale price adjusted to 2017 with the GDP deflator at US$1.58/kg (MRC 2003), an estimate of 38–52 thousand tonnes of fish in Lao PDR is worth about US$60–82 million per year. If the share of cost is 50 percent, then net benefit lost in fishery due to hydropower development in Lao PDR is estimated at US$30–41 million per year (0.2–0.3 percent of GDP in 2017). Projected climate variation in several years of the 24-year projected time horizon, combined with the loss of fish-based protein, is likely to create conditions of acute levels of food insecurity in communities in Lao PDR and Cambodia (MRC 2017a). The emerging trade-offs between hydropower and fisheries are substantial and suggest a project-by-project assessment to identify the most harmful and the most beneficial projects and choose the interventions that allow supporting the wellbeing of the Lao PDR's rural population.

4.5.3 Summary Costs of Hydropower Development

Table 4.18 presents the estimated annual costs of social, environmental and fishery externalities associated with hydropower development in Lao PDR. The resultant total annual cost is estimated to be US$91 million per year (0.5 percent of GDP in 2017). The potential hydropower development should be planned and budgeted with mitigating interventions in mind.

Table 4.18 Estimated Annual Cost of Externalities from Hydropower Development in Lao PDR

	Total, US$, millions	Share of GDP in 2017
Social cost	19	0.11%
Environmental cost	36	0.22%
Fishery cost	36	0.21%
Total cost	**91**	**0.54%**

4.6 Cost of Natural Disasters in Lao PDR

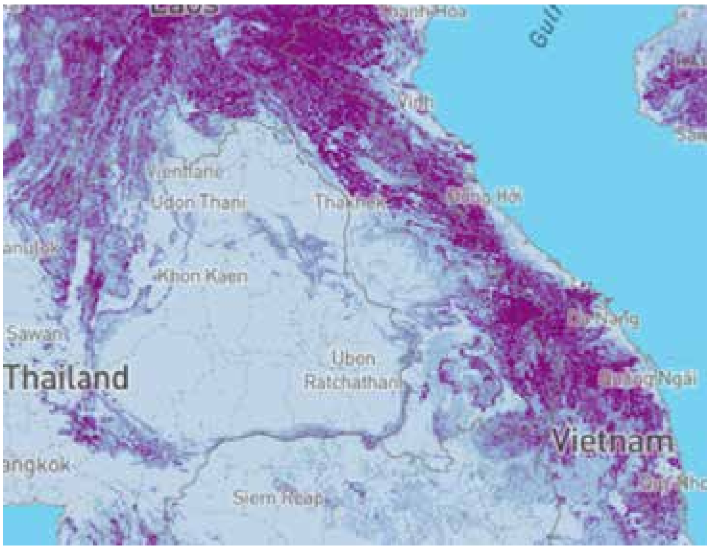
Monsoons are the most important cause of serious floods in the Mekong Basin, followed by the size, shape, and land use of the catchments, and by the drainage capacity of the corresponding streams. Additionally, flood impacts are intensifying from climate change (see section 4.8); as well as by natural changes in river morphology; and anthropogenic processes such as deforestation, and regulation. Floods intensify other natural hazards, like hazards of landslides that are especially dangerous on the eroded mountain slopes. Landslides' most frequent consequence is the loss of life. Currently, there is very little information on losses from landslides in Lao PDR, although landslide susceptibility is high[54].

Lao PDR updates the UNISDR site DesInventar with annual disaster data. The flood, storms, and flash flood annual events in Lao PDR, together with the directly affected population are reflected in 4.16 and Figure 4.17. Most of the floods occurred in the period 2007–2011. The maximum of the direct affected people was about 250 thousand in 2008.

4.6.1 Annual Costs from Floods

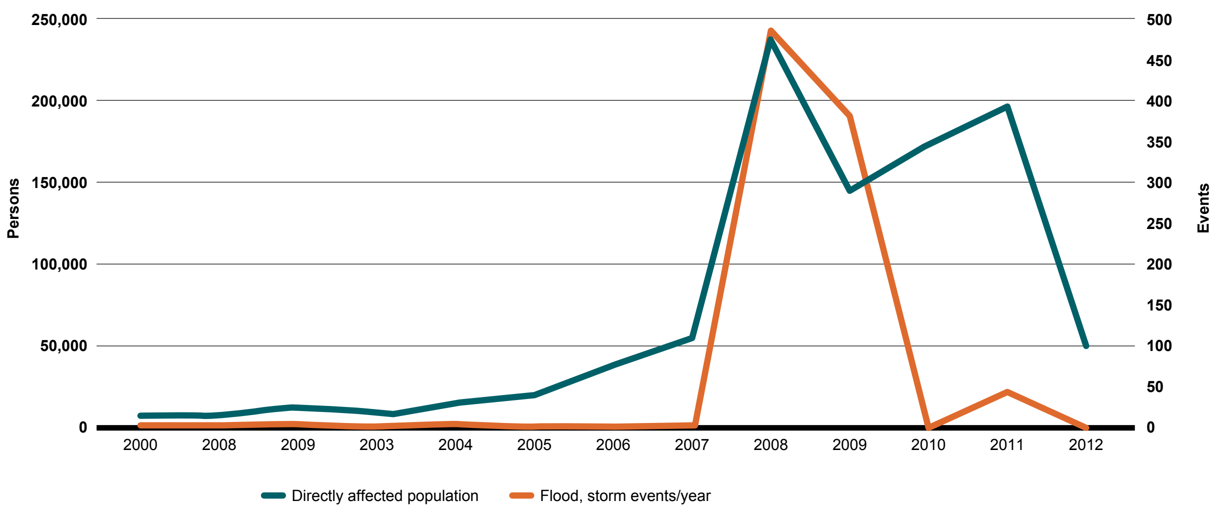
Table 4.19 presents estimated expected average annual cost that corresponds to annual losses as presented in DesInventar. The reported information is deemed reliable starting 2001. The latest year available for the information on natural disasters is 2012. The mean and standard deviation for annual average physical losses

Figure 4.16 Landslide Susceptibility in Lao PDR



Source: https://resourcewatch.org/data/explore/dis_007-Landslide-Susceptibility-Map

Figure 4.17 Flood Events and the Directly Affected Population in Lao PDR



Source: UNISDR DesInventar.

and their cost equivalent is estimated in table 4.19. Estimates for the average cost of house, education center, and hospital rebuilding in Lao PDR (US$10,000), cattle unit (US$500), nonfatal injury (US$950), and rural road rebuilding (US$40/meter) are based on various ADB reports. A damaged house is estimated at 0.1 of the house rebuilding, a directly affected person is estimated to lose 1 month of an average GDP per capita in Lao PDR in 2017, and an indirectly affected person—half of that. The average case of mortality and missing people are valued with the Value of Statistical Life (VSL) as in (Narain and Sal, 2016) that is estimated at about US$175,000 per case in Lao PDR. The mean annual cost of flooding in 2001–2012 is then estimated to be US$86 million, with a standard deviation of the estimate being US$155 million.

The risk adjusted (RA) annual cost of floods is estimated at US$148 million (0.9 percent of GDP in 2017). Risk Adjusted (RA) value is calculated as a sum of mean losses and an option value of flood losses in the long term that currently is uncertain. Option Value is calculated as 0.4 of the standard deviation.

This method of estimating the cost of floods in Lao PDR is based on short statistics from DesInventar. Another approach to estimating an annual cost of floods is based on a modeling of avoided risk of floods, while taking into account infrastructure for flood protection in Lao PDR. Such a system is designed to fully protect against small flooding events. However, it is very costly to protect against 50–year, 100-year, or even rarer catastrophic flood events, like the one that occurred in 2008.

There are models that allow for the estimation of the cost of annual average flood events, given a specific protection level achieved in the country. The Aqueduct Global Flood Analyzer (WRI AGFA) is a web-based interactive platform, which measures river flood impacts by urban damage, affected GDP, and affected population. The Analyzer allows estimation of the current flood risk for Lao PDR taking into account existing local flood protection levels (assumed at the range of protection between 5- and 10-year events). The tool also allows projection of future flood risk with three climate and socioeconomic change scenarios.

Table 4.19 Mean Annual Losses from Floods and their Cost in Lao PDR

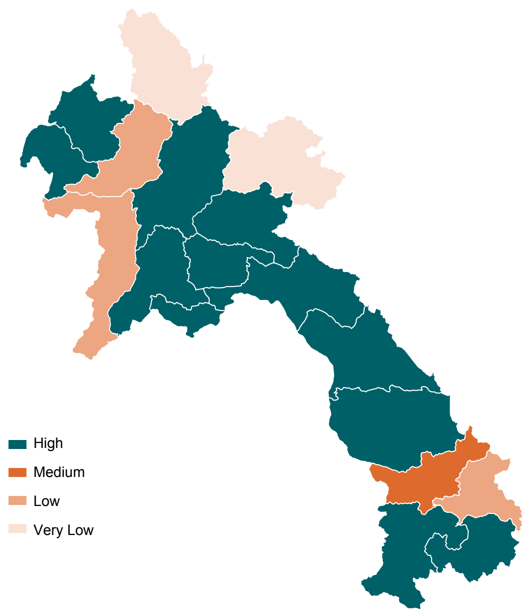
	Average in 2001–2012	Cost US$, millions	SD* in 2001–2012	US$, millions
Events	150		159	
Deaths	13	2	13	2
Injured	3,523	3	12,165	12
Missing	3	0.5	8	1
Houses destroyed	1,415	14	3,338	33
Houses damaged	6,212	6	13,533	14
Directly affected	35,774	7	78,628	15
Indirectly affected	262,369	26	421,439	41
Education centers	29	0.3	59	1
Hospitals	4	0	10	0
Damages in crops (hectares)	102,906	26	136,361	34
Lost cattle	1,805	1	3,779	2
Damages in roads (meters)	4,383	0.2	7,253	0
Total		**86**		**155**

Note: *SD=standard deviation.

River flood hazard in Lao PDR is presented in 4.18. In most of the country river flood hazard is high. This means that potentially damaging and life-threatening river floods are expected to occur at least once in the next 10 years.

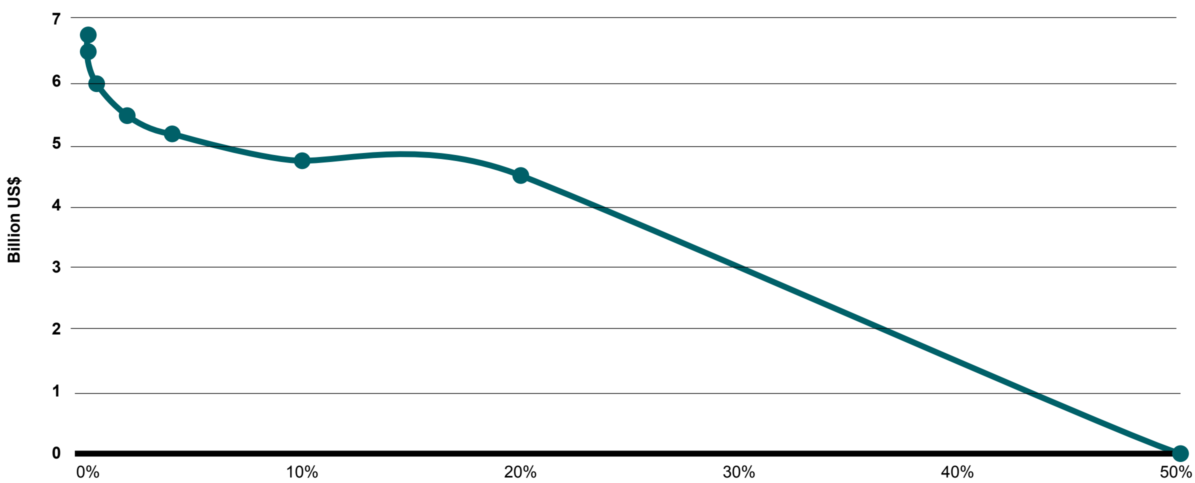
The affected GDP for Lao PDR is calculated for floods of the following magnitudes: 2-year (50 percent probability of occurrence), 5-year (20 percent probability of occurrence), 10-year (10 percent probability of occurrence), 25-year (4 percent probability of occurrence), 50-year (2 percent probability of occurrence), 100-year (1 percent probability of occurrence), 250-year (0.4 percent probability of occurrence), 500-year (0.2 percent probability of occurrence), and 1,000-year flood (0.1 percent probability of occurrence). The impact of a 2-year-flood event is estimated at zero. Scattered plot of risks that

Figure 4.18 River Flood Risk in Lao PDR



Source: http://thinkhazard.org/en/report/139-lao-peoples-democratic-republic/FL

Figure 4.19 Flood Risk Exceedance Curve for Lao PDR



corresponds to the event of each magnitude is a flood risk curve or exceedance probability-impact curve. The risk curve for Lao PDR fitted using Aqueduct model is presented in 4.19.

Annual expected GDP loss due to floods in Lao PDR depends on the level of flood protection. We assume that, with existing local flood protection schemes and early warning systems, the country is protected from 5- to 10-year flood events. We can then use low and high values of annual remaining affected GDP and affected population due to floods that are estimated from the Aqueduct model (Table 4.20).

The analysis in this study calculates an annual cost that affects productive flows in the country. Thus, annual expected affected GDP that is actually lost reflects the economic cost associated with floods. Assume that 30 percent of the affected GDP is lost due to floods. Applying these losses to the annual expected affected GDP, we then estimate that annual cost of floods in Lao PDR (with 5- to 10-year flood protection in place) is in the range US$112–211 million (0.66 percent to 1.25 percent of GDP in 2017). Note that the annual expected cost of floods depends on the effective flood protection in the country. The estimate takes into account probability and intensity of floods with different return periods in Lao PDR, as modeled by the Aqueduct Global Flood Analyzer (WRI AGFA 2018). The estimate based on the DesInventar information is close to the lower bound of the Flood Analyzer based estimate. The UNISDR Prevention Web 2018 reports the average annual loss from floods in Lao PDR to be about US$220 million, which is close to the upper bound of the Flood Analyzer estimate.

The Aqueduct Global Flood Analyzer also predicts the annual expected cost of floods under different climate change scenarios by 2030. This projected value is significantly higher than the current estimate; because it takes into account both socioeconomic changes and climate change in 15 years. With scenario B in place (severe climate change and current socioeconomic development trends) and using the same coefficients to transform the annual expected affected GDP into the annual cost of floods in 2030, the estimate is US$0.5–0.8 billion. Thus, annual cost of floods may increase 4 times by 2030. If the system of hydrological installations in Mekong River will be constructed to achieve protection from 100-year events (the Mekong commission estimates US$119 million investment required (MRC 2017a) then remaining expected annual flood cost is estimated at the level US$134 million, and the prevented annual cost at about US$330 million.

4.6.2 Annual Cost of Drought

Another hazard in Lao PDR is droughts. If there is insufficient rainfall in the year, or very uneven distribution of the rainfall, then drought sensitive areas will be affected. For the period spanning from 2003 to 2013 the Lao PDR has already experienced 2 years (2003 and 2007) with the devastating droughts (Mahachaleun and Phongpachith 2015). The CFSVA estimated that 46 percent of the rural population (around 188,000 households) is vulnerable to drought. Most of these households are in the lowlands, especially in the Southern regions and in the provinces of Xayabury and Luang Prabang.

Table 4.20 Estimated Annual Expected Economic Cost of Floods—Indicators in Lao PDR

	High (with 5-year flood protection)	Low (with 10-year flood protection)
Annual expected affected GDP	US$704 million	US$374 million
Annual expected affected population	214,000	114,000
Annual expected affected urban damage	US$77 million	US$49 million

Source: Aqueduct Global Flood Analyzer http://floods.wri.org

Table 4.21 Estimated Annual Cost of Natural Disasters in Lao PDR

	Low, US$, millions	High, US$, millions	Share (average) of GDP in 2017
Annual expected cost of floods	112	211	1%
Annual cost of droughts	3		0.01%
Total natural disasters cost	**115**	**214**	**1.01%**

Since official information on droughts is not available, DesInventar provides self-reported estimates that are based on collection of information on annual crops affected by droughts. This estimate on a national level amounts to the annual average expected damage of US$3 million. This estimate is significantly lower than flood cost, but frequency of droughts could increase with deforestation, altering of Mekong River flow, and climate change, and so the cost of droughts. Table 4.21 presents the estimated annual cost of natural disasters in Lao PDR.

4.7 Environmental Cost of Mining

Mining also contributes significantly to the Lao GDP (Figure 4.2 and Figure 4.5) and mining typically creates water quality problems and in the Lao PDR can create additional pressure on its forests. In 2014, Lao PDR produced a variety of mineral commodities, including barite, copper, gold, iron ore, lead, and silver (USGS 2017). There are a number of undeveloped mineral resources, and the government recognized mining as a critical sector of the economy and continued to support the development of the sector by promoting domestic and foreign investment. Employment in the mining sector, which comprised about 0.3 percent of the total population of the country, was 15,381, which represented an increase of 3.8 percent compared with 14,819 in 2013. The production of several mineral commodities increased significantly in 2014, such as clay (by 272 percent), barite (192 percent), potash (144 percent), tin (50 percent), salt (43 percent), and silver (23 percent). On the other hand, production decreased for limestone (by 80 percent), lignite (76 percent), sandstone (68 percent), gold (23 percent), and silicon (20 percent) (Mining also contributes significantly to the Lao GDP (Figure 4.2 and Figure 4.5) and mining typically creates water quality problems and in the Lao PDR can create additional pressure on its forests. In 2014, Lao PDR produced a variety of mineral commodities, including barite, copper, gold, iron ore, lead, and silver (USGS 2017). There are a number of undeveloped mineral resources, and the government recognized mining as a critical sector of the economy and continued to support the development of the sector by promoting domestic and foreign investment. Employment in the mining sector, which comprised about 0.3 percent of the total population of the country, was 15,381, which represented an increase of 3.8 percent compared with 14,819 in 2013. The production of several mineral commodities increased significantly in 2014, such as clay (by 272 percent), barite (192 percent), potash (144 percent), tin (50 percent), salt (43 percent), and silver (23 percent). On the other hand, production decreased for limestone (by 80 percent), lignite (76 percent), sandstone (68 percent), gold (23 percent), and silicon (20 percent) (Table 4.22).

The country's total exports were valued at about $2.66 billion in 2014, which was an increase of 17.6 percent compared with $2.26 billion in 2013. The value of all mineral commodity exports amounted to $1.29 billion (48 percent of total exports) and that of electricity exports amounted to $570 million (21.4 percent of total exports). Among the mineral commodities exported by Lao PDR, copper was valued at $1.07 billion, or 40 percent of total exports, and a 40 percent increase in value compared with that of 2013. Gold was valued at $140 million, or 5.3 percent of total exports, which was about a 9 percent decrease compared with that of 2013 (Bank of the Lao PDR 2014, cited in USGS 2014).

Table 4.22 Production of Mineral Commodities

Commodity (m tonnes)	2010	2011	2012	2013	2014
Barite	17,500	2,500	21,900	10,500	30,610
Cement	1,200,000	1,300,000	1,500,00	1,500,00	1,500,00
Clay	1,901,530	609,840	512,587	445,714	1,656,475
Copper content	67,806	59,897	63,285	64,885	71,155
Gold content (kg)	5,061	3,984	6,415	6,838	5,265
Iron Ore Gross	50,900	42,700	316,400	904,757	1,148,571
Lignite	501,622	511,700	578,068	403,925	99,144
Potash	NA	NA	42,798	86,499	210,983
Salt	13,421	23,395	11,980	6,099	8,706
Sandstone	3,695,838	339,331	1,214,668	1,211,899	391,186
Silicon	7,792	3,001	15,301	11,972	9,528
Silver	17,188	18,038	20,081	32,262	39,806
Tin	925	674	762	579	866

Source: USGS 2017.

Lao PDR has three types of mining systems: medium-large mines with modern production systems, small mines with obsolete machines, and traditional methods of artisanal gold mining without modern technology. Unregistered artisanal gold mines are probably leading to mercury being released to the watershed or directly into the waters. Many thousands of rural people do this to supplement family income (World Bank 2006). Estimates of gold reserves are significant, so artisanal gold mining is likely to continue. There are also anecdotal reports of unregulated copper mines creating serious water quality problems (Radio Free Asia 2018). The history of mining around the world has demonstrated that it often leads to serious metal pollution and acidic mine drainage into receiving waters. Mining operations almost always affect surrounding water bodies. Acid mine drainage brings water of low pH (high acidity) and high metal content into streams. This is true whenever mines are not properly regulated, and best management practices are not implemented.

In Lao PDR and neighboring countries in the Mekong delta floodplain, there are elevated concentrations of arsenic in drinking water tube wells, with a significant percentage exceeding the WHO guideline of 10 µg/l (Chanpiwat et al. 2011). The lower Mekong delta generally features saline groundwater. However, in areas with lower salinities and where rural populations started exploiting shallow groundwater as drinking water in replacement of microbial-contaminated surface water. In this groundwater, which is being used as drinking water, 37 percent of the studied wells had arsenic concentrations exceeding the WHO guidelines (Buschmann et al. 2008). Table 4.23 shows examples of mining operations north of the capital, Vientiane, and therefore the potential for water quality degradation. There is arsenic and other chemical contamination of surface water and drinking water sources. Chanpiwat et al. (2014) collected groundwater and hair samples from seven Lao provinces to determine the quantitative health impact of heavy metals through ingestion exposure. Contamination levels for arsenic (As; 46.0 percent) and barium (Ba; 16.2 percent) exceeded WHO guidelines, especially in Mekong River floodplains.

Table 4.23 Major Mining Operations in Nam Ngum River Basin, 2013

Company Name	Mineral type	District	Area (ha)	Concession period (years)
Phou Bia Mining Limited	Copper, gold, silver	Saysomboune	5,000.0	20
Qin Huang Dai Xin He	Ferrous	Saysomboune	15.0	20
Vangvieng Minerals	Ferrous	Kasy-Mat	220.1	10
Tangnay Ming Limited	Copper	Kasy	1.0	10
Bukane Limited	Lead-Zinc	Vangvieng	1.3	10
Lao First Pacific Limited	Coal			17
Cement Lao Limited	Coal	Vangvieng	53.5	20
Cement Lao Limited (II)	Limestone	Vangvieng	0.7	30
Sino Hydro Mining Limited	Potassium	Xaythany/Pakngum	39.4	30
Lao-Chinese Potassium Mining	Potassium	Xaythany/Pakngum	78.0	30
Lao-Yong Zieng Ferrous Limited	Ferrous	Perk	26.6	7

Source: Kallio 2014.

4.7.1 Health Impact Attributed to Artisanal Gold Mining

Artisanal mining, traditional in rural communities, consists of panning for gold and precious stones and is largely undertaken to supplement agricultural and other rural income. Mercury contamination is an important negative consequence of artisanal small gold mining that affects miners and water resources. As Poulin and Gibb (2008) report, mercury could be absorbed in an inorganic and organic form as methylmercury. Inorganic mercury vapor inhalation is the primary route of occupational exposure of gold miners, but mercury also can also be absorbed through skin. The most common form of organic mercury is methylmercury, which is formed when mercury in rivers is bio-transformed by aquatic microorganisms. Methylmercury is present in most aquatic species and bio-accumulates in the aquatic food chain, which may lead to high concentrations in fish, shellfish, and marine mammals. Environmental hotspots can occur near mining activities, where pollution of local water bodies may result in elevated levels of methylmercury in fish. There is no information available about exposure to methylmercury in Lao PDR. There is information about an exposure of artisanal gold mining workers (AGM) to inorganic mercury that is linked to health risk in miners.

Table 4.24 summarizes the health burden attributed to elementary inorganic mercury in artisanal gold mining workers. Steckling et al. (2017) estimates YLD attributed to moderate cases of chronic metallic mercury vapor intoxication (CMMVI) (mortality and severe cases are not included in the analysis). Steckling et al.'s estimates are based on the annual prevalence rate of CMMVI (24.2–29.9 percent) (Steckling et al. 2017), and disability weights (DWs) for moderate cases (DW: 0.368, UI: 0.261–0.484) and severe cases (DW: 0.588, UI: 0.193–0.907) (Steckling et al. 2015). The DW of moderate CMMVI, which is used in this analysis, is based on the same disease description presented in table 4.25. Severe cases of CMMVI are excluded because it is assumed that gold miners suffering from such severe health effects are no longer able to work and thus not included in the prevalence numbers. YLDs are presented with UIs indicating the impact of the uncertainty of the DW.

Table 4.24 Total Annual Cost Attributed to Exposure to Mercury of Miners in Lao PDR

	Low US$, millions	High US$, millions	Average US$, millions	%GDP
Mercury AGM	0.65	0.94	0.8	<0.1%

Table 4.25 Disease Profiles of the Moderate and Severe Cases of Chronic Metallic Mercury Vapor Intoxication (CMMVI)

Moderate case: Adults with high mercury body burden caused by chronic inhalation of metallic mercury vapor who show several of the following symptoms:	**Severe case:** Adults with a very high mercury body burden caused by chronic inhalation of metallic mercury vapor who show several of the following symptoms:
> Slight tremor of fingers, hands, and limbs; coordination problems; dysfunction of movement control; weakness > Reflexes abnormalities; peripheral nerve abnormalities; sensory disturbances > Sleep disorders; irritability; nervousness; fatigue; memory impairment; difficulty in concentration; shyness; depressive mood; loss of confidence; lack of self-control > Renal effects like enzymuria, proteinuria, and glomerular dysfunction, increased urinary excretion of N-acetyl-β-glucosaminidase (NAG) > Loss of appetite; salivation > Immunological changes	> Pronounced tremor in several parts of the body; severe coordination problems; dysfunction of movement control; weakness > Polyneuropathy > Insomnia; hyperirritability; nervousness; fatigue; loss of memory; difficulty in concentration; extreme shyness; depression; loss of confidence; lack of self-control; social avoidance > Abnormal renal function with enzymuria, high proteinuria, glomerular dysfunction, and rising urinary excretion of N-acetyl-β-glucosaminidase (NAG) > Anorexia; excessive salivation; gingivitis; stomatitis > Immunological changes > Difficulty seeing

Source: Adapted from Steckling et al. 2015.

It is estimated that from 0.17 to 0.3 YLD is lost annually per each miner. Lost YLDs are valued at GDP per capita in Lao PDR to come up with the annual health burden attributed to mercury exposure. In total, about 3,000 miners in Lao PDR as in Steckling et al. (2017) lose 262–378 healthy life years annually due to inorganic mercury exposure. The healthy life years lost are valued at GDP per capita in 2017. Health losses in the mining sector due to mercury exposure then amount to US$650–US$940 thousand.

4.8 Climate Change

Climate change will affect all natural, biological and agricultural resources of Lao PDR. The Lao PDR is located within the Southeast Asia Sub-region for the Fifth Climate Assessment Report of the International Panel on Climate Change (IPCC 2014). According to the IPCC, warming trends and increasing temperature extremes have been observed with high confidence, across most of the Asian region over the past century. There have been increasing numbers of warm days and decreasing numbers of cold days with the warming trend continuing. Precipitation trends including extremes are characterized by strong variability, with both increasing and decreasing trends observed in different parts and seasons of Asia. Water resources are important in Asia because of the massive population and these resources vary among regions and seasons. However, there is low confidence in future precipitation projections at a sub-regional scale and thus in future freshwater availability in most parts of Asia. Population growth and increasing demand arising from higher standards of living could worsen water security in many parts in Asia and affect many people in the future. Integrated water management strategies could help adapt to climate change, including developing water-saving technologies, increasing water productivity, and water reuse (IPCC 2014).

Rice production may be quite vulnerable to climate change. A range of general circulation models and emission scenarios show that higher temperatures will lead to lower rice yields because of shorter growing periods. Several regions are already near the heat stress limits for rice. However, carbon dioxide fertilization may at least in part offset yield losses in rice and other crops. In addition, sea level rise will inundate low-lying areas and will especially affect rice-growing regions (IPCC 2014). While Lao PDR is not coastal, some of its neighbors are, and Lao PDR is part of the larger Mekong River system, which will be affected.

4.8.1 Climate Trends in Lao PDR

Given Lao PDR's geographical location, its climate is dominated by monsoon variability, with the southwest monsoon particularly contributing to high rainfall and high temperatures from May to September. The monsoon contributes to a seasonal cycle of rainfall where more than 70 percent occurs during the wet season. In addition, the climate is driven by inter-annual rainfall variability that can be linked with extreme climate events such as frequent floods, mostly in the south, and droughts in the north (Lao PDR MoNRE 2013).

Rainfall patterns indicate that some parts of the country tend to have relatively high rainfalls, including Phongsaly, Oudomxay, Bokeo, Xayabury, Vientiane, and Bolikhamxay. In contrast, relatively drier areas encompass some parts of Xayabury and Vientiane. In general, many parts of the country are relatively rich in rainfall, while others are drier; such variance occurs even within the same regions. Historical rainfall data indicate increasing trends of seasonal and annual rainfall in the country. These upward trends are associated with the increased frequency of extreme events related to heavy rainfall in the region. Using probability analysis, it was found that monthly rainfall with an intensity of more than 600 mm has increased, while intensities between 300–500 mm have declined (Lao PDR MoNRE 2013). The warming climate has already affected biodiversity at the species and ecosystem levels, such as changing habitat conditions, and increasing vulnerability to pests and natural disasters (World Bank 2019).

Given that Lao PDR is particularly rich with water resources, including the Mekong's tributaries and countless smaller water bodies, increasing intensity of rainfall is of great concern. All Mekong tributaries contribute greatly to national macroeconomic development as well as livelihoods of local communities, but they are vulnerable to floods and droughts. The Mekong's 12 major tributaries in Lao PDR supply some 247 billion cubic meters of annual surface runoff, representing 35 percent of Mekong water flowing into its alluvial basin (Lao PDR MoNRE 2013).

WHO and UNFCCC (2015) and the World Bank Climate Portal identified the following climate trends in Lao PDR:[55]

- Under a high emissions scenario, mean annual temperature is projected to rise by about 4.5C° on average from 1990 to 2100. If emissions decrease rapidly, the temperature rise is limited to about 1.4C°;
- Under a high emissions scenario, the number of days of warm spells is projected to increase from less than 10 days in 1990 to about 170 days on average in 2100. If emissions decrease rapidly, the days of warm spell are limited to about 50 on average;
- Under a high emissions scenario, the number of days with very heavy precipitation (20 mm or more) could increase by about 7 days on average from 1990 to

2100, increasing the risk of floods. Some models indicate increases outside the range of historical variability, implying even greater risk. If emissions decrease rapidly, the risk is much reduced.

> Under a high emissions scenario, the longest dry spell is indicated to increase by about 10 days on average, from about 55 days on average in 1990, with continuing large year-to-year variability. If emissions decrease rapidly, the increase is limited to less than 1.5 days on average.

> Maximum monthly flows in the Mekong Basin will increase by 35–41 percent, while minimum monthly flows will drop by 17–24 percent by 2100, further exacerbating flood and drought risks.

4.8.2 Climate Hazards in Lao PDR

Lao PDR is inherently vulnerable to climate and other natural hazards due to its geographic and geophysical characteristics. It has high mountains and hills (steep slopes), considerable differences in elevation, narrow catchment areas, enormous river, water and wind forces (regular rain, raining season, river-flow dynamics, floods, strong winds, typhoons) that are changing and modulating the physical environment. Historically, because of full and dense coverage by forest and other protective vegetation, the landscape has exhibited considerable natural resilience to these influences, including climatic variability, occasional extreme weather events and other major hazard events. Forests, in particular, have played an important role in protecting mountain slopes, the banks of Lao's wide network of small and large rivers and other natural features from the impacts of extreme weather events. The economic, biological, social—and climate related—values of forests have long been recognized. The existing natural protective and regulatory functions of the forests as the country's first line of defense against a range of natural hazards including climate risks are therefore a major economic asset of the country.

Climate change has a wide range of increasingly less subtle impacts on biodiversity, including accelerated ecosystem succession, raised average temperatures, unseasonal frost on mountaintops, landslides and soil erosion, and flooding, amongst others. Observed changes in climate have already affected biodiversity at the species and ecosystem levels, including changing the timing of key life events, changing habitat conditions, and increasing vulnerability to pests and natural disasters. Through its contribution to ecosystem services, the protection and sustainable use of the biodiversity play a key role in enabling Lao PDR to better adapt to climate change. With its sensitive mountainous terrain, and its large agrarian population Lao PDR is particularly prone to climate change and increasing climate risks are placing further pressure on the environment and biodiversity values, including biodiversity. Floods, droughts, epidemics, and infestations occur regularly and, nationally, increasingly frequent climate-related hazards are anticipated because of climate change.

By maintaining high levels of biodiversity, the country will be in a better position adapt to extreme weather events that can be expected to increase in the future. Local landraces have been shown to provide more resilience to climate shocks and more yields compared to improved varieties in settings around the world. Genetic erosion, affected by land use change, is the main threat to landraces globally (World Bank 2019). Climate risks in the Mekong Basin are aggravated by a general forest cover reduction in the unique forest of the Lao PDR. These forests are crucial for the protection of the Mekong Basin. However, development in every sector of the economy contributes to this loss of forest cover and increases its vulnerability. Thomas (2015) analyzed major drivers of deforestation/forest degradation and estimated their relative contribution in the total forest cover loss/degradation in Lao PDR (Table 4.26).

With forest cover decreasing in the critical areas, climate hazards particularly floods, became apparently more frequent and have intensified in recent years. It was found that about half of these hazards occurred between 1966 and 1992, a period of 26 years, while the other half occurred between 1992 and 2009, a period of only 17 years. Thus, the frequency of the climate related hazards in Lao PDR increased from about once every two years before 1992 to every year or even twice a year after 1992. Areas affected by floods also grew at an accelerated pace during the last two decades (1992–2009). Areas flooded before 2002 generally were less than 1,200 km^2. However, in 2009 alone more than 2,500 km^2 of land was flooded (Lao PDR MoNRE 2013; WHO & UNFCCC 2015). Climate and Health Country Profile—2015: Lao PDR) project that by 2030, an additional 40,400 people may be at risk of river floods annually as a result of climate change and 27,800 people due to socioeconomic change above the estimated 48,200 annually affected population in 2010.

Although not as frequent and devastating as floods, drought hazards also have been more frequent and more intense in the last three decades. Between 1995 and 2005, drought conditions were characterized by higher and irregular increases in temperature. Abnormally high temperatures in 1996 and 1998 triggered the occurrence of drought in various areas and ecosystems, including ponds, streams and lakes (Lao PDR MoNRE 2013).

A recent thorough assessment of climate change in the LMB projected higher temperatures and reduced rainfall beyond suitability thresholds for many crops by 2050, under several climate-change scenarios. The flowers of traditional rain-fed rice, for example, become sterile at temperatures higher than 35°C. This is in the context of the IPCC's (2014) general conclusion that rice production is likely to decrease in this sub-region.

Table 4.26 Drivers of Deforestation and their Contribution to the Total Annual Deforestation

Sources	Impact	Annual rate of forest loss	Remarks
Wood extraction	Forest degradation	Estimated between 0.97 to 1.57 million m^3 per year from 2002 to 2009	Includes commercial logging, illegal logging and household consumption. The combined total represents the primary driver of unsustainable deforestation and degradation and is a high GoL priority to control.
Agricultural expansion	Deforestation	Commercial 34,200 ha/yr; small-holder 14,700 ha/yr	Since 2007, GoL has placed several successive moratoriums on new concessions.
Industrial tree plantation	Deforestation	6,000 ha/yr	GoL is prioritizing tree plantations; however, deforestation occurs when plantations replace natural forest.
Pioneering shifting cultivation	Forest degradation and deforestation	57,300 ha/yr degraded	GoL continues to make efforts to control shifting cultivation. However, such areas regenerate quickly.
Hydropower	Deforestation	13,100 ha/yr	The rate is likely to increase further as many more new hydropower projects are built.
Mining	Deforestation	5,100 ha/yr to 14,100 ha/yr	Only certain types of mining (for example, large-scale bauxite strip mining) are likely to cause extensive deforestation, but the cumulative effect of thousands of smaller, local artisanal mines is a bigger driver of deforestation.
Infrastructure	Deforestation	1,000 ha/yr to 2,000 ha/yr	Direct impact may be relatively small but indirect impact from increased accessibility (road construction, and so forth) is much higher.

Source: Thomas 2015.

In MRC (2017b), three climate scenarios to 2040 examined climate change impacts on the Mekong Basin. Each scenario had similar increases in temperatures, but different changes in rainfall, which is the main uncertainty for climate change forecasts in this region. The three scenarios tested were designed to cover the possible range of likely change based on RCP4.5 (IPCC 2013). The analysis looked at food security, including potential impacts to rice production. In different parts of Lao PDR, the study predicted only a relatively small decrease in the rice surplus. The range in the change of rice surplus was from no impact to one scenario, which had an impact only of minus 7 percent (MRC 2017b). These forecasts are quite different from what the IPCC (2014) expects regarding decreased rice production and are based on only one of the two lower emission pathways from the four RCPs (IPCC 2013).

By 2050, maximum temperatures in many areas of the LMB—such as Gia Lai in Vietnam's Central Highlands—are projected to exceed this threshold during the growing season, significantly lowering rice yield if proper adaptation measures are not taken (ICEM 2013). Modeling indicates that climate change will make land in the LMB less suitable for rubber and coffee, to the likely detriment of large rubber plantations in eastern Cambodia, southern Lao PDR, and Vietnam's Central Highlands.

Worldwide, climate change and increased climate variability are also expected to have substantial impacts on forests and related ecosystem services. Climate change could have the following impact on forest ecosystem services in the LMB: (i) reduced plant and animal productivity, (ii) decline and loss of a range of non-timber forest products, (iii) reduced regulation of erosion and sedimentation, (iv) reduced regulation of flash flooding and landslides, and (v) reduced nutrient cycling (ICEM 2013).

Some of the most contagious infections are also highly sensitive to temperature, precipitation, and humidity change. These aspects of climate have a strong influence on the life cycles of the vectors and the infectious agents and influence the transmission of water and food-borne disease. Socioeconomic development and health interventions, on the other hand, are reducing this health burden. Climate change negatively affects agricultural production and causes breakdown in food systems. These disproportionally affect those most vulnerable people at risk to hunger and can lead to food insecurity. Vulnerable groups risk further deterioration into food and nutrition crises if exposed to extreme climate events. WHO and UNFCCC (2015) projections are as follows:

> The Lao PDR population at risk of malaria will have a greater decrease towards 2070 under a low-emissions scenario (300 thousand reduction of malaria compared to a high-emissions scenario annually).

> The mean relative dengue fever transmission is projected to increase under a high-emissions scenario from the baseline of 0.55 to about 0.62 towards 2070. If global emissions decrease rapidly than dengue transmission could be limited to about 0.57 by 2070;

> Under a high-emissions scenario, heat-related deaths in the elderly (65+ years) are projected to increase to about 72 deaths per 100,000 by 2080 compared to the estimated baseline of about 3 deaths per 100,000 annually between 1961 and 1990. A rapid reduction in global emissions could limit heat-related deaths in the elderly to about 15 deaths per 100,000 in 2080.

4.8.3 Adaptation to Climate Change

The Lao PDR National Green Growth Strategy is focused on raising agricultural productivity to move away from expansion of production areas into a gradual increase of productivity per hectare. This will require use of new infrastructure in an increasingly effective manner, such as irrigation infrastructure (Lao PDR NIER 2018).

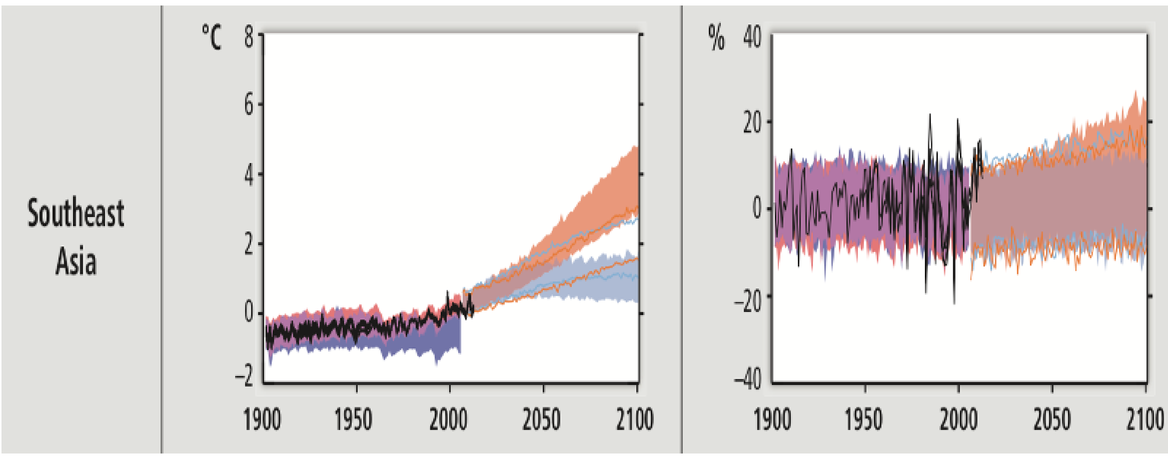
The National Adaptation Action and Policies for Lao PDR (World Bank 2016) are drafted based on information from submitted (Intended) Nationally Determined Contributions ((I)NDCs). Five sectors are highly vulnerable to climate change and require priority adaptation measures: agriculture, forestry, water resources, health, and urban development. The document aims to increase development planning and scale the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten sustainable development. Box 4.3 summarizes corresponding adaptation priorities in these sectors.

The cost of implementation of adaptation interventions is estimated at US$0.97 billion. About 70 percent of this cost is required to improve the resilience of agricultural production and agricultural productivity. This win-win strategy addresses the needs of the poor, who are most affected by climate change. Another 18 percent of the total cost is to be spent on sustainable urban planning where flood damage is relatively high and adaptation interventions will demonstrate higher efficiency.

It is difficult to assess quantitatively effectiveness of adaptation interventions given high uncertainties of climate change scenarios. Figure 4.23 from the IPCC (2014) illustrates the crucial uncertainties associated with future climate change in this region. Temperatures will steadily rise, although by an unpredictable amount. Evaporation rates will increase, affecting the overall hydrological system in some form. Long-term predictions for precipitation changes are extremely uncertain. It will be very difficult to predict whether and how much worse flooding will be. Future damages will be difficult to predict. If floods and droughts are more frequent or more severe, then the potential for agricultural losses will increase.

How much worse might flooding and drought become, and therefore what levels of infrastructure investment might be required? Managing the Mekong Basin system will become a classic risk-management problem. However, climate resilient sustainable development interventions will reduce cost of natural resource degradation, and simultaneously increase resilience to climate change. This will require thoughtful and flexible investment approaches to infrastructure development (Golub and Brody 2017).

Figure 4.20 Observed and Simulated Variations in Past and Projected Future Annual Average Temperature (left) and Precipitation (right) over Land Areas



Source: IPCC 2014.

Box 4.2 Adaptation Priorities in Lao PDR, Target Year 2020, Cost of Implementation US$0.97 billion

Agriculture (climate smart agriculture)—Implementation cost US$709 million:

- Improve appropriate resilient agricultural farming system practices and technologies, conservation of agricultural soil, animal health and disease outbreak monitoring and control, long term feed storage improvement, climate resilient crops, efficient water use cropping systems, short rotation cropping and maximize the use of indigenous climate resilient knowledge;
- Develop and improve crops and animal diversification and resilience, especially in the risk, flood and drought areas;
- Upgrade agricultural research and extension services.

Forestry and LULUCF (sustainable forest management)—Implementation cost US$40.5 million:

- Develop and enforce appropriate laws, regulations and implement guidelines for sustainable forest management;
- Strengthen capacity in integrated land use planning, watershed, forest management, reduction of slash and burn practices to increase resilience of forests;
- Promote integrated actions on watersheds, reservoir management, water storage for agroforestry, wildlife management, fisheries and tree varieties, prevention of drought;
- Forest survey and allocation for sustainable management and rural development;
- Strengthen the capacity of technical stuff and village forest volunteers;
- Promote forest seed and seedling production for reforestation and forest restoration;
- Research and select forest species resilient to pests, diseases, drought, and soil erosion.

Health (health services and infrastructure)—Implementation Cost US$5 million:

- Development of climate resilient health related infrastructure and facilities such as health care facilities, laboratories, rural water supply and sanitation systems;
- Increase capacity on climate change impact assessments, estimating financial needs and implementing resilience plans in the health sector;
- Improve education, research on climate change induced disease and health impacts, its treatment, monitoring and reporting;
- Improve medical and food supplies, nutritional surveillance, drinking water improvement by better management of its supply network;
- Increase public and vulnerable community awareness to climate change induced health risks and provide advisory and warnings, enhance first aid and promote self-help and access to health care services of communities;
- Develop policies to increase the ability of vulnerable groups and the poor to access health services.

Water (water infrastructure) – Implementation Cost US$44 million:

- Strengthen information gathering, modeling and vulnerability assessment for climate change in priority river basins in Lao PDR;
- Develop and implement reliable early warning systems, reporting and information dissemination services;

Box 4.2 continued.

Water (water infrastructure) – Implementation Cost US$44 million:

- Strengthen the protection of watersheds to safeguards and moderate downstream flow during periods of high and low flow;
- Study and promote conservation of wetlands as a part of climate resilient ecosystem-based approach;
- Develop and strengthen standards and procedures to ensure the safety of dams and other water resource related infrastructure;
- Design and build multi-purpose dam and reservoirs to ensure sufficient water supply in drought prone areas and seasons;
- Construct/rehabilitate dykes and enhance riverbank protection and irrigation systems to increase climate resilience;
- Increase awareness and technical capacity of stuff regarding climate change impact water resources and appropriate technologies, and wetland management;
- Study water treatment that has ground water and ecosystem impacts.

Urban (sustainable urban planning)—Implementation Cost US$190 million:

- Conduct climate risk audits for key infrastructure services;
- Ensure flood protection and drainage design for urban infrastructure;
- Ensure that urban water supply systems have adequate design and operational standards for climate change impacts, including access to low flows in water sources, water treatment capability and flood protection;
- Build storm surge/flood protection works for urban infrastructure.

Source: Word Bank 2016.

4.9 Conclusions

Lao PDR is a country of great natural wealth, natural resources, and biodiversity. The majority of the Lao PDR's people base their livelihood on their homeland's natural capital. As the country modernizes and promotes economic development, there are serious problems of environmental degradation that have led to quantifiable economic damages of US$822 million annually, or 4.7 percent of GDP in 2017 US$. Table 4.27 summarizes the estimated annual economic costs of environmental degradation across various sectors of the Lao PDR economy.

Protected areas and other forest resources are an important source of income for the poor. Most Mekong River Basin inhabitants are money-poor, but they can be resource-rich. When natural resources are depleted in the service of economic development, the poor lose a significant share of their livelihoods and their food security is at risk. Food security risks and malnutrition exacerbated by unsustainable exploitation practices and climate change pose great challenges. The poor bear most of the cost associated with natural resources degradation. The livelihoods of the rural poor include some combination of subsistence farming, fishing, hunting, and gathering. The rural poor depend heavily on living resources that are health. Opportunities from agricultural expansion are typically limited for most of the rural poor. To assist the poor during developmental changes requires their access to, and adoption of small-scale agroforestry, reforestation and forest conservation projects, and biodiversity corridors. Additional fisheries mitigation to counter the negative consequences of hydropower development is required. These interventions can be specifically targeted to help those who may lose out from the long-term economic development and modernization in Lao PDR.

Biodiversity protections are critical. Government decrees can further strengthen commitment to the nascent national park agenda and to the internationally recognized IUCN protected area categories. The MAF can clarify the roles at national, provincial, and district levels in supporting village forest management, as well as the role of private investments in socially and environmentally sustainable commercial plantations. Continued support for Lao PDR MoNRE's Department of Natural Resources and Environmental Policy to strengthen the application of environmental and social impact assessment of infrastructure projects in and around protected areas could reduce the impact on biodiversity, ecosystem function, tourism development, and local poverty reduction. Tourism concessions in PAs and other natural landscapes should provide clear steps and incentives for businesses to invest and allow sustainable businesses to operate at a profit. The government should invest in capacity building in protected area management, village forest management, and interagency law enforcement collaboration for mitigating illegal timber- and wildlife-related trade. Mainstreaming biodiversity into education and learning should be one of the country's priorities. Outreach and environmental education on climate change mitigation and adaptation should be promoted in village forest communities, as should research by relevant government research institutes, Lao universities, and concerned NGOs. The national park and protected area system could be strengthened by diversifying revenue into each reserve (World Bank 2019).

Large-scale mining and hydropower developments can result in severe negative environmental and social effects, even with implementation of standard control measures. Environmental sustainability of natural resource production will depend on the effective implementation of existing regulations. Environmental sustainability must be an integral part of natural resource exploitation. While the legal framework is mostly adequate, there is a crucial need to strengthen the government's capacity for implementing and enforcing those laws (World Bank 2010).

To better manage the Lao PDR's natural resources, this report recommends significant improvements to basic natural resource and environmental data, information, and analysis, including the following:

> Better and more-accurate maps of forests, both type and extent.

> Better quantitative estimates of soil loss from erosion, not just in the uplands, but also especially across all agricultural types of land and at the catchment level.

Table 4.27 Summary Costs of Environmental Degradation in the Lao PDR

	Total, US$, millions	Share of GDP in 2017
Cost of deforestation	275	1.6%
Cost of forest degradation	189	1.1%
Cost of natural disasters	165	0.9%
Soil degradation cost	101	0.6%
Cost of hydropower development and fish habitat destruction	91	0.5%
Cost of AGM exposure to mercury	0.8	<0.1%
Total	**822**	**4.7%**

> Resolving different estimates of agricultural land uses, productivity, and yield.

> Better information about the use of agricultural inputs, specifically chemical pesticides and fertilizers.

> Developing a comprehensive and accessible water quality monitoring system, especially downstream from mining.

> Forecasting upstream and downstream hydrological changes from hydropower development and changes to fisheries habitats.

> Developing regionalized probabilistic models of natural disaster risk management.

> Local/regional studies of climate that account for the higher RCPs and not just the lower ones, and that account for the latest IPCC analyses.

4.10 Notes

43 This chapter was prepared by Michael Brody and Elena Strukova Golub and draws upon additional material by the same authors and John Parr.

44 The Gridded Population of the World, Version 4 (GPW v4), Population Density Adjusted to Match 2015 Revision of UN WPP Country Totals, produced by SEDAC, consists of estimates of human population density, based on counts consistent with national censuses and population registers with respect to relative spatial distribution but adjusted to match the 2015 revision of UN World Population Prospects country totals for the years 2000, 2005, 2010, 2015, and 2020. https://resourcewatch.org/data/explore/soc_031-Gridded-Population

45 The Vice Minister of Foreign Affairs, H.E. Mr. Thongphan Savanhphet, mentioned opportunities to learn about how other countries in the region, including Cambodia, have managed their natural capital.

46 Produced capital and urban land encompasses machinery, buildings, equipment, and residential and nonresidential urban land, measured at market prices (Lange et al. 2018).

47 Natural capital, including agricultural land and forests, is measured as the discounted sum of the value of the rents generated over the lifetime of the asset (Lange et al. 2018).

48 Human capital is measured as the discounted value of the lifetime earnings of a person participating in the labor force (Lange et al. 2018).

49 Net foreign assets are measured as the sum of a country's external assets and liabilities (Lange et al. 2018).

50 The Deputy Director General of the Department of Forestry, Ministry of Agriculture and Forestry, Mr. Saysamone Phothisane, indicated that the GoL is trying to increase the forest cover to 70% of the national territory by 2020.

51 Deforestation estimates are based on Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. (2013) "High-Resolution Global Maps of 21st-Century Forest Cover Change." *Science* 342 (November 15): 850–53. Data available from: http://earthenginepartners.appspot.com/science-2013-global-forest.

52 Lao PDR MAF 2005 target calls for the establishment of 500,000 ha of industrial tree plantations. Achieved tree cover of 300,000 ha when combined with the area of industrial tree plantation (ITP) applications of companies submitted to Ministry of Planning and Investment (MPI) would already be close to the FS2020 target for ITP (FRA 2015. Lao PDR).

53 The Deputy Minister of Energy and Mines, H.E. Mr. Thongphat Inthavong, indicated that his ministry is coordinating with line ministries to mitigate the impacts of hydropower and mining projects, and to implement measures to protect the environment.

54 http://thinkhazard.org/en/report/139-lao-peoples-democratic-republic/LS

55 https://climateknowledgeportal.worldbank.org/sites/default/files/2018-10/wb_gfdrr_climate_change_country_profile_for_LAO_0.pdf

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5

ENVIRONMENTAL PLANNING AND ENVIRONMENTAL IMPACT ASSESSMENT[56]

Chapter Overview

The Lao People's Democratic Republic adopted legally binding Environmental and Social Impact Assessment (ESIA) regulations that build on environmental provisions of the Constitution, the Environmental Protection Law (EPL), and other laws. The Department of Natural Resources and Environmental Policy (DNEP) of the Ministry of Natural Resources and Environment (MoNRE) is the central authority responsible for ESIA approvals, and the Department of Natural Resources and Environmental Monitoring (DNREM) is responsible for monitoring, compliance assistance, and oversight of ESIA-related projects in Lao PDR.

Recent comparative analyses of ESIA capacity suggest that Lao PDR is showing leadership in reforms aimed at making ESIA an effective tool for managing project planning and environmental and social impacts. Several indicators place the Lao PDR ESIA regime among the most progressive in the region; however, there are still opportunities to improve information disclosure and public participation, and environmental management and monitoring. Taking advantage of these opportunities, an ESIA Decree enacted in January 2019 contains provisions to include cumulative and health impacts of investment projects.

The 2019 Decree also has provisions aimed at enhancing disclosure of information and public participation, with increased emphasis on giving a voice to project-affected persons (PAPs) while respecting their culture, religion, traditional beliefs, and gender roles. By 2020, public consultations should be conducted for each phase of investment projects to ensure transparency, justice, and efficiency. Disclosure of information and public involvement are important parts of the project owner's engagement and are essential to ensure the legitimacy of the ESIA and the acceptance of the project.

Other important reforms that are being endorsed include provisions to clarify roles and responsibilities of MoNRE and other national, provincial, municipal, and local authorities and setting timelines for the review and approval of ESIA applications, as well as deadlines for preparation and submission of relevant documents. While DNEP has been assigned a leading role in implementing the ESIA system, a strong effort is underway to make sectoral ministries and provincial and local governments active in the ESIA oversight process. Under the new decree, the duties of the agencies responsible for the management and inspection of ESIA activities are clearly defined.

5.1 Introduction

Environmental and Social Impact Assessment (ESIA) is a now ubiquitous tool for environmental and social impact analysis for proposed projects around the world. The first ESIA program worldwide was established by the United States Congress in the National Environmental Policy Act (NEPA) of 1969 (Park 2008). Section 102(2)(c) of NEPA established the basis for requiring US federal agencies to prepare an environmental impact statement for any project that would "significantly affect" the quality of human environment, by assessing the environmental consequences of development projects, analyzing alternatives, and ordering public disclosure of the report to affected groups (US CEQ 1997).

The main purpose of the US NEPA is to foster excellent action by requiring that a process be undertaken to "help public officials make decisions that are based on understanding of environmental consequences, and take actions that protect, restore, and enhance the environment."[57] Thus, under NEPA, ESIA could be described as a process to open up decision-making to public scrutiny (Ortolano et al. 1987). NEPA's provisions cover all US policies, regulations, and public laws, as well as recommendations or reports on proposals for legislation and other major federal actions[58] with the potential to significantly affect the quality of the human environment.[59]

During the 1980s, international nongovernmental organizations (NGOs) pressured International Financial Institutions (IFIs) and their shareholders to make these organizations adopt environmental management policies (Keck and Sikkink 1998; Nielson and Tierney 2003; Wade 1997). In 1989, the US Congress passed the provision known as the "Pelosi Amendment," which, according to Bowles and Kormos (1999), played an important role in the development of the World Bank's ESIA policy. The amendment required the US Executive Director to abstain from voting on proposed multilateral development bank loans with potentially "significant" environmental impacts unless an ESIA (including any relevant supporting documents such as environmental management plans, resettlement action plans, and so forth) had been made available at least 120 days in advance and disseminated to the public (Wirth 1998, 66).[60] Under the "Pelosi Amendment", US representatives on the IFIs' boards of directors had to promote the creation of "Environmental Departments" in all the multilateral development banks (Hicks et al. 2008). In October 1989, during the US Congressional debates over environmental impacts of projects funded by IFIs, the World Bank released its environmental assessment policy (Bowles and Kormos 1999).

During the 1990s, other International Organizations and Development Banks (IODBs) adopted their ESIA policies and practices. However, unlike NEPA, ESIA policies and practices adopted by IODBs did not aim to open decision-making to public scrutiny, but to mitigate the negative environmental impacts with the aim of ring-fencing IODB-financed projects. These policies are the basis of these organizations' safeguards systems. The safeguard systems were developed to address the general absence of corresponding client safeguard systems (legal frameworks and implementing institutions). This general absence of safeguard systems produced instances of severe adverse outcomes for the environment and project-affected peoples in IODB-supported projects (Rich 1995). Environmental assessment practices are not uniform across IODBs; however, their approach to ESIA is similar in many ways, particularly with respect to ring-fencing internationally funded projects by using a methodology that mainly aims to "do no harm."

Many of the objectives and principles of the IODBs' environmental assessment policies are also reflected in international conventions and legal instruments such as the Aarhus Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters, and the Espoo Convention on Environmental Impact Assessment in a Transboundary Context. These conventions have been ratified by many governments. The "do no harm" approach to many aspects of ESIA has been incorporated into best practice guidance notes, such as those developed by EIA practitioners, including the International Association for Impact Assessment and the Institute for Environmental Management and Assessment.

Many governments around the world have adopted legally binding ESIA regulations similar to IODBs' ESIA regulations, often with technical support from these organizations. This is the case of most countries in Asia and in Latin America and the Caribbean. This is also the case in Lao PDR, where the ESIA system has been two decades in the making. It dates back from requirements for ESIA preparation in the 1999 *Environmental Protection Law,* which were revised and updated in 2012, and then replaced by Lao PDR *Environmental Protection Law 041/NA*. Lao PDR's ESIA regime is similar to the ones in many developing countries, and it is governed by a number of specific regulations that build on environmental provisions in Article 19 of the Constitution (2003), the *EPL*, and other laws. In addition to ESIA-preparation criteria, the system includes provisions for an Initial Environmental Examination (IEE) process, which, according to the *EPL*, is the responsibility of the provinces (Earthrights International 2016).

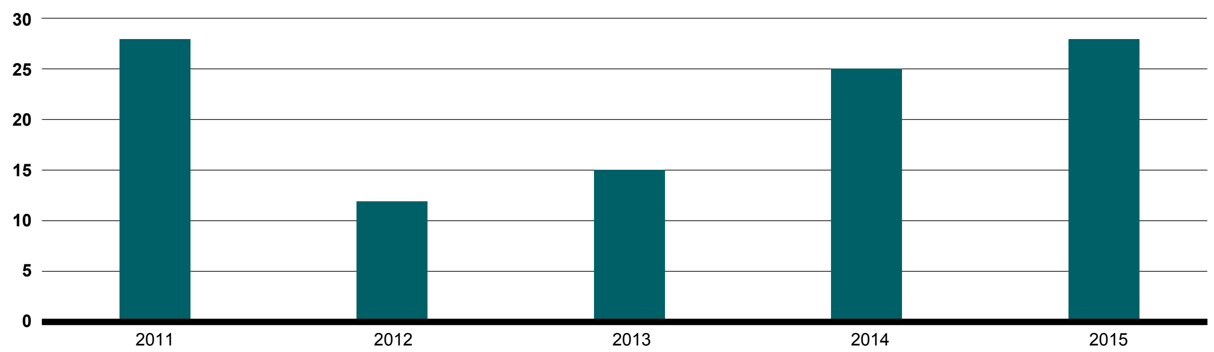
Within the *EPL* framework for environmental protection, ESIA requirements are contained in *EPL* Articles 17, 21, and 22. Under these articles, IEE and ESIA are designated new categories of tasks to prevent environmental damage. Article 19 details related provisions on Strategic Environmental Assessment.

Soon after enacting the 2012 *EPL*, MoNRE issued two Ministerial Instructions to implement the provisions of *EPL's* Articles 21 and 22: (i) Process of Environmental and Social Impact Assessment of the Investment Projects and Activities No 8030/MoNRE (Ministerial Instruction on ESIA 2013), and (ii) the Ministerial Instruction on the Process of Initial Environmental Examination of the Investment Projects and Activities No 8029/MoNRE (MoNRE 2013a; 2013b).

The Department of Natural Resources and Environmental Policy (DNEP) of MoNRE is the central authority responsible for ESIA approvals, and the Department of Natural Resources and Environmental Monitoring (DNREM) is responsible for monitoring, compliance assistance, and oversight of ESIA-related projects in Lao PDR. To date, DNEP has focused on the review and approval of ESIA applications, with comparatively less attention dedicated to other aspects such as monitoring and oversight of approved projects. DNEP issued an average of 22 ESIA approvals annually between 2011 and 2015 (Figure 5.1). The number of ESIAs under review and issued Environmental Compliance Certificates (ECC), following approval of an IEE at the provincial level or an ESIA at the ministry level, varies every year. However, there has been a steady growth since 2012. In 2017, 30 ESIAs were approved. Approved ESIAs include projects in the following sectors and areas:

- Energy (hydropower);
- Mining (active mines include copper, gold, barite, zinc, silver, lead, lignite, bauxite, iron, and potash);
- Industrial production (for example, steel processing, sulfuric-acid production, and pulp-paper production);

Figure 5.1 Number of ESIAs Certified by MoNRE per Year (2011–2015)



> Infrastructure (roads, bridges, hotels, and airports);

> Agriculture and planted forests (for example, sugarcane and banana plantations, and commercial tree plantations); and

> Enterprises in special economic zones (SEZs).

The limited available data about ESIA deployment in Lao PDR suggest that ESIAs can be important tools in educating stakeholders about the environmental and social implications of projects, both individually and cumulatively. Thus, ESIAs can provide stakeholder education that might otherwise be lacking. Educated stakeholders potentially become problem solvers, working with both the proponents of projects and the authorities. Ideally, stakeholders could also act as regulators of developers and authorities and contribute to improve the overall capacity for ESIA preparation and enforcement, although this is currently rare in practice in Lao PDR.

In developing countries, the influence of public participation or stakeholders' concerns on the final outcome of ESIA has been found to be weak (Chompunth 2011; Naser 2012; Song and Glasson 2010). The ultimate goal is to ensure that ESIAs improve the environmental efficacy of projects to advance Lao PDR's ambitious Green Growth Agenda.

5.2 ESIA and the Green Growth Agenda in Lao PDR

As part of Lao PDR's GG Development Policy Operations (GGDPO), the Lao PDR Ministry of Natural Resources and Environment (MoNRE) has led the development of new policies and implementing regulations to strengthen the application of ESIA legislation by improving coordination among key agencies during the review, approval, and monitoring of ESIAs of investment projects, as well as through improved disclosure of information to the public. The GoL has carried out a comprehensive review of the existing ESIA system and complementing regulations to improve its effectiveness, including on information disclosure. MoNRE also aims to adopt additional decrees to strengthen the quality and regulation of ESIAs, with provisions on screening, scoping, public participation, information disclosure, assessment requirements, reviewing and approval of ESIA reports, and budgetary allocation for compliance monitoring. These elements are essential for resource efficiency and avoiding or minimizing negative social, environmental, and climate impacts.

To complete this task, MoNRE has cooperated closely with the Office of the Prime Minister, the Ministry of Planning and Investment (MPI), the Ministry of Energy and Mines (MEM), the Ministry of Industry and Commerce (MoIC), the Ministry of Public Works and Transport (MPWT), the Ministry of Agriculture and Forestry (MAF), provincial and city governments, and other key stakeholders. These efforts have included a clear emphasis on improving disclosure of information and public participation in the ESIA process, especially by potentially affected parties and disadvantaged groups. This is a hallmark of best practice in ESIA procedures worldwide.

Policy reforms present an opportunity to improve ESIA procedures in Lao PDR, increasing ESIA effectiveness as both a planning and regulatory tool, in support of the current GG agenda. Such improvements have been deemed critical in most low- and middle-income countries, where self-assessment and accountability for the performance of the primary government agencies are often lacking and are an impediment to successful ESIA implementation (Kolhoff, Driessen, and Runhaar 2018).

MoNRE's aspirations for improving ESIA processes come at a time when environmental and related social challenges are increasing in Lao PDR. According to the 2020 Environmental Performance Index (EPI), Lao PDR ranks 130th of 180 countries on 32 performance indicators across 11 issue categories covering environmental health and ecosystem vitality (Yale Center for Environmental Law & Policy, Columbia Center for International Earth Science Information Network, and World Economic Forum 2020) (Table 5.1).

Table 5.1 Environmental Performance Index Rankings for Selected Countries, 2020

Indicator	Position of Lao PDR	Position of Cambodia	Position of Vietnam	World leader	Position of leader in Southeast Asia
Overall EPI ranking	130	139	141	Denmark	Singapore (39)
Environmental health	132	118	98	Finland	Singapore (22)
Air quality	135	125	115	Finland	Singapore (24)
Heavy metals	146	145	92	Denmark	Singapore (19)
Ecosystem vitality	126	145	176	Denmark	Indonesia (98)
Biodivesity & Habitat	62	92	150	Botswana	Laos (62)
Ecosystem services	165	163	166	Bahrain, Iceland, Malta, Micronesia, São Tomé and Principe, and United Arab Emirates	Brunei (89)
Water resources	134	134	119	Denmark, Finland, Netherlands, Singapore, and Sweden	Singapore (1)
Climate change	155	154	155	Denmark	Indonesia (78)

Source: Yale Center for Environmental Law & Policy, Columbia Center for International Earth Science Information Network, and World Economic Forum 2020.

At the same time, Lao PDR is asserting regional leadership on environmental and social justice topics that will be supported by its strengthened ESIA system. For example, as host of the 28th and 29th ASEAN Summits, Lao PDR oversaw the development of the ASEAN Plus Three (Japan, People's Republic of China, and Republic of Korea) Leaders' Statement on Promoting Sustainable Development Cooperation (Vientiane, September 7, 2016). Among the commitments in that ASEAN Leaders' Statement is rendering concerted efforts to fulfill the 17 Sustainable Development Goals (SDGs) over the next decades as part of the ASEAN Plus Three cooperation framework. Several SDGs, including sustainable production and consumption, are supported by effective ESIA processes in Lao PDR.

Improved application of the ESIA system in Lao PDR is expected to help green growth by minimizing the environmental impacts of investment projects. Adopting strict and stable environmental procedures for ESIA, and enforcing them in a clear and transparent manner, has improved the business climate in the most competitive countries. A country's business climate is crucial to enabling businesses to operate optimally and increase their productivity. Particularly in an economy—such as Lao PDR—that is heavily based on natural resources, the successful incorporation of environmental factors into a country's competitiveness structure makes the business climate more attractive to foreign investors, orients agriculture and industrial sectors toward higher market values, reduces the pressure of productive sectors on the natural resources base, and offers new business opportunities in global markets (Lopez-Claros et al. 2005).

In another important boost to business confidence, ESIA reforms may improve the reputation of Lao PDR government entities working with project proponents and the public as reliable and predictable regulators. ESIA reforms may also contribute to improving the competitiveness of the Lao PDR economy by increasing project proponents' confidence in ESIA as a project-planning tool, as well as informing project planners about compliance costs for environmental mitigation measures as an integral component of project operations. Progress in this arena will likely improve economic prospects in the country, particularly if these reforms enhance private-sector confidence in the consistency of government actors.

According to the 2017–2018 World Economic Forum Global Competitiveness Index, lack of confidence in government institutions is among several factors that contribute to Lao PDR's low ranking at 98th of 137 countries (a decline from Lao PDR's ranking at 93rd in 2016–2017) in the WEF survey (Schwab 2017).

Recent comparative analyses of ESIA capacity in Lao PDR and other Asian countries suggest that Lao PDR is showing leadership in reforms aimed at making ESIA an effective tool for project planning and for managing environmental and social impacts. In the 2016 report Strengthening ESIA in Asia, the Institute for Global Environmental Strategies (IGES) (see Sano et al. 2016) makes three recommendations for improving ESIA as a planning tool: innovations aimed at effective collaboration among ministries, better training and capacity development, and effective compliance mechanisms. In all three areas, the IGES study praises innovations in Lao PDR, including the development of a comprehensive online project-management database between MoNRE and MPI, and training on ESIA implementation for both national and local officials. In the challenging arena of designing effective compliance mechanisms, Lao PDR is singled out for three of four noteworthy initiatives in Asia (Sano et al. 2016, vi):

> *innovative approaches to address this issue include incorporation of the ESMMP [Environmental and Social Management and Monitoring Plan] as a part of the concession agreement for the project (Lao PDR), regular review of the environmental compliance certificate (Lao PDR), review of monitoring reports by an external institution (Korea), and establishment of independent monitoring bodies (Lao PDR).*

Yet, despite indicators that reforms in Lao PDR may place its ESIA regime among the most progressive in the region, recent international scrutiny of the ESIA regime in Lao PDR found several problems with the current system. For example, Sano et al. (2016); Wayakone and Makoto (2012); and Wayakone, Makoto, and Harashina (2013) identify major challenges and needs regarding implementation of the ESIA system in Lao PDR with respect to the quality of ESIA, information disclosure and public participation, and environmental management and monitoring. Lack of transparency in the ESIA system allows opportunities for unqualified and potentially corrupt actors to profit from the ESIA preparation process, thereby subverting its environmental and social objectives to improve project design and implementation. In addition, project developers are responsible for hiring the consultants who prepare the ESIA, resulting in a clear conflict of interests. Developers' main interests are meeting the bare minimum legal requirements and overcoming any potential objections to the project. Consultants thus have incentives to focus on these objectives, rather than on conducting rigorous environmental studies. In many countries, ESIA has become the main environmental management tool and is often the only instrument used to address complex environmental problems, serving as a de facto substitute for regulations in key areas, such as pollution control, biodiversity conservation, and effective land-use planning (Acerbi et al. 2014). This is also a risk in Lao PDR. The following sections discuss these risks in the context of the most recent ESIA legislation and current ESIA practice in Lao PDR.

5.3 Available Data on Environmental Assessment in Lao PDR

This section summarizes relevant information shared by DNEP and MoNRE's DNREM and provides statistics on ESIA and environmental monitoring up to December 2018.

Environmental Assessment

Table 5.2 shows the number of projects by sector with Environmental Compliance Certificates (ECCs) according to the category of assessment and project status. As of the end of 2018, there were 300 projects in the ESIA database, with ECCs covering seven different economic sectors. Energy projects make up just over a quarter (27%) of all projects listed that require some type of environmental assessment, and over 80% of energy projects are considered to require an ESIA. The table also shows that 84 projects (28% of all projects) have obtained an ECC without having conducted an ESIA or Environmental and Social Management and Monitoring Plan (ESMMP). This includes the majority of construction, roads, and bridge-building projects, airport projects, and special economic zones (SEZs). According to the statistics, four projects with ECCs have been cancelled, and a further 39 projects are not yet operational.

Table 5.3 shows projects with ECCs according to their current phase of operations. Almost half of the projects with ECCs (46%) are currently in the operational phase, and 28% have already been decommissioned. Approximately one-third of the projects with ECCs are either in the preconstruction or construction phase of development.

Figure 5.2 and Figure 5.3 provide a breakdown by sector of projects in the preconstruction and construction phases, respectively. Energy and mining projects together account for the majority of projects with ECCs at the preconstruction (83%) and construction (84%) phases of project development.

Agriculture and forestry projects account for more than a quarter (27%) of projects with ECCs in the operations phase of project development, followed by energy (22%), mining (18%), and transmission lines (Figure 5.4). Regarding projects in the closure phase, energy and road/bridge projects make up the vast majority (84%). Road and bridge projects could be integrated into either operation or closure categories when they are in use, so they have been classified as being in an unidentified phase (Figure 5.5).

Table 5.2 Statistics on ESIA by Economic Sector in 2018

Sector	Number of Projects with ECC	Type of Assessment*			Projects with ECC but no SIA/ESMMP	Cancelled Projects with ECC	Nonoperational Projects with ECC
		IEE	ESIA	ESMMP			
1. Energy	80	15	65	–	12	2	20
2. Transmission lines	27	18	9	–	9	–	1
3. Old industry	19	1	15	3	2	–	3
3. New industry	2	–	1	1	–	–	0
4. Old mining	49	4	40	5	–	2	11
4. New mining	10	–	8	2	–	–	0
5. Road-bridge	29	26	3	–	27	–	0
6. Building, airport, special economic zones	34	20	14	–	26	–	0
7. Agriculture-forestry	50	32	17	1	8	–	4
Total	**300**	**116**	**172**	**12**	**84**	**4**	**39**

Source: Department of Natural Resources and Environmental Policy, MoNRE 2019.

Note: * Type of assessment required. As per the next column, 84 projects have been granted an ECC without having conducted ESIA or ESMMP.

Table 5.3 Projects with ECCs According to their Phase of Operations

Project Phase	Preconstruction	Construction	Operation	Closure / Unidentified
Total	**47**	**51**	**139**	**83**

Source: Department of Natural Resources and Environmental Policy, MoNRE 2019.

Figure 5.2 Projects with ECCs at the Pre-Construction Phase of Operations

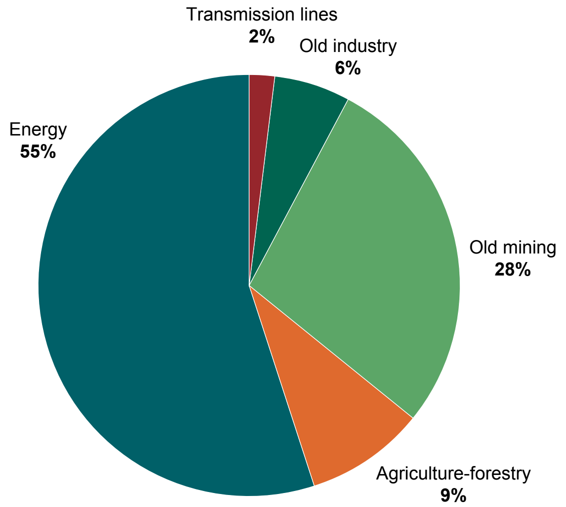


Figure 5.3 Projects with ECCs at the Construction Phase of Operations

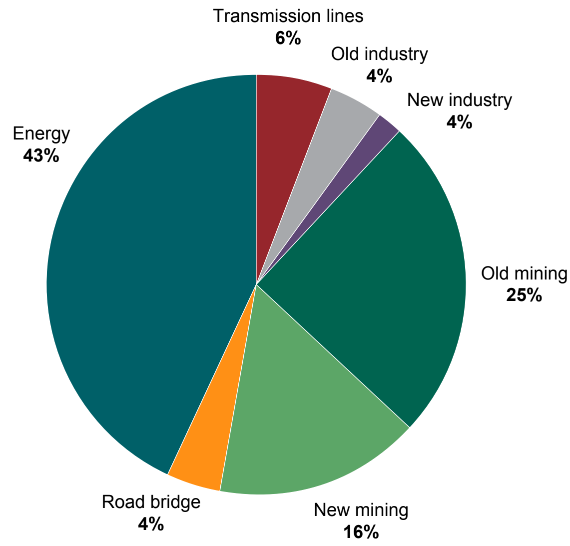


Figure 5.4 Projects with ECCs in the Operations Phase of Project Development

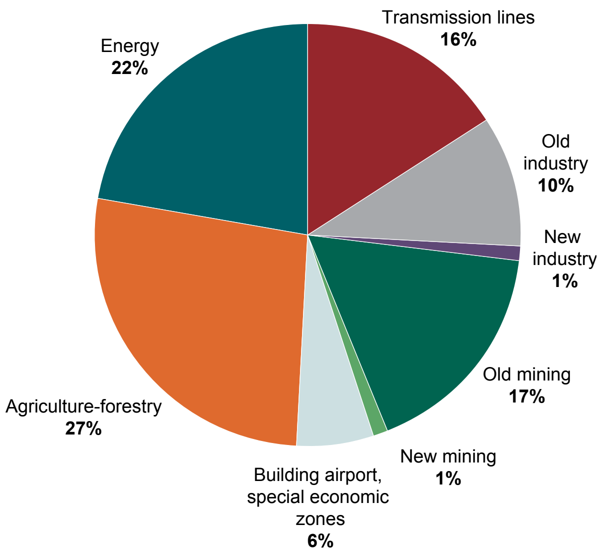
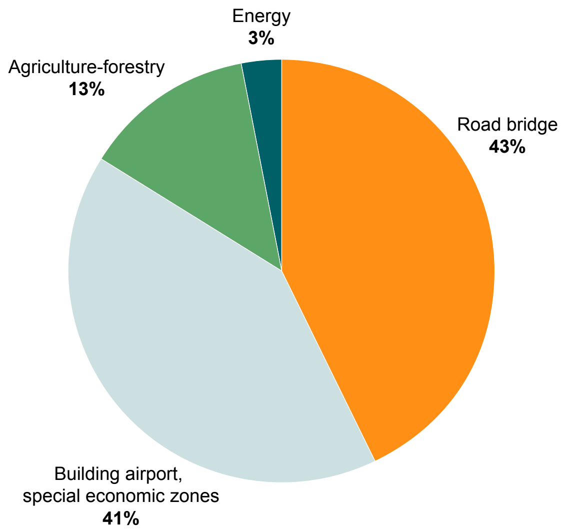


Figure 5.5 Projects with ECCs in Closure or Unidentified Phases



Environmental Monitoring

The information provided by the DNREM in Table 5.4 shows that 173 of the 300 projects in their database have committed to external monitoring by MoNRE and line agencies at the provincial and district levels. Of those 173 projects, 88 have already provided the corresponding budget to MoNRE, and monitoring is being conducted on a regular basis. The remaining 85 projects had not provided budget as of May 2019. MoNRE provided two reasons to explain why the other 127 projects were not being monitored. The first was that many projects are not considered to require ongoing monitoring after the construction phase (for example, road/bridge projects). The second was that some projects were developed long before the ESIA process was strengthened, and a GoL monitoring budget was not set as a requirement for the ECC at the time of project development.

Figure 5.6 and Figure 5.7 provide data on GoL monitoring of projects in the period January to November 2018. According to the data, a total of 50 monitoring missions were conducted over that period including 27 regular monitoring activities, 17 emergency monitoring events, 2 monitoring activities related to biomass removal in hydropower dam inundation areas, and 4 monitoring events as part of the ESIA review process. Mining and industry accounted for 48% of all monitoring activities, including 8 out of 17 emergency monitoring events and all ESIA review monitoring.

Regarding budget sources for monitoring, the majority of funding is sourced by the company either directly (72%) or via bank account (14%). The World Bank Lao Environmental and Social Project (LENS) also provided funds to monitor one energy (regular monitoring) and one mining project (emergency monitoring). Three projects were subjected to emergency monitoring utilizing funding from the Environmental Protection Fund.

Table 5.4 Projects with ECCs and a Commitment to GOL Environmental Monitoring

Sector	Projects have ECC, monitoring budget for GOL, and regular monitoring conducted	Projects have ECC, monitoring budget committed but not provided
1. Energy	27	19
2. Transmission lines	2	15
3. Old industry	7	7
3. New industry	0	2
4. Old mining	25	11
4. New mining	0	10
5. Road-bridge	0	2
6. Building, airport, special economic zones	4	4
7. Agriculture-forestry	23	15
Total	**88**	**85**

Source: Department of Natural Resources and Environmental Monitoring, MoNRE 2019.

Figure 5.6 GoL Environmental Monitoring by Type and Sector in 2018

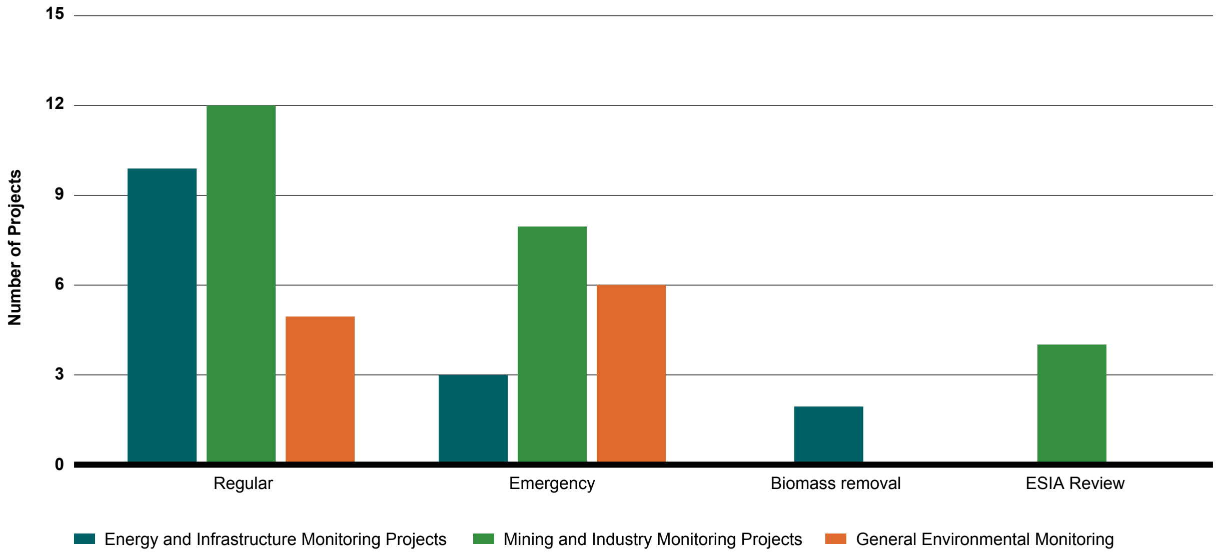
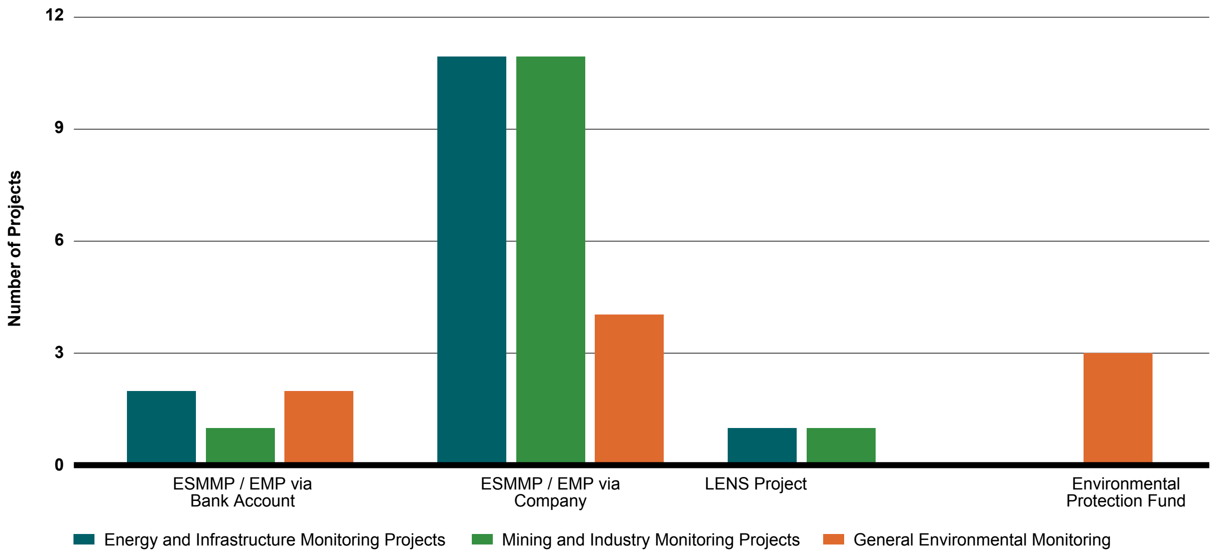


Figure 5.7 GoL Environmental Monitoring by Budget Source and Sector in 2018



5.4 Role of ESIA in the Lao PDR Environmental Management Framework

5.4.1 Mandated Agencies

MoNRE's Department of Natural Resources and Environmental Policy (DNREP) is responsible for the overall implementation and oversight of the ESIA system in Lao PDR. MoNRE's prominent role is associated with the conception of ESIA as an environmental management tool. Under this conception, the environmental authority acts as an evaluator that assesses whether the proposed action meets administrative criteria to obtain the environmental certificate (EC).

However, a strong effort is underway to make sectoral ministries and provincial and local governments active in the ESIA preparation and oversight process. Thus, while DNEP has been assigned a leading role in drafting the new Environmental and Social Impact Assessment (ESIA) Decree, this effort is in close cooperation with the Office of the Prime Minister, the Ministry of Planning and Investment (MPI), the Ministry of Energy and Mines (MEM), the Ministry of Industry and Commerce (MoIC), the Ministry of Public Works and Transport (MPWT), the Ministry of Agriculture and Forestry (MAF), the province/city, and other key stakeholders.

Under the new decree, the duties of the agencies responsible for the management and inspection of ESIA activities are clearly defined. These organizations are not limited to MoNRE, but include the provincial and district offices of natural resources and environment.

It is important to move beyond measuring the success of mandated agencies according to their procedural fulfillment of ESIA requirements and look at indexes of the substantive impact of the ESIA exercise on the environmental and social footprint of new projects. In Lao PDR, given the importance of the new green growth agenda, it is reasonable to expect more of MoNRE and other mandated agencies than simple fulfillment of the steps of ESIA compliance. Recently enacted investment-oriented laws in Lao PDR explicitly require adherence to environmental protection obligations, broadening the legal foundation for ESIA requirements on project proponents. Most noteworthy in this regard is the 2016 *Law on Investment Promotion*, Article 74.

5.4.2 Screening

Screening refers to the process "to determine whether or not a proposal should be subject to EIA and, if so, at what level of detail" (IAIA 1999). An effective and efficient screening process allows decision-makers to identify the actions that have the potential to generate significant environmental impacts and use their limited resources to carry out ESIAs of adequate depth for such projects.

In contrast, an ineffective and inefficient screening process typically results in a massive number of actions being subject to an ESIA, with each type of action being subject to a similar ESIA regardless of different potential impacts. Consequently, the authority must stretch its limited resources to carry out a myriad of ESIAs, resulting in lengthy delays in the issuance of the permits and licenses needed to undertake the action. In this context, the usefulness of ESIA is reduced substantially, since it becomes a bureaucratic hurdle for the development of projects with limited or negligible environmental impacts, while simultaneously failing to address with adequate depth the significant environmental impacts of other actions.

The screening procedure most commonly used around the world are lists that define the types of projects that require an ESIA. Evidence from other countries suggests that lists are often too rigid, which limits their ability to filter out the actions that would not generate significant environmental effects, and thus, a wide range of actions must complete the analysis.

In the case of Lao PDR, the new ESIA Decree classifies investment projects into the following groups:

> **Group 1**: investment projects and activities seen as causing less-severe or not-severe impacts on social and natural environment and therefore requiring an IEE;

> **Group 2:** investment projects and activities seen as causing huge or severe impacts on social and natural environment and therefore requiring an ESIA.

Projects estimated to have impacts on health also require a health impact assessment.

MoNRE, in coordination with concerned ministries and local administration agencies, determines the types and sizes of projects that fall into each category. The 2013 Ministerial Agreement on the Endorsement and Promulgation of List of Investment Projects and Activities Requiring for Conducting the Initial Environmental Examination or Environmental and Social Impact Assessment lists the projects and activities that are in Group 1 and Group 2, based on defined thresholds. If a project is not on the list, the natural resources and environment sector[61] will conduct the screening process and determine whether an environmental impact assessment is necessary.

In addition, ESIA is required for all projects (irrespective of type and size) that include resettlement and compensation in accordance with the *Prime Minister's Decree on Compensation and Resettlement of People Affected by Development Projects* N° 192/PM. An ESIA is also required if the planned project is in a socially or environmentally valuable area, such as a National Protected Area or National Protection Forest—areas that also require project approvals by the Lao PDR National Assembly.

5.4.3 Scoping

Scoping is the stage of the ESIA process in which the issues and impacts likely to be important are identified and, based on those issues and impacts, the Terms of Reference (TORs) for the ESIA are established (IAIA 1999). Whereas the screening mechanism is intended to help separate the actions likely to cause significant effect from those that are not, the scoping phase aims to distinguish the impacts of a specific action likely to be significant from those that are not. Thus, the scoping phase is critical for the ESIA process's effectiveness and efficiency, since scoping enables the lead agency, the action developer, and the rest of the stakeholders to center their resources where they are most needed, while limiting the attention that is given to nonsignificant issues.

Open scoping processes provide an opportunity for groups that may be affected by a proposed action to express their concerns and to ensure that the ESIA duly considers the impacts that may be more significant for them. In contrast, when public participation is not contemplated in the scoping processes, the ESIA may focus only on the impacts that the action's proponent or the responsible officials consider relevant.

In the case of Lao PDR, the 2019 ESIA Decree gives the project developer the responsibility of determining the scope of assessment and works prior to preparation of the ESIA. The scope of the project must be consistent with the regulations issued by MoNRE and determined by an environmental service provider that is duly licensed. MoNRE, in consultation with other concerned ministries and sectoral agencies, will review and approve the scoping report within 15 working days from the date of receiving the documents from the project owner.

The project owner is then required to prepare the comprehensive ESIA report and an Environmental and Social Management and Monitoring Plan (ESMMP). The ESIA report and the ESMMP are reviewed by MoNRE in conjunction with specialists from provincial and district offices. MoNRE collaborates with the project owner to convene consultation meetings with relevant stakeholders, including project-affected persons (PAPs).

5.4.4 Preparation and Review of the ESIA Report and Environmental and Social Management and Monitoring Plan (ESMMP)

ESIA systems worldwide vary in their provisions regarding who is responsible for selecting and hiring the consultants that will prepare the required ESIA report and other documents (Wayakone, Makoto, and Harashina 2013). In Lao PDR, as in most low- and middle-income countries, project owners are responsible for selecting and hiring duly-licensed consultants. This might result in conflicts of interest, because developers are mainly concerned with obtaining the ECC needed to develop the project. Given MoNRE's limited current capacity to monitor the ESIA process, it is largely up to the project owner to take the lead in the ESIA process. Yet, the project owner has incentives to hire a consultant that is not necessarily interested in enhancing the authority's decision-making process, but instead in meeting the minimum legal requirements set by the authority and overcoming any potential objections to the project. This does not necessarily mean that consultants generally aim to deceive the authority, but that they lack incentives to include in their documents information that may be relevant for the authority if such information may result in denial of the license or the setting of additional conditions for the approval of the proposed action.

As in many other countries, Lao PDR's ESIA system assigns the environmental authority (MoNRE) the responsibility for evaluating the ESIA report and associated documents, while government agencies from other sectors and levels of government have an opportunity to provide comments on relevant projects, at least as intended under current regulations (Wayakone and Makoto 2012; Wayakone, Makoto, and Harashina 2013). In Lao PDR, MoNRE must coordinate with the project owner to organize technical and consultation meetings at the provincial and central levels during the review period. In these meetings, the developer has an opportunity to present the ESIA report to representatives from all relevant government agencies, as well as to potentially affected stakeholders. MoNRE is then responsible for compiling all comments received during the technical and consultation meetings and sending them to the project owner, which is then responsible for addressing the comments in a revised ESIA report.

MoNRE is then responsible for approving or rejecting the ESIA report. Reasons for rejecting the report include the risk that the project would result in substantial, unavoidable, and unremedied social and environmental impacts, or that the proposed project or activity would not be consistent with the national environmental policies or strategic plans. As in many other countries, there is arguably significant discretion in the government official that ultimately evaluates the ESIA. For instance, different officials might have different interpretations about whether a specific project is consistent with the national environmental policy. This challenge is exacerbated by the lack of transparency in the process, which means that project developers and PAPs generally have little information about the rationale supporting the authority's decision.

The Ministerial Instruction contemplates a specific procedure for evaluating projects that MoNRE considers Complicated Investment Projects and Activities. For these projects, MoNRE must establish a technical expert committee consisting of experts and consultants not involved in the project or activity. The committee provides comments to help MoNRE evaluate the proposed project. The 2019 ESIA states that foreign specialists may be hired to assist in reviewing relevant documents.

Most ESIA systems worldwide include a follow-up mechanism that helps authorities to ensure that the conditions for approval are fulfilled, to monitor whether the action's environmental impacts are similar to those predicted by the ESIA, to assess whether the selected mitigation measures are effective, and to generate information to improve other ESIAs. In Lao PDR, the project developer is also required to prepare an Environmental and Social Management and Monitoring Plan (ESMMP) to be submitted (along with any other required reports such as resettlement action plans, gender and ethnic plans, public consultation and disclosure plans) as a separate report along with the ESIA report. The ESMMP must be updated every two to five years, in consultation with MoNRE. The reviewing of the ESMMP has two phases: the first review is done along with the ESIA, while the second review can be done as the project changes and develops and may require development of Construction ESMMPs and Site-Specific ESMMPs later in the project.

Once MoNRE has approved the ESIA report and the ESMMP, the project owner is granted an environmental compliance certificate (ECC). The ECC is valid throughout the execution of the project, but the ESMMP must be updated to reflect project changes and approved by MoNRE every two or five years. The issuance of the certificate can be refused if the project is believed to cause more damage than benefits or suspended if the activity violated the laws or if the project fails to comply with the conditions provided in the environmental certificate or the ESMMP.

Follow-up instruments, such as ESMMPs, are often used as remedies for the lack of legally established environmental standards or formal governmental programs. In many cases, such follow-up instruments serve as ad hoc regulations that set environmental performance measures that could be more efficiently established through general environmental standards. In many instances, the mitigation measures are not necessarily related to the impacts that the action is expected to generate, but to activities such as reforestation or education that are socially desirable but that the authority is unable to carry out because of its constrained resources.

A common feature of ESIA systems around the globe is that, although ESIA is extensively used as an environmental management tool through which the authority aims to ensure that a wide number of projects or activities operate within specific environmental parameters, most low- and middle-income countries rarely monitor the action's impacts after the corresponding license or permit has been issued, mainly due to lack of resources. In Lao PDR, this problem persists despite a requirement that all ESMMPs include a budget for periodic GoL monitoring by district, provincial, and central authorities. Project developers or their consultants are generally responsible for evaluating and reporting on the implementation of ESMMP and similar instruments.

5.4.5 Information Disclosure

The *EPL* includes a general provision regarding access to information, and this has been a foundation for the evolving public disclosure and participation provisions in subsequent regulations. In addition, Articles 16 and 20 of the *Law on Media* (2008) establish rights of access to information about matters within the country, creating another legal foundation for disclosure requirements in the ESIA system.

The 2019 ESIA Decree provides details about the information required for public disclosure, in conjunction with the 2013 Guidelines on Public Involvement in the ESIA Process. Disclosure of information and public involvement are important parts of the project owner's engagement. Periodic disclosure of the data and information of the project must be made in both the Lao and English languages through newspapers and other printed materials, television, radio, and internet. Both the relevant authorities and the project owner must disclose and provide access to the data and information related to the project, including the environmental impact, obligations, and mitigation measures; the preliminary/comprehensive environmental impact assessment report and the ESMMP; the outcomes of monitoring implementation; and other data. There is, however, a provision that allows information to be withheld by MoNRE upon request by the project owner, thus ESIA documentation may not always be made public. While this information should be contained in a stand-alone Public Consultation and Disclosure Plan, it is often simply included as a chapter of the ESMMP, further limiting its profile and availability.

5.4.6 Compensation

Under the *EPL*, the project proponent is responsible for any environmental damage caused by the project. In addition, Article 58 requires the provision of financial guarantees "to restore, remove pollutants and clean the environment affected by its operations, from commencement until completion."

The new ESIA Decree requires an environmental deposit to restore the environment as a condition of receiving the ECC and includes the restoration of the damaged environment as a project's owner obligation. In addition, project-affected parties have the right to receive compensation, resettlement, and occupational resumption benefits. When the project compensates losses and damages and relocates the place of living and occupation, a certification provided by the Resettlement and Livelihood Restoration Committee is requested prior to issuance of the ECC.

In Lao PDR, private investment projects in the natural resources sector—including hydropower projects, mining projects, and agriculture and forestry projects—are required to enter into a concession agreement with the Government of Lao PDR. The concession agreement (CA) for such projects may contain specific environmental and social obligations complementary to, and in addition to, the statutory requirements. In particular, for the hydropower sector, MoNRE has developed Standard Environmental and Social Obligations (SESO), which forms the basis for the project-specific environmental and social obligations in the concession agreement for the project. The SESO contains standard terms and conditions that in principle are non-negotiable, but the SESO also identifies the areas or issues where the environmental and social obligations have to be custom-made to fit the project-specific design, installations, layout, location, and surrounding social and environmental situation.

5.4.7 Inspection

Technical inspections are intended to be conducted throughout the project to ensure compliance with environmental obligations, conditions for issuance of ECC, ESMMP, compensation plan, relocation and resumption of occupations, and comprehensive management plan. Inspections are carried out during the construction and operation phases, and at the end of the project.

Project owners, the sectoral agency that regulates or supervises the investment project, and the natural resources and environment sector are the parties responsible for conducting the environmental technical inspection. In Lao PDR, this should occur at the district, provincial, and central levels, with a budget for inspections provided by the project proponent.

5.4.8 Consultation and Public Participation

The involvement of different stakeholders in the ESIA process, particularly the groups likely to be affected by the development of a project, is crucial to ensure the legitimacy and credibility of the ESIA and the associated decision-making process. Public participation within the ESIA process has multiple objectives, ranging from gathering data and information from the public about their human and biophysical environment, to seeking public input to identify potential impacts and mitigation or compensation mechanisms, to enhancing the quality of the decision-making process and increasing public acceptance and support for the proposed action (André et al. 2006).

Identified best-practice principles for public participation include, among others, the following: adapting the process to the specific social, institutional, and cultural context in which the project would be developed; acknowledging the right that people have to be informed early and in a meaningful way about proposals that may affect them; ensuring that public input is considered in the decision-making process and that the public is aware of such process; defining clear rules and procedures to guarantee that the consultation is credible, rigorous, and focuses on relevant, negotiable issues; facilitating access to information by making relevant, easily understandable documents available for the public; and considering the heterogeneity of stakeholders and the barriers that would limit the active participation of vulnerable or disadvantaged groups.

Public involvement of potentially affected persons and other stakeholders is required under Article 48 of the *EPL* and reaffirmed in the 2013 Guidelines on Public Involvement in the ESIA Process and the 2019 EIA Decree. Involving the public in preparation of the ESIA is fundamental to increase the acceptance of the project, including the understanding of how the project may affect living conditions and identifying impacts and issues not immediately obvious to the ESIA preparation team.

Under the 2013 Guidelines on Public Involvement in the ESIA Process and the 2019 ESIA Decree, public consultation is conducted in each phase of investment projects to ensure transparency, justice, and efficiency. Project owners must make a public involvement plan for each phase and must ensure that public participation includes gender equality, ethnic minorities, vulnerable sectors, and so forth.

5.4.8.1 Project Preparation

During preparation of an ESIA report, project owners must disseminate the public involvement plan and collect data on population, socioeconomic variables, and social and natural environment conditions in the project area and its surroundings. The project development plan, as well as information on environmental impacts and benefits, must be disseminated to people in the project area and other stakeholders. Dissemination activities will be held through meeting or other forms, in both Lao and the dialects of the ethnic minority, if necessary.

During the review of the report, the relevant provincial offices must liaise with the project owners to convene district-level meetings, technical-level meetings, and inspections trips. The ESIA consultation process specifies formal consultations of draft ESIA at the village, district, provincial, and central levels, including a technical workshop and site visit. The ESIA draft needs to be updated after consultation at each level, culminating in a central-level confirmation meeting before ESIA final approval.

The project-affected parties, village administration, district office of natural resources and environment, sector that governs the investment project, related district-level and provincial-level sectors, and other stakeholders will be welcomed to participate in the meetings and inspections.

5.4.8.2 Construction and Operation

Project owners are required to coordinate with relevant agencies and authorities to regularly inform stakeholders of project activities that may affect the environment. Documents must be disseminated via newspapers, televisions, radios, or internet. Project-affected parties and other stakeholders may express their opinions, concerns, or complaints regarding the implementation of the project. Grievances can be submitted to the project owner or the relevant governmental organization by phone, mail, e-mail, via a website, or through other means. In practice, however, ESIA consultants often informally handle grievances during the ESIA development process.

5.4.8.3 End of the Project

Project owners must notify the project-affected parties and other stakeholders of closure of the project and environmental restoration. Throughout this phase, affected parties can express their opinions on completed or pending activities. The natural resources and environment sector must approve the implementation of the ESMMP as a condition for the project closure.

5.5 Recent Developments and RECOMMENDATIONS

Sano et al. (2016) found important weaknesses in three main components of Lao PDR's ESIA policy and practice:

- The quality of the ESIA — The capacity of consultants to carry out ESIAs tends to be limited. The registration system for ESIA consultants is not transparent nor impartial. Little monitoring actually occurs. Central and local officials do not have enough technical capacity to properly review ESIAs. The capacity of Provincial/Capital Department of Natural Resources to review IEE is still limited.

- Information disclosure and public participation — Many projects do not disclose information to the public, and it is difficult to acquire ESIAs for many projects. MoNRE does not yet have the capacity/time to upload all ESIAs to the internet, or to provide ways in which the ESIAs can be queried by a wider public. Most ESIAs are secret, unless they have to be subject to the MRC's PNPCA process. Political space for community members and CSOs is limited in Lao PDR. Many projects do not conduct public participation, although the ESIA instruction said that MoNRE shall hold the technical and consultation meetings at the provincial/central level during the review period. For the projects that do conduct public participation, consultations are often limited to the government, excluding affected persons, civil society, NGOs, and the general public.

- Environmental management and monitoring — Monitoring is often not conducted or is highly superficial, in part due to lack of capacity by government staff.

Recent ESIA reform efforts have been focused on the design and implementation of a Ministerial Decree to improve ESIA procedures to address identified weaknesses. In essence, the requirements of Ministerial Instruction Nº 8029 on the Process of IEEs of the Investment Projects and Activities (IEE 8029), and Ministerial Instruction Nº 8030 on the ESIA Process of the Investment Projects and Activities (ESIA 8030) were upgraded to a Prime Minister-approved decree. This process was led by the DNEP of MoNRE and supported by the World Bank. This culminated in the January 31, 2019, signing of the ESIA Decree.

This new ESIA Decree aims to ensure uniformity in the conduct of Environmental and Social Impact Assessment by every proponent of investment projects and activities, both by domestic and foreign enterprises operating in Lao PDR, that cause or are likely to cause environmental and social impacts. The objective is that proponents of investment projects and activities shall conduct effective ESIAs, thereby contributing to the country's sustainable socioeconomic development while mitigating the effects of critical issues such as climate change.

The 2019 ESIA Decree also focuses on improving coordination among key agencies during the screening, scoping, review, approval, and monitoring stages of ESIAs for investment projects, including, notably, through improved disclosure of information to the public and public participation in the ESIA review process. Indeed, under current practice, Lao PDR ESIA documents are rarely publicly available unless the developer is seeking to meet international standards. Even then, these documents are not made publicly available until after they have been approved.

Several major themes are emphasized in the reforms introduced in the new ESIA Decree:

> One set of reforms focuses increasing attention on the kinds of investment projects that are subject to ESIA analysis in Lao PDR, and how changes in the scale and ownership of individual projects does and does not affect the project owner's execution of ESIA responsibilities.
>
> A second set of reforms focuses on the scope of ESIA analysis, with increased attention to proposed projects' cumulative and health effects.

A third set of reforms aims at enhancing the role of the public in the ESIA process, particularly those individuals and communities facing social and environmental impacts, with an emphasis on disadvantaged communities and those facing resettlement as a result of project implementation.

A fourth set of reforms aims to clarify the rights and responsibilities of project proponents and governmental actors in the ESIA preparation, review, and approval process.

A fifth set of reform efforts focuses on clarifying the timetables for ESIA document preparation, comment, and approval by the myriad constituents participating in the robust ESIA process envisioned by the decree.

Finally, the 2019 Decree tries to anticipate matters requiring further action to fully implement the ESIA regime in Lao PDR, particularly training and budget needs at all levels of government as they coordinate the enhanced ESIA public consultation and review processes included in the decree, as well as the importance of technical review panels to ensure the quality and consistency of ESIA reviews.

To improve the effectiveness of ESIA implementation in Lao PDR, the new ESIA Decree aims not only to improve the timeliness of ESIA document preparation and review, but also to establish new procedures for enhanced information disclosure and public engagement, especially among affected populations and vulnerable groups. There is an inherent conflict between these two goals, since meaningful public participation takes time and may increase ESIA preparation and revision time for both investors and officials required to review and approve ESIA documentation. The new ESIA Decree requires analysis at a greater depth of environmental and social impacts, including cumulative impacts.

The current Lao PDR ESIA system combines the function of an ESIA with an environmental planning tool. Further clarification of the policy objectives of ESIA reform will help DNEP set priorities and track progress in improving the effectiveness of the ESIA system. As this reform process proceeds, Lao PDR has an opportunity to incorporate global and regional best practices into its ESIA process, thereby improving ESIA as both a planning and environmental management tool to help address urgent environmental and social pressures of accelerating economic growth.

Several provisions of the new ESIA Decree focus on the range of investment projects subject to ESIA review, and aim to ensure that changes in the scope, timing, ownership, or life cycle of a given project do not interfere with compliance with ESIA requirements. In a diversifying economy with significant foreign investment, these reforms are critical to ensuring that ESIA responsibilities are not sidelined when changes in project ownership, scope, or other factors alter the initial conditions.

Article 6 of the 2019 Decree reiterates that foreign and domestic investors are on an equal footing with respect to ESIA responsibilities. Article 3 includes among its definitions details about what Lao PDR defines as *complicated projects* that require particular scrutiny under the ESIA regime, either because they deploy sophisticated technologies or otherwise potentially have severe social and environmental impacts, either locally or across borders. In total, these provisions make a significant contribution to avoiding inconsistencies in the implementation of ESIA responsibilities throughout each project's unique life cycle.

In an area with multiple projects in concurrent development, cumulative impacts may result that require a different measure of social or environmental impact mitigation. Finally, too often development is assumed to be going forward in ESIA analysis, without full consideration of a 'no action' alternative to project approval that may be important in understanding the full environmental and social impacts of a given proposal. The 2019 ESIA includes multiple provisions aimed at addressing the proper scope of ESIA analysis by giving attention to these issues.

Several references are made to the importance of considering cumulative and health impacts. In the case of impacts to the Mekong River, a clear instruction is given to comply with the terms and conditions in the Agreement on the Cooperation for Sustainable Development of the Mekong River Basin 1995. In other cases, it is not clear how the assessment of cumulative and health impacts is to be undertaken. In addition, provision is made for consideration of a least three project options, including a 'no project' option.

Disclosure of information and engagement of the public in the ESIA review and revision process have always been a part of the Lao PDR ESIA system. However, the new ESIA Decree goes even further than earlier regulation in this area, including several new provisions aimed at enhancing public participation, with increased emphasis on giving a voice in ESIA decision-making to vulnerable groups. Giving full effect to Decree 84 on Compensation and Resettlement (2016) is a priority of several new public-participation provisions in the new decree, including articles on submitting a separate social-impacts report in cases of resettlement, separate ethnic-minority reporting, and the requirement that minutes of the public-participation meeting must be included in ESIA application packages from the project owner.

In addition, the 2019 new decree requires compliance with Decree 84, stating that attention must be paid to an open consultation with the project-affected persons (PAPs), especially ethnic groups, women and children, and disadvantaged groups. The new decree gives strong voice to PAP participation in consideration and approval of the ESIA Report and ESMMP, suggesting that, beyond a robust public-participation process, a majority of the people affected by development projects will have a voice equal to relevant agencies and local administration in the approval process. It is not specified, however, how this expansive role for PAPs would be implemented.

Perhaps most importantly, the new decree includes expansive provisions for the rights of the public, particularly PAPs, including a right to health examinations and participation in field inspections, and the right to receive promotion and respect for culture, religion, traditional beliefs, and gender roles. The 2019 ESIA seeks to ensure that the public-participation process is fully funded by the project owner, a requirement that has been in place since at least 2013 but rarely implemented.

In addressing the form and content of both the project proponent's and the government's rights and responsibilities for the administrative and financial burden of implementing a robust ESIA system, the new decree includes several new provisions aimed at clarifying roles. MoNRE itself takes on many new and significant responsibilities, such as committing to work with provincial and local authorities in making a list of existing projects already in the construction and operation phases of development that have not yet received an ECC.

MoNRE also commits to develop technical guidelines about the ESIA process for nationwide application and continues to support the project owner in several areas related to ESIA preparation and approvals, including providing technical assistance directly and at consultation meetings at the district level as well as leading field inspections. Similar broad MoNRE responsibilities are identified during the construction preparation phase and for monitoring activities. While accompanying provisions for responsibilities of provincial, municipal, and local/village authorities may eventually assist MoNRE in meeting government burdens for the smooth and timely operation of the ESIA preparation and review process, at least initially these overlapping provisions will create an additional burden on MoNRE as it builds capacity at lower levels of government for ESIA review and monitoring capacity, as well as dispute-resolution capability.

MoNRE is setting ambitious timelines for its review and approval of ESIA applications, as well as deadlines for project proponents to prepare and submit ESIA documentation. For example, project owners must carry out the comprehensive ESIA within six months after approval for the scope of assessment and works. MoNRE is required to complete a preliminary review of new ESIA applications within ten working days of submission and advise the project proponent if additional documentation will be necessary and review the comprehensive ESIA report within ninety working days from the date of receiving the documents from the project owner.

Attention to both timeliness of decisions for applicants and giving the public adequate time to review ESIA documents is the best way to ensure advancement of the social and environmental protection goals of the ESIA system in Lao PDR, and the final version of the ESIA Decree should seek this balance. For example, for large-scale, high-impact projects, six months may be too short a time to carry out wet- and dry-season baseline studies. Moreover, MoNRE may lack resources to meet review and approval deadlines.

At the same time, the 2019 ESIA Decree sets review and approval deadlines for ESIA applications, it also broadens the scope of matters to be considered in assessing social and environmental impacts, most notably heightening the importance of considering the possible cumulative impacts of proposed projects. These are critically important factors in assessing the full potential of a project's environmental and social impacts. More generally, the responsibility of all levels of government to give the public access to information and an opportunity to comment is heightened in the new decree, suggesting that MoNRE must carefully consider whether the public will have adequate time to review and comment on proposals during a finite period for the review and approval process. Meaningful public participation often requires lengthening review timeframes before project approvals.

At a minimum, meeting tight timetables for project reviews will tax the capacity of DNEP to manage workload. Therefore, a critical component of effectively implementing ESIA reforms will be increasing staff capacity at DNEP. Such increased staff capacity will not only ensure timely ESIA approvals, but also investor confidence in the ESIA system. Overall, however, the GoL is looking at the temporal dimension of ESIA processing and approvals; timeliness of ESIA reviews is one of the most common criticisms of ESIA systems, yet it is rarely studied and given too little attention in reform efforts (Loomis and Dziedzic 2018). This is a key issue to be addressed in engaging both project proponents and the public in full implementation of the 2019 ESIA Decree mandates.

The comments that follow anticipate implementation challenges with the new ESIA in light of this tension between a thorough review of environmental and social impacts, and timeliness of decisions. The following recommendations may serve as a roadmap to implement the new decree:

> Encouraging attention by project owners, government reviewers, and the public to widely available information that will improve the accuracy of ESIA assessments of social and environmental impacts, including already approved ESIA documentation for similar or related projects made widely available through new databases or other technological innovations; and

> As noted above, the 2016 *Law on Investment Promotion*, Article 74, requires investors to meet environmental protection goals in Lao PDR through their activities. Continued attention in Lao PDR to the inclusion of environmental protection provisions in laws critical to the economic interests of current and future investors may be the most important means of providing government-wide support to the effective implementation of ESIA reforms in Lao PDR. The ESIA Decree should be cited in future investment laws.

5.6 Notes

56 This chapter was prepared by Santiago Enriquez, William Ward, and Ernesto Sánchez-Triana.

57 40 C.F.R. § 1500.1.

58 Federal actions are defined as those that require the approval of a governmental agency at the federal level.

59 42 U.S.C. § 4332.

60 This amendment applies exclusively to the action of the US Executive Director and does not preclude Board approval but requires the US Executive Director to abstain.

61 This sector consists of (i) the Ministry of Natural Resources and Environment, (ii) the provincial offices of natural resources and environment, and (iii) district offices of natural resources and environment.

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6

SOLID AND PLASTIC WASTE MANAGEMENT[62]

Chapter Overview

Solid waste generation will continue to increase with economic development, rapid urbanization, and changes in consumption patterns. In the Lao People's Democratic Republic, solid waste generation is expected to increase 20 percent by 2030 and 46 percent by 2050. While the country's per capita generation rate is among the lowest in the region, Lao PDR faces challenges related to solid-waste management; these challenges derive from deficient collection systems and inadequate disposal methods.

Limited economic resources restrict collection services to urban areas, leaving many remote locations underserved. Collection rates reach 60 percent in urban areas and 35 percent in rural areas. Insufficient collection systems and lack of awareness push citizens to turn to open burning, household burying, and dumping in vacant lands. Open dumps receive 60 percent of the collected waste while 30 percent is disposed of in landfills and only 10 percent is recycled. The country's landfills are operated as uncontrolled open dumpsites, since they do not meet sanitary standards and lack leachate-collection systems and monitoring wells. Hazardous waste is not collected or treated separately from general waste, resulting in toxic materials and medical waste being disposed of with municipal waste.

Inadequate solid-waste management practices such as open dumping and burning can harm human health and the environment. The burning of waste releases dangerous toxins like dioxins and furans into the air; such toxins are associated with cancer, neurological problems, hormonal disruptions, and reproductive issues. In addition, emissions such as greenhouse gases and short-lived climate pollutants are released when waste is burned; these emissions are also associated with climate change. Plastics are among the wastes that are burned and openly dumped. Plastic waste can accumulate on the banks of waterways and clog drains, leading to increased flooding and river pollution. Since rivers discharge into the sea, plastic pollution in waterways is directly linked to marine pollution. Although data are lacking, it can be assumed that Lao cities situated along the Mekong River and its tributaries significantly contribute to plastic waste pollution of the river and subsequently of the ocean.

Until the enactment of its National Sword policy in 2018 banning the import of plastic waste and other materials, China was the world's largest importer of plastic waste. With the ban, around a third of China's 1,700 importers have relocated to neighboring countries including Malaysia, Thailand, and Vietnam. Displaced facilities often relocate illegally and lack environmental controls, further increasing local pollution. As imports have shifted from China to these countries, governments have started to suspend import permits and impose restrictions on imported materials.

Several measures can be implemented to improve solid-waste management in Lao PDR. Recommendations include legislation to prohibit waste burning along with campaigns to educate the public on the health impacts of open waste burning; banning of imports of plastics, e-waste, and other recyclables; establishment of standards for landfills in urban areas; promotion of circular economy practices to improve resource-use efficiency; and legislation on hazardous and medical waste management. These actions require improving the institutional and regulatory framework. While environmental legislation has progressed in Lao PDR, the regulatory framework for solid-waste management is still limited and the responsibilities of different governmental agencies are not clearly defined.

6.1 Introduction

This chapter analyses the status, shortfalls, and potential actions to improve solid-waste management in Lao PDR. It first discusses the current solid waste situation in Lao PDR, followed by an overview of the institutional framework and actors in solid-waste management. Subsequently, this chapter addresses the emerging topic of plastic pollution and provides recommendations for improving solid-waste management and reducing plastic waste pollution in Lao PDR.

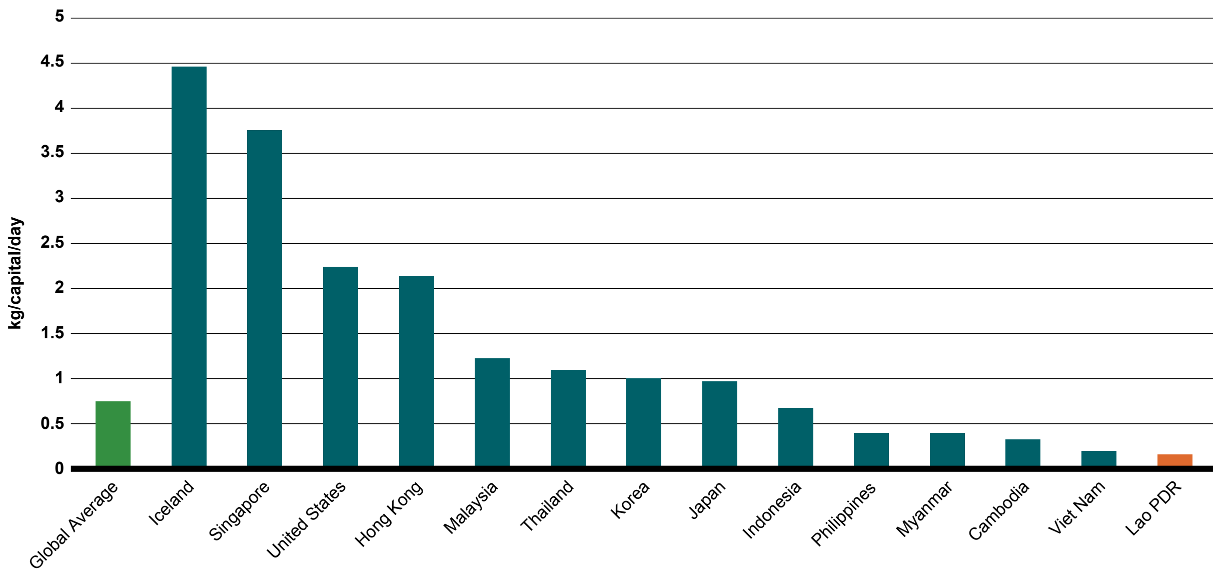
6.2 Solid Waste Situation in Lao PDR

6.2.1 Waste Generation and Composition

The *Environmental Protection Law* amended in 2012 defines waste as "objects, chemical substances or any things that persons or legal entities do not want and cannot recycle such as used oil, rubbish, wastewater and others, which are toxic or non-toxic." For this analysis, municipal solid waste (MSW) encompasses residential, commercial, and institutional waste. Generation of industrial, medical, hazardous, and electronic waste is reported separately from MSW for comparative purposes.[63] Lao PDR per capita generation of waste is among the lowest in Asia and in the world (Figure 6.1). In 2015, 351,900 tons of MSW were generated at an average rate of 0.15 kg per person a day. By comparison, in Singapore and Thailand, the per capita generation was 3.76 kg per day and 1.07 kg per day, respectively (Table 6.1). In addition, in 2015, Lao PDR generated 7,500 tons of electronic waste, 5,200 tons of hazardous waste, 49,500 tons of industrial waste, and 1,200 tons of medical waste (Table 6.2)[64].

During the last decade, waste generation has doubled in Vientiane. With economic development and changes in consumption patterns, under a business as usual scenario, waste generation in Lao PDR is expected to reach 0.18 kg/capita/day in 2030 and 0.22 kg/capita/day in 2050 (Kaza et al. 2018).

Figure 6.1 Per Capita Waste Generation



Source: Kaza et al. 2018

Table 6.1 Waste Generation in Asian Countries/Economies, 2015

Type of waste	kg/capita/day					
	China	Hong Kong SAR	Lao PDR	Singapore	South Korea	Thailand
Municipal waste	0.4196	2.1300	0.1447	3.7643	0.9836	1.0716
Electronic waste	0.0144	0.0263	0.0031	0.0489	0.0308	0.0153
Hazardous waste	0.0692	0.0206	0.0021	0.2183	NA	0.1375
Industrial waste	6.5351	NA	0.0204	NA	2.1493	1.4924
Medical waste	NA	0.0009	0.0005	NA	NA	0.0021

Source: Kaza et al. 2018.

Table 6.2 Waste Generated in Lao PDR, 2015

Type of waste	tons/yr	kg/capita/day
Municipal waste	351,900	0.1447
Electronic waste	7,500	0.0031
Hazardous waste	5,200	0.0021
Industrial waste	49,500	0.0204
Medical waste	1,200	0.0005

Source: Kaza et al. 2018.

As in many other developing countries, the major portion of municipal waste generated in Lao PDR is composed of organic materials (Figure 6.2). Food, garden, wood, and green waste make up 57 percent of the waste while dry recyclables such as glass, plastics, metal, paper, and cardboard are produced in smaller quantities, accounting for 22 percent of the waste.

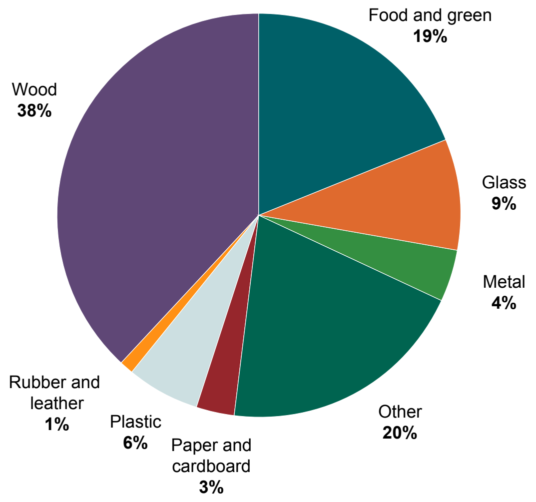
6.2.2 Waste Collection and Disposal

Collection and disposal of municipal solid waste take place in the four major cities: Vientiane, Luang Prabang, Savannakhet, Pakse and Champasak. While collection rates reach 60 percent in the urban areas, only about 35 percent of waste is collected from the rural areas (Figure 6.3). In urban areas, waste is generally collected once or twice a week from each household. The collection coverage depends on the number of trucks made available by the municipality and the waste collection fees paid by the residents. Due to lack of financial resources, collection services do not reach many remote areas.

In Lao PDR, open dumps receive 60 percent of the waste, remaining the principal mechanism for final disposal. As shown in figure 6.4, around 30 percent is disposed of in landfills and only 10 percent is recycled (Kaza et al. 2018).

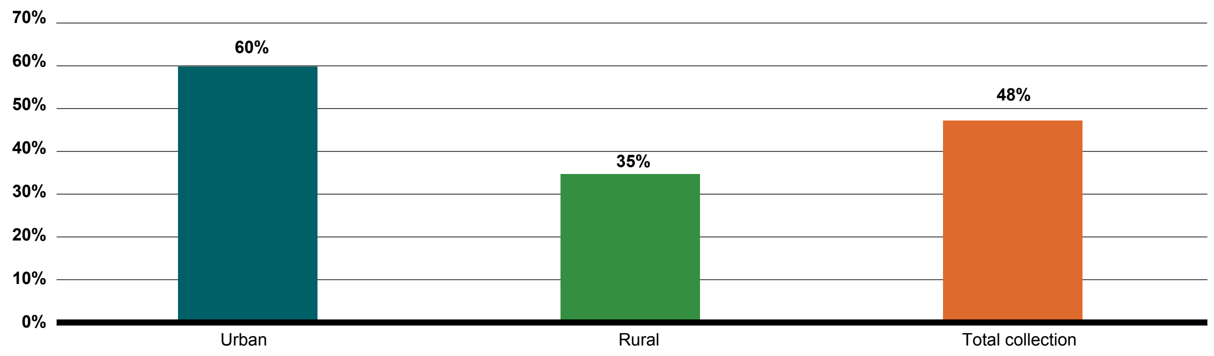
Given municipalities' limited resources, the country's landfills do not have leachate collection systems or monitoring wells. Sometimes, waste is burned at landfills to reduce the volume of waste and recover landfill space (IGES 2012). Due to the lack of appropriate collection systems, open burning, household burying, littering along roadsides and streams, and dumping in vacant lands are widespread practices in both urban and rural areas (CCAC 2015).

Figure 6.2 Solid Waste Composition



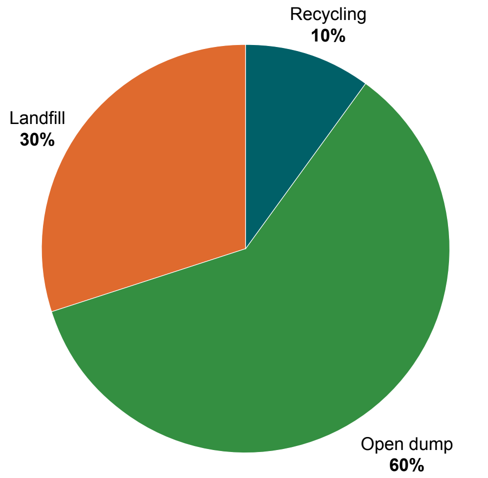
Source: Kaza et al. 2018.

Figure 6.3 Waste Collection Coverage



Source: Kaza et al. 2018.

Figure 6.4 Waste Disposal



Source: Kaza et al. 2018.

In some rural areas as Khammouane province, most residents confirm burning their garbage, including hazardous waste such as batteries, near their houses (Henderson 2017). Open burning further contributes to the air pollution issue in the country. Recent World Bank studies estimate that the cost of household and outdoor air pollution combined accounted for 9.4 percent of the country's GDP in 2017 (see chapter 3).

Waste segregation takes place either during the collection process or at the landfill. Separation at source is not practiced. Hazardous waste is not collected or treated separately from general waste; therefore, toxic materials such as batteries, aerosols, and medical wastes are often disposed of with municipal waste, increasing health risks and resulting in natural resource degradation, such as surface and ground water contamination (MoNRE 2013; MPWT 2013; World Bank 2018).

Although the recycling industry is not fully developed in Lao PDR, there are small and medium-sized enterprises that produce different products from washing, crushing, and breaking up recyclables into smaller pieces. Plastics, glasses, papers, cardboard, and metals that are collected are often exported for further treatment.

6.2.2.1 Waste Management in Vientiane

In Vientiane, the Vientiane City Office for Management and Service (VCOMS) offers annual contracts to private companies for collection services, specifying the districts where they can operate. Private companies charge a collection fee directly to their customers. In 2017, the fees were increased from KN 25,500/month to KN 41,550/month (US$3/month to US$5/month) (GGI 2018).[65] Households and the commercial sector are charged different rates. As of 2015, offices were charged KN 30,000–50,000/month (US$3.5/month to US$5.8/month); markets were charged KN 150,000–180,000/container (US$1.7–21.2/container) (CCAC 2015).

Part of the collected waste is first brought to a transfer station that operates solely as an unloading and reloading point where recyclables can be recovered by the station's workers. Seventeen small waste collection VCOMS trucks (3 tons/unit) enter the premises of the transfer station twice a day, where neither informal pickers nor the private companies are allowed. The facility has two mixing machines used to transfer waste from the small vehicles to three larger trucks (20 tons/unit) that transport waste two to three times a day to a landfill located 32 km from the city center (GGI 2018; World Bank 2018).

The landfill KM32 does not comply with standard operating conditions; instead, it is used as an open dumpsite. The facility receives around 352 tons/day of waste and does not have a leachate collection system; as a result, liquids from the facility flow into a natural pond. The landfill depends on a medical waste incinerator that is functional and in use; however, it is the only incinerator in the country. The annual amount of solid waste increased from 90,000 tons in 2014 to 127,000 tons in 2018 (World Bank 2018).

6.2.3 Plastic Pollution

Preliminary estimates indicate that plastic makes up around 12 percent of municipal solid waste in Vientiane. In 2016, the recycling rate in the city reached 10 percent, including plastics, paper, and metals (Kaza et al. 2018).

Data on the scale of plastic waste pollution in the country are not available. However, primary data suggest that most of the plastic in Lao PDR is either burned, contributing to air pollution, or openly dumped, often near waterways. The consequences include plastic waste scaling the banks of waterways, clusters of plastic waste floating in streams and polluting the waters and ultimately oceans, and plastic waste clogging canals, leading to increased flooding.

An estimated 30 million people depend on the Mekong Basin for their livelihoods. However, the river, flowing through Lao PDR, is increasingly loaded with plastic pollution and is among the ten waterways that contribute most of the plastics in the ocean. Plastic pollution coming from rivers is linked to that of the marine environment, because rivers ultimately discharge into the sea (Schmidt et al. 2017). Of the total mismanaged plastic waste, Lebreton et al. (2019)

estimate that 91 percent is transported via watersheds larger than 100 km^2, suggesting that rivers are the major pathways for plastic litter to the ocean.

All Lao PDR's major cities—including Vientiane, Pakse, Savannakhet, and Luang Prabang—are situated on the banks of the Mekong River. Although sound data are lacking, considering the inadequate solid-waste management systems in those cities and taking into account most-recent global knowledge, it can be assumed that Lao cities situated along the Mekong River and its tributaries significantly contribute to plastic waste pollution of the river and subsequently the ocean.

Plastic can take hundreds to thousands of years to biodegrade. Plastic waste causes floods by clogging drains, respiratory issues when burned, shortens animal lifespans when consumed, and contaminates waterbodies when dumped into canals and oceans (Baconguis 2018). Plastic waste has additional adverse impacts on food chains, as well as threatening a wide range of marine life that ingests plastic waste or becomes entangled in plastic debris (Frias 2019).

Although several studies provide first-order estimates of the amount of plastics entering the oceans and which countries and rivers are the key contributors, there is still significant variance in the available data. Consequently, there is an urgent need for more-reliable information on the quantities, sources, and types of plastics getting into the waterways. Lao PDR is no exception when it comes to this lack of data. Detailed information on waste quantities, sources, and types is lacking. Even so, key stakeholders agree that more action is needed.

As an ASEAN member state, Lao PDR is supporting the development of the Bangkok Regional Declaration on Marine Litter. ASEAN members are also planning to develop jointly an ASEAN Action Framework on Marine Debris. At the ASEAN Ministerial Meeting on Marine Debris in Bangkok in March 2019, member countries' ministers underscored their great concerns regarding the high levels of marine plastic debris in the region, and potential negative impacts on marine biodiversity, environment, health, society, and economy. They further emphasized the need to work together to prevent and reduce marine debris (ASEAN 2019). At the national level, the GoL encourages the use of recyclable bags in cafes and markets. *Green Vientiane*, a private initiative, has started to sell recyclable bags in downtown cafes and markets. However, more action is required in Lao PDR, particularly at the national and municipal levels, to address the continuously increasing amounts of plastic and solid waste. Although no plastic policy, regulation, or action plan is currently in place, during a bilateral meeting with the World Bank, the government expressed its willing to ban all single-use plastics by 2025. In addition, MoNRE intends to prepare a National Plastics Management Roadmap (World Bank 2018).

6.2.4 Impact of China's Ban on Imports of Plastic Waste

During the last decades, China was the world's largest importer of plastic waste, dealing with 95 percent of the plastics collected for recycling in the European Union, 70 percent of U.S. recyclables and other recycled materials from around the world. In January 2018, China enacted a National Sword policy that restricts the import of plastic waste and other materials, closing the market for exporting nations and causing several cities to incinerate or landfill recyclable waste.

With the ban, several plastics recyclers have relocated to other Southeast Asian countries. Displaced facilities often relocate illegally and lack environmental controls, further increasing local pollution. It is estimated that at least a third of China's 1,700 licensed importers have relocated to neighboring countries. Within months after the policy was passed, countries including Indonesia, Malaysia, Thailand, and Vietnam have increased their plastic imports. Between the first half of 2017 and the first half of 2018, imports of plastic have doubled in Vietnam, while Indonesia and Thailand have seen an increase of 56 percent and 1,370 percent, respectively. In the same period, Malaysia has become the biggest importer of plastic in the world. As imports have shifted from China to these countries, governments have started to suspend import permits and impose restrictions on imported materials.

6.3 Institutional Framework and Stakeholders

This section gives an overview of the institutional framework and key stakeholders involved in solid-waste management in Lao PDR.

6.3.1 Regulatory Framework for Waste Management

While environmental legislation has progressed in the country, the regulatory framework for solid-waste management is still limited; consequently, many gaps need to be filled. In addition, despite the existence of regulations, lack of resources has made their implementation difficult. Table 6.3 gives an overview of the regulatory framework and various laws related to solid-waste management in Lao PDR. Actors

Key actors in solid-waste management include the national government, municipal government, private sector, and informal sector. Their main roles and characteristics are outlined below.

6.3.1.1 National Government

At the national level, through the Department of Housing and Urban Planning (DHUP), the Ministry of Public Works and Transport (MPWT) has been the main body regulating the solid-waste management sector in Lao PDR. While the Ministry of Natural Resources and Environment (MoNRE) is the main authority responsible for preparing environmental laws and regulations, it has not been specifically engaged with the waste management sector (UNCRD 2012).

The Industrial Environment Division in the Ministry of Industry and Handicraft oversees industrial waste coming from factories (FAO 2011). The Ministry of Public Health is responsible for regulating medical waste management, including its collection and storage. The Ministry of Agriculture and Forestry (MAF) is charged with delivering policies and regulations that control the utilization of compost in agriculture (Global Growth Institute 2018).

6.3.1.2 Municipal Government

At the municipal level, Urban Development Administrative Authorities are responsible for the collection, transport, and disposal of municipal solid waste. Provincial decrees provide the legal framework for waste management within each city. They define the responsible agencies and fees charged to households, among others.

In Vientiane, the Vientiane Cleansing Unit under the Vientiane Urban Development Administration Authority (VUDAA) is the agency charged with solid-waste management. VUDAA delegates the collection of solid waste to a public company established under VCOMS and ten private companies directly contracted by VCOMS (Global Growth Institute 2018).

6.3.1.3 Waste Pickers

Informal waste pickers can recover recyclable waste either from the source of generation, through door-to-door collection, or from unsegregated waste directly from the landfill. Some public buildings, households, and hotels sell recyclables to waste pickers who sell the recovered waste to buying centers. The waste pickers receive only a daily fee from these buying centers upon delivery of the recovered waste. Apart from receiving this daily fee—which is determined by the buying centers—the waste pickers receive no other benefits and have no employment security.

Waste pickers also scavenge in the disposal site for their livelihoods, picking out metal, plastic, or other materials of value. The recovered materials are sold at lower rates than clean recyclables to a buying center that operates in the landfill site.

The World Bank estimates there are around 300 waste pickers in Vientiane whose contribution reaches 10 percent of the collected waste. It is estimated that 50 percent of waste pickers are women (Kaza et al. 2018).

Table 6.3 Regulatory Framework Related to Solid-Waste Management in Lao PDR

Date	Legal framework	Name	Purpose
1991	Constitution	National Constitution	Stipulates that all organizations and citizens must protect the environment and natural resources.
November 1994	Regulation	Industrial Waste Discharge Regulation	Prohibits the discharge of toxic or harmful waste to public water sources.
April 1999	Law	Environmental Protection Law	Defines protection measures for pollution control. It prohibits all littering and requires the allocation of waste disposal sites and separation of waste before its disposal, incineration, or burial.
April 2001	Law	Hygiene, Disease Prevention and Health Promotion Law	Includes waste management in hygiene considerations for production processes, hospitals, public spaces, markets, and so forth. It refers to environmental hygiene and pollution control.
July 2004	Decree	Waste Management from Health Care Facilities	Requests proper management of health care waste, including separation (infectious, sharp, and general waste), collection and storage, handling, and disposal.
December 2012	Law	Environmental Protection Law (Revised)	Introduces environmental management considerations of household businesses, national pollution control standards, and management and disposal of toxics and hazardous waste.
February 2015	Ministerial Instruction	Hazardous Waste Management	Identifies hazardous waste classification and regulates its import, export, transfer, storage, use, recycling, and disposal. It defines the roles and responsibilities of government agencies and waste generators.
February 2015	Ministerial Instruction	Pollution Control	Regulates soil pollution and defines the roles and responsibilities of the public, private sector, and the community.
May 2015	Vision	Vision Toward 2030	Targets the reduction of raw materials and waste generation, and the implementation of proper waste separation practices.
May 2015	Strategy	National Natural Resources and Environmental Strategy, 2016–2025	Aims to promote green production and the implementation of the 3R concept (reduce, reuse, and recover) within the country.
August 2017	Decree	Pesticide Management	Defines the principles, regulations, and measures regarding the use of pesticides, including their management and disposal.

6.4 Conclusions and Recommendations

Due to rapid urbanization and economic development, solid waste amounts are increasing throughout Lao PDR. A specific regulatory framework on solid-waste management is still missing[66]. The responsibilities of different governmental agencies in solid-waste management are not clearly defined.

The number of landfills in the country is limited, and the existing landfills are substandard or are operated as uncontrolled open dumpsites. Regulations for control of leachates and landfill gases do not exist.

Because of the lack of a proper waste management system, disposal and burning of waste in open dumpsites or into rivers is widespread throughout the country. The regular burning of waste has significant health impacts on residents, aggravating the already pressing air pollution issue, and pollutants ending up in rivers and aquifers damage ecosystems and present significant health risks to the public (CCAC 2015).

There are many ways to curb solid waste: by producing less, consuming less, and better managing the waste. Taking these actions requires engagement from numerous stakeholders in society, including citizens, governments, community organizations, businesses, and manufacturers. Policy solutions, increased awareness, and improved waste management, among other approaches, can minimize the impact of waste on society.

The implementation of the following measures is recommended to improve solid-waste management:

Ban on open burning waste. Lack of public awareness and deficient collection and disposal systems are the leading causes for waste burning, which continues to be among the most widespread practices for waste disposal in Lao PDR. Waste burning releases emissions that contribute to climate change as greenhouse gases and short-lived climate pollutants like black carbon. In addition, waste burning is a significant source of dangerous toxins like dioxins and furans that are associated with cancer, neurological problems, hormonal disruptions, and reproductive issues (Cogut 2016). Aside from campaigns to educate the public on the hazards of open waste burning, legislation to prohibit burning should be introduced and rigorously enforced. The use of pollution charges for transgressors should be explored, particularly in urban areas.

Ban on imports of plastics, e-waste, and other recyclables. After China's National Sword policy was enacted, recyclable wastes have been diverted towards Southeast Asian countries, overcoming their treatment capacities and imposing high environmental costs. Recycling processes often include washing and heating practices that produce wastewater and emissions, negatively impacting communities and the surrounding environment. To protect the country from this unsustainable waste trade, GoL might consider issuing a ban on imports of all waste (including e-wastes, plastics, paper, aluminum, and glass)[67].

Improving the institutional and regulatory framework for solid-waste management. Institutional capacity for planning, monitoring, and enforcement is limited in the country. To promote accountability, the body that regulates the waste management sector should be separate from the entity that operates the service. Therefore, responsibilities among the different ministries—Health, Public Works and Transport, and Natural Resources and Environment—should be more clearly defined. The capacity of the Department of Housing and Urban Planning (DHUP), which is dedicated to solid-waste management within MPWT, should be strengthened—within the context of a National Solid-waste management Strategy and Investment Plan (see below)—to ensure that planning activities are well coordinated and resources efficiently used. At the municipal level, a regulatory agency for solid-waste management should be clearly defined and the role of Urban Development Administrative Authorities overseeing private contractors should be enforced.

A solid waste regulatory framework at the national level, which includes specific laws and regulations for solid-waste management and considers all shareholders, should be developed. Efforts to enforce laws, including the implementation of fees and other penalties, should be deployed. At the municipal level, local regulations that cover specific aspects of waste management—such as source separation, household fees, and disposal sites—should be enacted.

Strengthening planning, information systems, and citizen engagement. The eventual development of a National Solid-waste management Strategy and Investment Plan—laying out targets, required activities, selection of priority low-cost investments, budget, and actor responsibilities—would help to streamline solid-waste management activities in Lao PDR. Such a strategy could develop in a phased manner focusing first, for example, on those areas with high levels of environmental issues. In addition, the establishment of solid waste information systems to provide sound data on collection rates, waste quantities by categories, dumping amounts at landfill sites, tracking of waste, financial data, and related matters, is recommended. Data collection improves planning and monitoring processes as well as decision-making and establishment of waste policies.

Waste management often starts at the household and individual levels, and strategies to educate and motivate citizens can dramatically change behaviors and outcomes. Awareness-raising campaigns can result in residents consciously reducing the amount of waste they produce, separating waste at home, and disposing of waste properly.

Promotion of a circular economy to improve resource use efficiency. A circular economy transitions from a traditional linear economy—in which resources are used to produce goods for use and disposal—to a circular model that keeps resources in use for as long as possible and recovers and regenerates materials at the end of their service life. This approach replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, and aims for the elimination of waste. With a circular economy approach, Lao PDR can leapfrog into a model where resources are efficiently used, and the environment protected. Several strategies could be implemented within the country's circular model, including recovery and reuse, circular design, economic instruments, and material substitution, among others. Goods manufactured in the country should be designed to be easily recovered, reused, or recycled, and the use of materials that are biodegradable should be prioritized. Internalizing the environmental costs associated with waste management into the process of production and pricing can lead to cleaner production and responsible consumption. Decentralized waste separation and collection for small communities, increased resource recovery, composting, recycling, and waste reduction are other forms of promoting a circular economy that can improve solid-waste management.

Legal requirements for hazardous and medical waste management. Despite the existence of a decree for waste management from health care facilities, non-compliance continues to prevail, since medical waste is often disposed of at the landfills. Similarly—due to lack of regulations—hazardous wastes such as toxic, corrosive, and inflammable materials are mixed with municipal waste. Specific regulations for medical and hazardous waste management, along with monitoring and enforcement practices, should be developed.

Establishment of standards for landfills in urban areas. Development of common standards will establish minimum requirements to mitigate risks to the environment and public health, including (i) restriction on landfill locations, (ii) use of bottom liners, (iii) operation of leachate collection systems, (iv) monitoring of groundwater quality, and (v) installation of composting platforms and landfill gas capture systems to reduce methane production.

6.5 Notes

62 This chapter is based on a background report prepared by Mayra Gabriela Guerra Lopez and Klaus Sattler.

63 Categories of waste discussed in this chapter include the following:

(i) Municipal waste—waste coming from residential, commercial, and institutional sectors; municipal waste includes, but is not limited to, food waste, paper, cardboard, plastics, textiles, leather, yard wastes, wood, and glass;

(ii) Industrial waste—nonhazardous solid waste generated by industrial processes such as light and heavy manufacturing, fabrication, power, and chemical plants. Such waste may include, but is not limited to, organic and inorganic chemicals, iron and steel, nonferrous metals, plastics and resins from manufacturing facilities, paper, rubber, and transportation equipment;

(iii) hazardous waste—wastes that are flammable, reactive, toxic, or corrosive (hazardous waste includes, but it is not limited to, solvents, paints, pesticides and other garden chemicals, batteries, and compact fluorescent lamps);

(iv) medical waste—waste coming from healthcare facilities or laboratories, including, but not limited to, sharp materials such as needles and scalpels, pathological and infectious waste, and pharmaceutical and biological waste; and

(v) electronic waste—including electronic products such as, but not limited to, computers, televisions, cellphones, stereos, copiers, fax machines, printers, and radios.

64 The Director General of Natural Resources and Environment, and Chief of Economic, Technology and Environment Committee, National Assembly, Mr. Onma Lathsavong, pointed out the need to find solutions to address problems with the use of chemicals and waste management.

65 KN = Lao Kip. US$1.00 = LAK 8,580 (exchange rate in effect on February 28, 2019).

66 The Vice Minister of Planning and Investment highlighted the importance of developing rules and regulations. As an example, he mentioned that the Extended Producer Responsibility policy approach would give business owners who import products such as batteries the responsibility for ensuring that used products are recycled and wastes are managed adequately.

67 The Vice Minister of Industry and Commerce, H.E. Mr. Phanthong Phitthoumma, mentioned that the Ministry of Industry and Commerce has signed an MoU to conduct a study on banning imports of plastic and waste. He also indicated that the ministry has plans to build a facility to manage electronic waste.

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7

POVERTY AND ENVIRONMENT[68]

Chapter Overview

The chapter's findings reveal strong linkages between environmental quality and poverty in the Lao People's Democratic Republic. Lao PDR has achieved rapid gross domestic product (GDP) growth and poverty reduction over the last two to three decades: Its rapid economic development was associated with a fall in the national poverty rate from 46 percent in 1993 to 18 percent in 2019. Agriculture development in the last two decades has contributed to household poverty reduction through expansion of arable land, and through increased size of household land holdings for agriculture, intensification and mechanization, commercialization, and crops of higher value-added.

However, income disparities have widened. The Gini index increased from 31 in 1993 to 39 in 2019, according to Lao poverty assessments. Rural areas' poverty incidence was over three times as high as in urban areas in 2019, and about 88 percent of the poor lived in rural areas. Poverty-alleviation efforts in Lao PDR need to be cognizant of the fact that the country's poverty-environment linkages are mainly rural.

The poor continue to depend on natural resources, since most of the poor are rural small holders. Non-timber forest products (NTFPs) are an important source of food consumption and income for the rural population and the poor, but some NTFPs are being over-harvested and are on the decline in several provinces. While Lao PDR still has substantial forested lands, degradation and deforestation disproportionately affect the poor.

The poor are vulnerable to climate risk. Household surveys point to how droughts are disproportionately affecting the poor, pointing to the need for more interventions for risk reduction and management in poor communities affected by droughts.

Lao PDR's national protected areas (NPAs) including three national parks cover about 16 percent of its territory. Many people reside within, or bordering, the NPAs and tend to be poorer than the average. This points to the importance of balancing the objectives of poverty reduction and conservation in the NPAs. Participatory approaches to resource management can enhance sustainability and reduce encroachment by outside commercial interests.

Land concessions and land leases in Lao PDR expanded rapidly from the early 2000s. Some large concessions harmed local communities, and moratoriums were implemented. More recently, banana-plantation expansion was halted because of health effects from pesticides and other agrochemicals as well as water pollution. Lao DECIDE Info—a joint initiative of the Lao PDR and Swiss governments—has developed a methodology for assessing the quality of land-concession investments to ensure sustainability and local-community benefits.

Analysis of household data along with maps of unexploded ordnance (UXO) contamination shows how UXO disproportionately affects the poor. Further targeting UXO clearance towards the poorest and most contaminated districts is needed, along with complementary poverty-reduction policies, programs, and projects.

The poor depend heavily on agriculture, capture fisheries, and NTFPs from local forest resources. The poor are also highly dependent on forest and vegetation covers that regulate water services and mitigate flash floods and soil erosion. Consequently, the protection, productivity, and quality of natural resources; the poor's access to these resources; and their sustainable management are essential for the poor's livelihood, food security, balanced nutrition, and poverty alleviation.

The poor suffer disproportionately from household air pollution (HAP), since they rely almost exclusively on highly polluting energies for cooking—that is, fuelwood—in contrast to better-off households' use of somewhat less-polluting energies such as charcoal as well as clean cooking energies such as LPG/electricity. Vietnam's experience transitioning to clean cooking energies suggests that a much larger share of Lao PDR's population, including among lower-income households, can make this transition from cooking with fuelwood to clean cooking energies.

The poor have far less access to improved sources of drinking water and sanitation than better-off households. The poor rely on the boiling of drinking water, using fuelwood for boiling that causes substantial negative health effects. Potential solutions include using clean treatment methods such as ceramic filtering or solar disinfection of drinking water (see chapter 9). The drinking water available to the poor is of lesser quality than for better-off households, underscoring the need for clean point-of-use treatment methods.

The largest disparity between the poor and better-off households is lack of access to improved sanitation and the practice of open defecation. While the situation has improved over the last decade, much remains to be achieved.

Environmental pollution often disproportionately affects young children, and poor children are more likely to die from pollution-caused illnesses, in part due to their poorer nutritional status and lesser access to health care. Mortality rates for children under five years of age from Lao PDR's two poorest population quintiles are more than twice those for children from the two richest quintiles. Children from the poorest quintile are nearly four times as likely to be underweight and nearly three times as likely to be stunted as children from the richest quintile. Household air pollution and inadequate drinking water and sanitation contribute to these disparities.

7.1 Introduction

Economic growth, targeted programs, and assistance to the poor have resulted in rapid poverty reduction in Lao PDR over the last two to three decades. The population living below the national poverty line declined from 46 percent in 1993 to 18 percent in 2019. Yet, disparities persist, and poverty incidence remains high in some geographic areas and among some population groups.

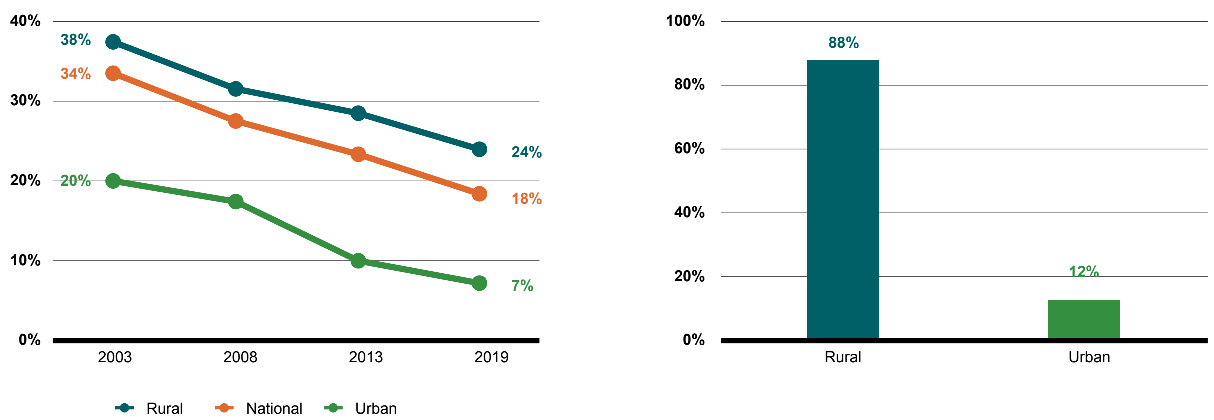
The poor suffer disproportionately from environmental pollution and from degradation of, loss of, and reduced access to natural resources that traditionally have formed the basis of their livelihood systems. The poor can less afford clean energies for cooking, have less access to safe drinking water and sanitation, and are excessively exposed to occupational environmental health hazards. The livelihood systems of the poor are highly reliant on natural resources for agricultural food and livestock production, wild food and income from the forest, and aquatic resources. Degradation of, loss of, or reduced access to these resources often cause increased hardship and deeper poverty.

7.2 Poverty in Lao PDR

Poverty-environment linkages in Lao PDR are largely a rural phenomenon, with as many as 88 percent of the poor living in rural areas in 2019. National poverty incidence declined by 45 percent, or from 34 percent to 18 percent, of the population from 2003 to 2019. Poverty reduction was most rapid in urban areas, with a decline of 65 percent—that is, dropping from 20 percent of the urban population in 2003 to 7 percent of the urban population in 2019. Poverty reduction in rural areas was more modest at 37 percent—that is, dropping from 38 percent in 2003 to 24 percent in 2019. This resulted in a rural poverty incidence that was over three times as high as the incidence in urban areas in 2019 (Figure 7.1).

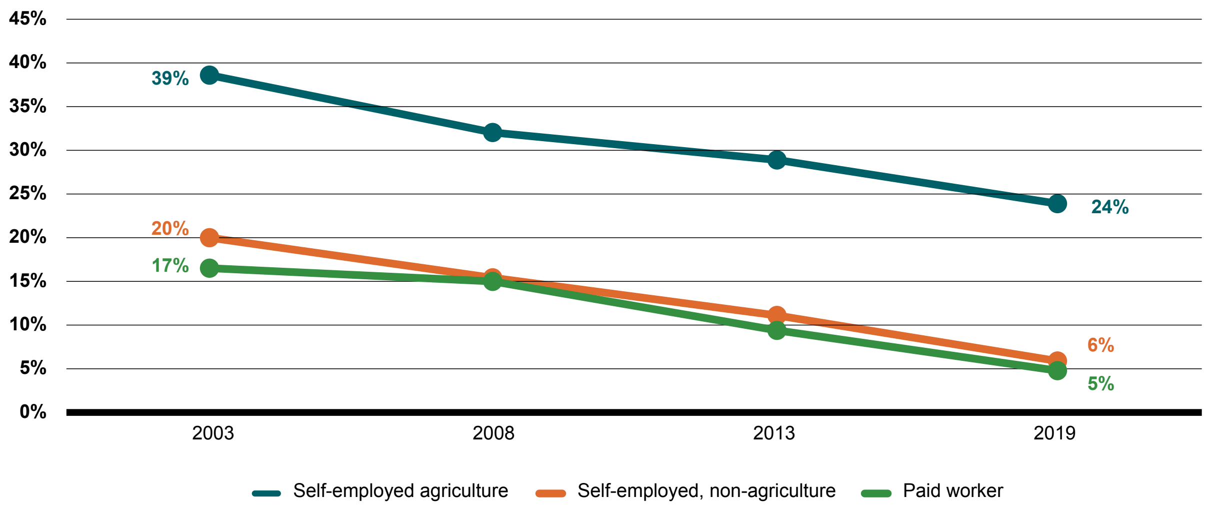
Poverty incidence by household economic activity reflects the rural-urban disparity. Poverty incidence among self-employed in agriculture was about four times as high as it was among self-employed in non-agriculture and paid workers in 2019, and poverty reduction was slowest among self-employed in agriculture from 2003 to 2019 (Figure 7.2).

Figure 7.1 Poverty Incidence and Distribution in Lao PDR, 2003–2019



Sources: Produced from LSB and World Bank 2014 and World Bank 2020.

Figure 7.2 Poverty Incidence by Economic Activity, 2003–2019



Source: Produced from LSB and World Bank 2014 and World Bank 2020

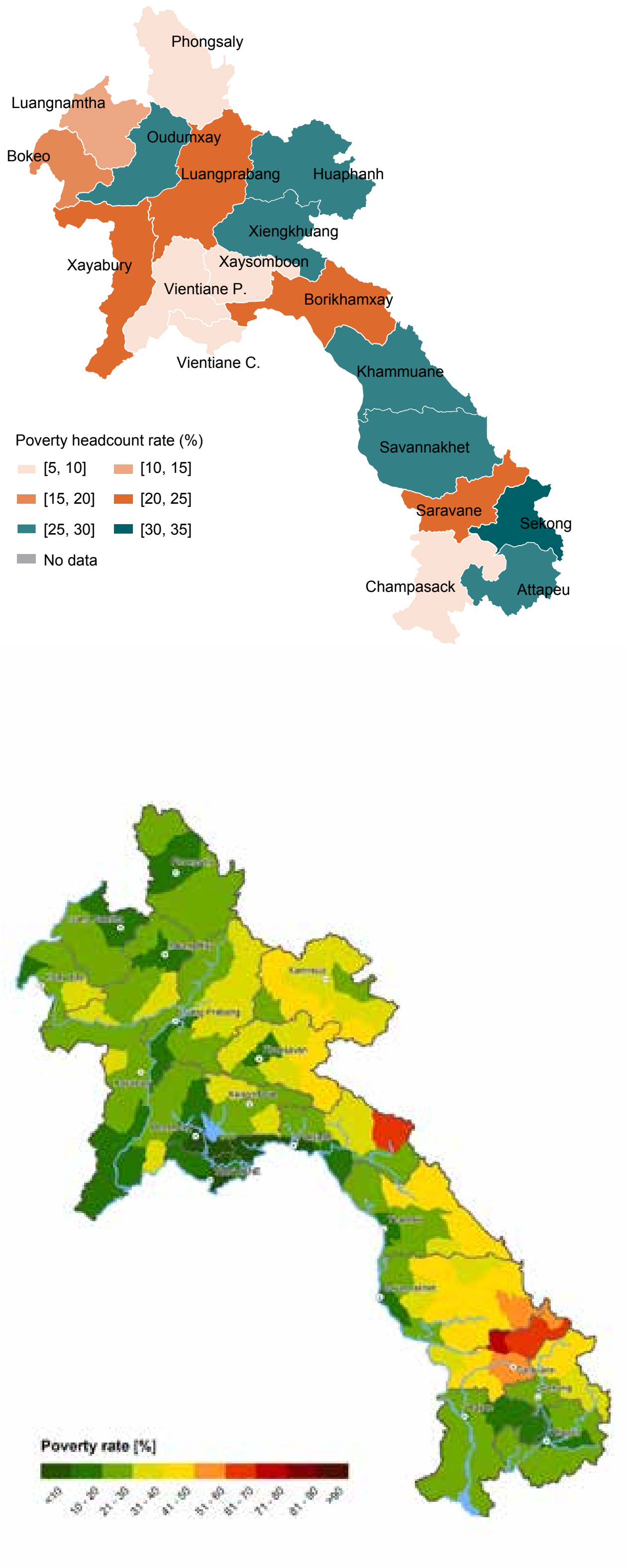
Large disparities in poverty incidence prevail across provinces and districts. Provincial poverty incidence in 2019 ranged from 5-10 percent in Vientiane Municipality and four provinces to over 30 percent in Sekong. At the district level in 2015, poverty incidence ranged from five percent in a district in Vientiane Municipality to 73 percent in a district in Saravane. Poverty incidence is generally highest in districts from north to south that border, or are near, Vietnam (Figure 7.3).[69] These districts tend to coincide with the Government of Lao PDR's (GoL's) 72 priority districts for poverty reduction.

The GoL identified 47 first-priority and 25 second-priority districts for poverty reduction (GoL 2003). The first-priority districts are concentrated along the border with Vietnam and in the northern region of Lao PDR. Poverty incidence in the first-priority districts declined from 50 percent in 2003 to 35 percent in 2013—that is, to the rate in the second-priority districts. Over half (53 percent) of the poor lived in the 72 priority districts in 2013, although these districts accounted for only one-third of the population of Lao PDR (Figure 7.4).[70]

Lao PDR is highly mountainous, sparsely populated with a density of less than 30 people per km^2 and has many remote areas with that are difficult to access and lack all-season roads. These features represent added challenges to poverty reduction. The country's topography can be categorized as *lowlands* with 56 percent of the population living near the Mekong River from Vientiane Province in the central region to Champasack in the south; *midlands* with 18 percent of the population at medium elevation; and *uplands* with 26 percent of the population in the mountainous areas of the northern region and along the border with Vietnam, covering 70 percent of the country's land area.

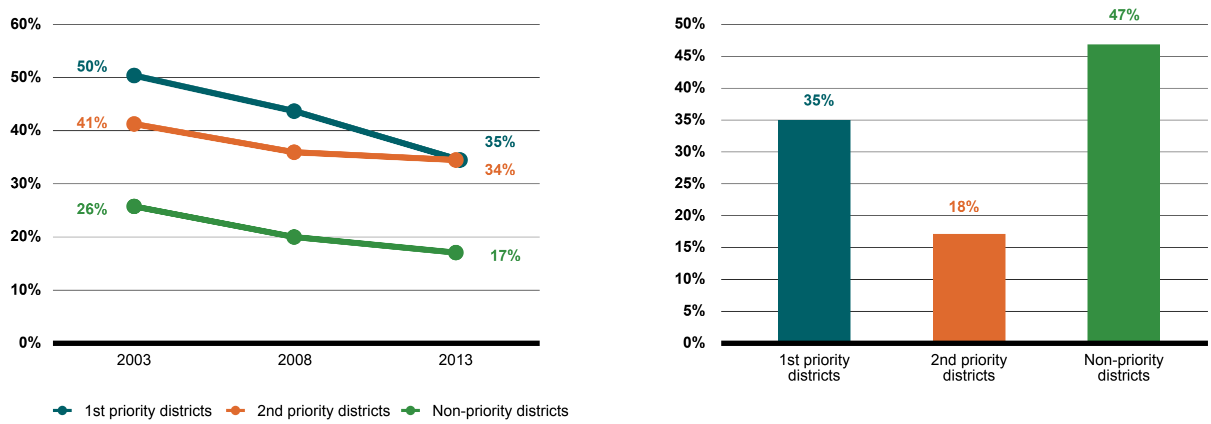
Poverty incidence is highest in the uplands and declined by only about 20 percent from 43 percent in 2003 to 34 percent in 2013. In contrast, poverty incidence declined by 40 percent in the midlands and 35 percent in the lowlands over the same period. Well over one-third of the poor now live in the uplands (Figure 7.5).[71]

Figure 7.3 Provincial and District Poverty Incidence in Lao PDR: Provincial Level (2019, top) and District Level (2015, bottom)



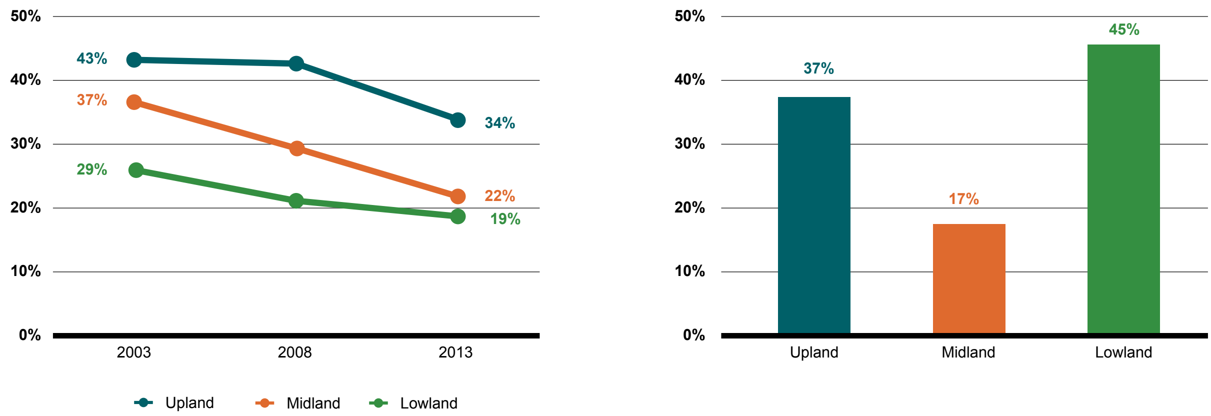
Sources: Province level from World Bank 2020. District level from LSB 2016a.

Figure 7.4 Poverty Incidence and Distribution in GoL Priority Districts for Poverty Reduction, 2003–2013



Source: Produced from LSB and World Bank 2014.

Figure 7.5 Poverty Incidence and Distribution by Topography, 2003–2013



Source: Based on LSB and World Bank 2014.

7.3 Environmental Health and Poverty

The cost of damage to health from pollution in Lao PDR is estimated as equivalent to 14.6 percent of GDP in 2017 (see chapter 3). A disproportionate share of this cost is borne by the poor. With as many as 88 percent of the poor living in rural areas in 2019, the major environmental health issues affecting the poor are mainly rural. The main issues are household air pollution (HAP) from the use of solid fuels, and inadequate drinking water and sanitation (WAS). The percentage of the district population that lacked improved sanitation, an improved drinking water source, and used wood for cooking in 2015 very much corresponds to the districts with high poverty incidence, especially in the southern half of the country (Figure 7.6).

Outdoor ambient air pollution (AAP) is also affecting the rural population, but pollution-exposure data are practically absent, making an analysis of AAP's effects on the poor very difficult. Major sources of rural ambient air pollution include burning of agricultural fields, burning of regrowth vegetation on fallow land in rotational agriculture, outdoor air pollution from household use of solid fuels, burning of waste, rural brick and charcoal kilns, and air pollution from other industry located outside urban areas. As to lead (Pb), little, if anything, is known about the socioeconomic dimensions of exposure in Lao PDR. Harmful exposure to pesticides has not been assessed in this report, but many cases of severe health effects in the country have been reported, mainly affecting low-income workers. The focus of this chapter is on household air pollution, drinking water, and sanitation.

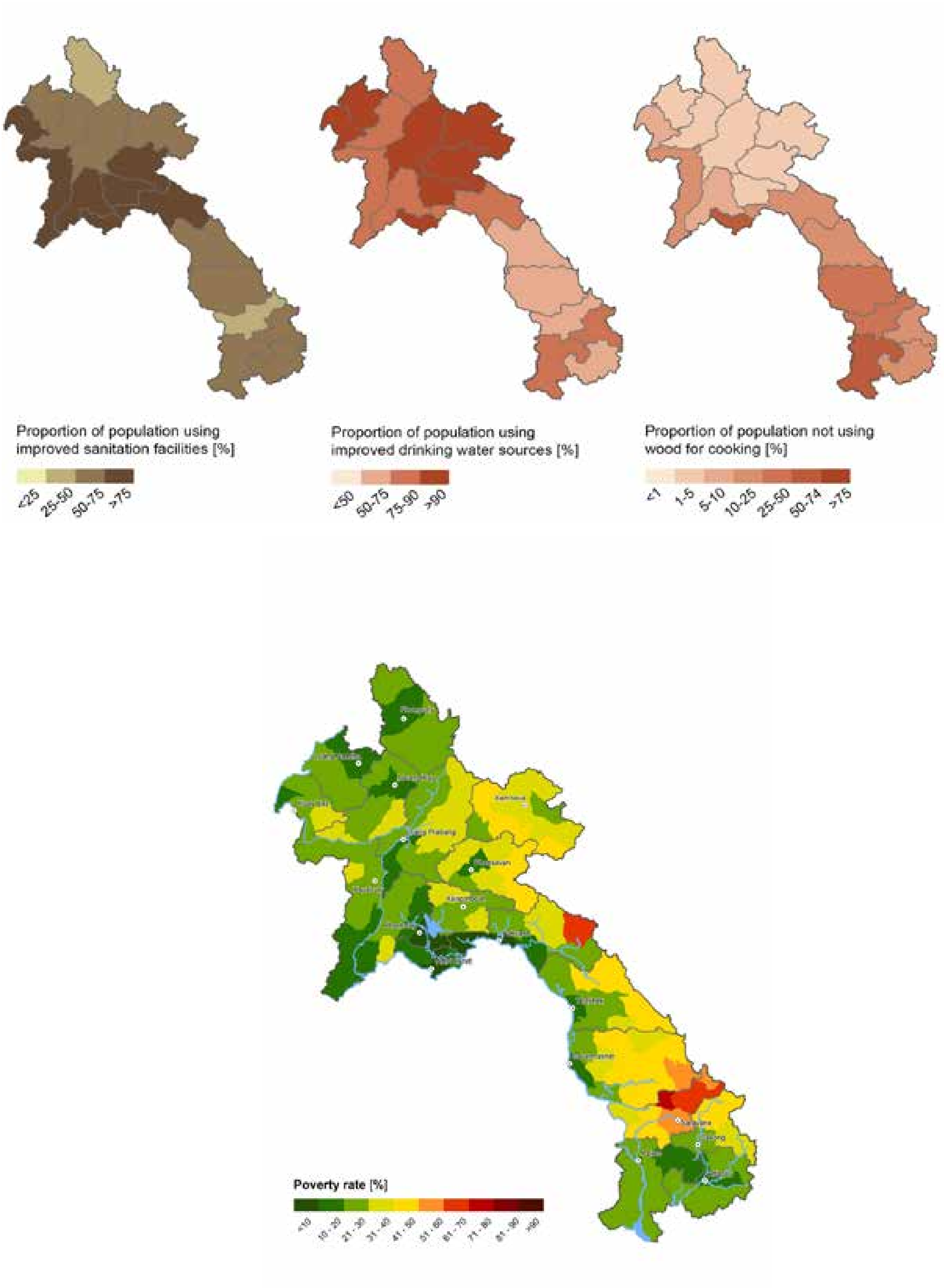
7.3.1 Household Air Pollution

Household use of solid fuels (wood and charcoal) causes severe air pollution and health effects in Lao PDR. However, the transition to clean energies (LPG, electricity) and cooking technologies has been remarkably slow. Over 93 percent of the population used solid fuels as their primary cooking fuel in 2017, according to the Lao Social Indicator Survey 2017 (LSB 2018a). As much as 98 percent of the rural population used solid fuels, and only two percent used clean energies. Even in urban areas, only 16 percent used clean energies. The use of clean energies, as well as charcoal, increases with living standard. Among the poorest quintile of the population, less than half a percent used clean energies, while among the richest quintile, 27 percent used clean energies and 51 percent used charcoal (Figure 7.7). While charcoal is a polluting fuel, it causes substantially less household air pollution than fuelwood and is often considered a transition fuel on the energy ladder towards clean energies.

Geographically, the use of clean energies is highest in Vientiane Capital followed by Bokeo and Borikhamxay. The use of charcoal is almost entirely in Vientiane Capital and Xayaburi, and in the provinces from Borikhamxay to Attapeu (LSB 2018a). Its use is highly concentrated along the Mekong River, as shown in the maps in the *Socio-Economic Atlas of the Lao PDR* (Epprecht et al. 2018), based on data from the Lao Population and Housing Census 2015 (LSB 2016b). A highly active charcoal-production industry and trade has developed, including regional exports, in these southern and south-central provinces (Barney 2016).

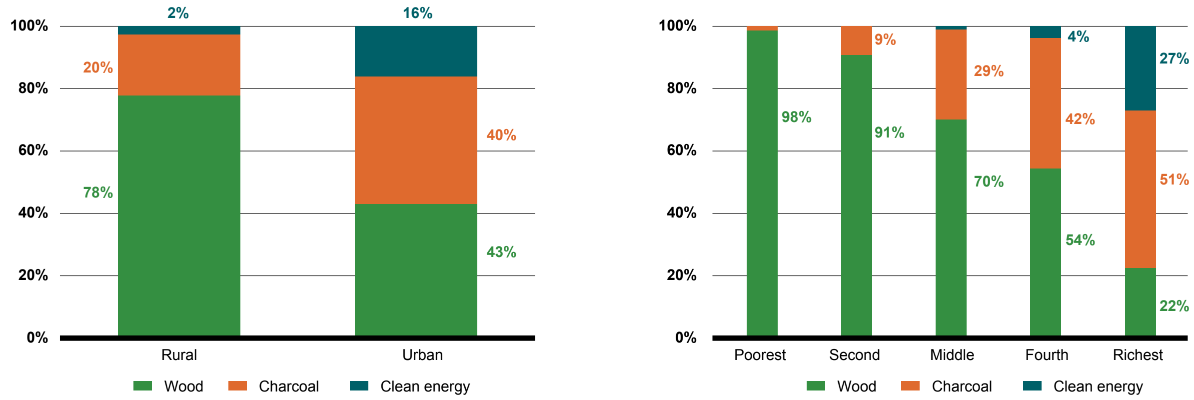
The limited use of clean energies for cooking in Lao PDR is in stark contrast to the situation in Vietnam, a country with very similar GDP per capita (Figure 7.8). About 48 percent of the rural population and 81 percent of the urban population used clean energies for cooking in Vietnam in 2014, in contrast to two percent and 16 percent, respectively, in Lao PDR. Almost every household (99 percent) in the richest quintile use clean energies in Vietnam, compared to 27 percent in Lao PDR. Even in the second-poorest quintile in Vietnam, as many as 26 percent use clean energies, or as many as in the richest quintile in Lao PDR. This underscores the potential for increased use of clean energies—even among lower-income households in Lao PDR—by raising awareness of the health benefits, providing the right financial incentives, and removing market and non-market barriers to adoption of clean energies.

Figure 7.6 District-Level Indicators of Sanitation, Drinking Water, and Household Air Pollution (Top 3 Maps), and Poverty (Bottom Map), 2015



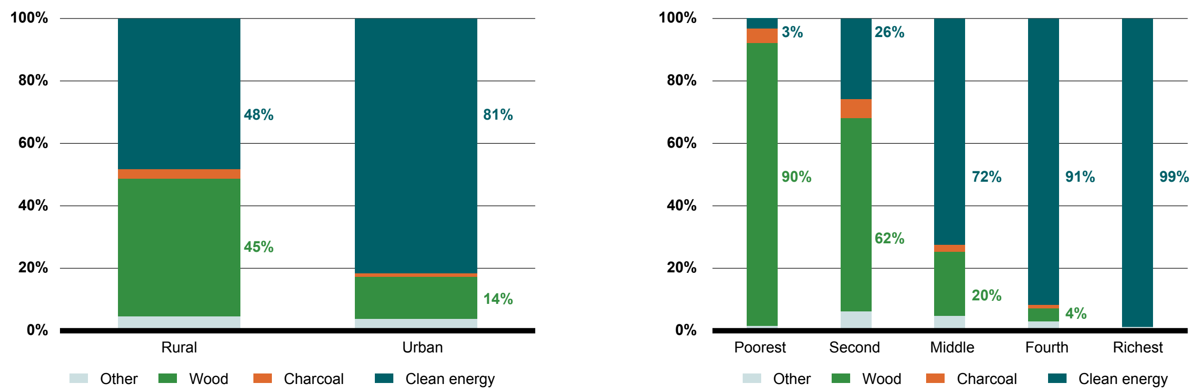
Source: LSB 2016a.

Figure 7.7 Household Cooking Energy Use in Lao PDR (% of Population), 2017



Source: Produced from LSIS II 2017 (LSB 2018a).
Note: Poverty quintiles are wealth quintiles based on household assets.

Figure 7.8 Household Cooking Energy Use in Vietnam (% of Population), 2014



Source: Produced from Vietnam MICS 2014 (GSO and UNICEF 2015).
Note: Poverty quintiles are wealth quintiles based on household assets.

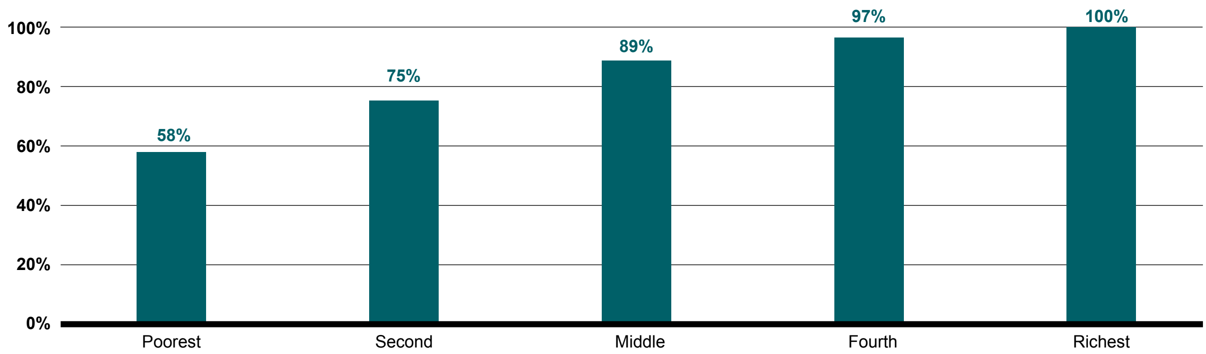
7.3.2 Household Drinking Water and Sanitation

An estimated 84 percent of the population in Lao PDR used an improved water source for drinking in 2017, according to the Lao Social Indicator Survey II 2017 (LSB 2018a). However, use of improved sources ranged from 58 percent among the poorest quintile of the population to practically 100 percent among the richest quintile (Figure 7.9).[72]

Geographically, the variation across provinces in the use of improved water sources for drinking is not very pronounced, but dips below 70 percent of the population in Bokeo (63 percent) and Luangprabang (68 percent), and is in the low 70s in Savannakhet (72 percent) and Saravane (71 percent), due to the use of unprotected springs in the north and unprotected wells in the south (LSB 2018a).

Perhaps the most significant development in the drinking-water sector in Lao PDR over the last decade has been the rapid increase in the purchase of bottled water. Bottled water is now the most prevalent source of drinking water, with as many as 48 percent of the household population using this source of drinking water in 2017, up from 26 percent in 2011–12 (LSB 2018a; MOH/LSB 2012). The use of bottled water is particularly prevalent among the two richest quintiles of households.

Figure 7.9 Household Use of Improved Sources of Drinking Water (% of Population), 2017



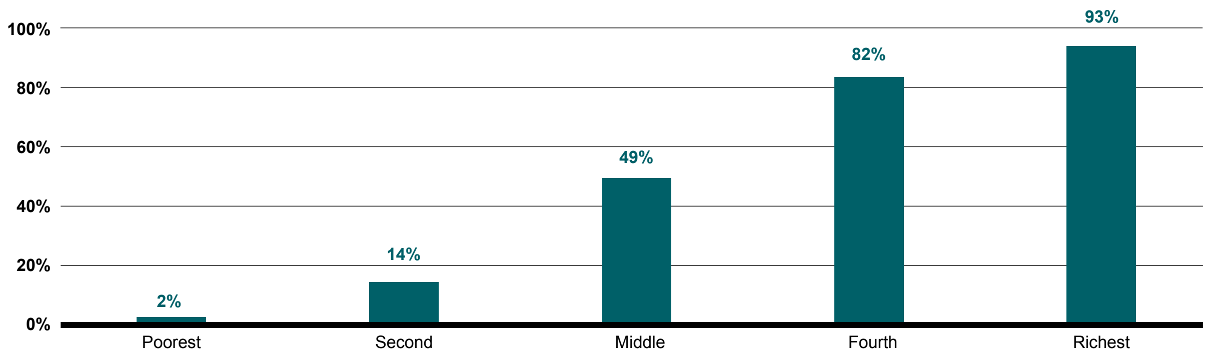
Source: Produced from LSB 2018a.

However, the use of bottled water is minimal among the two poorest quintiles (Figure 7.10).

In 2017, about 37 percent of the household population reported treating their water by an appropriate method prior to drinking it.[73] The main method of treatment was boiling (33 percent) and filtering of water (4 percent). The prevalence of drinking-water treatment is particularly low among the two richest quintiles of households (Figure 7.11). This coincides with these households mainly using bottled water for drinking. However, drinking-water treatment also declined from over 70 percent among the two poorest quintiles from 2011–2012 to 2017.

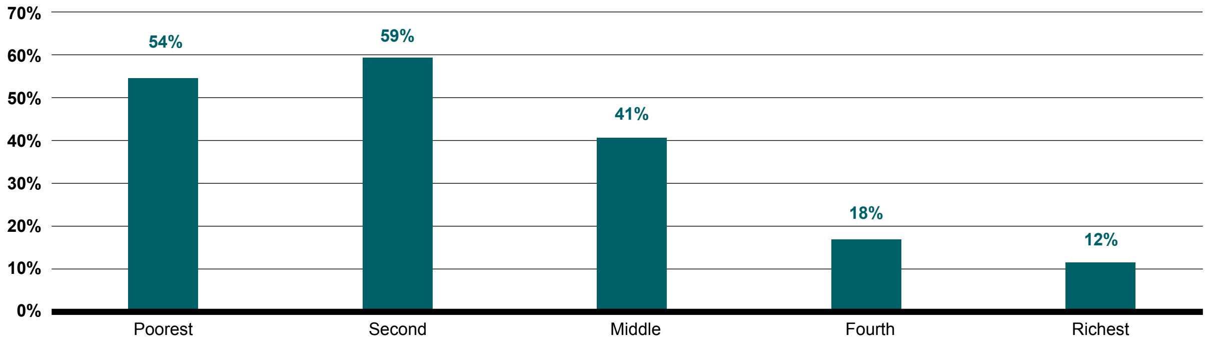
The boiling of drinking water provides protection against diarrheal disease, if water is not recontaminated prior to drinking. However, boiling of drinking water for all household members can involve the use of substantial amounts of fuelwood, equivalent to as much as one-fourth of fuelwood used for cooking. Boiling of water using fuelwood, as the poorer households in Lao PDR do, therefore causes substantial household air pollution and associated negative health effects, underlining the importance of promoting clean alternatives for drinking-water treatment such as ceramic filtering or solar disinfection.

Figure 7.10 Use of Bottled Water for Drinking in Lao PDR (% of Population), 2017



Source: Produced from LSB 2018a.

Figure 7.11 Household Treatment of Drinking Water in Lao PDR (% of Population), 2017



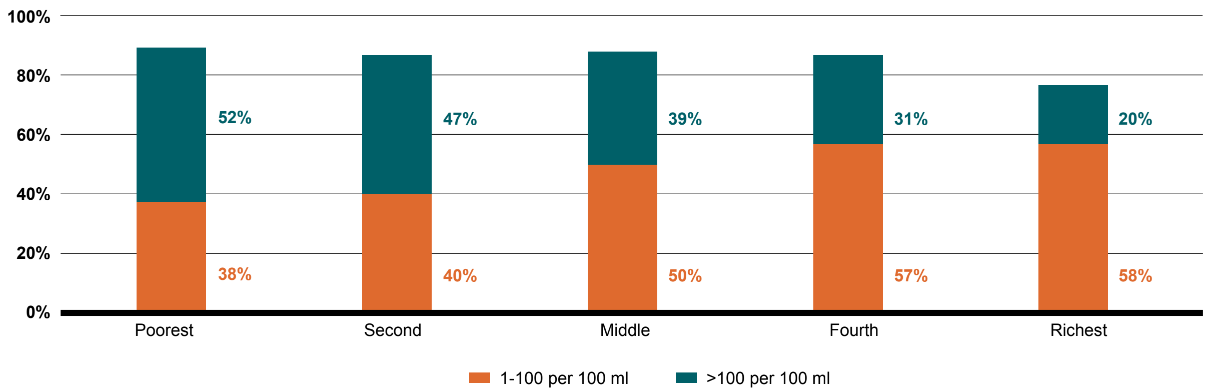
Source: Produced from LSB 2018a.

The Lao Social Indicator Survey II 2017 included testing for *E. coli* bacteria—an indicator of fecal contamination—in the drinking water of over 3,000 households throughout Lao PDR. As many as 86 percent of the household population had *E. coli* in their drinking water, and as many as 38 percent had very high concentrations (>100 *E. coli* per 100 ml).

The household prevalence of one or more *E. coli* per 100 ml of drinking water is very similar across household living standards. Only among the richest quintile of households is the prevalence somewhat lower at 78 percent compared to 87–90 percent. However, the prevalence of more than 100 *E. coli* per 100 ml of drinking water gradually declines from 52 percent among the poorest households to 20 percent among the richest households (Figure 7.12).

About 71 percent of the population in Lao PDR had access to improved, non-shared sanitation in 2017, while 24 percent practiced open defecation (OD), according to the Lao Social Indicator Survey II 2017 (LSB 2018a). However, access to sanitation and prevalence of open defecation varied greatly by household living standard. Just about 100 percent of the richest quintile of the population have improved

Figure 7.12 Household Drinking Water with E. coli by Household Living Standard (% of Population), 2017



Source: Based on LSB 2018a.

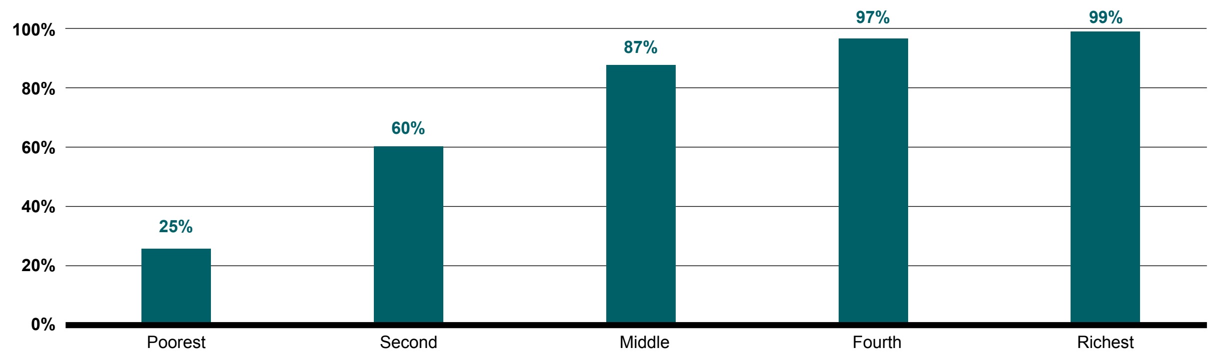
sanitation, while only 25 percent of the poorest quintile have it (Figure 7.13). However, this is an improvement from 2011–2012 when only 13 percent of the poorest and 35 percent of the second-poorest quintile of the population had improved sanitation, according to data from MOH/LSB (2012). As to open defecation, as many as 72 percent of the poorest quintile and 36 percent of the second-poorest quintile of the population practiced this form of sanitation in 2017, underlining the disparity in access to household sanitation facilities (Figure 7.14).

Geographically, the lack of household sanitation—that is, households practicing OD—is especially prevalent in Phongsaly and the central and southern provinces from Khammuane to Attapeu, reaching a high of 65 percent in Saravane (LSB 2018a). This is confirmed by data from the Lao Population and Housing Census 2015 (LSB 2016b) with maps presented in the *Socio-Economic Atlas of the Lao PDR* (Epprecht et al. 2018). The lack of household sanitation coincides with high incidence of poverty, but the lack is also prevalent in provinces that now have achieved relatively low incidence of poverty such as Attapeu and Pongsaly; these findings are shown in the *Socio-Economic Atlas of the Lao PDR.*

7.3.3 Some Health Indicators

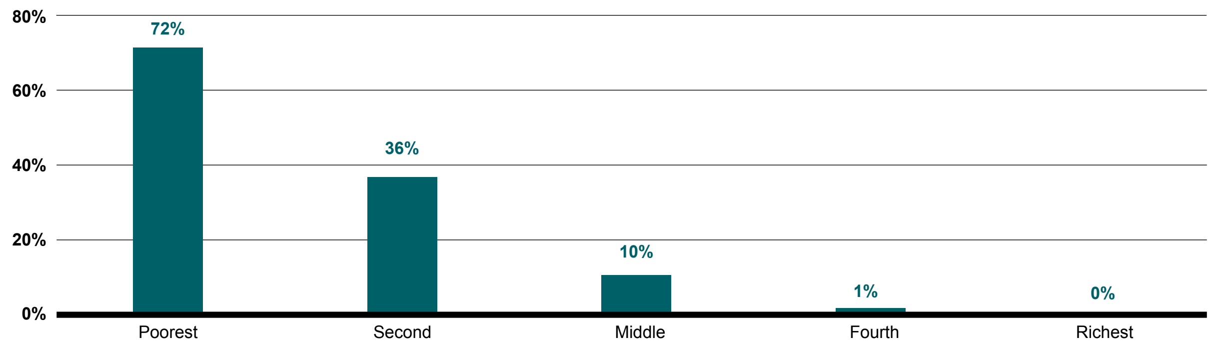
Data on the health status of the population by living standard are limited in Lao PDR. However, the Lao Social Indicator Survey (LSIS) II 2017 (LSB 2018a) provides some perspectives for young children. Young children are often disproportionately affected by

Figure 7.13 Access to Improved Sanitation in Lao PDR (% of Population), 2017



Source: Based on LSB 2018a.

Figure 7.14 Practice of Open Defecation in Lao PDR (% of Population), 2017



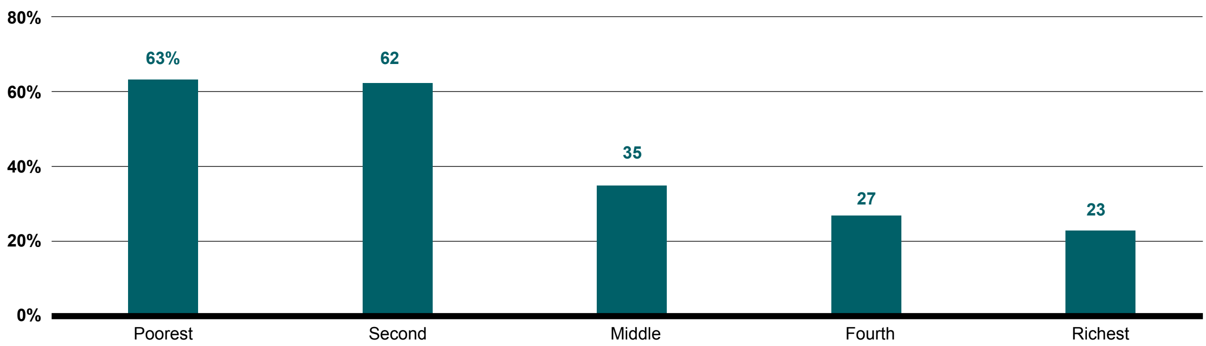
Source: Based on LSB 2018a.

environmental pollution and poor children are more likely to die from illnesses caused by pollution, in part due to poorer nutritional status and lesser access to adequate treatment and health care. Under-five child mortality rates in Lao PDR ranged from 62–63 per 1,000 live births among children from the two poorest quintiles of the population, to 23–27 among children from the two richest quintiles according to the LSIS II 2017 (Figure 7.15).

Diarrheal disease and acute respiratory infections (ARI) are among the leading causes of child mortality in Lao PDR. Inadequate drinking water and sanitation and household air pollution contribute substantially to these diseases. Data from the LSIS II 2017 indicate that the incidence of diarrheal disease among children under-5 years of age are about 75 percent higher among children from the two poorest quintiles of the population than among children from the richest quintile. The incidence of acute respiratory infections (ARI) seems to show no such pattern, but the fatality rate of ARI is substantially higher among the poor because of poorer nutritional status and lesser health care, as previously stated.

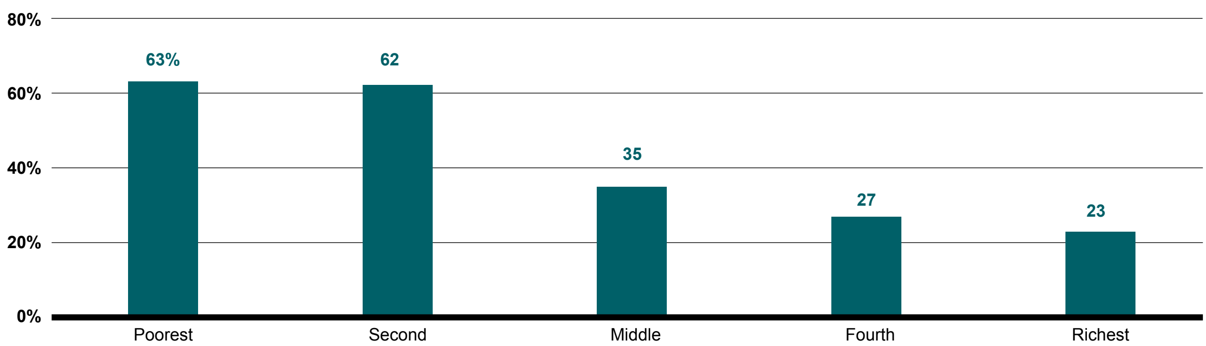
As to nutritional status, children from the poorest quintile of the population are nearly four times as likely to be underweight and nearly three times as likely to be stunted as children from the richest quintile (Figure 7.16. While there are multiple reasons for the high rates of poor nutrition status among poor children, repeated infectious disease, and especially repeated diarrheal

Figure 7.15 Under-5 Child Mortality Rates in Lao PDR, 2017



Source: Produced from LSB 2018a.
Note: Child mortality per 1,000 live births in the five years preceding the LSIS II 2017 survey.

Figure 7.16 Prevalence of Underweight and Stunting among Children under 5 in Lao PDR, 2017



Source: Produced from LSB 2018a.
Note: Prevalence of moderate and severe underweight and stunting

disease in early childhood, is often one of the causes (Fewtrell et al. 2007; World Bank 2008). Poor nutritional status in turn substantially increases the risk of mortality from infectious disease (Olofin et al. 2013), setting in motion a vicious circle disproportionately affecting the poor.

7.4 Natural Resources and Poverty

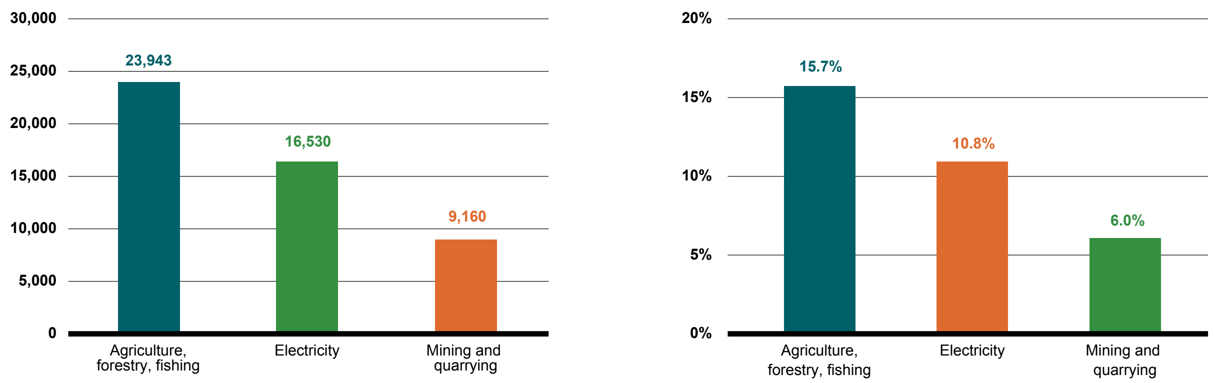
The poor are highly dependent on agriculture, capture fisheries, and non-timber forest products (NTFPs) from local forest resources. They are also highly dependent on forest and vegetation covers that regulate water services and mitigate flash floods and soil erosion. The protection, productivity and quality of these natural resources, the poor's access to these resources, and their sustainable management are therefore essential for the poor's livelihood, food security, balanced nutrition, and poverty alleviation.

7.4.1 Natural Resource Contribution to GDP

Natural resource sectors contributed one-third of GDP in Lao PDR in 2018. Agriculture, forestry, and fishing contributed the largest share, followed by electricity production and mining and quarrying (Figure 7.17). While value added per worker is many times higher in electricity production and mining and quarrying than in agriculture, forestry and fishing, the latter sectors provide for two-third of total employment and form the basis of the livelihood of the vast majority of the poor (World Bank 2019a).

However, the contribution of these sectors does not provide a full view of the contribution of natural resources to GDP and household income and consumption. Natural resources, such as NTFPs and fish, are important sources of household self-collected energy and food that may not be adequately reflected in GDP. Natural resources are also important for foreign tourism to Lao PDR as well as for domestic tourism and recreation. There are over 1,300 natural sites for tourism and 4.2 million foreign tourists visited Lao PDR in 2018 (LSB 2019). Tourist revenues were US$811 million for the year, an amount equivalent to 4.5 percent of GDP (MOICT 2019).

Figure 7.17 Natural Resource-based Sectors Contribution to GDP in 2018 (LAK Billion)



Source: Produced from LSB 2019.

Natural resources also provide an indirect contribution to GDP. Forests provide regulation services that reduce flash floods, flooding, landslides and droughts with damages to productive assets, and prolong the useful life of productive assets (for example, reduced sedimentation of reservoirs). The value of these regulation services has not been quantified.

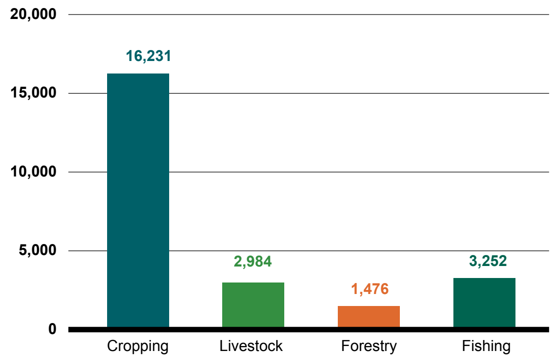
Agriculture, forestry, and fishing contributed 15.7 percent of GDP in 2018. Two-thirds of that 15.7 percent came from crop cultivation, followed by fishing, livestock, and forestry (Figure 7.18). While the agricultural, forestry, and fishing share of GDP has declined substantially over the past two decades from 34 percent in 1999 to 16 percent in 2018, total employment in the sectors increased by 12 percent and the real value added from the sectors increased by 80 percent (World Bank 2019a). This has contributed to a rise in farm population income, but agricultural, forestry and fishery GDP per worker in Lao PDR is only one-tenth of industrial and service sector GDP per worker,[74] shedding light on the poverty in the sectors, the need for increased agricultural productivity, access to off-farm natural resources, and off-farm income opportunities to alleviate poverty.

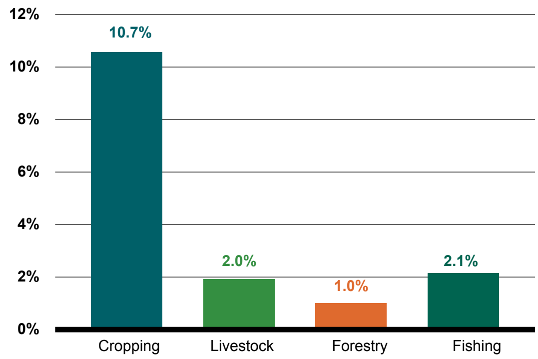
7.4.2 Agriculture

The agricultural sector in Lao PDR has undergone substantial changes over the last two decades, contributing to poverty reduction across the country. These changes include a substantial expansion of agricultural cropland, larger land holdings per farm household, crop diversification, a transitioning from subsistence to commercial agriculture, intensification, and mechanization with increased reliance on modern inputs (that is, improved seeds, chemical and organic fertilizers, and pesticides) and machinery (that is, tractors), and a substantial increase in cattle and pigs (LSB 2019; MAF 2012). Nevertheless, crop productivity remains far below potential (see section 4.4) and most of the rural poor in Lao PDR are agricultural small-holders.

Cultivated land increased by two-thirds from 0.85 million hectares in 1998/99 to 1.4 million hectares in 2010/11 (5.9 percent of total territory), according to the Lao Census of Agriculture 2010/11 Highlights (MAF 2012).[75] While farm households declined from 84 percent to 77 percent of all households over this time period, the farming population increased from 4 million to 4.5 million due to population growth. But average farm household land holding nevertheless increased from 1.6 ha to 2.4 ha; the share of farm households with less than 1 ha of land declined from 36 percent to 22 percent; the share of households with more than 2 ha increased from 27 percent to 46 percent; and the share of households with 1–2 ha remained relatively constant at about one-third (MAF 2012).

Figure 7.18 Agriculture, Forestry, and Fishery Contribution to GDP, 2018 (LAK Billion; % Share)





Source: Produced from LSB 2019.

Practically all farm households cultivated at least some rice. Maize was the second most common crop, grown by nearly 1/4th of all farm households in 2010/11, with a five-fold increase in area under cultivation from 1998/99. As many as 40 percent of farm households cultivated vegetables in 2010/11, up from 35 percent in 1998/99. As to permanent crops, 24 percent of farm households grew mango, 8 percent grew banana, and 6 percent grew rubber in 2010/11, representing a less than 20 percent increase from 1998/99.

The share of farm households producing mainly for sale increased from six percent in 1998/99 to 30 percent in 2010/11, underscoring the transformation that the agricultural sector is undergoing from subsistence to commercial farming. The share of farm households producing mainly for sale was about the same in lowlands, midlands and uplands, and in urban and rural villages with road access, but somewhat lower at about 20 percent in rural villages without road.

Agricultural intensification was also evident over this period. Chemical fertilizers were used by 42 percent of farm households in 2010/11, up from 29 percent in 1998/99; organic fertilizers were used by 41 percent, up from 34 percent; and 17 percent used pesticides, up from 11 percent. Ownership of 2-wheeled tractors increased from 7 percent to 34 percent of farm households while use of 2-wheeled tractors increase from 20 percent to 61 percent by 2010/11. Tractor ownership among rural households increased to 44–46 percent in 2017 according to national household surveys carried in 2017—that is, the LSIS 2017 (LSB 2018a) and the Lao PDR Labour Force Survey 2017 (LSB 2018b)—with ownership even higher among farm households.

Cattle ownership increased from 31 percent of farm households in 1998/99 to 38 percent in 2010/11, with a 68 percent increase in total cattle to an average holding of 5.3 animals. The share of farm households with buffalos, pigs, chickens and ducks somewhat declined from 1998/99 to 2010/11.

The agricultural sector has continued to expand since the last agricultural census in 2010/11. Paddy rice area has increased by another 10 percent, area under maize cultivation by 50 percent, the total cattle holding by another 25 percent, and holdings of pigs has quadrupled according to the Lao PDR Statistical Yearbook 2017 (LSB 2018c), all while total employment in the sector (including own farm labor) has remained constant and the sector's share of employment declined by 9 percentage points as employment increased in the industrial and service sectors (World Bank 2019a).

7.4.3 Forestland

Forested area in Lao PDR stood at 13.37 million hectares, or 58 percent of total territory in 2015, according to the new forest classification system by the Ministry of Agriculture and Forestry (GoL 2018; MAF 2018). This constituted mostly mixed forest (mixed deciduous, coniferous, and mixed coniferous and broadleaved), but also evergreen forest, dry dipterocarp, and plantation forest (Figure 7.19).[76]

Per the forest classification in Article 9 of the Lao PDR *Forestry Law* 2007, forested areas of protection forest, conservation forest, and production forestlands constituted over 44 percent of total territory in 2015 while *other forest* constituted nearly 14 percent (Figure 7.20).

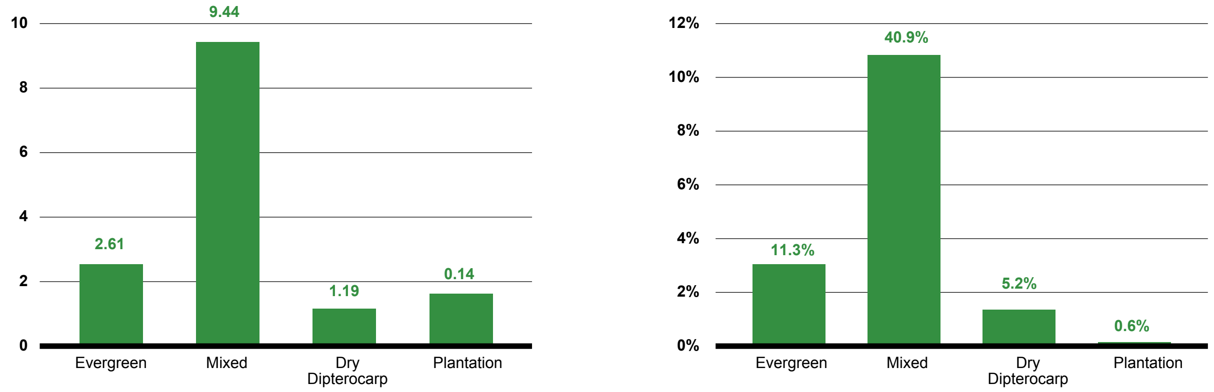
These forested areas are important sources of food and cash income, especially for the poor and semi-poor households, as discussed below. Deforestation and forest degradation, as detailed in section 4.3, therefore disproportionately affect these households.

7.4.4 Food and NTFPs

The rural poor in Lao PDR are highly dependent on their local natural resources for their food supply, from both on-farm agriculture and livestock, as well as from forests and water resources. These resources are also important sources of cash income.

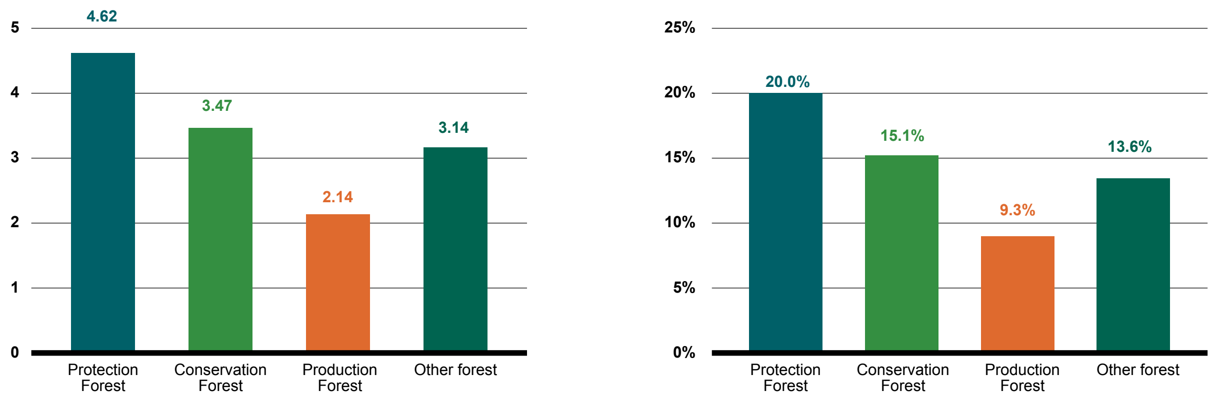
The rural poor's own produced food accounted for as much as 82 percent of their total food consumption in 2012/13. Nearly half of the food consumption of the rural poor was rice. Meat, fish, and vegetables and

Figure 7.19 Forested Area by Type of Forest in Lao PDR, 2015 (Million ha; % of Territory)



Sources: Produced from MAF 2018 and GoL 2018.
Note: Mixed forest refers to mixed deciduous, coniferous, and mixed coniferous and broadleaved.

Figure 7.20 Forested Area by Forest Classification in Lao PDR, 2015 (Million ha; % of Territory)



Source: Produced from GoL 2018.
Note: "Other forest" is "forest outside the above three forest categories."

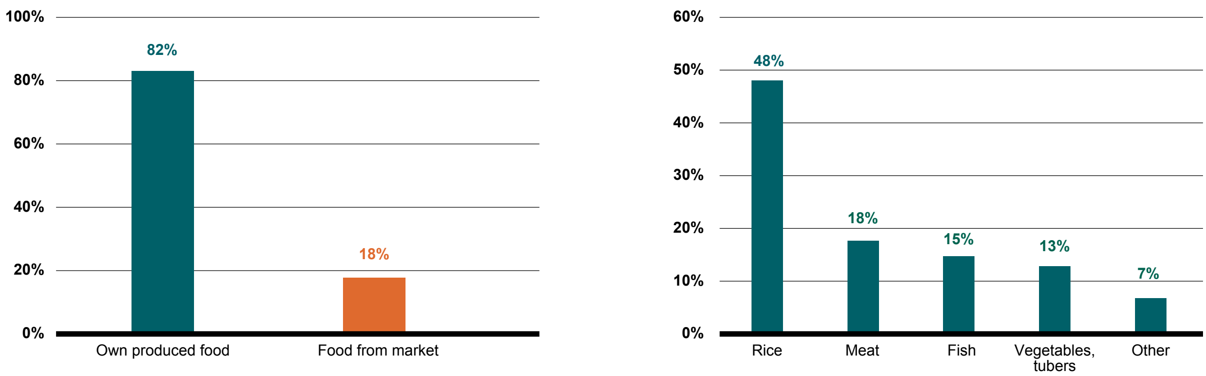
tubers accounted for about 45 percent (Figure 7.21). This includes food both from their agricultural production as well as food from the forest and water resources.

About 67 percent of farm households engaged in capture fisheries in 2010/11, about unchanged from 1998/99. About 77 percent of these households produced only for own consumption. Of the farm households engaged in capture fisheries, almost all households fished in rivers and as many as 37–40 percent also fished in lakes/reservoir or rice fields (Figure 7.22).

Nearly nine percent of farm households engaged in aquaculture in 2010/11, also nearly unchanged from 1998/99. About two-thirds of these households produced only for their own consumption.

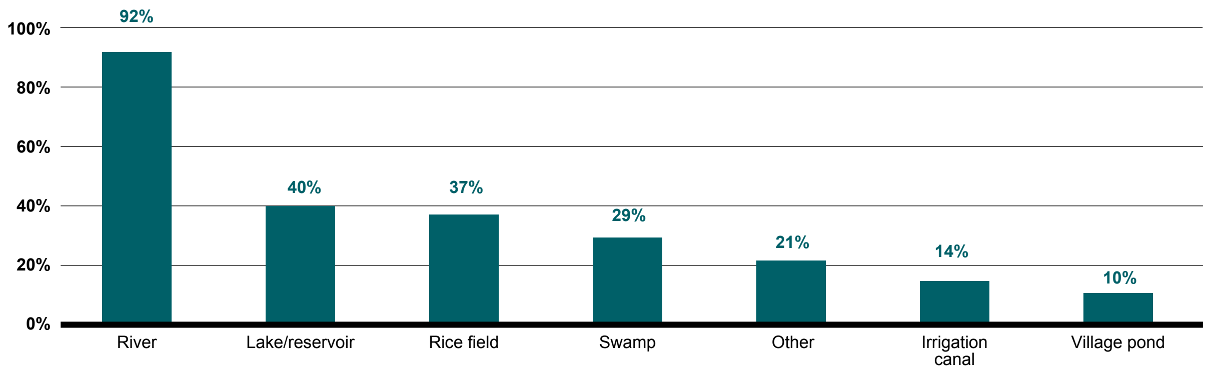
Nearly 70 percent of farm households exploited public forestland for various products in 2010/11. The most common products were fuelwood, mushrooms, fruits and vegetables, and bamboo (Figure 7.23). Nearly 40 percent of these households sold some of these products to supplement their income.

Figure 7.21 Food Consumption of the Rural Poor in Lao PDR (% of ConsumptionV), 2012–13



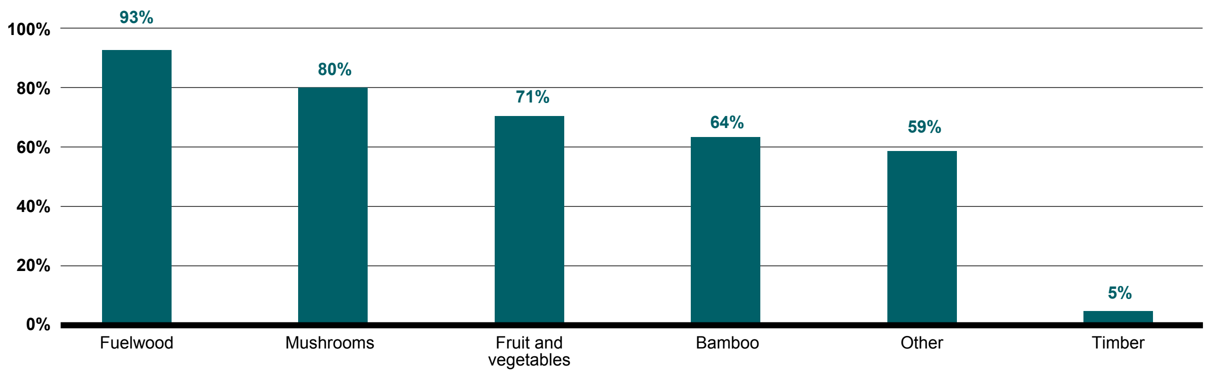
Source: Produced from LSB and World Bank 2014.

Figure 7.22 Farm Households Engaged in Capture Fisheries in 2010/11, Place of Fishing



Source: Produced from MAF 2012.

Figure 7.23 Farm Households Exploiting Pubic Forests in 2010/11, Type of Products



Source: Produced from MAF 2012.

A detailed analysis of the Lao Expenditure and Consumption Survey 2007/08 (LECS IV) confirms the importance to the poor of the food they produce themselves and of wild food (Fenton et al. 2010). As much as 76 percent of all food consumption among the poor is either on-farm own produced or wild food from forests and local water resources (Figure 7.24). This ranges from 54 percent of meat consumption to 85 percent of rice consumption. Rice consumption is practically exclusively from on-farm production while the source of vegetables and fruits and meat is evenly split between the farm and forests. Almost all fish consumption is from local water resources, mostly rivers.

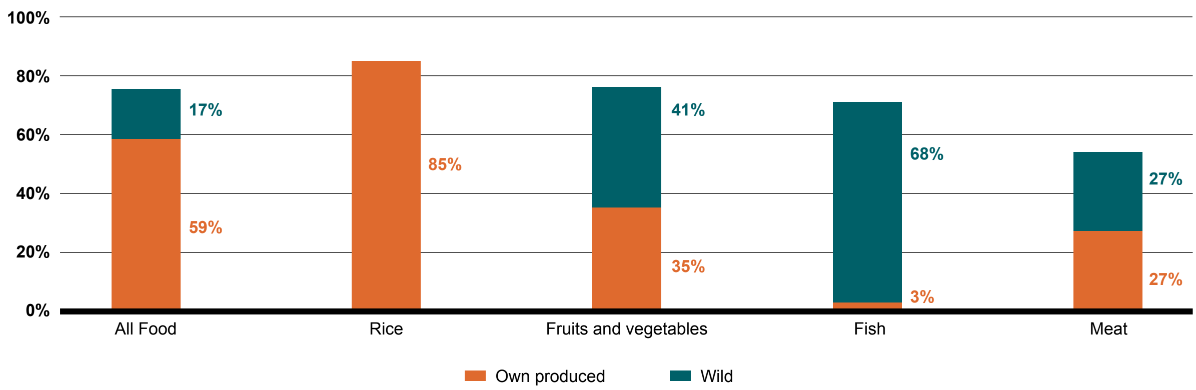
This points to the importance of the forests and water resources as sources of protein, dietary variety, and overall nutritional value. About 17 percent of all food consumption of the poor came from the forest and local water resources. Perhaps most importantly, forests and rivers are an essential safety net during times of crisis and low agricultural periods (Fenton et al. 2010).

A Poverty-Environment Nexus (PEN) Study in the lower Mekong subregion carried out a district survey of non-timber forest products (NTFPs) in Lao PDR in 2005 (World Bank 2006; 2012). The PEN Study reports that the 39 districts responding in the survey reported a total of 37 different marketed NTFP species. Eight species were reported as important marketed species in at least two of the three regions of Lao PDR and five other species were important in one region. Cardamom was reported as important in nearly 70 percent of the districts, and rattan in almost 60 percent. Only benzoin, an important local species, was absent in this analysis, because the producing districts in northeastern Lao PDR did not respond to the survey.

The PEN Study reports that NTFP species in Lao PDR are harvested from three clearly differentiated domains: old-growth natural forests, secondary forests, and young fallows. Only three of the thirteen main nationwide and regional species were reported as fully harvested from the *natural forest.* Four species were described as secondary forest species and two as fallow species. The remaining four species were classified as harvested in more than one domain.

The districts reported a noticeable decline in the availability of forest NTFP species and an increase in the two fallow species. Declining quality of NTFPs was also reported. District respondents attributed the NTFP resource decline primarily to overharvesting and the practice of rotational cultivation. Northern districts reported active market developments, especially close to the China border. Price increases were noted for forest species, together with declining availability of many species. Conversely, the two fallow species showed an increase in availability and marketed quantities. Some domestic cultivation, predominantly in the Northern provinces, was reported for seven of the thirteen main species and for five secondary species.

Figure 7.24 Shares of Food Consumption among the Poor in Lao PDR, 2007/08



Source: Produced from Fenton et al. 2010.

The PEN Study report concludes that market pressure from China and Vietnam is an important factor triggering NTFP resource decline. Communities' customary regulations are still in place but are weak in the face of high market demand and in the absence of a formal regulatory framework. The disappearance of some of the NTFP resources would substantially affect broad numbers of upland communities, where poverty incidence remains high (World Bank 2006; 2012).

More recently, an NTFP database has been developed by the TABI project.[77] The database is continuously updated and contains several sub-databases. As of the first half of 2017, the sub-databases contained (i) primary NTFP database with nearly 10,800 entries from 231 villages in 22 districts in 9 provinces; (ii) wood database with over 7,800 entries from 102 villages in 3 districts in Luangprabang Province; and (iii) aquatic database with over 8,400 entries from 257 villages, but had not been cleaned or maintained.

Analysis of the NTFP database in 2016–2017 shows that over 500 NTFP species were collected in forests, over 200 in riparian areas, over 200 in bush fallows, and over 300 species on other lands. As much as 50 percent of total collected NTFPs are used for food, 30 percent are sold, and 205 are for medicinal and other purposes. Various mushrooms, orchids, bamboo, and palm generate the most household income.

7.4.5 to Climate Risks

Natural disasters are imposing a substantial cost on Lao PDR each year, as discussed in section 4.6. Databases such as DesInventar and EM-DAT provide the basis for estimating these costs.[78] The large majority of natural disasters in Lao PDR recorded by these databases are flood and storm events. However, *silent* disasters—such as droughts—may be underreported. As many as 31 percent of rural villages reported in the Lao PDR Census of Agriculture 2010/11 that they are prone to flood and 70 percent reported they are prone to drought (MAF 2012). According to the Lao PDR Labour Force Survey 2017, 15 percent of rural households reported that their income declined from the previous year, of which nearly 5 percent reported that flooding was the main reason and 7.5 percent reported drought as the main reason (LSB 2018b).[79]

The Lao Expenditure and Consumption Surveys (LECS) conducted every five years by the Lao Statistics Bureau shed some light on the issue of flooding and drought in relation to poverty. Nearly 20 percent of households surveyed in LECS 2002/03 lived in villages that reported that recurrent drought is a major restriction on earnings, and about 30 percent lived in villages that reported that recurrent flooding is a major restriction. Analysis of the data found that poverty incidence was significantly higher among villages that reported recurrent drought being a major restriction on earnings than among villages that did not report this. Furthermore, poverty incidence was lower in villages that reported recurrent flooding being a major restriction on earnings.[80]

In the LECS 2007/08 survey, about 15 percent of villages reported that recurrent drought is a major restriction on earnings, and 21 percent reported that recurrent flooding is a major restriction. Drought as a major restriction on earnings is again correlated with poverty and most prevalent in the GoL's 47 priority districts for poverty alleviation, the group of districts with the highest poverty incidence.[81] There are, however, none of these relations with flooding as a major restriction on earnings.[82]

Thus, from a perspective of alleviating poverty, an increased focus is needed on mitigating and managing climate and natural disaster risks in terms of drought among the poorer communities. The LECS surveys can serve as an important instrument in identifying priority communities.

7.4.6 National Protected Areas

The system of National Protected Areas (NPAs) in Lao PDR was established in 1993. It consists of 20 NPAs and 3 National Parks areas covering about 38,600 km^2 or 16 percent of the total territory of Lao PDR. Most of the NPAs have low population densities of less than 10/km^2, some have low-medium densities of 10–30/km^2, and in rare instances do population densities exceed the national average of 29/km^2 (Figure 7.25).

Poverty status in the NPAs is, however, somewhat different. Poverty density—that is, number of poor people per km^2—is relatively high in some of the NPAs in the Mekong Corridor in the provinces of Savannakhet and Saravane, and of medium density in several NPAs in the northern region and south/central regions (Figure 7.26).

This points to the importance of balancing the objectives of poverty reduction and conservation in the NPAs. Participatory approaches to resource management can enhance sustainability, enhance new sustainable sources of income, as well as contribute to reducing encroachment by outside commercial interests.

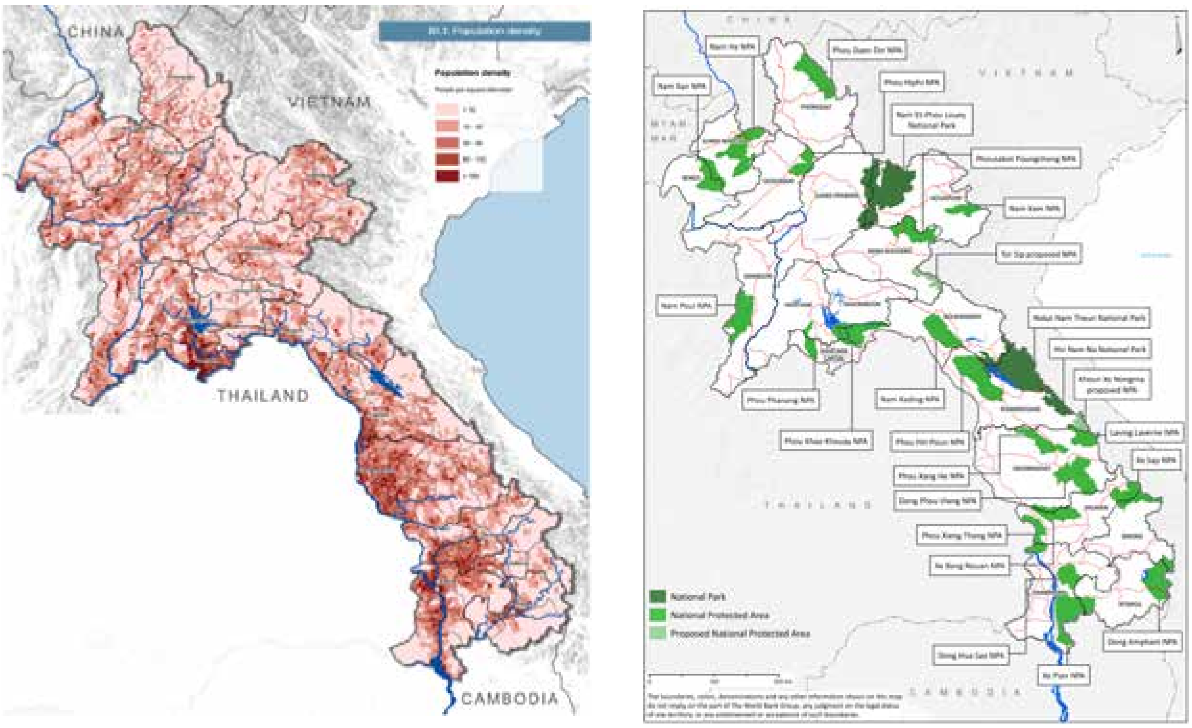
In a conservation and sustainable resource management project in the Hin Nam No National Protected Area in Khammuane Province, communities shortlisted NTFPs for income generation through sustainable management and marketing. The marketing and demand potential of these NTFPs were then assessed, and a final NTFP selected for sustainable income generation (AFC 2013).

7.4.7 Land Concessions

Natural resource sectors are often competing against one another for land and water. Agriculture and forestry plantations, mining, and hydropower development can provide high economic returns per hectare of land and water use, but potentially at the expense of the local population in terms of loss of access to natural resources for their livelihood, relocation, and pollution and health impacts.

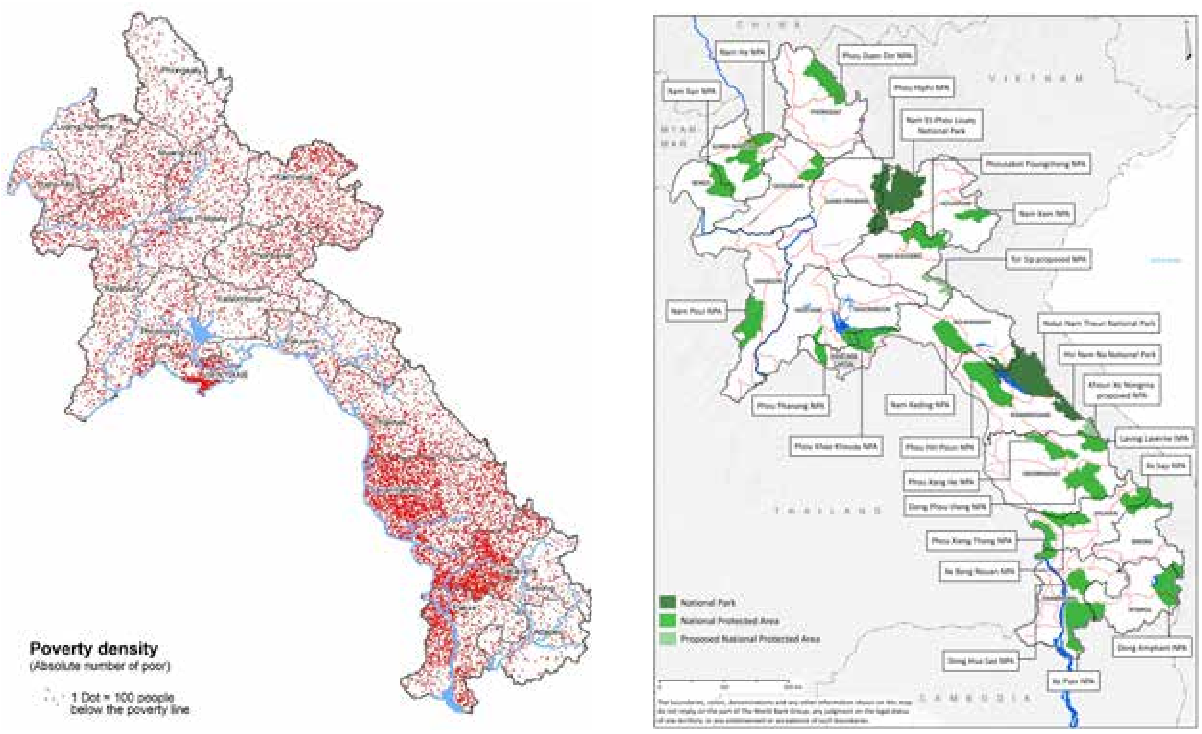
This underscores the importance of sustainable development of natural resource sectors with protection of the poor, including adequate and timely compensation for loss of natural resources that underpin the poor's livelihood.

Figure 7.25 Population Density and Location of National Protected Areas (NPAs) in Lao PDR



Sources: Population density in 2015 (left) from Epprecht et al. 2018. Map of NPAs (right) from World Bank 2019b.

Figure 7.26 Lao PDR Poverty Density (2015, left); Location of National Protected Areas (NPAs, Right)



Sources: Poverty density in 2015 is from LSB 2016a. Map of NPAs (dark green) is from World Bank 2019b.

Land concessions in Lao PDR have not been without controversy. As it became evident that many land concession projects were having negative effects on the environment and the local population, GoL issued moratoria on land concessions, the latest in 2012 for mining, rubber, eucalyptus, and some other plantations (Hett et al. 2018). The moratorium on eucalyptus and acacia plantations was lifted in 2018.

The State Land Leases and Concessions Inventory was the first national inventory of land concessions and leases and was prepared by the GoL between 2007 and 2010 with collection and analytical support from Germany and Switzerland. The inventory is detailed in Schoenweger et al. (2012). It contains a total of 2,642 land concessions and leases with a land area of 1.1 million hectares, or almost as much as all land under agricultural crop cultivation in Lao PDR at that time. Nearly half, or 1,291 concessions and leases, covering an area of 1.0 million hectares were in agriculture (140,000 ha), forestry (306,000 ha) and mining exploitation (549,000 ha).[83] The remaining 104,000 hectares were in tourism (75,000 ha), manufacturing/processing (23,000 ha), and various industrial and service sectors (6,000 ha).[84]

Agriculture: The inventory contains 360 agricultural projects covering 140,000 hectares. Sugarcane, jatropha, coffee, and cassava constituted 94,000 hectares, followed by livestock with over 31,000 hectares, and other concessions and leases with less than 15,000 hectares. Domestic investors stood for 40 percent of the projects covering 20 percent of the area of the concessions and leases. The largest foreign investors are Thai with 40 percent of the area.

Forestry: The inventory contains 367 tree plantation projects covering 306,000 hectares. As many as 225 of the projects are rubber plantations (130,000 ha), followed by 49 eucalyptus projects (96,000 ha), 5 acacia projects (40,000 ha), and 23 rubber and other species (15,000 ha). Another 65 projects invest in other species with an area of 26,000 hectares.

Foreign investment projects cover 79 percent of areas under forestry concessions and leases (ca. 242,000 ha), domestic projects cover 11 percent (34,000 ha), and joint ventures cover 10 percent (30,000 ha). The largest investors are Chinese (87,000 ha), Vietnamese (63,000 ha) and Indian (54,000 ha). China dominates in acacia plantations, Vietnam in rubber, and India in eucalyptus.

Mining exploitation: The inventory contains 564 mining exploitation concessions and leases with a total land area of 549,000 hectares. Nearly three-fourths, or 413, of these projects were by domestic investors covering 114,000 hectares. A total of 127 projects were by foreign investors covering 355,000 hectares, of which 69 projects (97,000 ha) by Chinese investors and 32 projects (233,000 ha) by Vietnamese investors. Joint ventures constituted 24 projects with an area of 80,000 hectares.

A total of 365 concessions and leases (57 percent) are sand/gravel, gravel/stone, and limestone projects mostly owned by domestic investors and of small and moderate size. Thereafter follows 116 zinc/tin, copper, iron, gold, bauxite, and coal projects (21 percent) with a total area of 453,000 hectares (83 percent of area).

At the time of the preparation of the concession and lease inventory, there were an additional 111 mining exploration concessions covering 1.0 million hectares, dominated by exploration for gold and copper, followed by iron, potash, bauxite, lead/zinc, and coal (Schoenweger et al. 2012).

One dimension of interest is the geographic distribution of land concessions and leases in relation to the socioeconomic status of villages in the areas of the concessions and leases. This dimension was assessed by mapping land concessions and leases with small area estimates of poverty incidence.[85] Schoenweger et al. (2012) found that poverty incidence in the areas with domestic invested concessions and leases in agriculture, forestry, and mining was substantially below the national average poverty incidence of 34 percent. But the total area of these concessions and leases is only a small fraction of the areas with foreign invested concessions and leases. Poverty incidence in the areas with foreign investments was 32 percent for agricultural concessions and leases, 36 percent for mining concessions and leases, and 39 percent for forestry concessions and leases. Thus, any negative effects on these communities only exacerbate their economic hardship and undermines the natural resource base of their livelihood.

Lao DECIDE Info—a joint initiative by the governments of Lao PDR and Switzerland—has been updating the inventory of land concessions and leases and has developed a methodology for assessing the quality of investments. This methodology was applied to an updated inventory of agricultural and mining concessions in Luangprabang Province (Hett et al. 2018). The updated inventory showed a 77 percent increase in the number of land concessions in the province from 2010 to 2014. Most of the concessions were domestic investments and were small-scale mining of sand and gravel, mostly with less than 1 hectare per project. Only 17 percent of the projects were foreign investment but occupied 81 percent of total land concession area. Rubber was the most dominant product in these concessions with an average area of nearly 3,000 hectare per project. The assessment found

- All livestock projects, 90 percent of sand projects, and 60 percent of gravel projects were generally perceived as positive by the affected villagers.
- In contrast, four out of five rubber plantation projects were perceived as predominantly negative.
- Rubber plantations were associated with land conflict, inadequate consultation of affected villagers, and loss of access to forest products.
- Small concessions were generally perceived as more positive than large concessions.

Since the time of the preparation of the inventory of land concessions and leases, banana plantations, mainly involving Chinese investors, took hold in Lao PDR. Total area harvested reached 28,600 hectares in 2016 and declined to 22,605 in 2017, according to FAO.[86] On the order of two-thirds of this area may be foreign invested plantations using imported banana species. The sector has been suffering from complaints of pervasive health effects among workers and pollution of land and water resources due to elevated use of pesticides and other agrochemicals. Provincial government authorities began prohibiting new banana plantations and closure of existing ones already two years ago.

7.4.8 Hydropower Development

Hydropower development in Lao PDR has facilitated an increase in household electrification from 15 percent in 1995 to 94 percent in 2018 (EDL 2019). Electric power generation has developed at a rapid pace in Lao PDR over the last decade with installed capacity increasing nearly ten-fold from 2009 to over 7,000 MW in 2018, with a majority of electricity production being exported to neighboring countries.

Around 75 percent of installed power generation capacity in 2018 was derived from hydropower on the tributaries of the Mekong River spread over more than 60 hydropower plants and one large coal fired power plant—Hongsa Thermal Power with 1878 MW—that came into operation in 2015/16. The first hydropower plant on the Mekong River in Lao PDR—Xayaburi Hydroelectric Power with 1,285 MW—commenced operations in late 2019 and Don Sahong with 260 MW in 2020.

Most of Lao PDR's hydropower plants are based on dams with reservoirs. Total inundated area by hydropower plants in operation, under construction and at planning stage is projected to be over 3,000 km^2, or 300,000 hectares, with an estimated total resettlement of 280,000 people (Fenton and Lindelow 2010). This population is generally poorer than the national average. Poverty incidence among the population living in areas to be inundated by hydropower development for which area of reservoirs is published was 47 percent in 2005, compared to a national average of 34 percent (Fenton and Lindelow 2010). Given the mixed experience with resettlement from hydropower development in the past in Lao PDR, it is therefore essential that resettlement practices receive full attention.

Hydropower development with reservoirs is very land intensive. To provide a perspective on the land requirement, 28 hydropower projects in Lao PDR in operation or under construction were analyzed during the preparation of this report for which size of reservoir is published. The total installed capacity of these projects is over 6,200 MW and are currently or will eventually inundate an area of more than 1,700 km.

The size of the reservoirs of the 28 hydropower plants ranges from 1.5–9.6 km^2 for eight of the plants, to 105–450 km^2 for five plants. From another perspective, reservoir size ranges from 2–9 hectares per MW for eight power plants, to over 40 hectares per MW for four power plants. On average, reservoir area is 27 hectares per MW, or about 5.1 hectares per GWh per year.[87]

In contrast, utility-scale PV solar plants would, in many locations in Lao PDR, require only about 1 hectare per GWh per year of electricity production.[88] So as the cost of utility scale PV solar electricity production continues to decline, hydro-solar hybrid solutions will become increasingly attractive. This will include floating PV solar plants on hydro reservoirs. Over 1 GW of floating solar was installed worldwide by mid-2018 (World Bank et al. 2018). In Lao PDR, utilizing on the order of 20 percent of the reservoir surface for floating utility-scale PV solar plants has the potential to double the electricity generation in the country.[89] Floating PV solar plants have already been proposed on a number of hydropower reservoirs in the Sekong River Basin (IFC 2018).

Utility-scale PV solar power is less land-intensive than hydropower, and it has far fewer environmental and social impacts. Solar power produces more electricity in the dry season during which hydropower production in Lao PDR declines.

Hydropower can nevertheless provide high economic benefits per hectare of land. The economic rent accruing to hydropower in Lao PDR—that is, the value of hydropower electricity above capital expenditure, variable cost, and normal return to capital—has been estimated at an average of about US$30/MWh (Boungnong and Phonekeo 2012). Two-thirds of this rent may accrue to Lao PDR, one-third to the importing country for the electricity that is exported, and some of the rent that accrue to Lao PDR is shared with the project developer (MacGeorge et al. 2010). For illustration, if half of total rent is accrued by GoL, then the economic value of hydropower is on average about US$3,000 per hectare per year of inundated land. However, most of the projects have an economic value in the range of US$3,000–13,000 per hectare per year, with only five projects having an economic value less than US$3,000 per hectare per year. Four of the five projects with reservoir larger than 100 km^2 have the lowest economic value per hectare—that is, US$330–1,875 per hectare per year.

In contrast, agricultural land values, in terms of rental value, have been reported to be about US$600 per hectare per year, illustrating the substantially higher value of most hydropower projects. However, this illustration does not account for environmental and social impacts of hydropower, nor does it reflect variation in economic value of hydropower across project locations.[90]

7.4.9 Unexploded Ordnance (UXO) Contamination

Lao PDR has included Sustainable Development Goal (SDG) 18 on reducing unexploded ordnance (UXO) obstacles to development. UXO affects 14 of Lao PDR's 17 provinces and more than 25 percent of the total land area. Nationally, over 25 percent of all villages and close to 25 percent of the total population in Lao PDR are affected by UXO. About 14 percent of villages are classified as having a high UXO contamination problem. UXO contamination affects agricultural land development and implementation of development projects, increases the cost of development, restricts movements between villages, slows transportation and communication work, undermines social and economic development, and has resulted in thousands of casualties since 1975 (World Bank 2012).

The Poverty-Environment Nexus (PEN) Study in Lao PDR found that poverty incidence and UXO contamination are highly correlated. This finding is from analysis of household data from the Lao Expenditure and Consumption Survey 2002/03 (LECS III), district level poverty incidence in 2005 derived from the Lao Housing and Population Census 2005 and LECS III, and village level UXO contamination data from the national UXO survey 1997. Findings from these data are that districts with a high share of villages affected by UXO had substantially higher poverty incidence than less affected districts, had less cultivated land per capita, had higher rate of rice insufficiency, had to spend more time on fuelwood and water collection, and had less access to improved water supply and sanitation (World Bank 2006; 2012). According to the Lao Census of Agriculture 2010/11 Highlights, UXO affect agricultural land in 16 percent of villages (MAF 2012).

The relation between UXO contamination and poverty has continued since 2005. The correlation between high district poverty incidence and high percentage of villages affected by UXO was just as pronounced in 2015 as in 2005. Reduction in poverty incidence from 2005 to 2015 in districts affected by UXO has been no faster than in less or not affected districts, despite increased efforts and funding for UXO clearance in Lao PDR.[91] This suggests that further targeting of UXO clearance towards the poorest and most contaminated districts is needed, along with complementary poverty reduction policies, programs and projects.

The GoL recognizes that UXO contamination poses severe threats to the population and represents a major barrier to green growth. The National Regulatory Authority for UXO and Mine Action in Lao PDR (NRA) was established in 2005 and become operational in 2006. NRA is tasked with coordinating and regulating the overall management of the UXO sector in Lao PDR, including national, commercial and humanitarian operators. The NRA leads the country's policy formulation with regards to the UXO/Mine Action sector, accredits operators, coordinates operational activities, manages information and data on UXO, and manages quality of operations in the sector.

UXO Lao was established in 1996 by the GoL, with a mandate to reduce the number of accidents and casualties from UXO and to increase the amount of land available for food production and other socioeconomic development. UXO Lao's approach includes educating people on the risks of unexploded ordnance, surveying land to find UXO, and destroying the found UXOs. UXO Lao works in the nine most-contaminated provinces in Lao PDR: Huaphanh, Luangprabang, Xiengkhuang, Khammuane, Savannakhet, Saravane, Sekong, Attapeu, and Champasack.[92]

Before 2014, UXO Lao focused on areas that were selected based on requests for clearance of land boundaries and UXO reports from villagers. As a result, the number of UXOs per hectare that was found was small. However, in 2014 UXO Lao adopted an evidence-based survey for cluster munitions, which were approved by NRA as national procedures in 2015. Using the evidence-based approach led to a more systematic development of surveys and destruction of UXOs. Between July 2014 and April 2017, 43,837 UXOs were destroyed.[93]

Several governments and international organizations have supported Lao PDR's UXO clearance agenda. The United Nations Development Program (UNDP) is currently implementing the project "Moving Towards Achieving SDG 18: Removing the UXO Obstacle to Development in Lao PDR."[94] The Project, to be implemented from 2017 to 2021 will include additional improvements in the approach used to find UXO, such as using data and prioritization to focus clearance in high priority and high contamination areas, thereby resulting in more UXO finding.

Given that UXO contamination is a significant obstacle to poverty reduction and green growth, further efforts to address it are required, in particular to focus on technical assistance to help UXO Lao and other organizations to use more-innovative UXO detection technologies. For instance, Sato and Kadoya (2018) propose using an innovative visualization system for a metal detector that does not use Global Navigation Satellite System (GNSS) information. These would be particularly useful in areas where dense bushes constrain the use of GNSS/GPS. They also noted that the metal detectors used by staff on the field were outdated, resulting in inefficiencies for UXO detection. UXO Lao has also identified the need to train its staff, particularly in areas such as use of computers and data analysis.

7.5 Summary

Poverty reduction has been rapid, albeit uneven, in Lao PDR over the last two decades. Poverty incidence in rural areas was more than three times as high as in urban areas in 2019. About 88 percent of the poor consequently lived in the rural areas, and the poverty-environment linkages in Lao PDR are therefore mainly rural.

7.5.1 Environmental Health

The poor suffer disproportionately from household air pollution, since the poor rely almost exclusively on more-polluting energies for cooking—that is, fuelwood—in contrast to better-off households' use of less-polluting energies such as LPG/electricity and charcoal. However, the experience of the transition to clean cooking energies in Vietnam suggests that a much larger share of the population in Lao PDR, including among lower-income households, should be able to transition to clean energies.

The poor have much less access to improved sources of drinking water and sanitation than better-off households. The use of purchased bottled water has increased rapidly in Lao PDR but is still beyond the means of the poor. The poor therefore rely on the boiling of drinking water, using fuelwood that causes substantial negative health effects. Potential solutions to this problem include the use of clean treatment methods such as ceramic filtering or solar disinfection of water prior to drinking. The poor are also facing drinking water of lesser quality than better-off households, again underscoring the need for clean point-of-use treatment methods. The largest disparity between the poor and better-off households is the lack of access to improved sanitation and the practice of open defecation. While the situation has improved over the last decade, there is still much to be achieved.

Young children are often disproportionately affected by environmental pollution, and poor children are more likely to die from illnesses caused by pollution, in part due to their poorer nutritional status and less access to adequate treatment and health care. Under-5 child mortality rates in children from the two poorest quintiles of the population are more than twice as high as children from the two richest quintiles. Children from the poorest quintile of the population are nearly four times as likely to be underweight and nearly three times as likely to be stunted than children from the richest quintile. Household air pollution and inadequate drinking water and sanitation contribute to these disparities.

Potential interventions to address major environmental health risks in Lao PDR are assessed in chapter 9. These interventions, if also benefiting the poor, have the potential to provide more equity in environmental quality and health.

7.5.2 Natural Resources

Natural resource sectors contributed one-third of GDP in Lao PDR in 2018. Agriculture, forestry, and fishing contributed the largest share, followed by electricity production, and mining and quarrying. However, the contribution of these sectors does not provide a full view of the contribution of natural resources to GDP in terms of the value of non-marketed goods, tourism, and the regulation services that forests provide for the protection of productive assets.

Agriculture development in the last couple of decades has contributed to rapid household poverty reduction through expansion of arable land, increased size of household land holdings for agriculture, intensification and mechanization, commercialization, and crops of higher value added.

The poor continue to depend on natural resources about as much as before, since most of the poor are rural small-holders. A substantial share of their food is from the forest and local water resources. Own-caught fish and wild meat are important sources of protein for the poor, and forest food contributes substantially to dietary variation and nutrition. NTFPs are also an important source of income for the rural population and the poor, but some NTFPs are being over-harvested and are on the decline in several provinces. While Lao PDR still has substantial forested lands, degradation and deforestation disproportionately affect the poor.

The poor are vulnerable to climate risk. A high share of the population is at risk of periodic flooding and drought. While major flooding events are well recorded, *silent* disasters such as droughts seem to be under-recorded, and household surveys point to how droughts are disproportionately affecting the poor, pointing to the need for more interventions for risk reduction and management in poor communities affected by droughts.

Lao PDR has many national protected areas (NPAs) that cover about 16 percent of its territory. Many people reside inside and at the boundary of the NPAs and tend to be poorer than the average. This points to the importance of balancing the objectives of poverty reduction and conservation in the NPAs. Participatory approaches to resource management can enhance sustainability and enhance new sustainable sources of income, as well as contribute to reducing encroachment by outside commercial interests.

Land concessions and leases expanded at a rapid pace from the early 2000s in Lao PDR, especially for agriculture, forestry plantations, and mining. Especially large concessions were not without negative impacts on local communities and moratoria were implemented. More recently, the expansion of banana plantations has been halted due to numerous reports of negative health effects from pesticides and other agrochemicals as well as water pollution. Lao DECIDE Info—a joint initiative by the governments of Lao PDR and Switzerland—has developed a methodology for assessing the quality of land-concession investments that may have the potential to be applied successfully to new projects to ensure sustainability and benefits for local communities.

Hydropower has proceeded rapidly over the last decade and a half. While the economic value of hydropower per hectare often is higher than many other uses of the land, large land areas have been and will be inundated with resultant relocation of communities. Hydropower development often also has numerous other negative effects on communities, the environment, and natural resources that need to be carefully mitigated and properly compensated, as well as fully internalized in calculations of its economic value relative to alternative development scenarios. Hydropower with reservoirs is land intensive, on the order of five times more than PV solar plants in Lao PDR. As the cost of PV solar continues to decline, there are likely to be substantial opportunities to incorporate PV solar (and other renewables) in electricity generation, and in particular hybrid solutions with floating PV solar on existing and planned hydropower reservoirs.

UXO contamination continues to affect communities in many parts of the country. Analysis of household data along with UXO contamination maps has shown how UXO disproportionately affects the poor. Reduction in poverty incidence from 2005 to 2015 in districts affected by UXO has been no faster than in less affected or unaffected districts, despite increased efforts and funding for UXO clearance in Lao PDR. This suggests that further targeting of UXO clearance towards the poorest and most contaminated districts is needed, along with complementary poverty reduction policies, programs, and projects. Furthermore, strengthening the use of data-driven analysis and incorporating the use of new technologies can potentially increase the efficiency of UXO clearance interventions.

The poor are highly dependent on agriculture, capture fisheries, and NTFPs from local forest resources. The poor are also highly dependent on forest and vegetation covers that regulate water services and mitigate flash floods and soil erosion. The protection, productivity, and quality of natural resources, the poor's access to these resources, and their sustainable management are therefore essential for the poor's livelihood, food security, balanced nutrition, and poverty alleviation.

7.6 Notes

68 This chapter was prepared by Bjorn Larsen.

69 Provincial poverty incidence is from LECS V (2012/13). District poverty incidence is a small-area estimation using a combination of LECS V and the Lao PDR Population and Housing Census 2015.

70 World Bank (2020) does not present poverty incidence in the GoL priority districts. The most recently available data are therefore from 2013.

71 World Bank (2020) does not present poverty incidence by topography. The most recently available data are therefore from 2013.

72 Improved sources of drinking water include delivered and packaged water (for example, bottled water), based on the new Sustainable Development Goal (SDG) definition (LSB 2018a).

73 Appropriate methods include boiling, bleaching/chlorination, filtering, and solar disinfection.

74 Workers in agriculture, forestry, and fishing include farmers' own labor. Calculated from World Bank (2019).

75 Temporary and permanent crops.

76 Forestlands (that is, as stated in the Lao PDR Forestry Law 2007: "all land plots with or without forest cover, which are determined by the state as forestlands"), however, constitute a much larger share of total territory in Lao PDR. For instance, current forest (58 percent) and potential forest (28 percent) (bamboo and regenerating vegetation) constituted 85 percent of total territory in 2015 (MAF 2018).

77 http://www.tabi.la/activity/ntfp/

78 See https://www.desinventar.net/ and https://www.emdat.be/ and https://www.preventionweb.net/english/

79 Other main reasons among rural households included enemy crop (8.4 percent), epidemics (2.3 percent), no agricultural production (20.6 percent), unemployment (18.5 percent), and price inflation (8.2 percent).

80 The correlations between poverty and drought and between non-poor and flooding are statistically significant at 99% confidence level.

81 The correlation is statistically significant at 99% confidence level.

82 No analysis of this issue has been undertaken of LECS V (2012/13).

83 Mining exploration concessions and leases were not included in the inventory; all reported areas are approximate.

84 The inventory did not include concessions for hydropower development; all reported areas are approximate.

85 Epprecht et al. (2008) prepared small-area estimates of poverty incidence for the year 2005 based on the Lao PDR Housing and Population Census 2005 and the Lao Expenditure and Consumption Survey 2002/03 (LECS III).

86 http://www.fao.org/faostat/en/#data/QC

87 Applying a plant factor of 0.6 reflecting an average for hydropower in Lao PDR.

88 Estimated based on an annual horizontal global solar irradiation of 1,850 kWh/m^2. World Bank et al. (2018) reports a global estimate of 0.8 hectares per GWh per year of electricity production from floating PV solar.

89 Calculated based on solar electricity production of 1 GWh per year per hectare.

90 Recall that the analysis assumes a fixed rent of US$30/MWh for all projects.

91 This analysis was undertaken as part of preparing this report, using district poverty incidence data from LSB (2016a). The district poverty incidence data were produced by combining data from LECS 2012/13 and the Lao Housing and Population Census 2015.

92 https://www.la.undp.org/content/dam/laopdr/docs/Project%20Briefs_Fact%20Sheets/UXO/UNXO%20Lao%20brochure.pdf

93 https://www.jmu.edu/cisr/_pages/CMRS/cmrs-pdfs/UXO-Lao.pdf

94 http://www.la.undp.org/content/lao_pdr/en/home/projects/Moving-Towards-Achieving-SDG-18-Removing-the-UXO-Obstacle-to-Development-in-Lao-PDR1.html

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8 MODELLING ECONOMIC GROWTH AND ITS LINKAGES WITH GREEN GROWTH[95]

Chapter Overview

This chapter presents the preliminary results of a study of the Lao economy, using a Computable General Equilibrium CGE model, based on a Social Accounting Matrix (SAM). The study focused on the two key dimensions of economic growth in the Lao People's Democratic Republic: natural capital and poverty. While both these dimensions lack a sufficiently detailed and reliable database, the model estimates that are obtained from available data capture some important features of the country's development pattern. These features include the widespread nature of poverty and the exclusion of the poor from most sources of, and prospects for, increased income and economic improvement.

These features are quantified in this chapter by several indicators based on the SAM as well as by the policy simulations performed with the CGE model. These indicators show that the poor are only scantly connected through the value chains for all activities. On the contrary, the non-poor appear to benefit greatly from backward-induced increases in demand for all industries, from agriculture to tourism. In this respect, the most pro-poor activities, where investment is likely to have the largest impact, appear to be agriculture, mining, public administration, and social services. Rents from natural resources also appear to play a largely positive role in complementing the income of the poor.

For an economy based on natural resources, such as the one that characterizes Lao PDR, the CGE methodology adopted here enables the study of a state whose economy is assumed to be at a market equilibrium, but whose supply and demand prices are not necessarily equal to each other. Rather, the basic SAM accounts register a persistent divergence between rents collected by households and firms. This divergence is attributable to the supply of regulatory and provisionary services, and payments to maintain and restore natural capital in order to conserve natural resources' regulatory and productive capacity.

The wedge between demand and supply prices is a consequence of the externality nature of the services provided by the environment. In large part, these environmental services are also public goods that can benefit a variety of sectors of the economy, institutions, and segments of the population, without being appropriated or marketed. In this regard, CGEs allow various market equilibrium solutions to be explored by running different policy experiments that internalize, to a lesser or greater extent, these externalities.

The services provided by the environment and their contribution to economic development are important for Lao PDR, which has been the second fastest growing economy in ASEAN and among the world's 15 fastest growing economies. This growth, however, has entailed progressive environmental losses through massive deforestation and land degradation, and the uncontrolled spread of poverty across Lao PDR's population.

The model design and the policy simulations presented in this chapter aim to capture the idea that environmental deterioration and poverty can be seen as the result of a distorted mechanism of capital accumulation, based on short-term perceived equality between the marginal productivity of capital and its opportunity cost. According to this interpretation, failure to invest in long-term projects and to take into account the nonmarket consequences of economic choices results in unequal distribution of real wealth over time, with the poisonous fruits of past and present pursuit of short-term riches hanging over future generations.

Conversely, strategies that combine investment in produced and natural capital are likely to enjoy important synergies and economies of scale as well as positive impacts on poverty reduction. In particular, the results of the simulations show that increases in the supply ecosystem services not only create values by directly increasing their flows for a wide range of beneficiaries, but also have a positive impact on the productivity of factors such as capital and land. The same results indicate that investing in natural resources may boost development and bring the economy to a higher path of value added and production. This in turn suggests the need to invest in natural resources to maintain the economy on a sustainable path, which could be put at risk by outright rent extraction not accompanied by appropriate maintenance and restoration activities.

In general terms, the simulations performed with the CGE model are consistent with two main indications for the economy's future evolution and for policy actions:

First, under increasing investment and progressive commitment to sustainable development (in the form of a greater share of resources devoted to conservation and restoration activities), Lao PDR's economy will be likely to expand according to a pattern more balanced across sectors and natural and physical capital than in the past. This development should be encouraged by conservation and land-use policies with these aims: (i) lowering the pressure on natural resources, and (ii) achieving better economic performance and greater environmental sustainability both in the short run and in the long run.

Second, while investments in both physical and natural capital are critical factors for the promotion and enhancement of economic growth, they are not sufficient to address the problem of non-inclusive development that has plagued the country despite its aggregate growth success in the recent past. To reach poor people and make economic development more inclusive and socially sustainable, public investment policies and appropriate incentives should be directed towards two major goals: (i) lessening the dependence of the poor on subsistence agriculture and rents from natural resources, and (ii) lessening the conditions of spatial and cultural isolation that presently tend to exclude the poor from participating in the economy's growth.

8.1 Introduction

Lao PDR's economy is undergoing a rapid transformation that is especially challenging for public policies aiming to create the conditions for sustainable and inclusive growth. As a landlocked country bordering Cambodia, China, Myanmar, Thailand, and Vietnam, Lao PDR shares many of the problems of the difficult transition process of its neighbors toward a fuller market-based economy. The country is divided into 18 provinces and has a total population of about 7 million people, most of whom still live in rural areas. According to recent UNDP data[96], this condition is changing rapidly, since urbanization is occurring at a rate of 4.9 percent each year. The country is largely mountainous, with the most-fertile land found along the Mekong plains. The economic situation in Lao PDR is affected by many climate hazards such as flooding, drought, landslides, storms, and typhoons.

As reported by Henderson (2018), from 1970 to 2010, 33 natural hazard events occurred in the country, particularly floods and droughts, which affected almost 9 million people and caused economic damages of over US$400 million. In 2013, five major monsoon storms hit the country between July and September: 12 provinces were severely flooded, and the disaster affected 347,000 people. The official estimated loss and damage from the disaster was US$219 million (OCHA 2017). July 2018 was characterized by heavy rains due to the southwest monsoon and Tropical Storm Son-Tinh, which damaged one of seven dams in a large hydroelectric network along the Xe-Pian River, in Attapeu Province. The collapse of the dam had devastating effects on 13 villages and more than 16,000 people—over 10% of the province's population. The heavy rains hit other provinces, and according to the Lao PDR government, there was flooding in 373 villages located in 10 provinces, and roughly 1.5 million people were affected (Henderson 2018).

This chapter presents the preliminary results of a study of the Lao PDR economy, using a Computable General Equilibrium CGE model, based on a Social Accounting Matrix (SAM), focusing on the two key dimensions of Lao PDR's economic growth: natural capital and poverty. While both these dimensions lack a sufficiently detailed and reliable database, the model estimates obtained from available data capture some important features of the country's development pattern. These features include the widespread nature of poverty and the exclusion of the poor from most sources and prospects of income increase and economic improvement. These features also relate to the largely positive and crucial role played by the distribution of rents from natural resources in complementing the income of the poor.

8.2 Lao PDR's Economic Structure

Recent economic growth in Lao PDR has been characterized by a shift away from the agriculture sector. The shares of value added of industry and services sectors in 2014 accounted for 28.8% and 44.2% and in 2019 30.9% and 42.6% respectively, while agriculture, forestry and fishing accounted for about 17.8% in 2014 and 15.3% in 2019 (World Bank data.worldbank.org/country/lao-pdr)". Initially, the value added of industry was mainly driven by growth in manufacturing, particularly in textiles and garments. However, starting in 2000, the value added was driven by non-manufacturing industries such as mining, construction, electricity, water, and gas. Agriculture remains largely subsistence-based, although in recent years investments in technology, connectivity, and capacity building are trying to transform the sector into a dynamic one (IFAD 2018).

Poor people in Lao PDR are engaged mainly in agriculture: About 60 percent of the workforce is employed in this sector (IFAD 2018). However, employment in trade, tourism, and food-related services has risen to about 25 percent (Coulombe et al 2016). Agricultural production has steadily grown due to higher crop yields and increases in production areas, while productivity is trailing. Rice cultivation accounts for 72 percent of the total cultivated area; the farmers also cultivate corn, taro, fruits, and vegetables. Coffee, cassava, sugarcane, and rubber are the main cash crops (IFAD 2018). According to IFAD's report (2018), the main factors limiting agricultural production and productivity typically involve secure access to land, farm inputs, technologies, and services, including markets and rural finance. At the same time, both agriculture and industrial sectors face the problem of the difficult business environment[97] that hampers investment, keeps firms small and informal, and thereby limits job creation (Coulombe et al. 2016).

Lao PDR has made significant progress in poverty alleviation over the past two decades: Poverty rates have declined from 46% in 1993 to 23% in 2013. While the country achieved the Millennium Development Goal target of halving poverty, today the main goal is to ensure that the benefits from high economic growth are evenly distributed—that is, the pursuit of inclusive and sustainable growth is crucial (UNDP 2019). The evidence shows that while the poverty rate in Lao PDR has declined, the pace of reduction has been considerably slower than in regional peers such as Cambodia and other resource-rich countries—such as Chile, Mongolia, Tajikistan, and Uzbekistan—where greater poverty reduction is being achieved through the effective use of redistribution policies. Between 1990 and 2015, Lao PDR's main progress in human development has been in (i) life expectancy, which increased by 13 years; and (ii) GNI per capita, which increased by over 200 percent (UNDP 2019).

Lying along the bank of the Mekong River, Lao PDR has the highest per capita water supply in Asia and has benefitted enormously from this abundant water resource. Hydropower production has made a large contribution to national output, and multiple hydropower plants are under construction. There is also interest in developing small hydropower projects that could create economic value and efficiency. One GoL goal is for hydropower to become the country's biggest source of revenue by 2025. However, neighboring countries such as Cambodia, Thailand, and Vietnam have raised concerns about the environmental impact of the dam-building projects.

In addition to water, other natural resources such as mines and forests were a key driver of growth. The average share of mineral exploration in the industry's value added was 21% in 2017, according to the Lao Statistical Yearbook 2017. Lao PDR has continued to legalize mining and processing activities along with the capitalization of assets in the mineral sector. During the 2000s, growth was driven by mining; however, more recently, a decline in prices and lower-grade reserves, as well as sector-regulation issues, lowered its contribution. The power sector has expanded significantly since the mid-2000s, and the associated construction activities and subsequent commercial operation, largely expected to meet demand in neighboring countries, drove growth. Lao PDR's installed capacity increased ten-fold between 2000 and 2016 to above 6,000MW, mostly through engagement with the private, mostly foreign, investors.

The main development challenge facing the country is to ensure that the benefits from high economic growth are more evenly distributed and translated into inclusive and sustainable human development. This means poverty reduction through high and inclusive growth, but also investment in conservation and restoration activities in natural capital, which has been severely taxed by mining, agricultural expansion, and deforestation. In fact, Lao PDR's economic boom has been driven primarily by foreign direct investment in natural resource extraction and hydropower. Contamination of the environment is worsened by the presence of unexploded ordinance (UXO) from the Second Indochina War; this UXO continues to destroy lives and limits agricultural production and expansion[98].

8.3 Social Accounting Matrix for Lao PDR

To estimate the 2016 Social Accounting Matrix[99] (SAM) of Lao PDR in a way that reflects key characteristics of its economic structure relevant to some of the country's unique challenges, we have used two input-output tables, respectively estimated by the LAO Statistics Bureau for 2007 and by the Asian Development Bank for 2016, as well as a national SAM (Khanal et al. 2014; Lao PDR Statistics Bureau 2016; OECD 2011; Sayto and Kabayashi 2007), integrating data on households, poverty, ethnicity, and environmental data from various sources (Coulombe et al. 2016; Ministry of Environment 2019; World Bank 2018 [World Bank Development Indicators])[100]. The SAM has been estimated by calibrating it to the 2016 data, valued at millions of US dollars, using the entropy algorithm described in Scandizzo and Ferrarese (2015) and is consistent with the official estimates of GDP for 2016 (respectively US$13,983 million and US$15,806 million in current prices).

The SAM estimates include fourteen production sectors, with the ecosystem components representing general provisioning services (labeled as "ecosystem services"), plus carbon catch and water. The values of the ecosystem services add to value added directly through the payments (if any) made by the various sectors, or indirectly through the increases in productivity of other factors (land, capital, and labor) and the corresponding rents created for factor owners. Thus, water incomes come from payments made by agriculture, water distribution, and tourism, while its rents go to agriculture and factors of production.

Primary sectors include agriculture and forestry, while the industrial sectors include manufacturing, energy distribution, and construction. The service sectors include transport, financial, and public services. The "carbon catch" sector accounts for the capture and release of CO2 on the part of various sectors/activities. Total emissions for the country in 2016 were estimated at 33 million tons of CO2. Four production factors are accounted for value added formation: unskilled labor, skilled labor, capital, and land. To estimate the distribution between skilled and unskilled labor, a recent enterprise survey (World Bank 2016) was used; this survey classifies labor according to formal level of education and employment sectors.

8.3.1 Backward and Forward Multipliers

Table 8.1 below shows the indexes of backward and forward linkages[101] computed from the estimated SAM for the value-added components. These indexes describe the direct and indirect connections between the different actors of the economy, whose accounts are represented in the SAM. Introduced by Hirschman (1958) for the input output table, the indexes of backward linkages are based on the average multipliers from the columns of the SAM inverse and can be interpreted as the increase in output of all activities, in response to an increase in the final demand for the products of one activity by one unit (Rasmussen 1957).

The SAM results presented in Table 8.1 can be re-interpreted as the increase in value added (or green value added, including the value of the ecosystem services) of all activities in response to an increase in demand for the products of one activity. The indexes of forward linkages are instead based on the row multipliers and quantify the extent to which a given activity depends on the entire economic system. They are indexes of sensitivity of dispersion, since they measure the increase in the value added produced by an activity driven by a unit increase in the final demand for all activities in the system.

The results presented above indicate that the backward linkages are stronger than the forward ones, denoting a higher level of backward connectedness of the value chains in the economy, and a low dependence of individual sector value added formation from the level of activity of the rest of the economy. In terms of green value added, nature-based sectors, such as agriculture and forestry, are highly connected both backward and forward.

Table 8.2 presents the backward income multipliers for the poor and non-poor groups, respectively indicated as BP and BNP. They are defined respectively as the increase in all incomes of the poor (BP) or non-poor (BNP) in the different ethnic and social groups in response to an increase in production of a specific industry. These indicators show that the poor are only scantly connected through the value chains for all activities. On the contrary, the non-poor appear to benefit greatly from backward-induced increases in demand for all industries, from agriculture to tourism. In this respect, the most pro-poor activities, where investment is likely to have the largest impact, appear to be agriculture, mining, public administration, and social services.

Table 8.1 Estimated Backward and Forward Value-Added Multipliers (Capital Formation and Rest of the World Exogenous)

	BW VA Multipliers	BW Green VA Multipliers	FW VA Multipliers	FW Green VA Multipliers
Agriculture	1.8032	2.3913	1.2866	4.2397
Forestry and logging	1.2048	1.5952	2.2537	2.9178
Mining and quarrying	1.9125	2.5253	0.1752	0.1579
Food and beverage manufacturing	1.0961	1.4505	0.7271	0.7097
All other manufacturing	1.3848	1.8535	0.5773	0.5166
Electricity and water supply	1.8213	2.4358	0.7221	0.6225
Construction	1.4731	1.9823	1.1111	1.0469
Transport and communication	1.0455	1.4016	0.5243	0.4854
Wholesale and retail trade	1.6168	2.1267	1.3599	1.5188
Banking, finance, and insurance	1.9323	2.5189	0.1946	0.2041
Real estate and business services	2.0514	2.6723	0.5965	0.6302
Public administration	1.8379	2.4183	1.2809	1.1754
Personal, community, and social services	1.8745	2.4624	0.1473	0.1281
Tourism	1.6165	2.1884	0.4377	0.4096

Table 8.2 Estimated Backward Poor and Non-Poor Income Multipliers

	BP (poor income multiplier)	BNP (non-poor income multiplier)
Agriculture	0.1524	1.5776
Forestry and logging	0.0843	1.0461
Mining and quarrying	0.1516	1.7541
Food and beverage manufacturing	0.0765	0.9760
All other manufacturing	0.0938	1.3105
Electricity and water supply	0.1207	1.5509
Construction	0.1043	1.4449
Transport and communication	0.0721	1.0174
Wholesale and retail trade	0.1028	1.4094
Banking, finance, and insurance	0.1009	1.5318
Real estate and business services	0.1171	1.6581
Public administration	0.1388	1.6874
Personal, community, and social services	0.1439	1.7182
Tourism	0.1095	1.6286

8.3.2 CGE Model

To perform an impact analysis of investment, a Computable General Equilibrium (CGE)[102] model was constructed based on the calibration of values provided by the SAM estimates discussed in the previous paragraph. The CGE model is based on the standard architecture described in Perali and Scandizzo (2018) and includes CES (Constant Elasticity of Substitution) production functions for production factors and ecosystem services, input output coefficients for intermediate goods, and CET (Constant-Elasticity-of-Transformation) functions quantifying limiting substitutability between domestic and international commodities.

The simulations conducted with the CGE model adopt a "Keynesian" closure of the economy, with an autonomous and exogenous investment component, wage as a numeraire, and the balance of trade as a residual variable, ensuring equilibrium between demand and supply. Investment as fixed capital formation is mapped into the sector production functions according to a capital distribution matrix, so that the model reproduces in a one-shot (long-term) equilibrium both the impact of investment expenditure on demand from capital producing sectors and its effects on increased production capacities of capital proprietary sectors.

Table 8.3 shows the SAM data and the base solution of the CGE results after calibration, given the SAM values for the investment vector. For natural resources, in line with the SAM estimates, the model recognizes three distinct sets of provisioning and regulatory services: (i) water services derived directly from the availability of underground and surface water; (ii) ecosystem services, including forestry, fishery, and other miscellaneous services provided mainly by forests and natural habitats; and (iii) carbon catch services.

Table 8.3 Comparisons of Estimated SAM Production Data and the Base Solution Results (US$, Millions)

	SAM	Base solution	Fixed capital formation by producing sector	Capital demand by proprietary sector
Agriculture	3,959.65	4,038.54	889.04	538.19
Forestry and logging	4,443.94	4,442.32	349.58	38.81
Mining and quarrying	2,258.34	2,071.66	46.59	457.04
Food and beverage manufacturing	1,208.81	1,245.64	514.29	233.90
All other manufacturing	931.59	947.84	225.07	350.47
Electricity and water supply	1,342.01	1,355.42	66.41	659.89
Construction	2,100.46	2,131.12	244.25	550.16
Transport and communication	579.85	594.14	287.81	163.47
Wholesale and retail trade	2,384.30	2,434.96	632.52	897.86
Banking, finance, and insurance	547.89	556.61	164.46	367.53
Real estate and business services	1,400.31	1,437.90	177.94	972.10
Public administration	3,166.58	3,209.69	329.07	230.45
Personal, community, and social services	356.92	367.72	161.60	32.88
Tourism	746.27	767.11	156.64	179.22
Total	**25,426.92**	**25,600.67**	**4,245.27**	**5,671.97**

All these components can be considered flows of natural capital and are mostly linked to forests, water sources, and other features characterizing a country's natural habitat. As explained for the SAM estimates, but more specifically modelled in the CGE equations, rents accrue to households through the increases in productivity determined by the water and the other ecosystem services, and by the reduction of carbon catching capacities determined by deforestation and the increase of agriculture or urban areas. Natural capital formation, in the form of investment in conservation, restoration, and maintenance, is modeled to counter these effects through both mitigation and adaptation activities. Increased pressure on natural resources from their increased demand and fixed supply is also registered by the model shadow prices. These can be interpreted as the increased values of ecosystem services for the holders of rights (the households) to benefit from the rents that they provide.

8.3.3 Policy Simulations

According to OECD (2013), Lao PDR's long-term development agenda is based on its gradual transformation from a closed and centrally planned economy to an open, private-sector–led economy. However, the report claims that the range of instruments—defined in NSEDP 2011–2015—is broad and it is difficult to assess the impact expected from specific measures. The strategies of the plan involve diversifying and deepening economic activities, significantly scaling up human capital, improving labor productivity, and promoting the inclusion of women, ethnic groups, and those living in remote areas. Moreover, the environmental sectoral plan provides for a set of restoration and conservation policies to safeguard ecosystem services, stop deforestation and land degradation, and restore natural sites. These strategies should also be combined with selected investment actions to boost the economy and achieve higher inclusiveness through a progressive integration of household and enterprise activities in efficient markets (OECD 2013).

Following the broad outline of the government strategy, the CGE model was used to simulate two policy scenarios and their impacts on the economy. The simulation was conducted using two alternative hypotheses on investment increases:

> Business as usual (BAU) scenario

> Natural resource scenario (NATRES)

The first set of simulations (BAU) explores the impact of increasing investment by US$600 million per year in three subsequent phases (for example, years) according to the historical investment pattern. The second set of simulations (NATRES) instead assumes that, along with the BAU investment, an additional amount of public investment is spent for programs of conservation and restoration of natural resources, according to the pattern envisaged in the Environmental Sector Plan and reaching about US$320 million per year in the highest scenario (corresponding to the third simulation). The total amount of investment envisaged thus ranges from 3 percent to 5 percent of GDP, which corresponds to the range of public investment estimates in Lao PDR (https://www.ceicdata.com/en/laos/public-investment). Table 8.4 shows the breakdown of the investment pattern simulated under the alternative scenarios.

Table 8.5 presents the main simulation results of the different hypothesized investment scenarios, in terms of value-added effects[103].

In addition to the impact on factor incomes as the main components of value added at market prices, ecosystem services effects are also estimated as determinants of "green value added" at shadow prices. These values are estimated as external effects in the model. Once added to value added at market prices, they yield an estimate of and extended form of value creation comprising market and non-market effects of value creation of the investment policies examined. As table 8.5 shows, value added from additional labor and capital employment and higher remunerations of both factors significantly rise under the impact of increased investment in all scenarios. In the NATRES scenario, the highest increases are up to 51 percent (entirely from larger employment) for unskilled labor, and up to 103 percent for skilled labor.

For natural resources, it is assumed that their supply is fixed to the levels estimated for the base solution in the BAU scenarios while it increases in proportion to the natural resource investment in the NATRES scenarios. Consequently, the value of natural resource services (ecosystem services, water, and carbon catch) rise significantly in all these scenarios. In the BAU case, this is due only to the increase in their shadow prices; however, in the NATRES scenarios, the value of the natural resource services produced by the investment in natural resource conservation/restoration programs increases up to 197 percent of their base-year values. This results from the increased volume and unit values (shadow prices) of the services rendered. The rise in the value of natural resources is matched by a parallel increase in natural capital formation (conservation, maintenance, and restoration activities).

Table 8.4 Comparisons of Estimated Public Investment in the Simulations (US$, Millions)

	Base solution	BAU I	BAU II	BAU III	NATRES I	NATRES II	NATRES III
Public investment in infrastructure	4,001	4,601	5,201	5,801	4,601	5,201	5,801
Public investment in natural capital	4,455	4,455	4,455	4,455	4,586	4,672	4,777
Total capital formation	**8,456**	**9,056**	**9,656**	**10,256**	**15,500**	**16,242**	**17,075**

Table 8.5 Comparisons of Estimated Impact on Value Added in the Simulations (US$, Millions)

	SIM I		SIM II		SIM III	
	BAU	NATRES	BAU	NATRES	BAU	NATRES
Unskilled labor	4,573.14	4,640.25	5,069.42	5,261.48	5,846.80	6,479.95
Skilled labor	2,988.94	3,054.11	3,561.15	3,779.00	4,549.33	5,407.44
Capital	6,702.03	6,881.32	7,550.05	8,082.80	9,088.43	10,974.25
Land	1,431.62	1,417.23	1,469.30	1,477.77	1,600.17	1,817.92
Value added (GDP) at factor cost (A)	**15,695.74**	**15,992.92**	**17,649.93**	**18,601.05**	**21,084.72**	**24,679.56**
Ecosystem services	6,136.68	6,436.27	8,101.76	8,992.79	11,630.16	14,749.28
Carbon catch	659.40	738.42	910.14	1,113.59	1,346.18	1,936.60
Water services	599.19	664.06	823.67	992.12	1,215.09	1,712.41
Green value added (B)	**7,395.28**	**7,838.75**	**9,835.57**	**11,098.51**	**14,191.44**	**18,398.29**
Extended value added (A) + (B)	**23,091.01**	**23,831.67**	**27,485.51**	**29,699.56**	**35,276.16**	**43,077.85**

Figure 8.1 Value Added and Investment (Estimates)

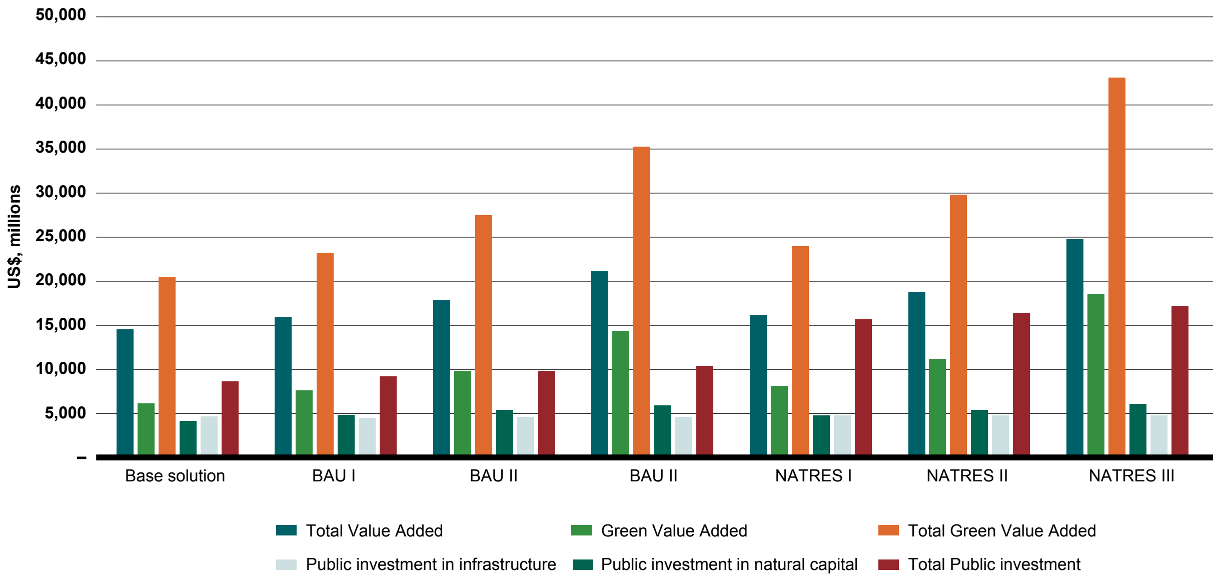


Table 8.6 and Figure 8.2 compares the different value-added multiplier paths of the investment simulations in the BAU and NATRES cases. The multiplier indicates the increase in value added, through both direct and indirect effects, in response to different levels of investment in the three scenarios considered.

In all the investment scenarios examined (see Figure 8.2), investment multipliers (which in this case are a measure of economy-wide productivity of public investment) increase more than proportionally with the increase in investment, although the BAU multiplier simulated with only the historical investment in natural resources is almost flat. However, both the value-added NATRES multiplier (the VA multiplier in response to the additional investment in natural resources) and the total green multiplier (the multiplier on factor and natural resource value added of the investment with the additional investment in green resources) are much larger and increasing exponentially.

The increasing returns suggested by these results are mainly due to the fact that generally equilibrium effects tend to amplify the impact of investment by increasing not only factor employment for all factors, but also the remunerations of non-labor factor incomes and rents from natural resources. On the other hand, the results for the green multipliers depend mostly on the positive externalities associated with ecosystem services, and the limited substitutability between natural resources and production factors as well as between domestic and internationally tradeable commodities.

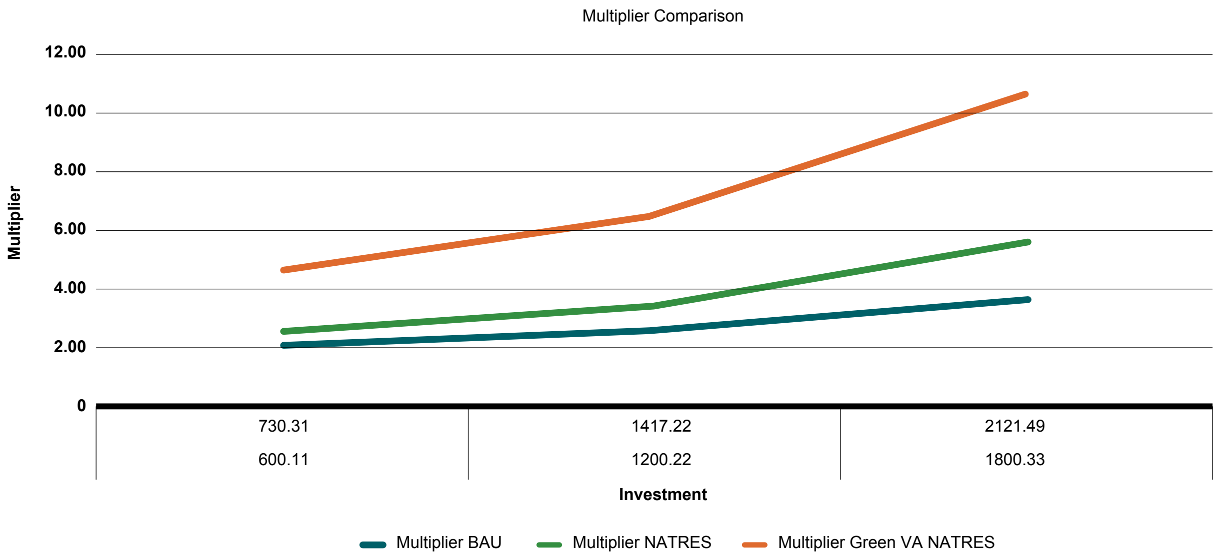
Therefore, increases in the supply ecosystem services not only create values by directly increasing their benefit flows, but also a positive impact on the productivity of factors such as capital and land. These results suggest that investing in natural resources may boost development and bring the economy to a higher path of value added and production. The results presented here also indicate the need to invest in natural resources to maintain the economy on a sustainable path, which could be put at risk by outright rent extraction not accompanied by appropriate maintenance and restoration activities.

Table 8.7 and Figure 8.3 show the production effects of the different simulations. While all production in all sectors increases at positive rates, forestry production is stationary in all simulations, while mining and quarrying falls drastically—up to 60% in the highest natural resource simulation. For forestry and for mining and quarrying, the result is due to short land supply and the destruction of natural capital through deforestation

Table 8.6 Value-Added Investment Multipliers (Estimated)

	SIM I BAU	SIM I NATRES	SIM II BAU	SIM II NATRES	SIM III BAU	SIM III NATRES
Unskilled labor	0.49	0.60	0.66	0.82	0.87	1.22
Skilled labor	0.54	0.65	0.75	0.93	1.05	1.52
Capital	1.17	1.47	1.29	1.74	1.72	2.76
Land	-0.14	-0.17	-0.04	-0.03	0.05	0.17
Total	**2.05**	**2.55**	**2.66**	**3.45**	**3.68**	**5.67**

Figure 8.2 Estimated Value Added Impact of an Increasing Investment Shock



and depletion. Mining is modeled as having negative effects on natural capital by reducing the country's endowment of exhaustible resources and damaging the environment. This result emphasizes the importance of the Lao PDR government maintaining its commitment to sustainable mining (http://mric.jogmec.go.jp/kouenkai_index/2012/briefing_120316_1.pdf).

Table 8.8 and Figure 8.4 show that rents from natural resources grow smoothly from the low natural capital (NC) simulation to the high one. As Figure 8.5 shows, shadow prices as indicators of the marginal values of ecosystem services grow smoothly under the three phases of the BAU scenarios, since natural resource services tend to increase with the expansion of the economy. Once the environmental measures are introduced in the NATRES scenarios, the same shadow prices at first decline as conservation and restauration activities progressively undertaken tend to expand supply. However, as the economy expands, the parallel increase of production and incomes tends to increase demand and usage of eco-services more than proportionally, so that the shadow prices rise again and reach higher levels than in the BAU case. Investing in the environment to the extent simulated in the NATRES scenarios thus appears to be beneficial on the market and the environmental sides, but ultimately insufficient to prevent an increasing scarcity of natural resource services.

Table 8.7 Estimated Impacts on Production (%)

Industries	BAU			NATRES		
	SIM I	SIM II	SIM III	SIM I	SIM II	SIM III
Agriculture	5.	12	19	8	16	25
Forestry and logging	0	1	1	0	0	1
Mining and quarrying	-18	-32	-48	-24	-42	-60
Food and beverage manufacturing	8	20	36	8	21	39
All other manufacturing	6	19	36	6	20	39
Electricity and water supply	4	19	37	4	19	39
Construction	5	17	31	5	17	34
Transport and communication	7	22	40	8	24	46
Wholesale and retail trade	8	23	43	9	25	48
Banking, finance, and insurance	9	24	44	9	26	47
Real estate and business services	7	22	41	8	24	46
Public administration	4	9	18	4	11	22
Personal, community, and social services	10	23	39	11	25	47
Tourism	7	20	37	9	24	46
Total	**3**	**10**	**19**	**3**	**11**	**21**

Figure 8.3 Estimated Impacts on Production

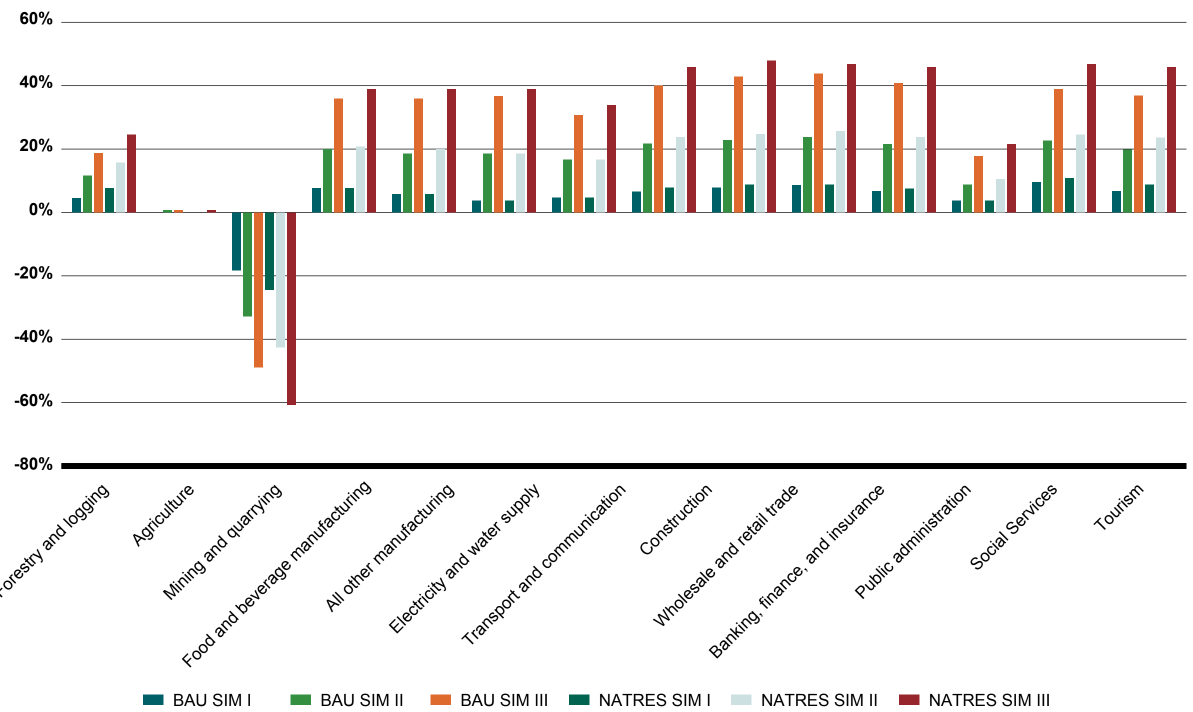


Table 8.8 Estimated Impacts on Rents from Natural Resources (US$, millions)

	Base solution	BAU I	BAU II	BAU III	NATRES I	NATRES II	NATRES III
Ecosystem services	4,970.82	6,136.68	8,101.76	11,630.16	6,436.27	8,992.80	14,749.28
Carbon catch	510.48	659.40	910.14	1,346.18	738.42	1,113.59	1,936.60
Water services	468.89	599.19	823.67	1,215.09	664.06	992.12	1,712.41
Total	**5,950.19**	**7,395.28**	**9,835.57**	**14,191.44**	**7,838.75**	**11,098.51**	**18,398.29**

Figure 8.4 Estimated Impacts on Rents from Natural Resources (US$, Millions)

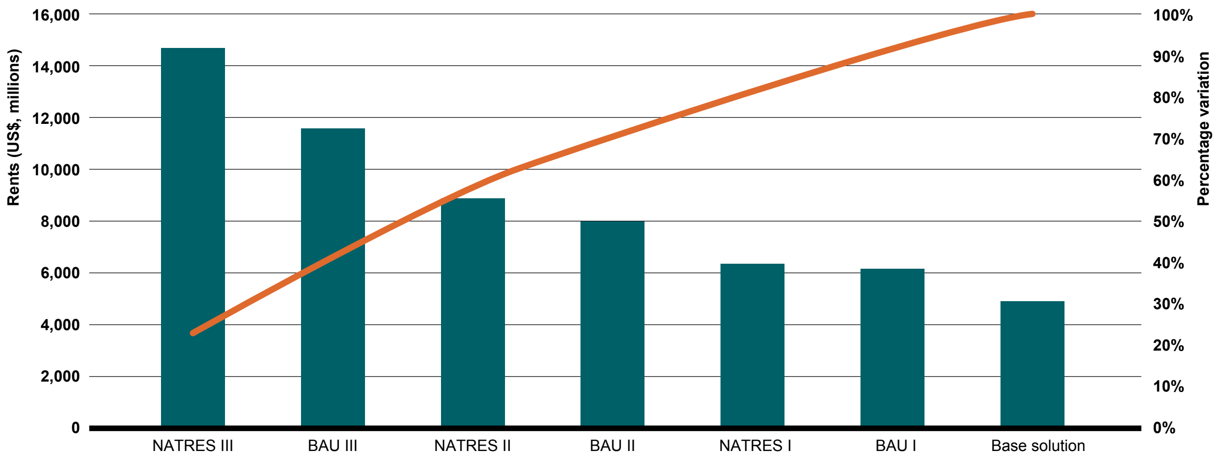
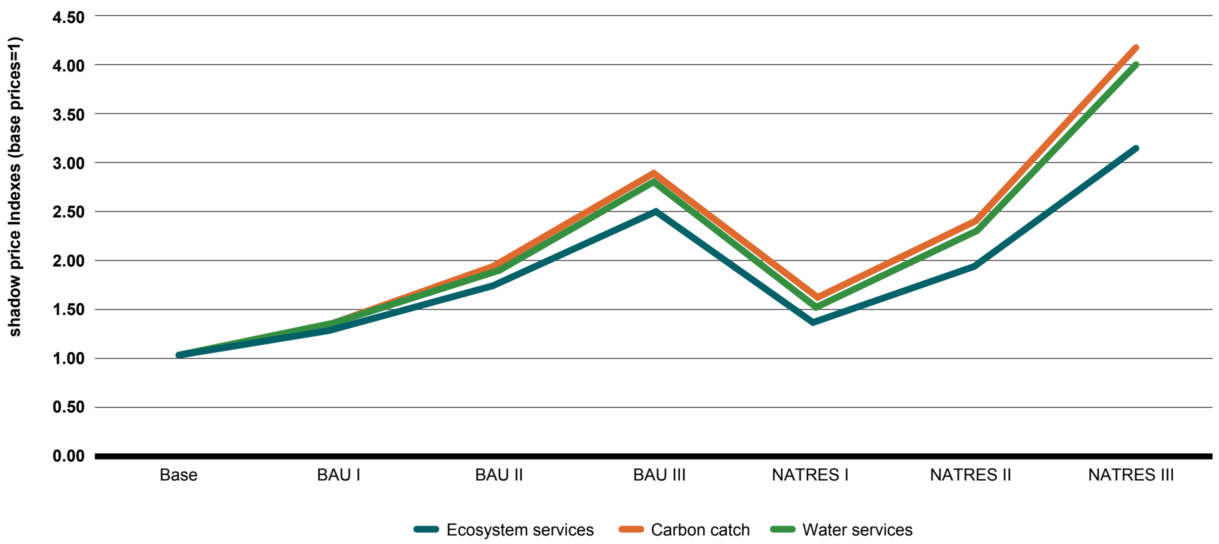


Figure 8.5 Estimated Impacts on Shadow Prices of Natural Resources (Relative Prices with Respect to the Base)



8.4 Impact on Income Distribution and Poverty

Table 8.9 and Figure 8.6 show the impacts that different simulations have on the incomes of different households.[104] Most of the benefits accrue to the non-poor income groups, who hold the largest portion of total income (about 90 percent compared with a population share of 23 percent).

Table 8.10 presents the estimated impacts that different investment approaches may have on incomes and poverty. The simulations carried out for this chapter show that these different approaches affect poor and non-poor population groups differently. The results indicate that, in both the BAU and NATRES scenarios poor people would account for only a low and slightly increasing share of total growth, hovering around 6 percent. The increase in their incomes per unit of investment would also be rather low (the multiplier would be only slightly more than 0.5 in the best scenario and about 0.24 in the worst one). Nevertheless, the income per capita of the people who are now below the poverty line, including the rents obtained from natural resources, would increase considerably, reaching more than US$1,800 per year in the best scenario.

While we lack specific data on the income distribution by ethnic groups, the model simulations may be used to give some overall indication of the investment impact in terms of poverty count and average poverty levels. To this aim, we utilize the income distribution estimates under the poverty line from the World Bank Poverty and Equity Data Portal POVcal (http://povertydata.worldbank.org/poverty/home/).

Table 8.9 Estimated Impacts on Incomes

	% Change SIM I BAU	% Change SIM II BAU	% Change SIM III BAU	% Change SIM I NATRES	% Change SIM II NATRES	% Change SIM III NATRES
Lao-Tai urban poor	9	22	44	12	29	68
Lao-Tai urban non-poor	12	28	58	14	37	88
Lao-Tai rural poor	10	27	57	12	35	86
Lao-Tai rural non-poor	14	38	81	18	50	122
Mon-Khmer urban poor	7	18	37	8	23	51
Mon-Khmer urban non-poor	11	26	53	14	35	83
Mon-Khmer rural poor	9	27	58	12	35	88
Mon-Khmer rural non-poor	16	45	96	21	59	144
Chino-Tibet urban poor	16	42	87	23	60	141
Chino-Tibet urban non-poor	11	24	49	13	32	76
Chino-Tibet rural poor	12	32	66	15	41	96
Chino-Tibet rural non-poor	16	44	94	21	58	142
Hmong-Lu Mien urban poor	7	18	37	8	23	51
Hmong-Lu Mien urban non-poor	11	25	50	13	33	78
Hmong-Lu Mien rural poor	12	32	66	15	41	97
Hmong-Lu Mien rural non-poor	16	45	95	21	59	144
Total	**13**	**36**	**76**	**17**	**47**	**115**

Figure 8.6 Estimated Impacts on Incomes (%)

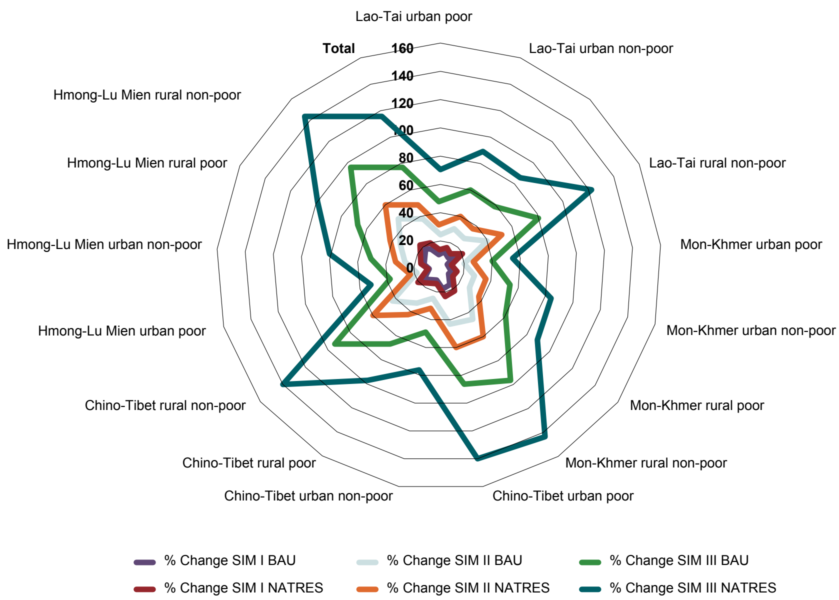


Table 8.10 Estimated Impacts on Incomes and Poverty

	Model Variables	SIM I	SIM II	SIM III
BAU	Increase in per capita income of the poor (US$/year)	1,068.85	1,237.95	1,531.77
	Total Increase in the income of the poor (US$, millions)	1,662.07	1,925.01	2,381.90
	Poor income share of total growth (%)	6.00%	6.29%	6.32%
	Poor income investment multiplier (total income increase divided by investment)	0.24	0.34	0.48
	Total Non-poor income increases (US$, millions)	18,846.74	22,651.56	29,392.61
	Non-poor income share of total growth (%)	94.00%	93.71%	93.68%
	Non-poor income investment multiplier (total income increase divided by investment)	3.77	5.06	7.11
NATRES	Increase in per capita income of the poor (US$/year)	1,095.16	1,317.53	1,813.72
	Total Increase in the income of the poor (US$, millions)	1,702.98	2,048.75	2,820.33
	Poor income share of total growth (%)	6.02%	6.26%	6.28%
	Poor income investment multiplier (total income increase divided by investment)	0.31	0.44	0.72
	Poor green income multiplier (total income increase divided by green investment)	0.24	0.35	0.55
	Total Non-poor income increases (US$, millions)	19,477.40	24,536.60	36,029.28
	Non-poor income share of total growth (%)	93.60%	93.68%	91.96%
	Non-poor income investment multiplier (total income increase divided by investment)	4.82	6.63	10.80
	Non-poor green income multiplier (total income increase divided by green investment)	3.73	5.25	8.28

Figure 8.7 below shows the distribution of income under the international poverty line (1.90 PPP$ [Purchasing Parity Dollars] per day in 2012) corresponding to a poverty headcount of 22.7 percent of the population. According to our estimates, the poverty headcount yields a range of 1,487,851 to 1,555,165 people and between US$1,549.42 million and US$1,641.21 million, including rents from natural resources (the average values would be 1,521,508 people and US$1,595.32 million). Thus, the poverty income adjusted for natural resource rents can be estimated at around US$1,055 per year or US$2.9 per day.

Projecting the model results for the NATRES scenario (first year), the distribution of incomes is estimated to vary in a way that makes the number of people below the poverty line fall from 1.55 million to around 1.41 million, with about 140,000 people going above the poverty line. Given the estimates of the distribution of people between rural and urban areas and the distribution by ethnic group from LECS 5 (World Bank 2014), we obtain a rough estimate of the number of people crossing the poverty line by ethnic group (Table 8.11).

Figure 8.7 Estimated Income Distribution and Lorenz Curve

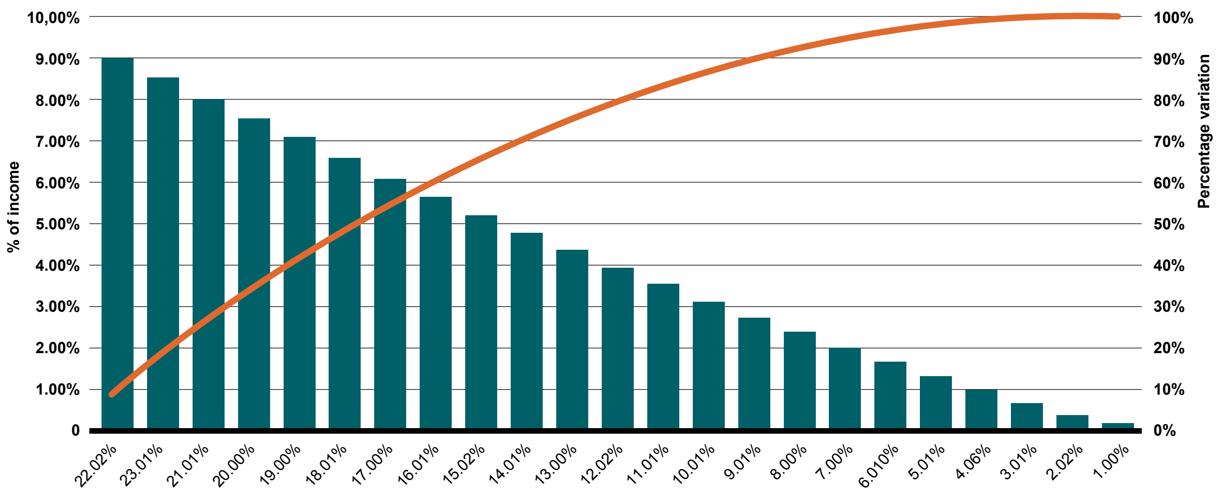


Table 8.11 Estimates of Ethnic People Moving above the Poverty Line after Project (SIM I NATRES Scenario)

	Number of people moving above the poverty line by ethnic group (000)	Share of people moving above the poverty line by ethnic group	Rural (000)	Urban (000)
Lao-Tai	90.58	0.65	79.71	10.87
Mon-Khmer	32.90	0.24	28.95	3.95
Chino-Tibetan	4.06	0.03	3.57	0.49
Hmong-Lu Mien	12.46	0.09	10.96	1.50
Total	**140.00**	**1.00**	**123.20**	**16.80**

8.5 Conclusions

This chapter has examined the economic impact of public investment policy in Lao PDR according to two alternative hypotheses: (i) a "business as usual" scenario, in which public investment increases gradually, reproducing the composition of expenditure realized in the recent past; and (ii) a natural resource oriented scenario, in which an environmental set of policies is added to address problems such as conservation and restoration of natural capital. The impact of the two scenarios has been simulated using a Computable General Equilibrium (CGE) model, based on a Social Accounting Matrix (SAM), estimated to account not only for the basic industrial structure of the economy, but also to capture some of the relevant details and relations across income distribution, poverty, and natural resources.

The results suggest that the Lao PDR's economy is dominated by agriculture and rents from natural resources, but with locally developed value chains having significant forward and especially backward connections. Factor markets also show strong connections, especially through their forward linkages as inputs in the production process. As in most countries, income distribution is characterized by stronger forward linkages of middle- and high-income groups, with the highest groups appropriating a large part of any income increases. The poorest groups appear to have the potential for contributing more than average spillover effects to the expansion of the economic system through the increase in their final demand.

The results obtained for the value-added multipliers indicate that both backward and forward linkages of some primary sectors, such as agriculture, mining, and forestry, are stronger than the industrial sectors. This suggests a segmented economy, with a relatively high degree of integration within the rural areas, and a somewhat higher dependence of the urban economy on imports, rather than on domestic supply of intermediates and raw materials. However, agriculture and forestry are characterized by very high forward multipliers, indicating that they would benefit most by a balanced increase in the activity level of the whole economy.

Regarding green value added, nature-based sectors such as agriculture and forestry are highly connected both backward and forward, indicating that they are important inputs for many key sectors and that, in turn, their contribution to economic activity is larger when the economy's total growth is larger. The estimates of the income multipliers show that the poor are only scantly connected through the value chains for all activities—even for those such as agriculture, mining, public administration, and social services whose output appears to be accruing to them in the largest relative proportions. On the contrary, the non-poor appear to benefit greatly from backward-induced increases in demand for all industries, from agriculture to tourism.

The simulations performed with the CGE model show that investment, modeled in accordance with its historical composition, is rather effective in promoting growth across a broad spectrum of sectors and factors of production, and that its impact on the economy increases more than proportionally with its size. The ensuing economies of scale are mostly due to the externalities produced by natural resources, through their contribution to total factor productivity, especially in the nature-based sectors such as agriculture and its value chains. However, natural resources are also important factors in constraining the expansion of the different sectors, since they are available in fixed supply, and some of their effects may be higher relative costs of expansion of some activities compared to others.

Under increasing investment and progressive commitment to sustainable development (in the form of a greater share of resources devoted to conservation and restoration activities), the economy expands according to a balanced pattern. However, while production in all other sectors increases at positive rates, forestry production is stationary in all simulations, while the mining and quarrying sector falls drastically in the highest-investment scenario. For forestry, this is due to the historical negative investment from deforestation and degradation, while the fall in mining production depends on its negative effects on natural capital, through reduction of the country's endowment of exhaustible resources and damages to the environment.

The results of the simulations also suggest that investments in both physical and natural capital are critical factors for the promotion and enhancement of economic growth. At the same time, such investments are not adequate to address the problem of non-inclusive development that appears to have characterized the country in spite of its aggregate growth success in the recent past. Poor people tend to be excluded from participating in the economy's growth for different reasons, including spatial and cultural isolation. In the model, this isolation takes the form of low connections with the markets, low participation in the value chains, and dependence on direct uptake and natural resource rents. Natural resources play a key role in ensuring the survival and a minimum of well-being for the largest part of the population, which is mostly poor by international standards. Natural resources increase total factor productivity and provide much-needed payoffs to all income groups and especially the poor. However, natural resources are clearly not sufficient in their present supply, as well as under the natural capital enhancing scenarios explored by the model, to promote substantial improvements in the country's pursuit of inclusive and sustainable growth.

8.6 Notes

95 This chapter was written by Pasquale Lucio Scandizzo, Daniele Cufari, and Maria Rita Pierleoni.

96 http://www.la.undp.org/content/lao_pdr/en/home.html

97 Lao PDR ranked 134th out of 189 economies on the 2016 Ease of Doing Business rankings (World Bank 2016).

98 Between 1964 and 1973, more than 2 million tons of bombs were dropped on all provinces, with 30 percent of those failing to detonate. According to UNDP, 42 of the 46 poorest districts have UXO contamination, signaling a high correlation between UXO and poverty.

99 A Social Accounting Matrix (SAM) is a representation of an economic system (at the national, subnational, or local level) capturing the circular flow of incomes and expenditures across producing sectors and institutions (households, enterprises, government, finance, and international trade actors). The SAM accounts are organized in the form of a square matrix (with payments along the columns and receipts along the rows and are generally consistent with the United Nations Standardized National Accounting (SNA) Guidelines.

100 The "National Accounts System of United Nations, 1993 (NAS93)" and the 2003 UN Manual, named SEEA03 (System Environmental and Economic Accounting), provide prescriptions to collect and incorporate in national accounts the costs of physical flows linked to the environment and their connection with the monetary flows associated with production activity and consumption. The manual includes the design of a hybrid Social Accounting Matrix, called SAMEA and subsequently SEAM, which combines economic and environmental flows in an integrated set of accounts.

101 The SAM accounts quantify a set of connections between purchasing and selling sectors that are characterized by a series of reciprocal exchanges (transactions) along and across value chains. The detailed accounting of these transactions allows the researcher to quantify the linkages across sectors and institutions in an economy through the so-called multipliers. These are measures of the increase, through direct and indirect effects, of the money inflows (revenues) or outflows (expenditures) of each sector/institution in response to exogenous shocks (for example, an increase in public investment) of different types.

102 A Computable General Equilibrium (CGE) model is a mathematical representation of an economy. The CGE has a SAM as a core set of data, but it adds to the static information on the transactions recorded by the system of accounts, a detailed set of hypotheses and quantitative estimates on the technologies adopted, the preferences and the behavior of households, firms, and other institutions. A CGE thus aims to represent, in a way consistent with the economic theory, the reaction of the economic system to changing external or internal conditions.

103 Value added is the notion utilized in the UN system of national accounts to compute GDP. Value added at factor cost is defined as the sum of the remunerations accruing to the basic factors of production (labor, capital, and land) in the period considered (for example, a year). The notion of green value added is an extension of this definition that includes the value of the ecosystem services rendered in the factors of production.

104 Households in the model are disaggregated according to three criteria: (I) Ethnicity: 49 different ethnic groups, divided into four main categories: Lao_Tai; Mon_Kmer; Cino_Tibetan and Hmong lu Mien. (II) Area (rural/urban). (III) Poverty (poor/non_poor) .

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9

BENEFIT-COST ANALYSIS OF INTERVENTIONS TO ADDRESS PRIORITY ENVIRONMENTAL HEALTH RISKS[104]

Photo credit: Nam Kat Yorla Pa

Chapter Overview

In the Lao People's Democratic Republic, the annual cost of environmental pollution associated with four major environmental health risk factors is estimated at the equivalent of 14.6 percent of gross domestic product (GDP) in 2017, as noted in chapter 3. The present chapter provides an analysis of the benefits and costs of potential interventions to mitigate the health effects of these risk factors. This analysis helps identify appropriate interventions for these environmental health issues.

Estimates of benefits and costs of twenty-five interventions for mitigating the leading environmental health risks in Lao PDR are presented. Eight interventions are assessed for controlling household air pollution, which is the leading cause of environmental health effects in Lao PDR. Eleven interventions, including arsenic mitigation in some parts of the country, are assessed for improving drinking water quality and for providing improved household sanitation to the population that still practice open defecation. Six interventions are assessed for controlling ambient $PM_{2.5}$ *air pollution in Vientiane Capital. While lead exposure may be continuing to impose a significant toll on health, sufficient data are not available to conduct a meaningful assessment of benefits and costs of interventions for lead exposure.*

The setting of priorities is a powerful lever for addressing the intersection of environmental pollution and the health of the Lao people. Developing MoNRE's capacity to conduct benefit-cost analysis—in addition to cost of environmental degradation assessments—would further support analytically sound foundations for setting environmental priorities across sectors and budget allocation in response to those priorities. The budgetary allocation for environment should be informed by a priority-setting mechanism such as analysis of the cost of environmental degradation and benefit-cost analysis of potential interventions.

9.1 Introduction

Benefits and costs of interventions in this chapter are compared by using their ratio: A benefit-cost ratio (BCR) greater than one indicates that benefits exceed costs and that it therefore would be beneficial to undertake the intervention. For instance, a ratio of three means that benefits are three times larger than the costs of the intervention, or, equivalently, the benefits are LAK 3 for every LAK 1 spent on the intervention. The ratio is calculated as the present value of benefits over the present value of costs, or, alternatively, as annualized benefits over annualized costs. An annual discount rate of 3 percent is used in the calculations the present value of benefits and costs.

> Benefit-cost ratios (BCRs) of eight interventions for the control of household air pollution are in the range of 2.1–4.0. The largest BCRs are for gasifier stoves (3.9–4.0) and improved fuelwood cookstove (3.4). The lowest BCRs are for improved charcoal cookstove (2.1). The BCRs for cooking with LPG and electric stove are somewhat higher at 2.7. However, at electricity tariffs paid by smaller residential users, the BCR of using electricity for cooking rises to 4.9[105].

> BCRs of 7 drinking water and sanitation interventions are in the range of 1.5–7.5. The largest BCRs are for rural sanitation (7.5), and ceramic filtering (6.5) and solar disinfection of drinking water (5.1). The lowest BCR is for boiling of drinking water using fuelwood (1.5) due to the large health damages of household air pollution from the use of this fuel. BCRs for boiling water with electricity or LPG are 2.7–2.8. However, the BCR for using electricity rises to 4.4 for small electricity users that pay a lower tariff rate for electricity. The BCR for high quality bottled water is 2.3 due to the high cost of this intervention.

> BCRs of 4 arsenic in drinking water mitigation interventions are in the range of 8.5–23. The largest BCRs are for deep tubewells (23), household filtering of drinking water (18), and pond sand filter (17) while the BCR for high quality bottled water is 8.5.

> BCRs of 6 ambient $PM_{2.5}$ air pollution control interventions in Vientiane Capital are the range of 0.2–6.6. The largest BCRs are for improved fuelwood cookstoves (6.6) and LPG or electricity (2.9) for households cooking outdoors. The lowest BCRs are for retrofitting of in-use diesel vehicles with diesel particulate filters (DPFs) (0.2–0.4)[106].

9.2 Benefits and costs of Household air pollution control interventions

This section assesses benefits and costs of cookstove interventions that help reduce household $PM_{2.5}$ air pollution from the use of solid fuels for cooking in Lao PDR. The interventions are promotion programs for household adoption of cooking with improved biomass cookstoves, gasifier stoves, and LPG and electric stoves.

Over 93 percent of the population in Lao PDR used solid fuels as their primary cooking fuel in 2017. Approximately 67 percent of the population relied on wood and 26 percent on charcoal, according to the Lao Social Indicator Survey 2017 (LSB 2018). Cooking with clean energies (for example, electricity, LPG, and gas/biogas) was practiced by less than 7 percent of the population nationwide.

Not many households in Lao PDR cook with improved biomass stoves of high standard in terms of energy efficiency and reduced $PM_{2.5}$ emissions. A survey in three provinces in the north—Luangprabang, Oudomxay, and Xiengkhuang—found that more than one-third of households used rudimentary cooking devices such as iron tripods and three stones with open fire. The most common stoves were Tao Dum for charcoal and wood (33 percent), Tao Prayat (or Tao Thai) for wood (17 percent), and Tao Cement for wood (8 percent). These stoves are inexpensive single-burner portable bucket stoves with low durability.

Testing of the stoves showed that they provide little or no improvement over three-stone stoves for indoor PM emissions, although they do offer improved thermal efficiency (GERES-LIRE 2013). A survey of rural and peri-urban households in Vientiane Capital and the provinces of Vientiane, Borikhamxay, and Khammuane found that only 9 percent of households had stoves with a chimney or hood (World Bank 2013). However, the LSIS 2017 found that less than one percent of households nationwide have a chimney or exhaust fan (LSB 2018).

9.2.1 Pollution Control Interventions

The solid fuel use situation in Lao PDR differs somewhat from the majority of developing countries insofar as charcoal is widely used in Lao PDR as a cooking fuel. Consequently, improved fuelwood stoves and improved charcoal stoves are assessed separately to provide an adequate perspective on the economic and public health merits of household air pollution mitigation options.

This chapter assesses the benefits and costs of the following household cooking interventions for household air pollution (HAP) control among households cooking with biomass fuels over open fire or traditional, unimproved cookstove:

- Promotion of cooking with improved fuelwood cookstoves (ICS-W);
- Promotion of cooking with improved charcoal stoves (ICS-C)
- Promotion of cooking with biomass gasifier stoves (GS) for fuelwood or charcoal users;
- Promotion of cooking with LPG stoves (LPG) instead of fuelwood or charcoal; and
- Promotion of cooking with electric stoves (ES) instead of fuelwood or charcoal.

These interventions are assessed independently in three household cooking environments with different air pollution exposure levels:

- Cooking in the house;
- Cooking in a separate building; and
- Cooking outdoors.

The intervention stoves need to have at least two burners, in contrast to single-burner stoves, so that households are less likely to continue using their traditional stove(s) along with the intervention stove for their cooking needs. The interventions have the following characteristics:

- The improved fuelwood cookstove (ICS-W) that is assessed is a Rocket stove that burns biomass more efficiently and emits less harmful smoke.
- Several improved charcoal stoves (ICS-C) are being promoted by various enterprises and with international donor support globally.
- Biomass gasifier stoves turn biomass at very high temperatures into clean burning gas. These stoves are being promoted in Asia and Africa (World Bank 2014; 2015).
- The LPG and electric stoves have at least two burners.

This chapter discusses pre- and post-intervention assessments with respect to (i) household member $PM_{2.5}$ exposure reduction; (ii) health benefits of reduced $PM_{2.5}$ exposure; (iii) non-health benefits (that is, fuel savings and cooking time savings); (iv) stove and energy costs of interventions; and (v) comparison of benefits and costs of each intervention (that is, benefit-cost ratios).

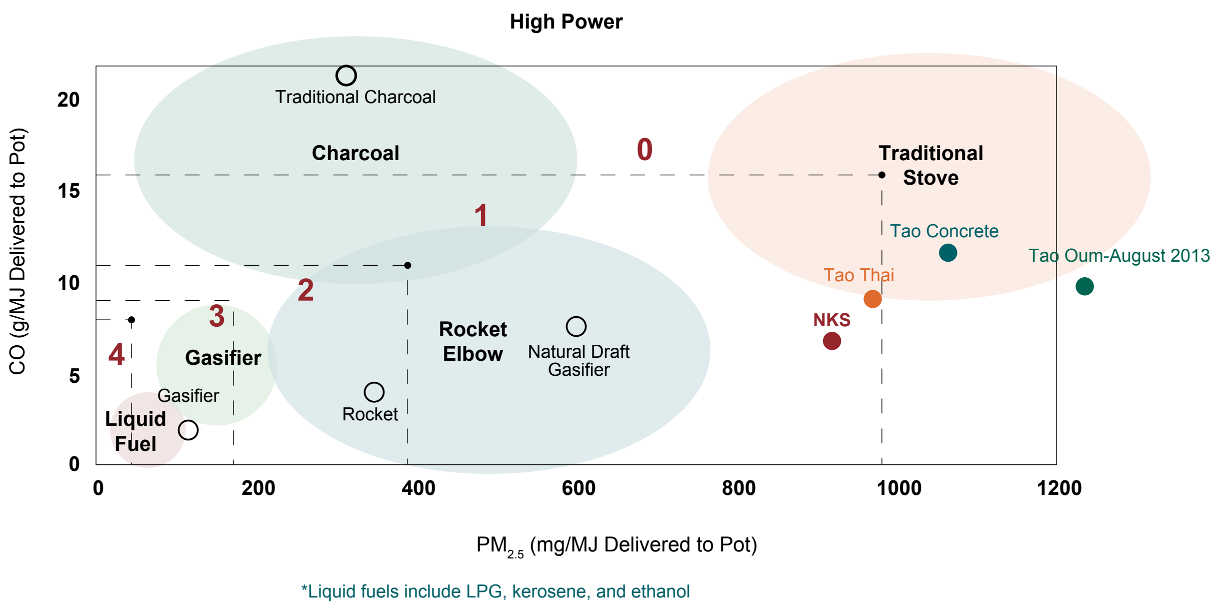
Household use of solid fuels has community effects. Smoke from fuel burning enters dwellings of other households and contributes to outdoor ambient air pollution. An improved stove with a chimney, or simply the venting of smoke through a hood from any stove or open fire, may be effective for the household installing these devices, but contributes to increased outdoor ambient pollution and indoor pollution in nearby dwellings. Only clean energies and technologies prevent these negative effects.

To achieve the maximum benefits per unit of expenditure on household energy and stove interventions, all households would need to participate, and thus achieve a *clean energy* community or, in the interim, an *improved cookstove* community. This concept may be especially applicable to rural areas where communities are spatially clustered and is like the concept in the sanitation sector of an *open defecation free* community (a community free of open defecation), a goal often promoted and achieved through community-led or total sanitation campaigns.

9.2.2 Pre-Intervention $PM_{2.5}$ Exposures

The stoves that are most commonly used by households, according to a survey in northern Lao PDR, have been laboratory tested for $PM_{2.5}$ emissions. This included the Tao Dum, Tao Concrete, and Tao Thai stoves. These stoves are all inexpensive portable single-burner bucket stoves with relatively low durability. $PM_{2.5}$ emissions ranged from nearly 1,000 mg/MJ to over 1,200 mg/MJ of delivered energy to the pot. This is 3 to 4 times as high as emissions from an improved stove with Rocket technology *(Rocket #1 stove)* or traditional charcoal stove, and 10 to 12 times higher than a forced-draft gasifier stove (*Gasifier #1*) according to Figure 9.1. An inexpensive Cambodian woodstove model (NKS) was also tested and showed somewhat better performance than the stoves used in northern Lao PDR.

Figure 9.1 $PM_{2.5}$ Emissions from Selected Stoves



Source: GERES 2014.

The laboratory tests demonstrate that there is plenty of opportunity to reduce household air pollution by using high-quality improved biomass cookstoves, gasifier stoves, and clean energies (for example, LPG and electricity). However, $PM_{2.5}$ concentrations in the household environment depend on many factors and vary substantially, not only in relation to type of fuel and stove, but also in relation to cooking location, ventilation practices, cooking duration, and structure of dwelling. Household members' personal exposure to $PM_{2.5}$ from combustion of solid fuels depends additionally on their activity patterns in the household environment.

A recent study in three villages in Savannakhet found that average 48-hour $PM_{2.5}$ kitchen concentrations were 439 μg/m^3 in a sample of 72 households cooking with solid fuels (University of California, Berkeley, and Berkeley Air Monitoring Group 2015). Average 48-hour personal exposure of the main cook was 119 μg/m^3, or 12 times the WHO annual outdoor air quality guideline (AQG) of 10 μg/m^3. Average outdoor ambient $PM_{2.5}$ in the villages was as high as 52 μg/m^3, mainly due to the solid fuels used for cooking.

Table 9.1 and Table 9.2 present the pre-intervention personal exposures to $PM_{2.5}$ used for estimating health benefits of intervention exposure reductions of $PM_{2.5}$. Exposure of the main cook is used as a reference point for personal exposure of adult women. This is because the person cooking in the household is most often a woman, and the exposure measurement study discussed above is in reference to the person cooking. Exposures of other household members (that is, adult men and young children) are set at 60 percent to 85 percent of adult women's exposure, since adult men and young children generally spend less time in the household environment and the kitchen than adult women (Smith et al. 2014). Cooking in the house is used as the reference location. Personal exposures from cooking outdoors or in a separate building are set at 60 percent to 80 percent of exposure from cooking in the house (Table 9.1). The exposure levels reflect that a portion of biomass smoke from outdoor cooking or cooking in a separate building also enters the indoor living and sleeping areas.

Table 9.1 Relative Exposure Levels by Household Member and Cooking Location

		Household member (H)		Location (L)
1	Adult women	100%	In house	100%
2	Adult men	60%	Separate building	80%
3	Children <5 years	85%	Outdoors	60%

Table 9.2 Long-term Personal $PM_{2.5}$ Exposure by Cooking Location in Households Using Traditional Cookstoves with Fuelwood or Charcoal (μg/m^3)

	Fuelwood traditional stove/open fire			Charcoal traditional stove		
	Adult women	Adult men	Children <5 years	Adult women	Adult men	Children <5 years
In house	120	72	102	72	43	61
Separate building	96	58	82	62	37	53
Outdoors	72	43	61	54	32	46

An average exposure level of 120 μg/m^3 is applied to adult women cooking in the house with wood over an open fire or traditional cookstove. Average exposure levels of adult men and children under five years of age and in various cooking locations are calculated in relation to the exposure level of adult women cooking in the house by applying the relative exposure factors in able 9.1. For instance, the exposure level of adult men in a household cooking outdoors is 120 μg/m^3 * H2 * L3 = 120 μg/m^3 * 60% * 60% = 43 μg/m^3 (Table 9.2).

Very few measurement studies globally have been conducted of personal exposure from cooking with *charcoal*. This is mainly because charcoal is a primary cooking fuel in only a minority of countries. Cooking with charcoal is generally associated with lower personal exposure levels of $PM_{2.5}$ than cooking with fuelwood. Personal exposures from cooking with *charcoal* are set at 60 percent, 65 percent, and 75 percent of personal exposures from cooking with fuelwood in the house, in a separate building, and outdoors, respectively (Table 9.2).

9.2.3 Post-Intervention $PM_{2.5}$ Exposures

The use of improved biomass cookstoves (ICS), gasifier stoves, and LPG and electric stoves is expected to reduce household members' exposure to $PM_{2.5}$ from cooking. A review of personal exposure studies before and after installation of an ICS indicates a median reduction in exposure of greater than 50 percent (Larsen 2017). However, studies of exposure reductions are most often measured within a relatively short time after the installation of the ICS. Exposure reductions over the life of the ICS are likely to be somewhat less, since the quality of the ICS deteriorates over time.

A 40 percent exposure reduction from an ICS—using wood or charcoal—over its lifetime is therefore likely to be more realistic even with good stove maintenance and is applied in this chapter to households cooking in the house. Exposure reductions from an ICS for households cooking in a separate building or outdoors may be less than for households cooking in the house. This is because the relative contribution to exposure from pollution originating from other households cooking with solid fuels in the community is larger for households cooking in a separate building or outdoors than for households cooking in the house. Thus, exposure reductions of 35 percent and 25 percent are applied to households cooking in a separate building and outdoors, respectively.

Table 9.3 summarizes the percentage exposure reductions from ICS. The reductions are relative to the exposure levels using traditional cookstoves (TCS) presented in Table 9.2, and are applied to adult women, men, and children.

Table 9.3 Household Member Exposure Reduction from ICS in Relation to Cooking Location

In house	40%
Separate building	35%
Outdoors	25%

Combustion of LPG results in very little $PM_{2.5}$ emissions and is therefore considered a relatively clean cooking fuel. However, studies have found that household $PM_{2.5}$ concentrations among users of LPG often remain as high as 40–60 μg/m^3, presumably due in part to the community pollution from neighboring households using solid fuels, but also the continued use of solid fuels as secondary cooking fuels. It is therefore stipulated here that exposure levels associated with cooking exclusively with LPG are on average 30 μg/m^3. This exposure level is applied to adult women and children. A somewhat lower exposure level of 20 μg/m^3 is applied to adult men, since this household-member group often spends considerable time away from the immediate community, and presumably in locations with less pollution. These exposure levels are also applied to the use of gasifier and electric stoves.

The exposures associated with LPG and gasifier and electric stoves are independent of cooking location, since these cooking options do not cause significant $PM_{2.5}$ emissions. The main sources of $PM_{2.5}$ exposure in these households are other sources of $PM_{2.5}$ in their own household environment and community pollution (for example, other households using solid fuels).

Table 9.4 Household Member Air Pollution Exposure by Intervention and Cooking Location (μg/m³)

	Pre-intervention		Post-intervention		
	TCS wood	TCS charcoal	ICS wood	ICS charcoal	LPG, GS, ES
Adult female					
Outdoors	72	54	54	41	30
Separate building	96	62	62	41	30
In house	120	72	72	43	30
Adult male					
Outdoors	43	32	32	24	20
Separate building	58	37	37	24	20
In house	72	43	43	26	20
Children					
Outdoors	61	46	46	34	30
Separate building	82	53	53	34	30
In house	102	61	61	37	30

Note: TCS = Traditional cookstove (open fire or unimproved stove); ICS = improved cookstove; LPG = liquefied petroleum gas; GS = gasifier stove; ES = electric stove.

Personal exposure levels in households using LPG and gasifier and electric stoves may decline to levels below those discussed above. Joon et al. (2011) found a 24-hour average $PM_{2.5}$ exposure for the cook of 25 μg/m³ among rural households using LPG in Haryana, India. Titcombe and Simcik (2011) measured an average $PM_{2.5}$ personal exposure of 14 μg/m³ in households in the southern highlands of Tanzania cooking indoors with LPG.

Pre- and post-intervention levels of personal exposure to $PM_{2.5}$ are presented in Table 9.4 and reflect the exposure reductions from ICS and levels associated with LPG and gasifier and electric stoves discussed above. The exposure levels are broad averages and will vary substantially across individual households. The exposure levels represent households living in a community in which other households, to a varying extent, continue to use biomass fuels in unimproved and/or improved cookstoves or in which air quality is affected by other sources of $PM_{2.5}$ pollution (that is, affected by community pollution or pollution originating outside the community).

9.2.4 Costs of Interventions

9.2.4.1 Demand for Interventions

The success of stove promotion programs—that is, achieving high household adoption rates, sustained use, proper maintenance and repair of the cookstove, and repeat adoption of an improved stove or clean energies—will depend on factors such as household acceptability of the characteristics of the stoves being promoted, stove-financing arrangements, household perceptions of benefits of the cookstoves, and program follow-up in terms of monitoring and promotion of sustained use of the stoves as well as proper stove maintenance and repair (Hanna et al. 2016; Miller and Mobarak 2015; Mobarak et al. 2012).

Many improved cookstove programs have suffered from low adoption and user rates, poor maintenance, and outright abandonment of the improved cookstove in favor of the old traditional stove. This is particularly the case with programs that are not demand driven—

that is, when stoves are distributed for free or at a highly subsidized rate whether or not households want the stoves (Hanna et al. 2016).

For large-scale adoption of cleaner cookstoves and cooking energies to occur in Lao PDR, several factors influencing adoption rates must be addressed, such as

- High initial cost of improved stoves;
- High annual fuel cost of LPG fuel and electricity;
- Tailoring to consumers' preferences for stove characteristics;
- Installment financing of stoves and LPG auxiliary equipment (tank, hose, and connection);
- Well-targeted information campaigns; and
- Community focus like total sanitation and open defecation free community programs.

Kar and Zerriffi (2015) present a theoretical framework for achieving successful stove promotion programs. The framework is based on the claim that behavior change is not a discrete event but a process that unfolds over time through a series of six distinct stages. The stages are (i) pre-contemplation, (ii) contemplation, (iii) preparation, (iv) action, (v) maintenance, and (vi) termination. Stove-promotion programs must give due consideration to each of these stages to be successful. This includes well-designed behavioral change communication (BCC) strategies; overcoming obstacles to stove adoption (for example, identify desirable stove technology and design, stove financing, warranty, and stove-satisfaction guarantees); stove servicing; and maintenance follow-up.

Lewis et al. (2015) report the results of a piloting of improved cookstoves in eight villages across three states in India. The piloting tested various aspects of stove marketing related to (i) behavioral change communication (BCC), (ii) type of stoves, (iii) purchase options (installment payment and stove return option) and rebates for prolonged use, and (iv) access and institutional delivery. All households in the village were given the opportunity to purchase a stove at or close to manufacturer's suggested retail price, and interviews were conducted with a subset of households. Stove prices ranged from US$15-US$45. Stove sales varied across villages from 0 percent to 60 percent. Sales reached 60 percent among randomly selected households in the village in which the most intensive marketing and BCC was undertaken and multiple stove options, installment plan, rebates for prolonged use, and/or stove-return option were offered. Sales were lowest in the villages in which only one type of stove was offered, full upfront payment was required, and rebates and/or stove return option were not offered. All monitored households continued to use their stove through the installment payment period (3–4 months).

The opportunity to assess the sustainability of use of improved cookstoves was limited in the study by Lewis et al. (2015). In contrast, Pillarisetti et al. (2014) assessed the usage of an advanced cookstove (gasifier stove) in Haryana, India. The use of the stove declined by about 60 percent over a period of about 1 year, with usage falling fastest in first 100 days and stabilizing after about 225 days. The stove was distributed to households for free and was not demand driven, likely negatively affecting long-term usage. In addition, the stove required that biomass fuel be chopped into small pieces, possibly affecting the attractiveness of the stove.

In a study in rural Guatemala of households that had adopted a chimney stove, the stoves were used 90 percent of the days over a monitoring period of 32 months (Ruiz-Mercado et al. 2013). Factors that contributed to the high usage rate included (i) high initial stove acceptance in the region, (ii) familiarity of new users with the stove, (iii) frequent follow-up by study/project personnel, and (iv) continued encouragement to use the stove.

The above discussion about success of stove-promotion programs is highly relevant for a benefit-cost assessment. This is because benefits per unit of cost critically depend on stove adoption rates, long-term user rates, and sustained benefits of stoves (through proper maintenance and repairs). For a given promotion program, a high adoption rate lowers the cost per household that adopts an improved stove. Once a household has acquired a stove, high long-term user rate and sustained benefits increase the total benefits of the program or benefits per household that acquired a stove.

In light of the above literature review, an initial adoption rate of 30 percent and a long-term user rate of 65 percent of initial adoption are applied in the benefit-cost assessment for improved fuelwood and charcoal stoves. The adoption rate is the midpoint in Lewis et al. (2015). The long-term user rate is the midpoint of findings in Pillarisetti et al. (2014) and Ruiz-Mercado et al. (2013). For LPG, electric stoves, and gasifier stoves, an initial adoption rate of 15 percent is applied in light of the high energy cost of LPG and electricity and high initial cost of gasifier stoves. A long-term user rate as high as 90 percent of initial adoption is applied for LPG and electric stoves, because once households have decided to use LPG and electricity, the long-term user rate is likely to be high, given the ease of use of these cooking options. However, for gasifier stoves, the long-term user rate applied is the same as for improved fuelwood and charcoal stoves—that is, 65 percent due to lower ease of use than LPG and electric stoves (Table 9.5).

The factors discussed above can be assessed and addressed through pilot programs prior to full scale-up of promotion programs. This report focuses exclusively on benefits and costs of the cook stove options (including LPG and electricity) to elucidate if such promotion programs are likely to provide larger benefits than costs, if properly designed and implemented and households (at least to some extent) adopt and use the stoves being promoted. Costs of interventions are (i) stove and equipment cost, (ii) stove maintenance and repair cost, (iii) intervention promotion program cost, and (iv) energy cost.

9.2.4.2 Cost of Stoves and Equipment

Cost of improved biomass cookstoves varies tremendously depending on fuel and emission efficiency, durability, materials, and technology. Basic improved stoves can cost less than US$10 but these stoves often do not provide fuel savings beyond 25 percent, provide limited emission reduction benefits, and have poor durability. Intermediate improved stoves cost US$25–35 and include Rocket stoves. These stoves can provide up to 50 percent fuel savings and substantial emission reduction benefits. Biomass gasifier stoves come in various models, technologies and prices (World Bank 2014; 2015). Advanced stoves such as natural or forced draft gasifier stoves cost US$50–75 but often have only one burner. The price of an LPG stove or electric stove with a single burner can cost less than US$40.

Stove costs and useful life of the stoves applied in this chapter are presented in Table 9.6. The cost is for stoves that have two burners or, alternatively, for two single stoves, so that cooking with the traditional, unimproved stove or open fire can be avoided.

Costs are annualized at an annual discount rate of 3 percent and a useful life of the stoves ranging from 4 to 10 years. Annualized cost per sustained user is calculated by dividing the cost per initial user by the long-term user rates.

Table 9.5 Initial Adoption and User Rates of Interventions

	ICS (W)	ICS (C)	LPG	Electric stove	Gasifier stove
Initial adoption rate of promoted intervention	30%	30%	15%	15%	15%
Long-term user rate (% of initial users)	65%	65%	90%	90%	65%

Table 9.6 Cost of Stove and Equipment, LAK per Household, 2017

	ICS (W)	ICS (C)	LPG	Electric stove	Gasifier stove
Cost of stove (US$)	40	50	60	60	120
Cost of stove (LAK)	330,000	410,000	490,000	490,000	990,000
Cost of starter kit (bottle, hose, and regulator) (LAK)			250,000		
Useful life of stove (years)	4	4	10	10	7
Annualized cost per initial user (LAK)	86,200	107,100	84,200	55,800	154,300
Long-term user rate (% of initial users)	65%	65%	90%	90%	65%
Annualized cost per sustained user (LAK)	132,600	164,750	93,600	62,000	237,350

Note: Discount rate is 3%/yr.

9.2.4.3 Cost of Stove Maintenance and Repair

Stoves need maintenance and repair for proper functioning. It is assumed here that the cost of maintenance and repair is 5 percent of initial stove cost. This cost is applied only to the long-term users of the stoves (Table 9.7).

9.2.4.4 Cost of Promotion Program

Achieving household adoption of improved stoves and clean energies for cooking requires a promotion program. The cost applied here is US$3, or about LAK 25,000, per targeted household. The program also contains monitoring and follow-up to maximize long-term user rates and proper stove maintenance and repair, here at a cost of US$2, or LAK 16,500, per household for each year of stoves' useful life. Annualized program cost per targeted household is then LAK 19,300–22,950, based on the useful stove life of 4 to 10 years. Annualized cost per initial user is LAK 76,500–135,600, calculated by dividing the cost per targeted household by the initial adoption rates. Annualized cost per sustained user is LAK 117,700–208,600, calculated by dividing the cost per initial user by the long-term user rates (Table 9.8).

9.2.4.5 Cost of Energy

In a benefit-cost analysis presenting benefit-cost ratios (BCRs) of interventions, benefits and costs must be treated consistently so that BCRs across interventions can be compared. BCRs are calculated by placing all benefits in the numerator and all costs in the denominator. This is straightforward for most types of benefits and costs. However, for energy consumption, the situation can be more complex. For consistency, 100 percent of pre-intervention energy consumption is treated as energy saving or benefit in all interventions and placed in the numerator of the BCR, and post-intervention energy consumption is treated as a cost and placed in the denominator.

Fuelwood: Nearly 75 percent of households using fuelwood for cooking live in rural areas. Most of these households collect fuelwood from nearby areas. Many of the urban households that use fuelwood also collect the fuel. Therefore, it is important to impute a value of self-collected fuelwood. A common approach is to impute a value based on the amount of time that households spend on fuelwood collection.

Table 9.7 Cost of Stove Maintenance and Repair, LAK per Household, 2017

	ICS (W)	ICS (C)	LPG	Electric stove	Gasifier stove
Annual stove maintenance and repair (% of stove cost)	5%	5%	5%	5%	5%
Annual cost per user (LAK)	16,500	20,500	24,500	24,500	49,500

Table 9.8 Cost of Promotion Program, LAK per Household, 2017

	ICS (W)	ICS (C)	LPG	Electric stove	Gasifier stove
Cost of program per targeted household (LAK) —first year	25,000	25,000	25,000	25,000	25,000
Cost of program per targeted household (LAK) —from second year	16,500	16,500	16,500	16,500	16,500
Annualized program cost per targeted household (LAK)	22,950	22,950	19,300	19,300	20,350
Initial adoption rate (% of targeted households)	30%	30%	15%	15%	15%
Annualized cost per initial user (LAK)	76,500	76,500	128,700	128,700	135,600
Long-term user rate (% of initial adoption)	65%	65%	90%	90%	65%
Annualized cost per sustained user (LAK)	117,700	117,700	143,000	143,000	208,600

Note: Discount rate is 3%/yr.

Households surveyed in three provinces in the north—Luang Prabang, Oudomxay, and Xiengkhouang—report that they spend on average over 6 hours per week on fuelwood collection and consume 9 kg of fuelwood per day (GERES-LIRE 2013). A second survey in the provinces of Luang Prabang and Vientiane reports that rural households spend a little over 2 hours per week on fuelwood collection (LIRE 2013). Even if adjusting for the fact that *only* two-thirds of the surveyed households collect fuelwood[107], collection time is 3.2 hours per week.

A collection time of 30 minutes per household per day is applied here for households cooking with fuelwood using unimproved stoves or open fire. The value of this collection time is estimated using average female wages, and a value of time equal to 50 percent of the female wage. A female wage rate is applied since most fuel collection is carried out by women (or children). The estimated value of fuelwood collection is then LAK 545,100 per household per year.[108] This is the pre-intervention energy cost for households using unimproved fuelwood stoves. With an improved fuelwood cookstove, energy savings generally exceed 20 percent and can be up to 70 percent.[109] A 30 percent energy saving by using an improved cookstove is applied here. The energy cost associated with an improved fuelwood cookstove is therefore LAK 381,570 per household per year (Table 9.10).

Gasifier stove: A gasifier stove uses biomass that is chopped into small pieces. It may use 50 percent less biomass fuel that an unimproved fuelwood stove and therefore involves 15 minutes per day in collection time if the fuel is self-collected (Servals 2012). The chopping of biomass into small pieces also takes time, here assumed to take 15 minutes per day.[110] Total fuel collection and fuel preparation time is therefore 30 minutes per household per day, the cost of which is LAK 545,100 per year as in the case of a household cooking with unimproved fuelwood stove (Table 9.10).

LPG, electricity, and charcoal: It is assumed here that LPG consumption is 30 kg per person or 140 kg per household per year for households that exclusively use LPG for cooking. This is in line with estimates for several countries in Africa, Asia, and South America (Kojima et al. 2011). Based on the energy content of fuels and electricity and on stove efficiencies, cooking exclusively with electricity or charcoal would then require 1,487 kWh or 750 kg, respectively, per year, yielding an annual effective energy of 3,480 MJ. This consumption of charcoal is for an unimproved charcoal cookstove. An improved charcoal stove can yield at least 30 percent fuel saving, reducing consumption to 525 kg per household per year (Table 9.9).[111]

The energy cost of interventions ranges from LAK 381 thousand per household per year for improved fuelwood cookstove (ICS (W)) to about LAK 1.3 million for LPG, electricity, and charcoal. The energy cost of a gasifier stove is somewhat higher than for an ICS (W) (Table 9.10).

The economic price of LPG and charcoal is assumed to be LAK 9,000/kg and LAK 2,500/kg, respectively, based on information from energy companies, JICA et al. (2013), and World Bank (2013). Residential electricity prices are according to block tariffs that range from LAK 348/kWh for the first 25 kWh of consumption per month to LAK 965/kWh for consumption over 400 kWh per month. Cooking exclusively with electricity implies electricity consumption of 124 kWh per month, which would bring most household to a monthly consumption of 150–300 kWh with a tariff rate of LAK 799/kWh, or to a consumption of 300–400 kWh with a tariff rate of LAK 880/kWh as applied in Table 6.10. At a tariff rate of LAK 799/kWh, the energy cost of electric stoves would drop from LAK 1.31 million to LAK 1.19 million. For households that currently use very little electricity, cooking exclusively with electric stove could cost LAK 0.6 million based on a tariff rate of LAK 414/kWh for consumption up to 150 kWh per month.

Table 9.9 Estimated Household Energy Consumption for Cooking

	LPG	Electricity	Charcoal (unimproved stove)	Charcoal (improved stove)
	kg	kWh	kg	kg
Energy content (MJ/unit)	45.2	3.6	31	31
Stove efficiency	55%	65%	15%	21.4%
Effective energy (MJ/unit)	24.86	2.34	4.65	6.62
Consumption (units per person per year)	30			
Consumption (units per household per year)	140	1,487	750	525
Total effective energy (MJ per year)	3,480	3,480	3,480	3,480

Table 9.10 Cost of Energy per Household per Year, LAK, 2017

	ICS (W)	ICS (C)	LPG	ES	Gasifier
Energy consumption (kg; kWh)		525	140	1,487	
Cost per unit (LAK per kg; kWh)		2,500	9,000	880	
Cost per household per year (LAK)	381,570	1,312,500	1,260,000	1,308,868	545,100

Note: Economic costs are exclusive of value-added tax (VAT)
ICS = improved cookstove; LPG = liquefied petroleum gas; GS = gasifier stove; ES = electric stove.

9.2.4.6 Total Costs

Total costs of interventions amount to LAK 0.65–1.62 million per household per year (Table 9.11). Costs are the same for all cooking locations. Costs are lowest for improved fuelwood cookstove (ICS (W)) followed by gasifier stove. This is largely because of the lower energy costs of these interventions. Costs are highest for LPG, electric stove (ES), and improved charcoal cookstove (ICS (C)), mainly due to the higher energy cost of these interventions. The costs of LPG, electric stove, and gasifier stove are the same whether households' pre-intervention fuel is fuelwood or charcoal.

The largest cost component is energy cost for all interventions. This is followed by cost of promotion program and the cost of stove and equipment. Stove maintenance and repair have the lowest cost.

9.2.5 Benefits of Interventions

9.2.5.1 Health Benefits

Health benefits of interventions moving from pre-intervention to post-intervention exposure levels of $PM_{2.5}$ are estimated by using the integrated $PM_{2.5}$ exposure health risk methodology from GBD 2016 (Gakidou et al. 2017) in Larsen (2019: annex 1) and the potential impact fraction (PIF) formula in Larsen (2019: annex 7).

Table 9.12 presents the estimated percentage reductions in health effects of interventions. The reductions—or health benefits—are larger among households cooking in the house than among households cooking in a separate building or outdoors, due to the larger exposure reductions in the former group of households.

Table 9.11 Costs of Interventions (LAK, Millions, per Household per Year), 2017

	Cooking with fuelwood (pre-intervention)				Cooking with charcoal (pre-intervention)			
	ICS (W)	LPG (W)	ES (W)	Gasifier (W)	ICS (C)	LPG (C)	ES (C)	Gasifier (C)
Stove and equipment	0.13	0.09	0.06	0.24	0.16	0.09	0.06	0.24
Stove maintenance and repair	0.02	0.02	0.02	0.05	0.02	0.02	0.02	0.05
Promotion program	0.12	0.14	0.14	0.21	0.12	0.14	0.14	0.21
Energy cost	0.38	1.26	1.31	0.55	1.31	1.26	1.31	0.55
Total costs	**0.65**	**1.52**	**1.54**	**1.04**	**1.62**	**1.52**	**1.54**	**1.04**

Note: ICS = improved cookstove; LPG = liquefied petroleum gas; GS = gasifier stove; ES = electric stove.

Table 9.12 Reduction in Health Effects from Cookstove Interventions

	ICS wood	ICS charcoal	LPG, GS, ES from wood	LPG, GS, ES from charcoal
In house	25%	28%	56%	41%
In separate building	23%	25%	50%	35%
Outdoors	17%	18%	41%	29%

Note: ICS = improved cookstove; LPG = liquefied petroleum gas; GS = gasifier stove; ES = electric stove.

It should also be noted that the percentage reduction in health effects from adopting an ICS with wood or charcoal or switching to LPG, gasifier stove, or electric stove is substantially smaller than the percentage reduction in $PM_{2.5}$ exposure. This is because of the nonlinear relationship between exposure level and health risks.

Moreover, switching to LPG, gasifier stove, or electric stove will provide more than twice as high health benefits as switching to ICS among current fuelwood users, and 45–60 percent higher health benefits among current charcoal users. Nevertheless, substantial health effects of household air pollution remain even for households switching to LPG, gasifier stoves, or electric stoves unless a community achieves *clean energy* status, due to the community air pollution caused by households that continue to use solid fuels.

Control of household air pollution is unlikely to instantaneously provide full benefits for health outcomes that develop over long periods of $PM_{2.5}$ exposure—that is, for heart disease, stroke, chronic obstructive pulmonary disease (COPD), and lung cancer. It is therefore assumed that reduced incidence of and deaths from these diseases are gradually realized over ten years. However, for acute lower respiratory infections (ALRI) among young children, full health benefits are realized in the same year as $PM_{2.5}$ exposure reduction. This means that over a time horizon of 20 years, annualized health benefits are 90 percent of full benefits using an annual discount rate of 3 percent.

Avoided deaths and illness are monetized by using various benefit-valuation measures. A common approach that reflects how much people are willing to pay to reduce the risk of mortality is the use of the so-called value of statistical life (VSL) for valuation of avoided premature deaths. Avoided deaths are valued at a VSL of LAK 1.5 billion, or 74 times GDP per capita in Lao PDR in 2017. Avoided morbidity is valued at 100 percent of average wage rates per day of illness (see also Larsen [2019: annex 5]).

Health benefits of interventions are LAK 1.2–3.1 million per household per year. These are averages for all cooking locations (Table 9.13). Benefits per household are higher for households cooking in the house and lower for households cooking in a separate building or outdoors, due to differences in pre-intervention and post-intervention exposure levels of $PM_{2.5}$. Health benefits of switching from fuelwood to clean cooking solutions (LPG, electricity, and gasifier stoves) are more than 100 percent higher than adopting an improved fuelwood stove. The health benefits of switching from charcoal to clean cooking are 40 percent higher than adopting an improved charcoal stove.

9.2.5.2 Non-Health Benefits

Switching to an improved cookstove (ICS) or to a gasifier stove (GS), LPG, or electric stove also has non-health benefits. The main benefits are reduced biomass consumption, whether self-collected or purchased, and reduced cooking time. The magnitude of these benefits will depend on current cooking arrangements, type of improved stove, household cooking patterns, and household member valuation of time savings.

Table 9.13 Health Benefits of Interventions by Cooking Location (LAK, Millions, per Household per Year), 2017

	Cooking with fuelwood (pre-intervention)				Cooking with charcoal (pre-intervention)			
	ICS (W)	LPG (W)	ES (W)	Gasifier (W)	ICS (C)	LPG (C)	ES (C)	Gasifier (C)
In the house	1.61	3.53	3.53	3.53	1.34	1.92	1.92	1.92
In separate building	1.28	2.80	2.80	2.80	1.07	1.51	1.51	1.51
Outdoors	0.79	1.92	1.92	1.92	0.69	1.13	1.13	1.13
Average all locations	1.40	3.09	3.09	3.09	1.17	1.69	1.69	1.69

9.2.5.2.1 Fuel Savings

All pre-intervention household fuelwood and charcoal consumption used for cooking is treated here as fuel savings of interventions. All post-intervention consumption is treated as a cost.

Fuelwood: A collection time of 30 minutes per household per day is applied here for households exclusively cooking with fuelwood using unimproved stoves or open fire. The value of this collection time is estimated using average female wages, and a value of time equal to 50 percent of the female wage. A female wage rate is applied, since most fuel collection is carried out by women (or children). The estimated value of fuelwood collection, or fuel savings from no longer using the unimproved stove (that is, by switching to another fuel or improved cookstove), is LAK 545 thousand per household per year (Table 9.14).[112]

Charcoal: A household that exclusively cooks with an unimproved charcoal cookstove is estimated to have an annual charcoal consumption of 750 kg (section 9.2.4.6). At a cost of LAK 2,500/kg, annual charcoal fuel saving from no longer using this unimproved stove (that is, by switching to another fuel or improved cookstove), is LAK 1.875 million per household per year (Table 9.14).

Table 9.14 Estimated Value of Household Fuel Savings, 2017

	LAK/household/yr
Fuelwood savings	545,100
Charcoal savings	1,875,216

9.2.5.2.2 Cooking Time Savings

A survey of rural and peri-urban households in Vientiane Capital and the provinces of Vientiane, Borikhamxay, and Khammuane found that households spend on average 2.25 hours per day on meal preparation (World Bank 2013).

Hutton et al. (2006) report that it takes 11–14 percent less time to boil water with a Rocket stove (improved cookstove) or LPG stove than over an open fire. Habermehl (2007) reports that monitoring studies have found that cooking time declined by 1.8 hours per day with the use of a Rocket Lorena stove. One-quarter of this time, or 27 minutes, is considered time savings by Habermehl, since the person cooking often engages in multiple household activities simultaneously. Siddiqui et al. (2009) report that daily fuel-burning time for cooking in a semi-rural community outside Karachi was 30 minutes less in households using natural gas than in households using wood, and that the time spent in the kitchen was 40 minutes less. Jeuland and Pattanayak (2012) assume that an improved wood stove saves around 10 minutes per day, and that LPG saves one hour per day in cooking time. Garcia-Frapolli et al. (2010) report that cooking time from using the improved Patsari chimney stove in Mexico declined by about 1 hour per household per day. Effectively 15–30 minutes of this time are saved, since the person cooking often engages in multiple household activities simultaneously.

A saving in cooking time of 15 minutes per day from the use of an improved cookstove (wood or charcoal) and 30 minutes from the use of a gasifier stove, LPG, or electric stove is applied here compared to an unimproved cookstove or an open fire. As for fuel-collection time savings, a value of time equal to 50 percent of female wage rates is applied to estimate the value of savings of cooking time. Table 9.15 presents annual values of time savings per household.

Table 9.15 Estimated Value of Cooking Time Savings, 2017

	LAK/household/yr
Improved cookstove (fuelwood or charcoal)	272,550
Gasifier stove, LPG, electric stove	545,100

9.2.5.3 Total Benefits

Total benefits of interventions amount to LAK 2.2–4.2 million per household per year (Table 9.16). These are averages for all cooking locations. Benefits are lowest for improved cookstove with fuelwood (ICS (W)) followed by improved cookstove with charcoal (ICS (C)). This is largely because of the lower health benefits of these interventions. The benefits of ICS (C) are still substantially higher than for ICS (W) because of the high value of fuel savings associated with the ICS (C).

Total benefits of LPG, electric stove (ES), and gasifier stoves amount to over LAK 4 million per household per year. The health benefits are largest for the households adopting these interventions that currently use fuelwood, because the pre-intervention $PM_{2.5}$ exposure levels are substantially higher for households currently using fuelwood than for households using charcoal. However, the fuel savings are largest for households currently using charcoal.

Total benefits per household are somewhat higher than presented in Table 9.16 for households cooking in the house and somewhat lower for households cooking in a separate building or outdoors, due to differences in health benefits across cooking locations.

9.2.6 Benefit-Cost Ratios of Interventions

Benefits and costs of interventions are compared by using their ratio: A benefit-cost ratio (BCR) greater than one indicates that benefits exceed costs. The ratio can be calculated as the present value of benefits over the present value of costs, or as annualized benefits over annualized costs. An annual discount rate of 3 percent is used in the calculations for benefits and costs.

Table 9.17 presents the BCRs of the interventions for each household cooking location and by the type of solid fuel that households are using prior to intervention—that is, fuelwood or charcoal. The average BCRs for all cooking locations are in the range of 2.1–4.0. The BCRs are somewhat higher than the average for households cooking in the house and somewhat lower for households cooking in a separate building or outdoors.

The BCR is highest for gasifier stoves, followed by improved cookstove using fuelwood (ICS (W)), electric stoves (ES), and LPG. The lowest BCR is for improved cookstove using charcoal (ICS (C)).

Figure 9.2 and Figure 9.3 summarize the benefits and benefit-cost ratios of the interventions, with health and non-health benefits presented separately.

Table 9.16 Benefits of Interventions (LAK, Millions, per Household per Year), Average for All Locations, 2017

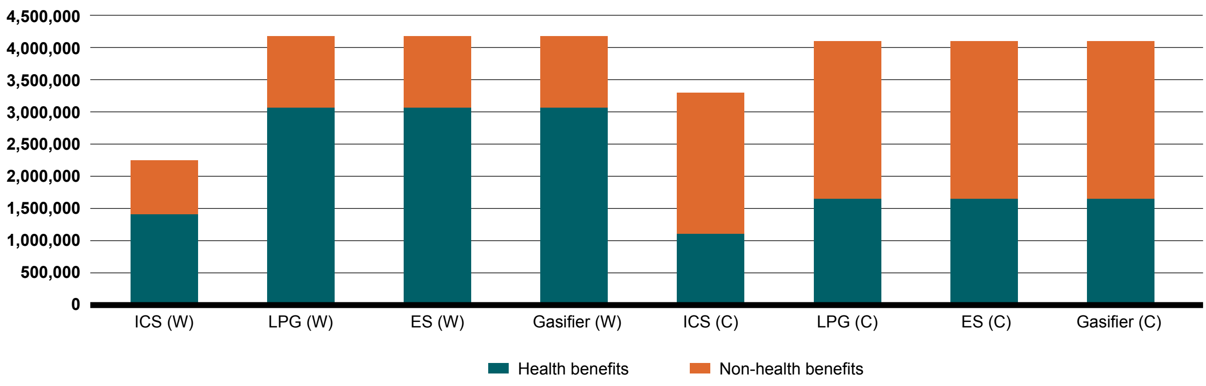
	Cooking with fuelwood (pre-intervention)				Cooking with charcoal (pre-intervention)			
	ICS (W)	LPG (W)	ES (W)	Gasifier (W)	ICS (C)	LPG (C)	ES (C)	Gasifier (C)
Health benefits	1.40	3.09	3.09	3.09	1.17	1.69	1.69	1.69
Fuel savings	0.55	0.55	0.55	0.55	1.88	1.88	1.88	1.88
Cooking time savings	0.27	0.55	0.55	0.55	0.27	0.55	0.55	0.55
Total benefits	**2.22**	**4.18**	**4.18**	**4.18**	**3.32**	**4.11**	**4.11**	**4.11**

Note: ICS = improved cookstove; LPG = liquefied petroleum gas; GS = gasifier stove; ES = electric stove.

Table 9.17 Benefit-Cost Ratios of Household Air Pollution Control Interventions by Cooking Location, 2017

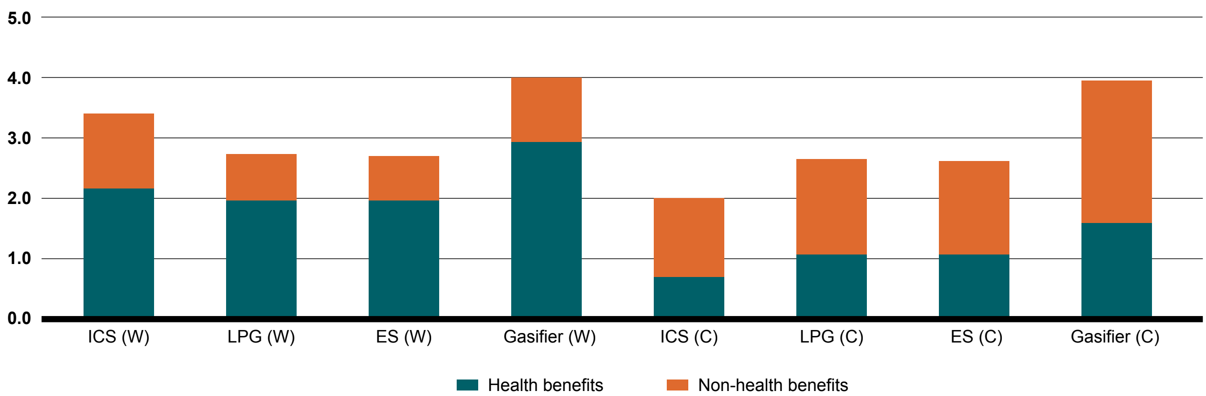
	Cooking with fuelwood (pre-intervention)				Cooking with charcoal (pre-intervention)			
Cooking location	ICS (W)	LPG (W)	ES (W)	Gasifier (W)	ICS (C)	LPG (C)	ES (C)	Gasifier (C)
In the house	3.7	3.0	3.0	4.4	2.2	2.8	2.8	4.2
In separate building	3.2	2.5	2.5	3.7	2.0	2.6	2.6	3.8
Outdoors	2.5	2.0	2.0	2.9	1.8	2.3	2.3	3.4
Average all locations	3.4	2.7	2.7	4.0	2.1	2.7	2.7	3.9

Figure 9.2 Health and Non-Health Benefits of Interventions (LAK per Household per Year), 2017



Note: Average for all locations.
ICS = improved cookstove; LPG = liquefied petroleum gas; GS = gasifier stove; ES = electric stove.

Figure 9.3 Benefit-Cost Ratios of Interventions for Control of Household Air Pollution, 2017



Note: Average for all locations.
ICS = improved cookstove; LPG = liquefied petroleum gas; GS = gasifier stove; ES = electric stove.

The benefits are averages for all beneficiary households. Health benefits per household dominate for all interventions for households that currently (pre-intervention) cook with fuelwood (W). Health benefits are smaller for all interventions for households that currently cook with charcoal, because of the lower pre-intervention $PM_{2.5}$ exposure levels associated with the use of charcoal (C). However, non-health benefits (fuel and cooking time savings) are larger for these households due to the larger value of fuel savings because of the high cost of charcoal.

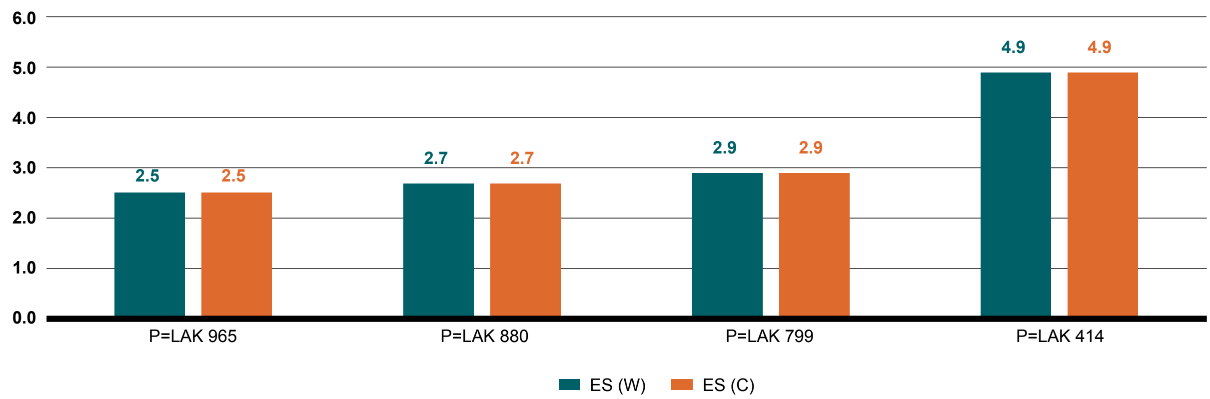
It is noteworthy that the BCRs for electric stoves (ES) are practically the same as for LPG. For rural households that currently use very little electricity, the BCR of an electric stove would be even larger, because these households would mostly pay LAK 414/kWh according to the block tariff system, and not LAK 880/kWh as applied in Table 9.17. The BCRs would then be 4.9 for households switching from an unimproved fuelwood cookstove or an unimproved charcoal cookstove (Figure 9.4).

While benefit-cost ratios of improved cookstoves using fuelwood may be higher than for LPG and electric stoves at the higher electricity tariff rates, clean energies are the only option for effectively combatting the health effects of solid fuels, especially when achieved community-wide. In other words, improved cookstoves using fuelwood may be an efficient, but not a very effective, solution. Improved charcoal stoves, while having smaller health effects than improved fuelwood stoves, have environmental effects, since the production of one ton of charcoal requires the use of 6–7 tons of wood.

9.3 Benefits and Costs of Improved Drinking Water and Sanitation Interventions

Recent household surveys of population-drinking water, point-of-use treatment (POUT), drinking-water quality, and sanitation in Lao PDR guided the selection of interventions for which benefits and costs are assessed here. Benefits of interventions included in the assessment are health improvements and potential time savings. The main literature utilized to assess health benefits is from studies worldwide. Wolf et al. (2014) present a meta-analysis of relative risks (RRs) of disease and mortality associated with various types of household-drinking water and sanitation in low- and middle-income countries globally. Although many factors cause diarrheal disease and intestinal infections, the RRs provide the health benefits of improved drinking-water supply and sanitation (relative to unimproved drinking-water supply and unimproved or no sanitation),

Figure 9.4 Benefit-Cost Ratios of Electric Stoves at Varying Electricity Prices, 2017



Note: Average for all locations.

as well as the health benefits of household POUT of drinking water from various sources. The RRs associated with each intervention are applied to the baseline diarrheal and intestinal infectious disease burden in Lao PDR reported by the Global Burden of Disease to estimate health benefits.

The meta-analysis by Wolf et al. includes studies of 20 comparisons of alternative drinking-water supplies, 48 comparisons of POUT versus no POUT of drinking water, and 12 comparisons of improved versus unimproved sanitation. Prüss-Ustün et al. (2014) utilize the RRs in Wolf et al. and provide a framework and methodology for estimating preventable disease burden from inadequate drinking water and sanitation. Olofin et al. (2013) provide a methodology for estimating child mortality associated with the poor nutritional status of children, and Fewtrell et al. (2007) provide guidance on the magnitude of the effect of diarrheal disease in early childhood on children's nutritional status.

9.3.1 Drinking-Water Interventions

The use of unprotected drinking water sources—mainly unprotected wells/springs and surface water—declined from 24 percent in 2011/12 to 16 percent in 2017 according to the Lao Social Indicator Surveys I & II (LSIS I & II) (LSB 2018; MoH/LSB 2012). Consequently, 84 percent of the population in Lao PDR had access to an improved drinking-water source in 2017. This includes the 48 percent of the population purchasing bottled water for drinking, up from 26 percent in 2011/12. However, the increase in the use of bottled water has coincided with a decline in household point-of-use treatment (POUT) from 57 percent of the household population in 2011/12 to 37 percent in 2017.

The LSIS II included testing for *E. coli* bacteria—an indicator of fecal contamination—in the drinking water of well over 3,000 households throughout Lao PDR. As many as 86 percent of the household population had *E. coli* in their drinking water, and as many as 38 percent had very high concentrations (>100 *E. coli* per 100 ml). The situation was not much better for households using bottled water, with 85 percent of users having *E. coli* in their bottled water and 29 percent of users with very high concentrations.

The drinking-water interventions assessed here are therefore three household POUTs as well as high-quality bottled water:

- Solar disinfection of drinking water;
- Ceramic filtering of drinking water;
- Boiling of drinking water using (i) wood, (ii) LPG, or (iii) electricity; and
- Purchase of high-quality bottled water free of *E. coli.*

9.3.2 Cost of Interventions

Table 9.18 presents the annual costs of the drinking-water interventions. The costs reflect consumption of 1.5 liters of drinking water per person per day. The interventions with the lowest and almost identical cost are solar disinfection, ceramic filtering, and boiling of drinking water with fuelwood in locations where fuelwood is relatively abundantly available (for example, most rural areas). The cost of boiling drinking water with LPG or electricity and purchasing high-quality bottled drinking water is about twice as expensive as the three former interventions.

Incremental time spent by the household on practicing any one of these drinking-water treatment methods is a significant cost component. An incremental time use of 10 minutes per household per day for solar disinfection and 5 minutes for ceramic filtering and boiling of water is applied. Time is valued at 50 percent of average hourly wage rate in Lao PDR in 2017, estimated at LAK 7,400/hr.[113] No incremental time use is applied to the purchase of high-quality bottled water, which is mostly delivered to household premises in 20-liter containers.

Table 9.18 Annualized Cost of Drinking-Water Interventions (LAK per Household per Year), 2017

	Solar disinfection	Ceramic Filter	Boiling of water (wood)	Boiling of water (LPG)	Boiling of water (electricity)	High-quality bottled water
Annualized capital cost		35,353				
Recurrent cost		25,000	127,035	313,013	325,156	514,650
Incremental time use	225,065	112,533	112,533	112,533	112,533	
Annualized promotion-program cost	17,468	17,468	17,468	17,468	17,468	17,468
Total annualized cost	**242,533**	**190,354**	**257,035**	**443,014**	**455,157**	**532,118**

A promotion program to encourage households to adopt any one of the drinking water interventions is an additional cost component. The program is assumed to be effective for five years, upon which time the program needs to be repeated. The cost of the program is LAK 80,000 per household, with annualized cost discounted at a rate of 3 percent per year. Initial capital and recurrent costs are discussed below.

9.3.2.1 Solar Disinfection of Drinking Water

Solar disinfection has repeatedly been demonstrated to be effective for eliminating microbial pathogens (Clasen 2009). Disinfection of water is based on the combined effect of thermal heating and UV radiation (McGuigen et al. 2012). A common method of solar disinfection is placement of 1-liter to 2-liter transparent plastic bottles (for example, beverage bottles) in the sun for a period of about 6 hours in locations with high solar radiation and up to two days under cloudy conditions. To avoid recontamination, the disinfected water should be kept in the bottles until consumed (Clasen 2009). Transparent glass bottles can be used instead of plastic bottles (Asiimwe et al. 2013).

All that is required for practicing this method of drinking-water treatment is transparent plastic or glass bottles; thus, no initial capital cost of significance is incurred. However, the method does involve some incremental time for filling bottles with water, placing bottles under sunlight, collecting bottles, and cleaning bottles, here assumed to be 10 minutes per household per day.

9.3.2.2 Ceramic Filtering of Drinking Water

Ceramic filters can be very simple and effective for removing pathogens in water. One such filter is the ceramic water purifier (CWP) introduced in multiple countries including Cambodia. The CWP consists of a porous ceramic filter coated with colloidal silver and a ceramic filter pot (fired clay) set in a plastic receptacle to store filtered water. The device produces 20–30 liters of purified water per day with 2 to 3 fillings. It is easy to clean and of light weight and portable.[114]

The ceramic filtering system has a useful life of 3–5 years and a reported cost mostly in the range of US$7.50–9.50 (World Bank 2007). A useful life of 3 years and a cost of LAK 100,000 is applied in Table 9.18, with an annualized cost of LAK 35,000 based on a discount rate of 3 percent per year. A recurrent cost of LAK 25,000 is added to reflect the replacement of the filter element every 1–2 years.

9.3.2.3 Boiling of Drinking Water

Boiling is the most prevalent form of household treatment of drinking water in Lao PDR. The cost of boiling depends largely on the type of fuel used for boiling, ranging from LAK 127 thousand per household per year when using self-collected fuelwood to LAK 313–325 thousand when using LPG or electricity (Table 9.19). Cost is estimated based on quantity of drinking water, energy requirement for heating of water, efficiency of stoves, energy content of fuels, and cost of energy per unit.

Table 9.19 Cost of Boiling Drinking Water (LAK per Household per Year), 2017

	Wood	LPG	Electricity
Quantity of water for boiling (liters per person per day)	1.5	1.5	1.5
Energy requirement for heating of water (Joules/liter/1 degree Celsius)	4,200	4,200	4,200
Stove efficiency for heating and boiling of water	15%	55%	65%
Energy requirement for boiling water (units per household per year)*	506	34.8	369.5
Cost of energy (LAK per unit)*	251	9,000	880
Cost of boiling water (LAK per household per year)	127,035	313,013	325,156

Note: *Unit is kg for wood and LPG and kWh for electricity. Economic energy prices are exclusive of value-added tax (VAT).

Estimated cost of self-collected fuelwood for boiling of water is based on average household collection time of 0.5 hours per day for all fuelwood needs, average annual fuelwood consumption of 2 tons per household per year for all needs[115,] and time valued at 50 percent of average hourly wage rate in Lao PDR.[116] Cost of LPG is LAK 9,000/kg delivered in cylinders for household use. Cost of electricity is LAK 880/kWh, which is the tariff rate for consumption of 300–400 kWh per household per month. This means that the cost of boiling drinking water using electricity is about the same as the cost using LPG.

9.3.2.4 Purchase of High-Quality Bottled Water

Bottled water is now the most prevalent form of drinking water in Lao PDR, but quality appears to be suboptimal in a majority of bottled-water samples consumed by households for drinking, according to the LSIS II 2017. Cost of bottled water is about LAK 4,000 per 20-liter containers delivered to the premises of households and is expected by consumers to be of high quality. All bottled water needs to be treated to high standards, such as by reverse osmosis, and all bottled-water companies should be required to produce bottled water of high standards. Regular monitoring and enforcement need to be strengthened for this purpose.

9.3.3 Benefits of Interventions

Health benefits of interventions assessed here pertain to diarrheal disease and intestinal infections (typhoid/paratyphoid), and infectious disease mortality associated with child underweight in part caused by repeated diarrheal disease in early childhood. Reductions in these disease burdens from interventions are estimated using the potential impact fraction (PIF) formula in Larsen (2019: annex 7). The formula requires knowledge of the risk of disease among a population after receiving an intervention relative to the risk before receiving the intervention. The relative risks from a meta-analysis of studies of POUT by filtering of drinking water are reported in Table 9.20, corresponding to the risk of disease after receiving an intervention. The relative risks range from 0.55 to 0.72 depending on source of water. A risk of 0.65 is applied to the assessment of health benefits here. This relative risk is also applied to solar disinfection and boiling of water based on professional views and evidence in Clasen (2009) and Prüss-Ustün et al. (2014), although each method has its own potential drawbacks such as inadequate time of solar disinfection and recontamination of boiled water. The relative risk is also applied to high-quality bottled water for bottled-water producers that are subject to proper monitoring and enforcement of high water quality.

Table 9.20 Relative Risk of Diarrheal Disease and Mortality for Household Point-of-Use Treatment (POUT)

Baseline drinking water source	POUT (filtering and safe storage)
Unimproved drinking water source	0.55
Improved drinking water source other than piped to premise	0.62
Basic piped water to premise	0.72

Sources: Prüss-Ustün et al. (2014); Wolf et al. (2014).

9.3.3.1 Valuation of Health Benefits

Health benefits of the interventions, in terms of avoided deaths and illness, are estimated using the potential impact fraction (PIF) formula in Larsen (2019: annex 7). Avoided deaths and illness are then monetized by using various benefit-valuation measures. A common approach that reflects how much people are willing to pay to reduce the risk of death is the use of the so-called value of statistical life (VSL) for valuation of avoided deaths. Avoided deaths are valued at a VSL of LAK 1.5 billion, or 74 times GDP per capita in Lao PDR in 2017. Avoided morbidity is valued at 50 percent of average wage rates per day of illness (see also Larsen [2019: annex 5]). Mortality benefits account for 85 percent of total benefits.

Table 9.21 presents benefits per beneficiary household per year. Benefits in terms of reduction in infectious diseases are the same for all interventions, because the same relative risk reduction in infectious disease is applied to all interventions.

However, the use of fuelwood for boiling of drinking water has additional health implications: It causes household air pollution. The health-damage cost of household air pollution in Lao PDR is estimated at LAK 8,550 billion per year (see section 9.2). This is on average LAK 6.2 million per household per year using solid fuels for cooking. Fuelwood requirement for boiling of drinking water is about 500 kg per household per year, as previously presented. This is about 25 percent of fuelwood used for cooking. Since the household air pollution exposure and health-response function relationship is nonlinear (see section 9.2), the health-damage cost of boiling drinking water with fuelwood will be less than 25 percent, here estimated at 15 percent. Thus, the health-damage cost or negative health benefit is LAK 844 thousand per household per year, and net health benefits of boiling drinking water with fuelwood are reduced to LAK 394 thousand per household per year.

Table 9.21 Benefits of Drinking-Water Interventions (LAK per Household per Year), 2017

	Solar disinfection	Ceramic filter	Boiling of water (wood)	Boiling of water (LPG)	Boiling of water (electricity)	High-quality bottled water
Infectious disease benefits	1,238,043	1,238,043	1,238,043	1,238,043	1,238,043	1,238,043
HAP health damage			-843,847			
Net health benefits	1,238,043	1,238,043	394,196	1,238,043	1,238,043	1,238,043

9.3.4 Benefit-Cost Ratios of Interventions

Benefits and costs of interventions are compared by using their ratio: A benefit-cost ratio (BCR) greater than one indicates that benefits exceed costs. The ratio can be calculated as the present value of benefits over the present value of costs, or as annualized benefits over annualized costs. A discount rate of 3 percent is used here in the calculations for both benefits and costs.

Table 9.22 presents the BCRs of the interventions. The BCR is lowest for boiling of drinking water with fuelwood, because of the damages to health from household air pollution that fuelwood causes. The BCRs are highest and quite similar for solar disinfection and ceramic filter. BCRs range from 5.1 to 6.5 for these interventions. The BCR for boiling of water using LPG or electricity and for high-quality bottled water is less than half of the BCRs for solar disinfection and ceramic filter. However, for relatively small electricity users, the electricity tariff rate would be LAK 414/kWh, and the BCR for boiling water using electricity would be 4.4.

9.3.5 Sanitation Intervention

About 71 percent of the population had access to improved, non-shared sanitation in 2017, up from 57 percent in 2011–12 according to the LSIS I & II (LSB 2018; MoH/LSB 2012). The predominant type of sanitation facility in both urban and rural areas is flush or pour-flush toilet connected to a septic tank or pit. Less than 3 percent uses other types of sanitation facilities such a dry pit, VIP, composting toilet, or bucket/hanging toilet. As many as 24 percent practiced open defecation (OD) in 2017, predominantly in rural areas. Therefore, the household sanitation intervention assessed here is the provision of a pour/flush toilet with pit or septic tank to households currently practicing open defecation in rural areas.

9.3.5.1 Cost of Intervention

The cost of the household sanitation intervention includes initial capital cost of the sanitation facility, regular cleaning of the facility, and annual operations and maintenance (O&M). An initial capital cost of LAK 1,700,000 is applied. This is for the toilet, installation, and construction of superstructure (base and building). Cleaning of the sanitation facility is assumed to take 1 hour per week, with time valued at 50 percent of rural wage rates. Annual operations and maintenance (O&M) cost is 5 percent of initial capital cost.

Annualized cost per rural household is estimated at LAK 345,000 based on a 20-year useful life of the facility and a 3 percent annual discount rate (Table 9.23). Cost of cleaning constitutes over 40 percent of the cost.

9.3.5.2 Benefits of Intervention

The benefits of providing sanitation to households that currently practice open defecation (OD) include health improvements and productivity benefits in terms of time savings of not having to walk to a place of OD. Sanitation also provides more-intangible benefits such as status and comfort and, in some instances, safety. There are also community benefits such as reduced fecal contamination of land and water bodies, with reduced risk of contamination of drinking water sources and other pathways of human exposure, and thus further health benefits especially if the intervention eliminates OD in the community.

Table 9.22 Benefit-Cost Ratios of Drinking Water Interventions, 2017

	Solar disinfection	Ceramic filter	Boiling of water (wood)	Boiling of water (LPG)	Boiling of water (electricity)	High-quality bottled water
BCR	5.1	6.5	1.5	2.8	2.7–4.4	2.3

Table 9.23 Cost of Household Sanitation (LAK per Household per Year)

	LAK	Remark
Initial capital cost	1,700,000	Initial cost
Cost of cleaning	145,000	1 hour per household per week
O&M cost	85,000	5% of capital cost per year
Annualized cost, LAK	345,000	Per household

Note: Discount rate is 3%/yr.

The benefits quantified in this assessment are health benefits and productivity benefits (time savings), since the intangible benefits are difficult to quantify without detailed household surveys. Health benefits of the intervention pertain to diarrheal disease and intestinal infections (typhoid/paratyphoid), and infectious disease mortality associated with child underweight in part caused by repeated diarrheal disease in early childhood.

Reductions in these disease burdens from interventions are estimated using the potential impact fraction (PIF) formula in Larsen (2019: annex 7). The formula requires knowledge of the risk of disease among a population after receiving an intervention relative to the risk before receiving the intervention. The relative risks from a meta-analysis of studies of improved household sanitation relative to unimproved or no sanitation is reported in Table 9.24, corresponding to the risk of disease after receiving an intervention.

Table 9.24 Relative Risk of Diarrheal Disease and Mortality for Sanitation

Baseline sanitation	Improved sanitation facility
Unimproved sanitation facility	0.72

Sources: Prüss-Ustün et al. 2014; Wolf et al. 2014.

Health benefits of the interventions, in terms of avoided deaths and illness, are estimated using the potential impact fraction (PIF) formula in Larsen (2019: annex 7). Avoided deaths and illness are then monetized by using various benefit-valuation measures. A common approach that reflects how much people are willing to pay to reduce the risk of death is the use of the so-called value of statistical life (VSL) for valuation of avoided deaths. Avoided deaths are valued at a VSL of LAK 1.5 billion, or 74 times GDP per capita in Lao PDR in 2017. Avoided morbidity is valued at 50 percent of average rural wage rates per day of illness (see also Larsen [2019: annex 5]).

Productivity benefits or time savings for those who no longer would practice open defecation (OD) are 20 minutes per household member per day. This is the average time spent on OD reported by adults in rural Lao PDR and by all age groups in five other East Asian countries, according to the Economics of Sanitation Initiative (ESI) by the Water and Sanitation Program, World Bank.[117] Time savings are valued at 50 percent of rural wage rates for all beneficiaries 5+ years of age.

Table 9.25 presents benefits per beneficiary household per year. Health and productivity benefits represent 45 percent and 55 percent of total benefits, respectively.

Table 9.25 Benefits of Household Sanitation Interventions (LAK per Household per Year), 2017

	LAK
Health benefits	1,154,410
Productivity benefits (time savings)	1,404,424
Total benefits	**2,558,834**

9.3.5.2 Benefit-Cost Ratio of Intervention

Table 9.26 presents the BCR of the intervention. An annual discount rate of 3 percent is used in the calculations for benefits and costs.

Table 9.26 Benefit-Cost Ratio of Household Sanitation Interventions, 2017

	Household sanitation
BCR	7.5

9.3.6 Summary

Figure 9.5, Figure 9.6, and Figure 9.7 summarize the benefits and costs of the seven drinking water and sanitation interventions. Health and productivity benefits and financial and productivity costs are presented separately. The benefits and costs are averages for all beneficiary households. Some households may value health benefits relative to productivity benefits. Similarly, financial cost may influence intervention-adoption decisions more or less than incremental time use. Thus, poorer households may prefer interventions with lower financial cost and instead accept higher incremental time use associated with the interventions.

Health benefits per beneficiary household are somewhat lower for sanitation than for the drinking-water interventions, but sanitation has substantial productivity benefits, making total sanitation benefits twice as large as the benefits of most of the drinking-water interventions (Figure 9.5).

Solar disinfection has the lowest financial cost, but substantial productivity cost in terms of incremental time use. High-quality bottled water has the highest financial cost followed by boiling of drinking water using LPG or electricity (Figure 9.6).

Rural sanitation has the highest benefit-cost ratio (BCR). Over half of the BCR is from productivity benefits. The BCRs associated with the highest health benefits are ceramic filtering and solar disinfection. Boiling of drinking water using wood has the lowest BCR, because of the substantial health effects associated with household air pollution from the burning of this fuel (Figure 9.7).

Figure 9.5 Health and Productivity Benefits of Interventions (LAK per Household per Year), 2017

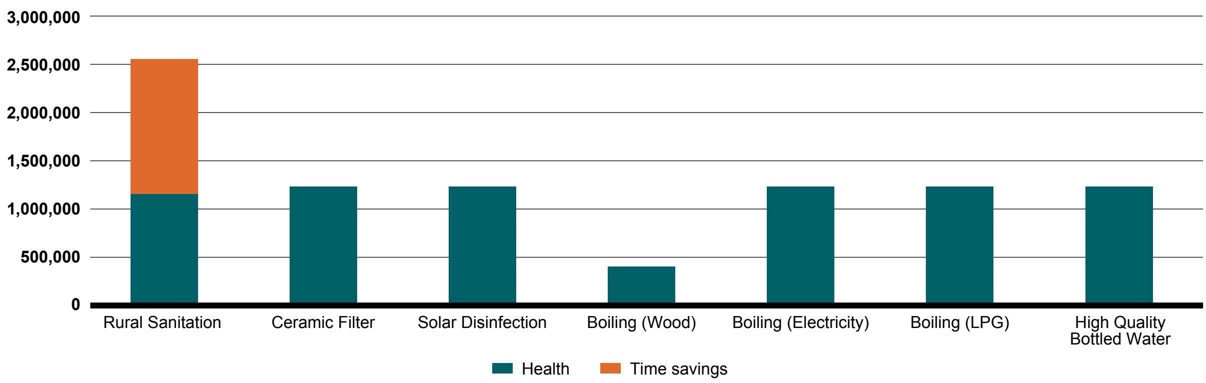


Figure 9.6 Financial and Time Use Cost of Interventions (LAK per Household per Year), 2017

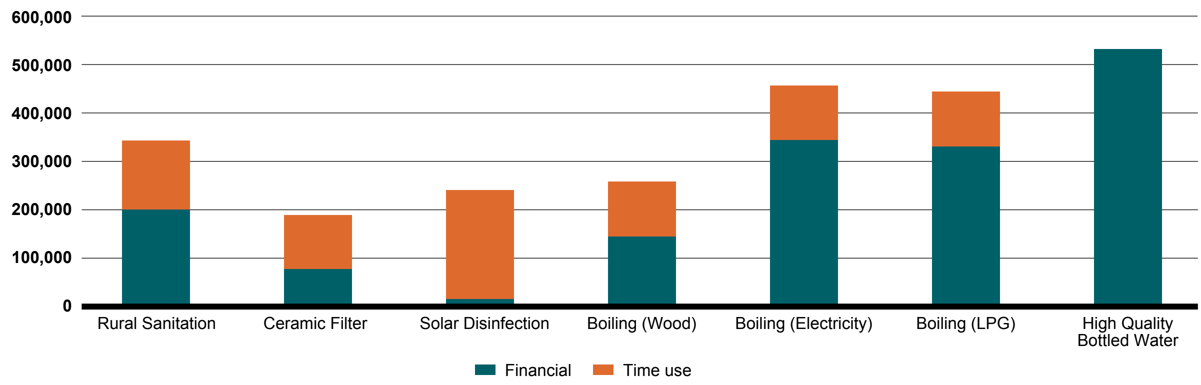
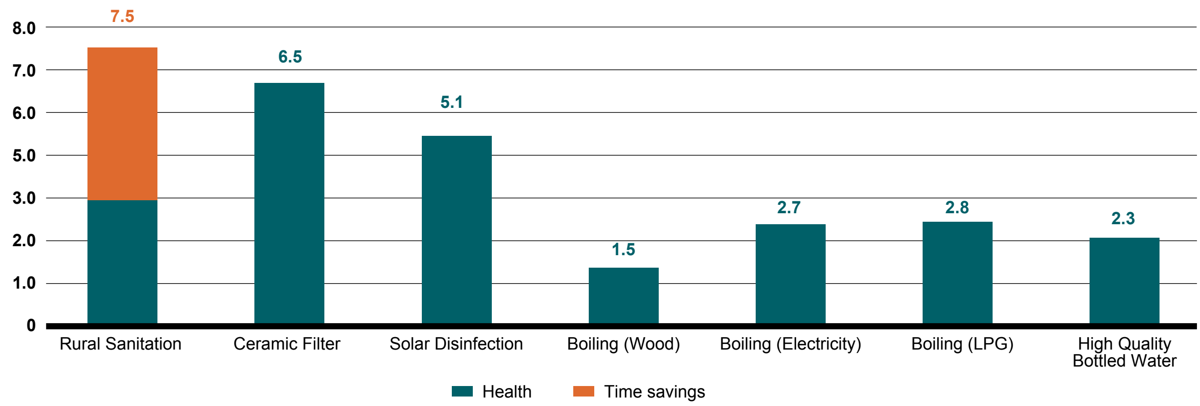


Figure 9.7 Benefit-Cost Ratios of Interventions for Drinking Water and Sanitation, 2017



9.4 Benefits and Costs of Mitigating Arsenic in Drinking Water

Exposure to arsenic in drinking water has been found to be associated with various health effects including skin lesions (Argos et al. 2011; Karagas et al. 2015), and various forms of cancer, kidney and liver failure, and ulcer (FAO et al. 2010). Increased risks of lung and bladder cancer and of arsenic-associated skin lesions have been found from ingestion of drinking water with arsenic concentrations below 50 µg/liter (WHO 2011). There is also increasing evidence that prenatal arsenic exposure is associated with morbidity and mortality later in life (FAO et al. 2010). Many studies have also documented various neurological impairments from arsenic exposure, such as poor cognitive performance; reduced intellectual function; learning deficits; mood disorders; and visual, speech, attention, and memory disturbances (Brinkel et al. 2009; Tyler and Allan 2014).

Several studies have also documented the effect of arsenic in drinking water on mortality: All-cause and chronic disease mortality (Argos et al. 2010); non-accidental mortality, cancers, cardiovascular-disease mortality, and infectious-disease mortality (Sohel et al. 2009); heart-disease mortality (Chen et al. 2011); lung-disease mortality (Argos et al. 2014); mortality in children (Rahman et al. 2013), and stroke mortality (Rahman et al. 2014).

The assessment of health benefits of potential arsenic-mitigation interventions in central and southern Lao PDR presented in this report is based on the elevated risk of premature mortality from long-term exposure to arsenic in the studies by Argos et al. (2010) and Sohel et al. (2009) in Bangladesh. An estimate of morbidity is also included by estimating days of illness from data on *years lived with disability* (YLDs) reported by the Global Burden of Disease Project for major causes of death associated with arsenic exposure (section 3.4.3).

9.4.1 Arsenic Mitigation Interventions

Arsenic contamination of drinking water is a health concern in several central and southern provinces of Lao PDR, as a study conducted in 2008 found elevated levels in many shallow tubewells with depth varying from 4 to 55 meters (Chanpiwat et al. 2011). Finding cost-effective solutions with acceptable benefit-cost ratios is a priority. An intervention to avoid arsenic exposure is provision of deep tubewells that access groundwater at depths not containing arsenic. Another intervention is household point-of-use (POU) filtering, such as the SONO filter developed in Bangladesh that uses iron and sand filtration. The SONO filter has been demonstrated to effectively remove arsenic in drinking water (Neumann et al. 2013). Yet another intervention is the purchase of bottled drinking water. In some locations, ponds with a sand filter may also be an option. Rainwater harvesting for drinking would also solve the problem of arsenic, although this would likely be only a seasonal solution.

Four arsenic mitigation interventions are therefore assessed:

> Deep tubewells;

> Community pond sand filter;

> Household point-of-use (POU) filtering of drinking water; and

> Purchase of bottled water (20-liter bottles).

9.4.2 Cost of Interventions

Table 9.27 presents the costs of arsenic-mitigation interventions. Capital cost is highest for tubewells and pond sand filter. Maintenance and repair costs are highest for pond sand filters and POU filters. A program to promote the interventions is also included, with a one-time initial cost. Incremental time use for some of the interventions is valued at 50 percent of average hourly wage rate in Lao PDR in 2017, estimated at LAK 7,400/hr.[118]

9.4.2.1 Deep Tubewells and Pond Sand Filters

The costs of deep tubewells and pond sand filters are adapted and inflation-adjusted from UNICEF (2011). These interventions are shared by 10 households. Costs are presented per household. Additionally, it is assumed that households receiving a community deep well or pond sand filter need to use five more minutes per day to fetch drinking water compared to their current source of drinking water supply (that is, shallow tubewells mostly in or near their dwelling).

9.4.2.2 Household Filtering of Drinking Water

A household point-of-use (POU) drinking-water filtering device for removal of arsenic is relatively inexpensive. The SONO filter is reported to cost US$25–35 and can produce as much as 30 liters of filtered water per hour and can last at least 5 years (Akter and Ali 2011). Therefore, a cost of LAK 300,000 is applied here. Incremental time use of five minutes per household per day is also included for POU filtering of water.

9.4.2.3 Purchase of Bottled Water

Cost of bottled water is based on 2 liters per capita per day for drinking and cooking, an average household size of 4.7,[119] and a cost of LAK 4,000 per bottle (20 liters).

Table 9.28 presents annual costs of interventions. An annual discount rate of 3 percent is applied for annualization of costs. The largest annualized cost component for deep tubewells, pond sand filter, and POU filter is incremental time-use. The largest cost component for bottled water is recurrent purchases.

Total annualized intervention costs per household per year for deep tubewells, pond sand filter, and POU filter are quite similar, ranging from LAK 190 thousand to LAK 247 thousand. Annual cost of bottled water is about 5 times as high at LAK 1.145 million.

9.4.3 Benefits of Interventions

The interventions assessed can mitigate nearly all health effects of arsenic exposure if fully implemented, assuming that 95 percent of deep tubewells, 100 percent of pond sand filters, and 95 percent of household POU filtering would comply with the WHO guideline maximum of 10 µg of arsenic per liter of drinking water. However, diarrheal disease incidence may change—here assumed to increase by 10 percent with replacement of current drinking-water sources (that is, relatively shallow tubewells) by pond sand filters, since these water sources can become bacteriologically contaminated during handling and storage. Additionally, diarrheal disease incidence may decrease by 35 percent with replacement of current drinking-water sources by high-quality bottled water. No change in diarrheal incidence is assumed by substitution to deep tubewells or use of POU filtering devices for arsenic removal. Health benefits associated with diarrheal disease are estimated using the potential impact fraction (PIF) formula in Larsen (2019: annex 7).

The interventions are unlikely to instantaneously provide full benefits for health outcomes that develop over long periods of exposure such as from arsenic exposure. Therefore, it is assumed that the health benefits of arsenic mitigation are gradually realized over ten years. Thus, over a time horizon of 20 years, annualized health benefits are 75 percent of full benefits at an annual discount rate of 3 percent. For diarrheal diseases, the full health benefits of interventions are realized in the same year the intervention is implemented.

Table 9.27 Cost of Arsenic Mitigation Interventions, 2017

	Deep tubewell	Pond sand filter	POU filter	Bottled water
Capital cost (LAK per household)	800,000	600,000	300,000	
Useful life (years)	20	20	5	
Recurrent purchases (LAK per household per year)				680,000
Maintenance and repair (LAK per household per year)	20,000	90,000	60,000	
Program promotion (LAK per household)	80,000	80,000	80,000	80,000
Incremental time use (minutes per household per day)	5	5	5	0

Table 9.28 Annualized Cost of Arsenic Mitigation Interventions (LAK per Household per Year), 2017

	Deep tubewell	Pond sand filter	POU filter	Bottled water
Annualized capital cost	52,206	39,155	63,598	
Recurrent purchases				680.000
Annualized program cost	5,221	5,221	5,221	5,221
Recurrent maintenance and repair	20,000	90,000	60,000	
Incremental time use	112,533	112,533	11,2533	
Total annualized cost	**189,960**	**246,908**	**241,352**	**685,221**

Table 9.29 Benefits of Arsenic Mitigation Interventions (LAK per Household per Year), 2017

	Deep tubewell	Pond sand filter	POU Filtering	Bottled water
Arsenic removal	4,353,863	4,583,014	4,353,863	4,583,014
Change in diarrheal disease	0	-353,727	0	1,238,043
Total health benefits	**4,353,863**	**4,229,287**	**4,353,863**	**5,821,057**

Avoided deaths and illness from the interventions can be monetized by using various benefit-valuation measures. A common approach that reflects how much people are willing to pay to reduce the risk of death is the use of the so-called value of statistical life (VSL) for valuation of avoided deaths. Avoided deaths are valued at a VSL of LAK 1.5 billion, or 74 times GDP per capita in Lao PDR in 2017. Avoided morbidity is valued at 50 percent of average wage rates per day of illness. Mortality benefits account for 85 percent of total benefits. Table 9.29 presents the benefits per beneficiary household per year.

9.4.4 Benefit-Cost Ratios of Interventions

Benefits and costs of interventions are compared by using their ratio: A benefit-cost ratio (BCR) greater than one indicates that benefits exceed costs. The ratio can be calculated as the present value of benefits over the present value of costs, or as annualized benefits over annualized costs. An annual discount rate of 3 percent is applied in the calculations for benefits and costs.

Table 9.30 presents the BCRs of the four interventions. The BCRs are quite similar for deep tubewells, pond sand filters, and POU filtering, albeit somewhat larger for deep tubewells. BCRs range from 17 to 23 for these three interventions. The BCR for bottled water is less than half of the BCRs for the first three interventions, although still quite large at 8.5.

9.4.5 Summary

Figure 9.8, Figure 9.9, and Figure 9.10 summarize the four interventions for mitigating arsenic in drinking water. Health benefits, and financial and productivity costs, are presented separately. The benefits and costs are averages for all beneficiary households. Financial cost may influence intervention-adoption decisions more or less than productivity cost—that is, incremental time use. Thus, poorer households may prefer interventions with lower financial cost and instead accept higher incremental time use associated with the interventions.

Health benefits per beneficiary household are highest for bottled drinking water (Figure 9.8). However, the cost of bottled drinking water—all financial costs—is also much higher than the cost of the other interventions. Deep tubewell has the lowest financial and total cost per household (Figure 9.9).

Deep tubewells have the highest benefit-cost ratio (BCR). Bottled water has the lowest BCR because of the high cost of this intervention, although bottled water has the highest health benefits if the water is of high quality (Figure 9.10).

Table 9.30 Benefit-Cost Ratios of Arsenic Mitigation Interventions, 2017

	Deep tubewell	Pond sand filter	POU filtering	Bottled water
BCR	23	17	18	8.5

Figure 9.8 Health and Productivity Benefits of Interventions (LAK per Household per Year), 2017

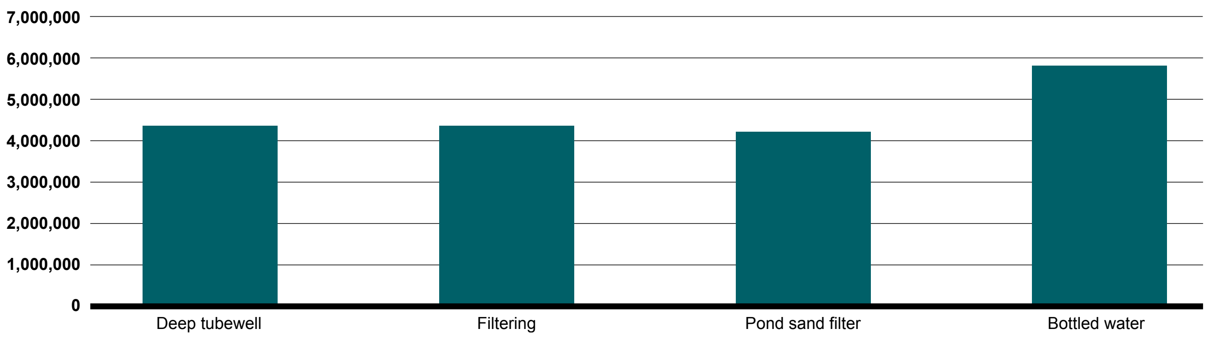


Figure 9.9 Financial and Time Use Cost of Interventions (LAK per Household per Year), 2017

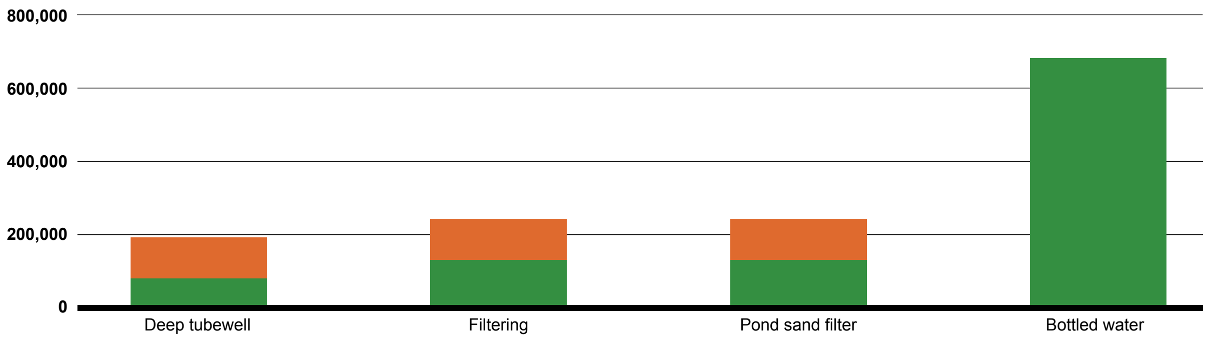
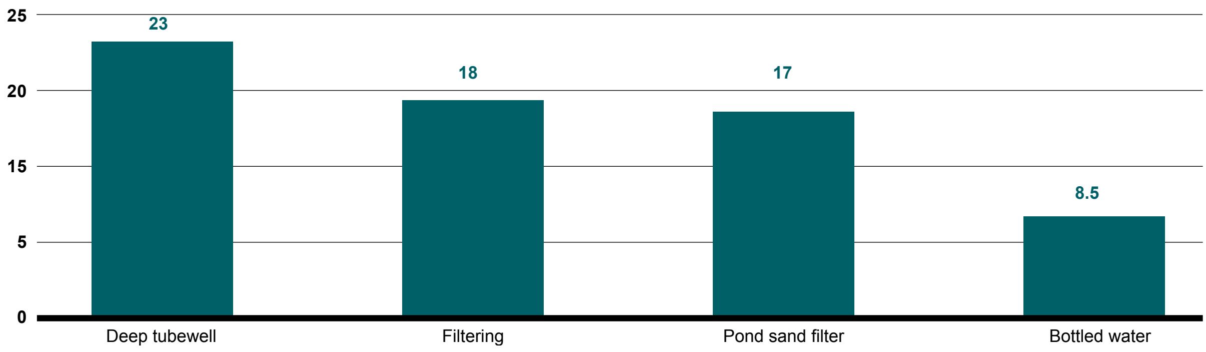


Figure 9.10 Benefit-Cost Ratios of Interventions for Arsenic Mitigation, 2017



Note: Estimated.

9.5 Benefits and Costs of Ambient $PM_{2.5}$ Air Pollution Control

9.5.1 Ambient $PM_{2.5}$ Pollution Control Options

Ambient $PM_{2.5}$ air pollution in the outdoor environment stems from many sources. The road-transport sector is generally a major contributor to ambient $PM_{2.5}$, and power generation and industry are often major contributors. Household use of solid fuels for cooking and heating is also a major contributor in some countries. The burning of solid waste also contributes substantially in some countries, as does seasonal agricultural field burning and forest fires.

Secondary particulate formation (sulfates and nitrates) from sulfur dioxide, nitrogen oxide, and ammonia emissions are also important contributors to outdoor ambient $PM_{2.5}$. Coal burning is often the major source of sulfur-dioxide emissions, as can be combustion of high-sulfur petroleum products. Road vehicles are often a major source of nitrogen oxides. Agriculture is often a major source of ammonia emissions.

In Lao PDR, rising pollution from a rapidly increasing vehicle fleet—especially diesel vehicles—and continued air pollution from household burning of waste/debris, high levels of dust from streets and other sources especially during the dry season, and cooking with solid fuels (that is, wood and charcoal) are likely to be among the main sources of air pollution.

This report does not assess the benefits and costs of $PM_{2.5}$ abatement from all the diverse sources of $PM_{2.5}$, but it does provide an initial attempt at providing some perspectives related to a few intervention options. Two policy dimensions of abatement are briefly discussed: taxation and pricing policies. This is followed by estimates of cost and benefits of $PM_{2.5}$ abatement options in four areas: (i) household cooking, (ii) solid-waste management, (iii) diesel-fuel quality, and (iv) road-vehicle technologies.

9.5.2 Benefits of Interventions

Estimating the benefits of $PM_{2.5}$ emission abatement for ambient air quality improvement is a complex process. Health benefits are a major component of these benefits. Health benefits can be estimated by applying multiple tools and data including health-risk assessment (for example, health effects per μg/m^3 of $PM_{2.5}$ ambient concentrations); $PM_{2.5}$ emissions inventories; atmospheric emission dispersion modeling; $PM_{2.5}$ source-apportionment studies; and $PM_{2.5}$ intake fraction methodology. These tools require input data such as ambient $PM_{2.5}$ measurements, $PM_{2.5}$ source emission measurements, atmospheric/meteorological data, and geographic distribution/density of population and emission sources.

Most of these data and applications are not readily available for any location in Lao PDR. Consequently, any estimates of benefits of $PM_{2.5}$ emission abatement in Lao PDR will be highly uncertain and can at best only be indicative of actual benefits.

Intake fraction methodology is applied here to provide a possible indication of health benefits per ton of $PM_{2.5}$ abatement. The methodology is applied to Vientiane Capital, since this is the location with the largest population and largest health effects of ambient $PM_{2.5}$ pollution in Lao PDR.

An intake fraction designated in parts per million (ppm) is a measure of how much of a ton of emissions in a geographic area is breathed in by the exposed population. The higher the intake fraction, the larger are the health damages and thus the health benefits of emissions reductions. Apte et al. (2012) estimate the intake fraction of distributed ground-level emission sources in over 3,600 cities of the world with a population greater than 100 thousand in the year 2000 based on geographic, meteorological, and demographic location-specific data. Population-weighted intake fractions by country range from less than 10 ppm to over 100 ppm, and by major city from less than 5 ppm to over 250 ppm.

$PM_{2.5}$ intake fractions in the range of 35 ppm to 50 ppm of distributed ground-level emissions are applied here to Vientiane Capital (see also Larsen [2019: annex 8]), reflecting a high level of uncertainty regarding actual intake fractions in the city. The intake fractions are relevant for $PM_{2.5}$ emissions from road vehicles, street dust, household waste-burning, burning of solid fuels for cooking, and very low-stack emissions. They are not valid for medium- and high-stack emission sources.

The intake fractions imply health benefits per ton of $PM_{2.5}$ emission reduction of LAK 105–150 million (Table 9.31).[120] This estimate reflects that outdoor ambient air pollution control is unlikely to instantaneously provide full benefits for health outcomes that develop over long periods of $PM_{2.5}$ exposure—that is, for heart disease, stroke, chronic obstructive pulmonary disease (COPD), and lung cancer. Therefore, it is assumed that reduced incidence of, and deaths from, these diseases are gradually realized over ten years. However, for acute lower respiratory infections (ALRI), full health benefits are realized in the same year as $PM_{2.5}$ exposure reduction. Thus, over a time horizon of 20 years, annualized health benefits, at a 3 percent annual discount rate, are 92 percent of full benefits.

Table 9.31 Benefits of Ambient $PM_{2.5}$ Emission Reductions in Vientiane Capital, US$, 2017

	Low	High
$PM_{2.5}$ intake fraction (ppm)	35	50
Health benefits of $PM_{2.5}$ emission reductions (LAK million per metric ton)	105	150

To provide estimates of benefit-cost ratios of interventions for improving ambient $PM_{2.5}$ air quality, costs of interventions need to be estimated and expressed as costs per ton of $PM_{2.5}$ abatement.

9.5.3 Taxation and Pricing Policies

Taxation and pricing policies are important instruments for demand management and internalization of externalities. While direct tax and pricing instruments for $PM_{2.5}$ abatement are often difficult to design, indirect instruments can provide $PM_{2.5}$ emission reductions at lower cost to society than regulatory, command-and-control options. This is because these instruments allow polluters to identify and select lowest-cost options, including reducing polluting behavior (for example, driving less). Indirect instruments include fuel taxes, vehicle taxes, and tax rebates on $PM_{2.5}$ control technology. Since $PM_{2.5}$ emissions are often correlated with other externalities of energy combustion and transportation, $PM_{2.5}$ emission reductions can be achieved as a co-benefit of tax policies addressing congestion, cost recovery of wear-and-tear of transport infrastructure, and/or climate change emissions. These instruments are particularly effective in the long run for shaping transport demand and modalities, encouraging smaller and more fuel-efficient transport vehicles, and development and use of cleaner energies. Block tariffs for electricity pricing, with users paying different amounts for different consumption levels of electricity, can also serve as an instrument for encouraging less well-off households to switch to electricity for cooking instead of using highly polluting solid fuels.

9.5.4 Household Cooking

Household use of solid fuels not only causes serious air pollution in the immediate household environment, but also contributes to outdoor ambient $PM_{2.5}$ pollution. This is particularly the case if households use unimproved, inefficient stoves and cook outdoors or vent the smoke out of the dwelling. These emissions can affect many people, especially in the urban environment. As many as 22 percent of the household population in Vientiane Capital cook outdoors, according to the LSIS 2017 (LSB 2018).

Two options for abating $PM_{2.5}$ emissions from household use of solid fuels are assessed: (i) improved fuelwood cookstoves, and (ii) switching to LPG or electricity. The cost of switching from unimproved to improved cookstove using fuelwood is estimated at LAK 65 million per ton of $PM_{2.5}$ abatement. The cost of cooking with LPG, instead of using unimproved fuelwood cookstove, is estimated at LAK 121 million per ton of $PM_{2.5}$ abatement.[121]

Ambient air pollution (AAP) benefits are LAK 105–150 million per ton of $PM_{2.5}$ abatement, as previously presented. The benefits per ton of $PM_{2.5}$ abatement are the same for the two cooking options. To this can be added the value of fuelwood savings, amounting to LAK 40 million per ton of $PM_{2.5}$ abatement.[122] The two cooking options also provide the benefits of reduced personal exposure to $PM_{2.5}$ in the household and cooking time savings. These household air pollution (HAP) benefits are estimated at LAK 258 million per ton of $PM_{2.5}$ abatement for improved fuelwood cookstove, and LAK 179 million per ton of $PM_{2.5}$ abatement for LPG.[123] These values are for households cooking outdoors.[124]

These estimates of benefits and costs result in benefit-cost ratios (BCRs) of 6.2–6.9 for improved fuelwood cookstoves and 2.7–3.1 for cooking with LPG (Table 9.32). The BCR for cooking with electricity is almost identical to the BCR for LPG, since the only difference is a slight variance in cost per unit of energy.[125] While the BCRs for improved cookstoves are higher than for LPG or electricity, switching to LPG or electricity provides larger total health benefits than improved cookstoves.

The BCRs are for households cooking outdoors. It is uncertain how much of $PM_{2.5}$ emissions from indoor cooking contributes to outdoor ambient air quality. However, household benefits alone of improved cookstoves and cooking with LPG or electricity far exceed the costs of these interventions—as seen in the discussion of household air pollution control (section 9.2)—and should therefore be pursued on their own merits even if ambient air quality benefits may be minor.

Table 9.32 Costs and Benefits of Improved Fuelwood and LPG Cookstove, LAK Millions and BCRs

	Cost per ton of $PM_{2.5}$ abatement	Benefit per ton of $PM_{2.5}$ abatement		BCRs	
		Low	High	Low	High
Improved fuelwood cookstove					
AAP benefits		105	150		
+ fuelwood savings		40	40		
+ HAP health and cooking time benefits		258	258		
Total	**65**	**403**	**448**	**6.2**	**6.9**
LPG instead of fuelwood for cooking					
AAP benefits		105	150		
+ fuelwood savings		40	40		
+ HAP health and cooking time benefits		179	179		
Total	**121**	**325**	**370**	**2.7**	**3.1**

Note: AAP = Ambient air pollution; HAP = Household air pollution.

9.5.5 Solid-Waste Management

Uncontrolled burning of waste and debris by households contributes to urban ambient $PM_{2.5}$ pollution. Improved municipal solid-waste management can reduce waste burning. The cost of solid-waste management, including waste collection and sanitary landfill disposal, is estimated at US$45–115 per ton of waste in lower middle-income countries by the World Bank.[126] This translates to US$6,400–16,400 or LAK 53–135 million per ton of $PM_{2.5}$ abatement from avoiding burning of waste.[127] Consequently, the benefit-cost ratio (BCR) is in the range of 0.8–2.8, depending on the cost of improved solid-waste management (Table 9.33).

9.5.6 Diesel Fuel Quality

The quality of vehicle fuels greatly influences $PM_{2.5}$ emissions. This is especially the case of diesel. Low-sulfur diesel, discussed below, directly reduces $PM_{2.5}$ emissions, reduces formation of secondary particulates (sulfates) from lower sulfur dioxide emissions, and allows installation of particulate-control technology on diesel vehicles.

The majority of primary $PM_{2.5}$ emissions from vehicle fuel combustion come from diesel vehicles. With ultra-low sulfur diesel and modern particulate-control technologies, such as diesel particulate filters (DPFs), $PM_{2.5}$ emissions from new diesel vehicles or older vehicles retrofitted with DPFs are very low and approach $PM_{2.5}$ emissions from gasoline vehicles. However, nationwide fuel quality (for example, high-sulfur diesel) in most developing countries is not good enough for effective functioning of DPFs, and vehicle fleets are often old with no or minimal PM-emission controls. Lowering of sulfur in diesel directly results in less $PM_{2.5}$ emissions per km driven, and, importantly, allows the introduction of diesel vehicles with effective PM control technologies as well as the retrofitting of in-use diesel vehicles.

In recognition of the road-transport sector's contribution to air pollution, there is globally a major push for ultra-low sulfur (<50 ppm) diesel for road vehicles. According to global data by UNEP, most high-income OECD countries allow a maximum of 15 ppm sulfur in diesel. A handful of developing countries have adopted a maximum limit of 50 ppm, compatible with EURO 4 vehicle emissions standards. A substantial number of developing and transition economies have a standard of below 500 ppm, compatible with EURO 2 standards. However, many countries continue to use diesel with up to 2,000 ppm sulfur (EURO 1).[128]

The cost of $PM_{2.5}$ abatement by reducing sulfur in diesel depends on several factors including initial sulfur content, incremental refinery costs or market-price differentials, and vehicle characteristics. Reducing sulfur from around 500 ppm to 50 ppm is estimated to cost US$1–2 per barrel of diesel.[129] These costs translate to roughly US$9–19 thousand per ton of $PM_{2.5}$ abatement, or LAK 77–153 million. Consequently, the benefit-cost ratio (BCR) is in the range of 0.7–2.0, depending on the cost of ultra-low sulfur diesel (Table 9.34).

Table 9.33 Costs and Benefits of Improved Solid-Waste Management, LAK millions and BCRs

	Low	High
Benefit per ton of $PM_{2.5}$ abatement	105	150
Cost per ton of $PM_{2.5}$ abatement	53	135
Benefit-cost ratio (BCR)	0.8	2.8

Table 9.34 Costs and Benefits of $PM_{2.5}$ Abatement from Ultra-Low–Sulfur Diesel (<50 ppm), LAK Millions and BCRs

	Low	High
Benefit per ton of $PM_{2.5}$ abatement	105	150
Cost per ton of $PM_{2.5}$ abatement	77	153
Benefit-cost ratio (BCR)	0.7	2.0

9.5.7 Road Vehicle Technologies

Technical control options are available to reduce emissions from major sources of $PM_{2.5}$ such as road transport, power generation, and industry. These options are available in multiple forms: (i) production process technology and engine technology, (ii) end-of-pipe technology installed at the time of manufacturing of industrial equipment or vehicles, (iii) end-of-pipe technology for retrofitting of in-use equipment or vehicles, and (iv) change of technology in in-use equipment or vehicles. *Option i* and *Option ii* can often be achieved at lower cost than retrofitting or change of technology in in-use equipment or vehicles. Retrofitting *(Option iii)* or technology change *(Option iv)* are often the only options for equipment stocks or vehicle fleets with substantial remaining life.

Option iii is assessed here, corresponding to retrofitting of in-use diesel vehicles with diesel particulate filters (DPFs). These retrofit DPFs cost several thousand US dollars and can reduce PM emissions by over 90 percent once ultra-low sulfur diesel (<50 ppm) is available. Cost per ton of $PM_{2.5}$ abatement is in the range of US$33–103 thousand, or LAK 268–845 million, for relatively high usage vehicles (40 thousand km/yr to 60 thousand km/yr) used primarily within cities. The equipment cost of DFPs are higher for heavy-duty vehicles (HDVs) than for light-duty vehicles (LDVs), but the quantity of $PM_{2.5}$ emission reductions is larger for HDVs. Therefore, the cost per ton of $PM_{2.5}$ abatement is lower for HDVs than for LDVs (Table 9.35).

The benefit-cost ratio (BCR) is in the range of 0.1–0.3 for diesel-fueled LDV and 0.2–0.6 for HDV (Table 9.35). This indicates that costs are larger than the health benefits. Therefore, it is important to further assess this option to accurately determine pre-intervention $PM_{2.5}$ emissions from high-usage diesel vehicles (commercial LDVs, buses, and HDV trucks), the quantity of emission reductions from DPF, and ascertain the cost of DPFs.

The cost of DPF abatement of $PM_{2.5}$ is substantially higher than the previous options assessed, but highly effective. The cost of diesel oxidation catalysts (DOCs) is substantially lower than the cost of DPFs, but the abatement efficiency of DOCs is also substantially lower.

Table 9.35 Costs and Benefits of $PM_{2.5}$ Abatement from DPFs, LAK Millions and BCRs

	DPF for light-duty vehicles (LDV)		DPF for heavy-duty vehicles (HDV)	
	Low	High	Low	High
Benefit per ton of $PM_{2.5}$ abatement	105	150	105	150
Cost per ton of $PM_{2.5}$ abatement	474	845	268	639
Benefit-cost ratio (BCR)	0.1	0.3	0.2	0.6

9.5.8 Benefit-Cost Ratios of Interventions

Table 9.36 summarizes the benefit-cost ratios (BCRs) of the interventions discussed above for the control of ambient $PM_{2.5}$ in Vientiane Capital, and Figure 9.11 presents midpoint estimates. The options with the highest BCRs are improved fuelwood cookstove (ICS (W)) and LPG. Improved solid-waste management (SWM) and clean diesel (<50 ppm sulfur content) also appear to be attractive options, if the cost of interventions is at the lower end of the costs presented in this section. However, clean diesel does have additional benefits not reflected in the BCRs here, because clean diesel is a prerequisite for effective functioning of particulate-control technology on new diesel vehicles.

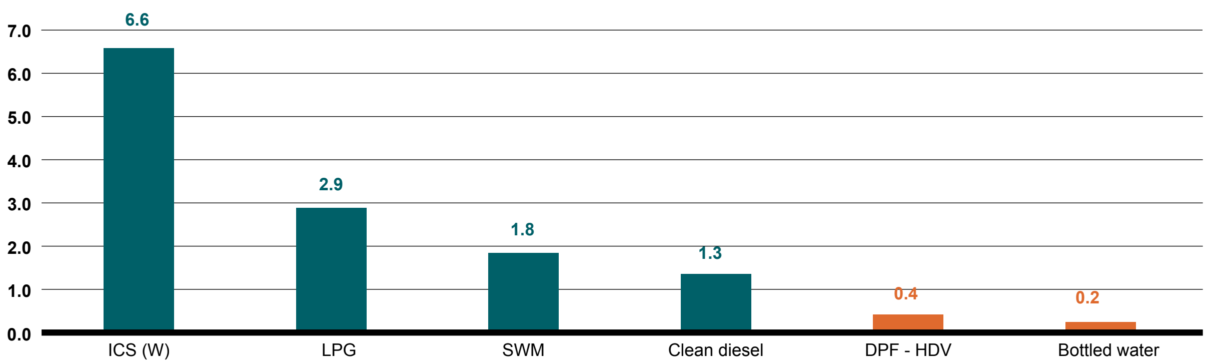
Retrofitting of in-use diesel vehicles with DPFs appears to not provide health benefits that exceed the costs of filters. Since diesel vehicles are likely a major source of ambient $PM_{2.5}$ air pollution in Vientiane Capital, additional $PM_{2.5}$ emission-control options need to be assessed.

It should be emphasized again that the estimates of benefits and costs of $PM_{2.5}$ emission abatement in Vientiane Capital presented above are highly uncertain and can at best only be indicative of actual benefits and costs. First and foremost, ambient air quality monitoring needs to be developed in the city, and $PM_{2.5}$ source-apportionment studies undertaken.

Table 9.36 Benefit-Cost Ratios of Interventions for the Control of Ambient $PM_{2.5}$ in Vientiane Capital, 2017

	Low	High
Improved fuelwood cookstove (ICS (W))	6.2	6.9
LPG instead of fuelwood for cooking (LPG)	2.7	3.1
Improved solid-waste management (SWM)	0.8	2.8
Ultra-low sulfur diesel vehicle fuel (from 500 ppm to 50 ppm) (clean diesel)	0.7	2.0
DPF for diesel-fueled light-duty vehicles (DPF–HDV)	0.1	0.3
DPF for diesel-fueled heavy-duty vehicles (DPF–LDV)	0.2	0.6

Figure 9.11 Benefit-Cost Ratios of Interventions for the Control of Ambient $PM_{2.5}$ in Vientiane Capital, 2017



Note: BCRs are midpoint estimates.

9.6 Summary and Conclusions

The environmental health risk factors assessed in this chapter are estimated to have caused 10,000 deaths in Lao PDR in 2017. This was 21.6 percent of all deaths in the country. The risk factors also caused nearly 100 million days of illness in 2017. Household air pollution (HAP) from the use of solid fuels caused 44 percent of the deaths, while a quarter was from drinking-water pollution, sanitation, and hygiene (WASH), and a quarter from outdoor $PM_{2.5}$ ambient air pollution (AAP). Exposure to lead among adults caused the remaining 6 percent of deaths, and lead exposure among children caused the loss of 340,000 IQ points per year (Table 9.37).

The annual cost of the health effects is estimated at LAK 17.6–23.6 trillion in 2017. This is equivalent to 12.5 percent to 16.7 percent of GDP, with a central estimate of 14.6 percent. Household air pollution (HAP) accounts for 39 percent of these costs, followed by water pollution, sanitation, and hygiene (WASH) at 20 percent, outdoor $PM_{2.5}$ ambient air pollution (AAP) at 24 percent, and lead (Pb) exposure at 17 percent of total cost (Table 9.38; Figure 9.12).

Table 9.37 Annual Deaths and Days of Illness from Environmental Risk Factors in Lao PDR, 2017

	Deaths			Days of illness (million)		
	Low	Central	High	Low	Central	High
Household air pollution	3,962	4,313	4,663	44.1	48.0	51.9
Ambient air pollution	2,371	2,693	3,041	24.4	27.7	31.2
Water, sanitation, and hygiene	1,549	2,283	3,002	13	20	27
Microbiological pollution	1,379	2,074	2,754	11.6	17.9	24.2
Arsenic in groundwater	169	209	248	1.3	2.0	2.8
Lead (Pb) exposure—children (IQ points)				0.30	0.34	0.38
Lead (Pb) exposure—adults	496	562	620	2.0	2.2	2.5
Total	**8,378**	**9,851**	**11,327**	**84**	**98**	**113**

Table 9.38 Estimated Annual Cost of Environmental Health Effects in Lao PDR, 2017

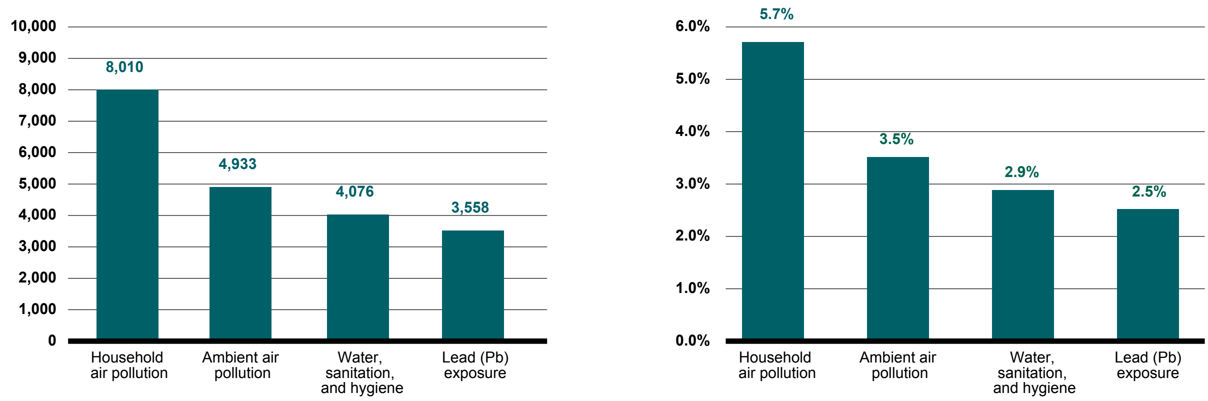
	Cost (LAK, billions)			Cost (% equivalent of GDP)		
	Low	Central	High	Low	Central	High
Household air pollution	7,359	8,010	8,661	5.22	5.68	6.14
Ambient air pollution	4,344	4,933	5,571	3.08	3.50	3.95
Water, sanitation and hygiene	2,745	4,076	5,384	1.95	2.89	3.82
Microbiological pollution	2,449	3,698	4,923	1.74	2.62	3.49
Arsenic in groundwater	296	379	462	0.21	0.27	0.33
Lead (Pb) exposure	3,112	3,558	3,967	2.21	2.52	2.81
Lead (Pb) exposure—children	2,297	2,635	2,948	1.63	1.87	2.09
Lead (Pb) exposure—adults	814	923	1,019	0.58	0.65	0.72
Total	**17,559**	**20,577**	**23,583**	**12.45**	**14.60**	**16.73**

The annual cost of lead (Pb) exposure per person among children exposed to this health hazard is several times higher than the cost per person exposed to arsenic in groundwater, HAP, WASH, AAP, or Pb among adults (Figure 9.13). The annual cost per person exposed to arsenic in groundwater is second highest (along with HAP). However, the extent of lead and arsenic exposure, and thus annual cost, is also the most uncertain, pointing to the importance of measurements of lead in blood and arsenic in groundwater in each Lao PDR province, since current data are very scarce.

9.6.1 Benefits and Costs of Mitigating Leading Environmental Health Risks

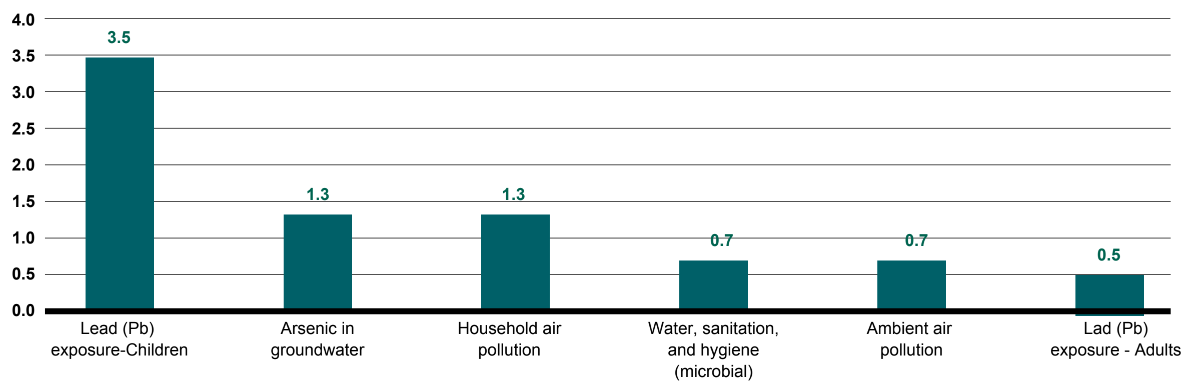
Household air pollution: This chapter assesses the benefits and costs of eight cooking interventions for the control of household air pollution (see Figure 9.14). The interventions involve promotion programs for household adoption of cooking with improved biomass cookstoves, gasifier stoves, LPG stoves, and electric stoves. Benefits of interventions include health improvements, energy savings, and cooking time savings. Costs include cost of stove and equipment, cost

Figure 9.12 Central Estimate of Annual Cost of Environmental Health Risks in Lao PDR, 2017 (LAK Billions and % Equivalent of GDP)



Note: HAP = household air pollution; WASH = water supply, sanitation, and hygiene; AAP = ambient air pollution.

Figure 9.13 Central Estimate of Annual Cost of Environmental Health Risks per Exposed Person (LAK, Millions)



of stove maintenance and repair, cost of intervention-promotion program, and cost of energy used for cooking. Benefit-cost ratios are in the range of 2.1–4.0. They are highest for gasifier stoves switching from unimproved fuelwood stoves (W) or from unimproved charcoal stoves (C), followed by improved cookstove using fuelwood (ICS (W)), electric stoves (ES), and LPG. The lowest BCR is for improved cookstove using charcoal (ICS (C)) (Figure 9.14).

It is noteworthy that the BCRs for electric stoves (ES) are practically the same as for LPG. This is associated with the relative cost of energy. For rural households that currently use very little electricity, the BCR of electric stoves would be even larger, because these households would mostly pay LAK 414/kWh according to the block tariff system, and not LAK 880/kWh. The BCRs would then be 4.9 for households switching from unimproved fuelwood cookstove or unimproved charcoal cookstove, bringing the BCR above the ratio for gasifier stoves and improved fuelwood stoves (Figure 9.15).

While the BCRs of improved cookstoves using fuelwood may be higher than for LPG and electric stoves at the higher electricity tariff rates, the health benefits of improved fuelwood cookstoves are less than half those of the clean cooking energies (for example, LPG and electricity). Consequently, clean energies are the only

Figure 9.14 Benefit-Cost Ratios of Household Air Pollution Control Interventions, 2017

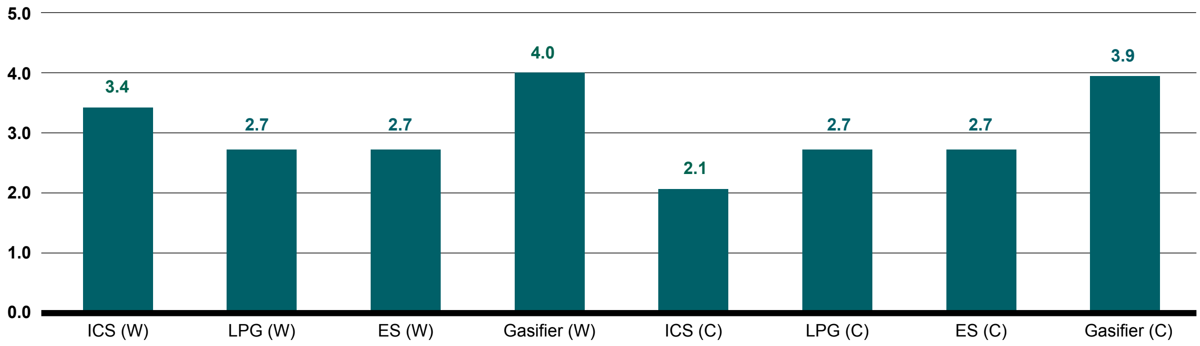
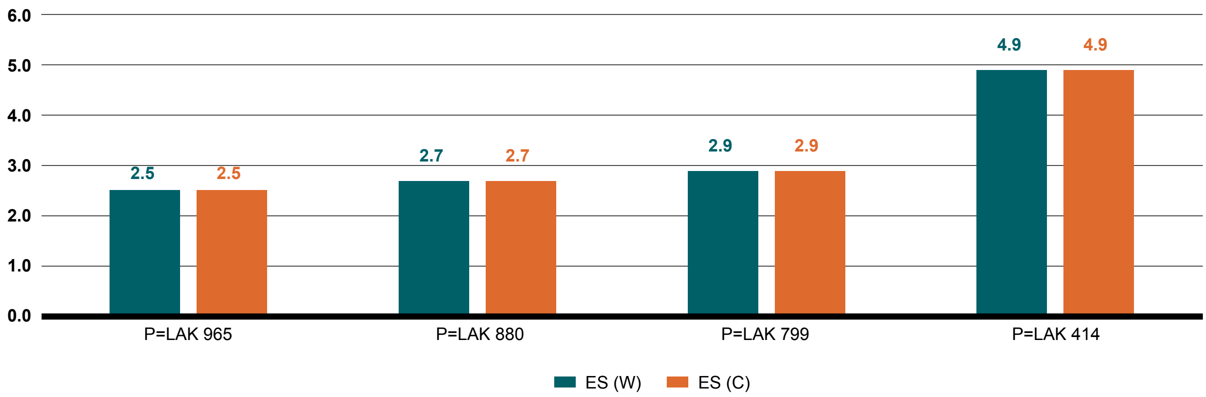


Figure 9.15 Benefit-Cost Ratios of Electric Stoves at Varying Electricity Prices (/kWh), 2017



option for effectively combatting the health effects of solid fuels. In other words, improved cookstoves using fuelwood may be an efficient, but not a very effective, solution. The use of improved charcoal stoves, while having smaller health effects than improved fuelwood stoves, have environmental effects, since the production of one ton of charcoal requires 6–7 tons of wood.

The continued household use of solid fuels in a community also affects other households. Smoke from fuel burning enters the dwellings of other households as well as contributes to outdoor ambient air pollution. An improved stove with a chimney, or simply the venting of smoke through a hood from any stove or open fire, may be effective for the household installing these devices, but contributes to increased outdoor ambient pollution and indoor pollution in nearby dwellings. Only clean energies and technologies prevent this problem of externalities.

Therefore, to achieve the maximum benefits per unit of expenditure on household energy and stove interventions, all households would need to participate, and thus achieve a *clean energy community* or, in the interim, an *improved cookstove community.* This concept may be especially applicable to rural areas where communities are spatially clustered and is like the concept in the sanitation sector of a *community free of open defecation*, which is often promoted and achieved through community-led or total sanitation campaigns.

Drinking water and sanitation: Benefits and costs of seven drinking water and sanitation interventions are assessed in this chapter (Figure 9.16). Rural sanitation has the highest benefit-cost ratio (BCR). Over half of the BCR is from productivity benefits. The BCRs associated with the highest health benefits are attributable to ceramic filtering and solar disinfection. Boiling drinking water using wood has the lowest BCR, because of the substantial health effects associated with household air pollution from the burning of this fuel.

Arsenic mitigation: The benefits and costs of the four mitigation interventions for arsenic in drinking are assessed in this chapter (Figure 9.17). Deep tubewells have the highest benefit-cost ratio (BCR). Bottled water has the lowest BCR, because of the high cost of this intervention. However, bottled water has the highest health benefits if the water is of high quality.

Ambient $PM_{2.5}$ air pollution: The benefits and costs of six interventions for the control of ambient $PM_{2.5}$ air pollution in Vientiane Capital are assessed in this chapter (see Figure 9.18). The interventions are household cooking interventions to reduce $PM_{2.5}$ emissions from the use of solid fuels, improved solid-waste management to prevent household burning of waste and debris, ultra-low sulfur diesel (<50 ppm S) for road vehicles to reduce $PM_{2.5}$ emissions and allow the use of particulate control technologies on diesel vehicles, and retrofitting in-use light and heavy-duty diesel vehicles with diesel particulate filters (DPFs). Assessed benefits of interventions are limited to health improvements, and, for household cooking interventions, savings of fuelwood and cooking time.

Benefit-cost ratios are in the range of 0.2–6.6. They are highest for improved fuelwood cookstoves (ICS (W)) and LPG or electricity for households cooking outdoors. This is followed by improved solid-waste management (SWM) for prevention of household burning of waste and debris, and then by clean diesel (<50 ppm S). The lowest BCRs are for retrofitting in-use diesel vehicles with diesel particulate filters (DPFs) (Figure 9.18).

The estimates presented above of benefits and costs of $PM_{2.5}$ emission abatement in Vientiane Capital are highly uncertain and can at best only be indicative of actual benefits and costs. First and foremost, ambient air quality monitoring needs to be developed in the city, and $PM_{2.5}$ source-apportionment studies undertaken.

Figure 9.16 Benefit-Cost Ratios of Drinking Water and Sanitation Interventions, 2017

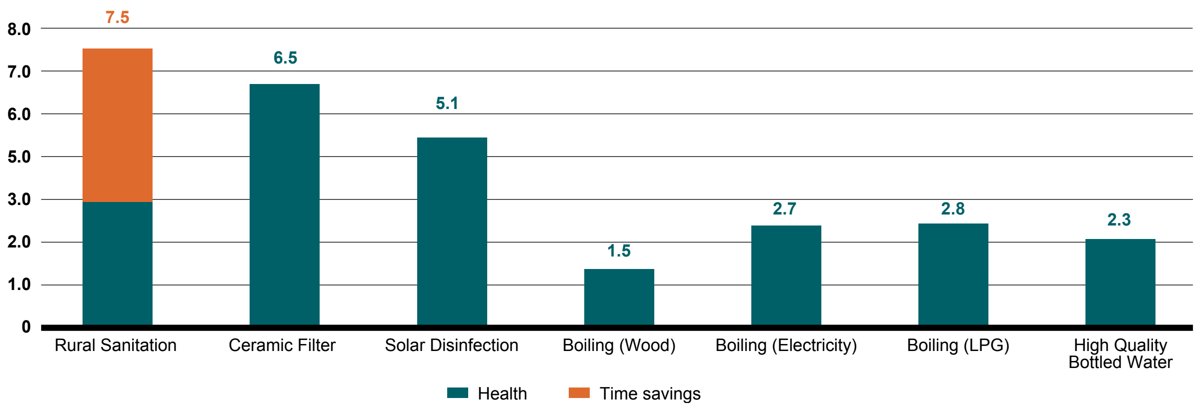


Figure 9.17 Benefit-Cost Ratios of Arsenic Mitigation Interventions, 2017

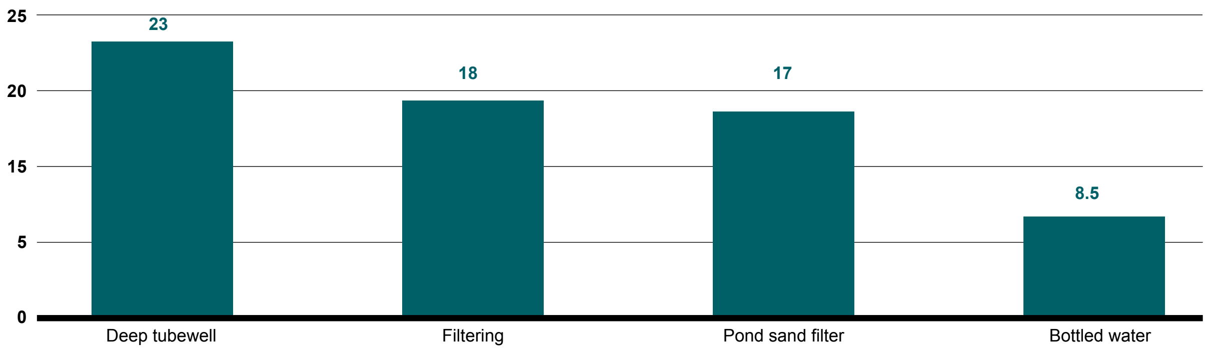
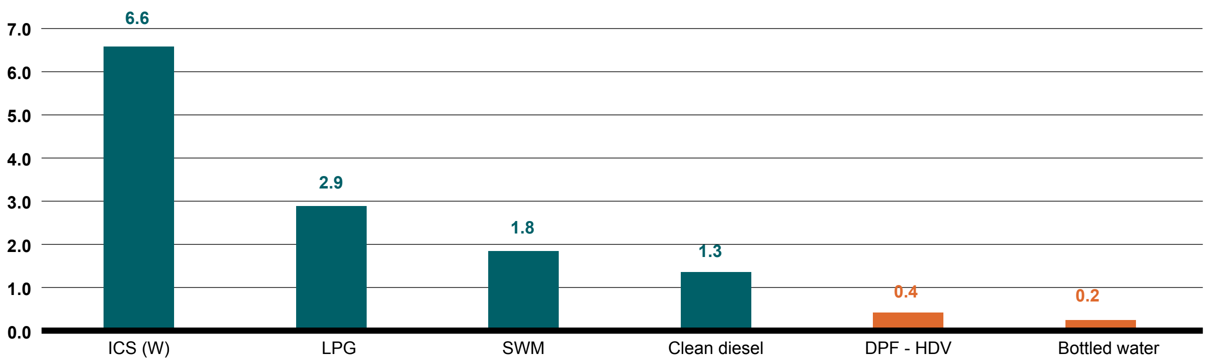


Figure 9.18 Benefit-Cost Ratios of Interventions for the Control of Ambient $PM_{2.5}$ in Vientiane Capital, 2017



Note: BCRs are midpoint estimates.

9.6.2 Key Priorities

The following key environmental health priorities are identified:

Household air pollution: One overriding priority is to achieve 50 percent clean energy use for cooking over the next 10 years by households increasing the use of gas (LPG) and electric stoves. The use of electric stoves is a cheaper option than LPG for small users of electricity that can benefit from lower residential block tariff rates for electricity. With residential block tariffs for electricity pricing, cooking with electricity provides an opportunity to also achieve adoption of this cooking option by less well-off households. If this turns out to be difficult, a second option needs further assessment: remove any price and non-price obstacles and provide incentives for adoption of LPG for cooking.

Drinking water and sanitation: Four priorities emerge in the drinking-water and sanitation sector: (i) further investigation into the status of household drinking-water quality, (ii) a pilot promotion program for household point-of-use treatment (POUT) of drinking water focusing on ceramic filtering and solar disinfection, (iii) addressing arsenic contamination of drinking water in the center and south of Lao PDR, and (iv) rural sanitation to end open defecation.

Ambient air pollution: Three priorities are evident for combatting ambient air pollution: (i) implement ambient air quality monitoring first and foremost in Vientiane Capital; (ii) undertake $PM_{2.5}$ source-apportionment studies in Vientiane Capital to identify priority sectors for air pollution control, and design cost-effective interventions; and (iii) implement no-regret interventions including control of $PM_{2.5}$ emissions from household cooking and diesel vehicles, halting of household burning of waste/debris, and combatting street dust.

Lead (Pb) exposure: Two priorities are crucial regarding assessing the status of lead (Pb) exposure: (i) undertake a blood lead level (BLL) measurement study of children to determine exposure levels; and (ii) undertake a lead source identification study, including in the household environment, outdoor community environment, school environment, and specific sources such as lead-based paint, toys, ornaments and jewelry, traditional medicines, cosmetics, and utensils.

9.7 Notes

104 This chapter was prepared by Bjorn Larsen and draws upon additional material by the same author presented in a background report (Larsen 2019) containing a series of annexes in support of the estimates.

105 The Deputy Minister of Natural Resources and Environment, H.E. Dr. Xaynakhone Inthavong, mentioned that MoNRE will implement a project to distribute 100,000 clean cookstoves. The project aims to reduce air pollution.

106 The Vice Minister of Natural Resources and Environment explained that MoNRE coordinates the implementation of a pollution-free initiative under the Clean Development Mechanism.

107 The remaining rural households use purchased charcoal with a small minority purchasing fuelwood.

108 This is likely somewhat of an underestimate of the value of fuelwood used by households, since households also purchase some of their fuels at a higher price than reflected in the valuation of collection time.

109 Common energy efficiencies for unimproved fuelwood stoves, or cooking over open fire, are in the range of 13 percent to 18 percent. Reported efficiencies of improved fuelwood cookstoves are 23 percent to 40 percent (Malla and Timilsina 2014). This means that efficiency gains from using an improved stove instead of an unimproved stove or open fire generally exceed 25 percent and can be more than 100 percent depending on type of stoves, cooking practices, and type of food cooked. Consequently, fuelwood savings generally exceed 20 percent and can be nearly 70 percent (a doubling of efficiency implies a 50 percent fuel saving).

110 A household in Lao PDR that cooks with fuelwood in an unimproved cookstove consumes on average at least 2 tons of fuelwood per year for cooking, or nearly 6 kg per day. With 50 percent fuel saving, cooking with a gasifier stove would require nearly 3 kg of wood to be chopped into pieces each day.

111 Two improved charcoal cookstoves—the D&E Eco Recho stove (Ashden 2013) and the Prakti Wouj stove (Bossuet and Serrar 2014)—are reported to provide as much as 43 percent to 55 percent fuel saving.

112 This is likely somewhat of an underestimate of the value of fuelwood used by households, since households also purchase some of their fuels at a higher price than reflected in the valuation of collection time.

113 Estimated as follows: W = gdp* s / L / (264*8) where gdp is GDP per capita, s is labor income share of GDP, and L is labor force (% of total population), assuming an 8-hour workday and 264 working days per year (22 days per month).

114 See, for instance, https://www.who.int/household_water/resources/Roberts.pdf

115 One survey reports household collection time of as much as 6 hours per week and fuelwood consumption of 9 kg per household per day in three northern provinces—provinces in which many households use fuelwood for heating in the cold season. Another survey in Vientiane and Luang Prabang reports a rural household collection time of 0.3 hours per day.

116 This implies that a quantity of 25 percent of annual fuelwood consumption is needed for boiling of drinking water throughout the year.

117 https://www.wsp.org/content/economic-impacts-sanitation

118 Estimated as follows: W = gdp* s / L / (264*8) where gdp is GDP per capita, s is labor income share of GDP, and L is labor force (% of total population), assuming 8-hour workday and 264 working days per year (22 days per month).

119 Lao Statistics Bureau 2018. Lao Social Indicator Survey II (LSIS II) 2017. https://dhsprogram.com/pubs/pdf/FR356/FR356.pdf

120 The benefits are estimated by using a combination of results shown in Larsen (2019: annexes 1, 5, 7, and 8). They are estimated at $PM_{2.5}$ ambient concentrations of 40 μg/m^3 in Vientiane Capital (see section 3.3 on Ambient Air Pollution).

121 Cost is calculated using an emission factor of 7.0 kg of $PM_{2.5}$ per metric ton of fuelwood; household baseline consumption of fuelwood of 2 tons per year for cooking; 30 percent fuelwood saving from the improved cookstove and 100 percent fuelwood saving from using LPG; and the intervention costs used in section 10.2 regarding household air pollution control (cost of stove, maintenance and repair, and intervention-promotion program).

122 This is calculated using an emission factor of 7.0 kg of $PM_{2.5}$ per metric ton of fuelwood and the value of household fuelwood consumption estimated in section 10.2 regarding household air pollution control.

123 This is calculated using the same emission factor as above, and the benefits of interventions estimated in section 10.2 regarding household air pollution control. Benefits per ton of $PM_{2.5}$ abatement are smaller for LPG than for improved fuelwood cookstove. This is because there are other sources of $PM_{2.5}$ in the household environment (for example, emissions from other households) that prevent a one-to-one reduction in $PM_{2.5}$ personal exposures from the reduction in PM emissions associated with switching from fuelwood to LPG.

124 The health benefits per ton of $PM_{2.5}$ abatement are higher for households cooking in the house or in a separate building. However, only a portion of $PM_{2.5}$ is likely to escape to the outdoor environment with impacts on ambient air quality.

125 This is the case for electricity priced at LAK 880/kWh for household consumption of 300–400 kWh per month.

126 http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/AnnexE.pdf

127 Calculated using an emission coefficient of 7 kg of $PM_{2.5}$ per metric ton of organic/burnable waste.

128 https://www.unenvironment.org/partnership-clean-fuels-and-vehicles-regulatory-toolkit

129 These cost figures are largely based on refinery sector studies of Brazil, China, and India (Hart Energy and MathPro 2012), as well as market information regarding petroleum products.

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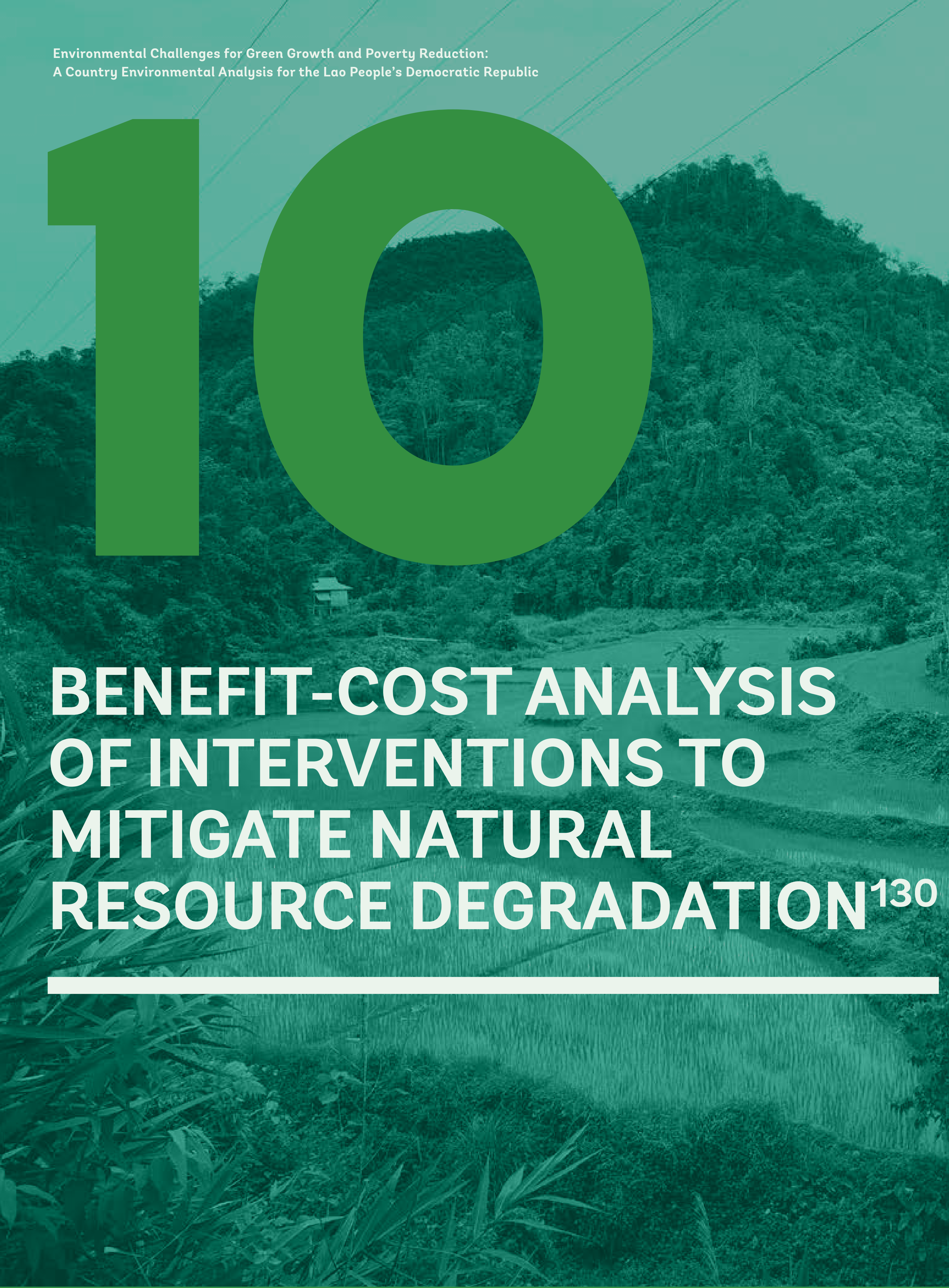


10

BENEFIT-COST ANALYSIS OF INTERVENTIONS TO MITIGATE NATURAL RESOURCE DEGRADATION[130]

Chapter Overview

The main objective of this chapter was to calculate the benefit-cost ratios of interventions to mitigate the negative effects of existing environmental problems and various proposed aspects of future economic development in the Lao People's Democratic Republic. Chapter 4 presented calculations of the economic costs of natural resource degradation across the following sectors: deforestation, forest degradation, natural disasters, soil degradation, hydropower development and fish habitat destruction, and exposure to mercury from mining practices. These Costs of Natural Resource Degradation (CoNRD) can be mitigated through various interventions. Thus, Benefit-Cost Analysis (BCA) shown in this chapter can be used to prioritize the recommendations for interventions to mitigate those sectoral damages. The BCA can also be used to improve environmental management and to increase natural resource conservation.

Sustainable forest management and conservation in Lao PDR is the foundation for ecosystem conservation in the Lower Mekong Basin (LMB). However, most forest ecosystem benefits are intangible and not monetizable. The analysis demonstrated that interventions in agriculture exhibit the highest benefit-cost ratio. A holistic approach revealed a connection between interventions in agriculture and reduction of deforestation and forest degradation. This is due to an increase in agricultural productivity with new technologies like agroforestry, which combines continuous growth of agricultural production with forestry practices, thus increasing food security and forest protection. Agroforestry interventions provide the greatest net benefits.

Natural disasters (floods and droughts) are an important climate hazard that are projected to intensify. Enhancement of early warning systems among exposed populations will practically eliminate property damage. Investments in early warning systems are shown to be highly effective. Economically viable fisheries mitigation to counter the negative consequences of hydropower development should also be promoted. Hydropower projects must include carefully designed fish passages, but due to uncertainty regarding the rate of success, BCRs for these passages were relatively low. Thus, large-scale, highly productive aquaculture should be considered and promoted among local communities, because such aquaculture has the highest benefit-cost ratio.

Mining has become a significant part of the Lao PDR economy, with large-scale metal mining creating long-term water pollution problems. This polluted water can become a source of serious health risks. Constructing wetlands to absorb these polluted flows can be an effective and efficient way to reduce these flows of contaminants into Lao PDR's various waterbodies. However, artisanal mining by the poor, which often leads to serious exposure to neurotoxic compounds, can be nearly impossible to regulate. Perhaps the only practical approach to reduce this practice is to provide subsidies to the poor so they no longer engage in artisanal mining.

Assumptions and limitations of the study were due to using secondary sources of data to estimate costs of natural resource degradation. Only quantifiable costs are covered in this chapter, which considers a significant portion of the issues, but is not exhaustive. Methodological and data limitations make it impossible, at this point, to quantify other costs and foregone opportunities from mitigating interventions—opportunities such as the lost amenities due to water pollution associated with mining, and the health cost of exposure to other heavy metals that contaminate rivers, soils, and popular food items. However, this lack of a quantitative cost estimate does not mean that the cost of an environmental degradation could not be reduced; it just means that, at this time, it could not be calculated.

10.1 Introduction

The objective of this chapter is to provide detailed analyses of options that mitigate a number of the natural resource impacts identified and quantified in chapter 4. Specifically, benefit-cost analysis is applied to evaluate interventions across the following categories: (i) reduction of economic cost of deforestation, (ii) mitigation of costs associated with agricultural land degradation, (iii) costs of fishery-habitat degradation arising from the construction and operation of large dams, (iv) mitigation of flooding disasters, and (v) prevention of water-quality degradation associated with mine drainage.

10.2 Interventions to Reduce Deforestation Cost

Since deforestation is an ongoing process in Lao PDR, there is substantial deforested land and land with degraded forest in the country. These lands that have lost some degree of their natural productivity through human activity account for over 20 percent of former forest and agricultural lands. The agriculture, mining, hydropower development, and forestry sectors are growing and exerting great pressure on natural areas. About 60 thousand hectares are deforested, and 55 thousand hectares are degraded each year. In addition, land degradation is a major driver in the region's greenhouse gas emissions.

Deforestation in the tropics, and the associated loss of biodiversity and ecosystem services, has become a global concern, leading to several policy reforms intended to promote the sustainable management of forest resources. Accordingly, in recent years, the Government of Lao PDR has introduced several policy instruments and incentives to boost forest cover by promoting the development of forests throughout the country.

Forest and landscape restoration can offer a solution to these increasing pressures. Reforestation is one of the main National Forestry Strategies: The government intends to restore the forest cover to 70 percent by the year 2020 (Lao PDR MAF 2005) through tree planting, and protection and restoration of natural forest.

However, this goal may be unattainable based on the current rate of legal and illegal forest conversion described above. In 2015 plantations were only 140 thousand hectares (FIPD 2015). Plantation targets are constantly being missed (Radio Free Asia 2017). Tree plantations are likely to make only a small contribution (covering perhaps 0.5 million ha) to the overall plan to restore 7 million ha of forest. Conversion of degraded lands to secondary forests rather than to monoculture plantations of exotics is seen as the main restoration approach for meeting the diverse product needs of the local people, other stakeholders, and changing market demands, while simultaneously enhancing biodiversity and ecosystem services. The outcomes from pure plantation expansion are being criticized by conservation groups and nongovernment organizations of Lao PDR (Ketphanh, Foppes, and Russell 2012). We consider reforestation with commercial species (rubber) and natural species (acacia) as two possible interventions for reforestation.

Wong et al. (2014) estimate the average cost of rubber plantations in the range of US$149–$1,021/ha. Rubber yield is 0.3–1 tonne/ha, and rubber price US$1,610/tonne. Rubber trees start to be productive in year 7, but they increase the risk of soil erosion and are associated with health risks from pesticide use. Table 10.1 presents the BCR for rubber plantations in Lao PDR. The effectiveness of rubber plantations varies; the benefits include only commercial revenues from rubber sales. High initial costs make it impossible for the poor farmers to develop rubber plantations.

Effective forest restoration (Forest Trends 2015) should reestablish fully functioning ecosystems through direct or indirect actions based on three main objectives: (i) the reconstruction of species-rich functional communities that are capable of evolving, (ii) the stimulation of any potential for self-recovery that remains in the area (resilience) whenever possible, and (iii) taking into account a landscape perspective in the

Table 10.1 Benefits and Costs of Rubber Plantations (US$/ha)

Discount rate	Costs low	Costs high	Benefits low	Benefits high	NPV low	NPV high	BCR low	BCR high
3%/yr	3,213	22,013	7,536	25,119	4,323	3,105	1.1	2.3
5%/yr	2,520	17,265	5,471	18,236	971	2,951	1.1	2.2
10%/yr	1,545	10,587	2,695	8,982	−1,606	1,150	0.8	1.7

Source: Estimated based on Wong et al. 2014.
Note: 30-year cycle.

Table 10.2 Benefits and Costs of Reforestation on Abandoned Lands (US$/ha)

Discount rate	PV Costs	PV Benefits	NPV	BCR
3%/yr	2,829	5,073	2,244	1.8
5%/yr	2,362	4,221	1,859	1.8
10%/yr	1,763	3,029	1,266	1.7

Source: Estimated based on Graham et al. 2016.
Note: 30-year cycle.

Table 10.3 Benefits and Costs of Reforestation on Protected Lands (US$/ha)

Discount rate	PV Costs	PV Benefits	NPV	BCR
3%/yr	1,106	2,537	1,431	2.3
5%/yr	923	2,111	1,187	2.3
10%/yr	689	1,515	826	2.2

Source: Estimated using Graham et al. 2016.
Note: 30-year cycle.

planning of restoration actions. We consider natural regeneration based on community contracts as an intervention to reduce deforestation cost. Average NPV (30-year cycle) is estimated in Graham et al. (2016). Reforestation strategy is identified as restoring forests for carbon storage on cleared or degraded land that is not being actively used for plantations or logging and restoring forests. The costs include O&M costs, as well as transaction costs for monitoring, verifying, and reporting carbon. On the other hand, carbon sequestration is included in project benefits at an average level for Lao PDR. Project benefits per hectare reflect a gradual flow of reforestation benefits from restored forest as presented in Table 10.2. Table 10.3 presents the BCR for reforestation with native plants on abandoned lands in Lao PDR.

About 35 percent of all forests are protected in Lao PDR (FIPD 2015). If reforestation strategy focuses on investing in improving protected-area management to prevent forest carbon loss through illegal clearing, logging, and fire (carbon benefits and transaction costs are similarly accounted for), then costs are different, and only 50 percent of total annual forest benefits per hectare are associated with the project implementation.

Agroforestry is the last intervention considered in this chapter. Agroforestry involves the use of various tree options, usually woody perennials very common in rainfed areas and various crops. Another type of agroforestry involves ruminant animals—silvopastoral systems. The benefits of these systems emerge due to synergistic interactions of the components:

For example, in agroforestry, the various options (such as planting leguminous trees) improve the system to mutual advantage. With silvopastoral systems, stratification of the production system enables not only increased meat production, but also achieves savings in the use of weedicides, and increases soil fertility yield of fruit trees (Devendra 2012). We analyze agroforestry systems in Vietnam and use that analysis as the basis for estimating benefits and costs in Lao PDR.

Van Thang et al. (2015) present different agroforestry systems in the uplands of Vietnam that are like conditions in the Lao PDR. Table 10.4 presents BCR for all agroforestry projects considered in this chapter.

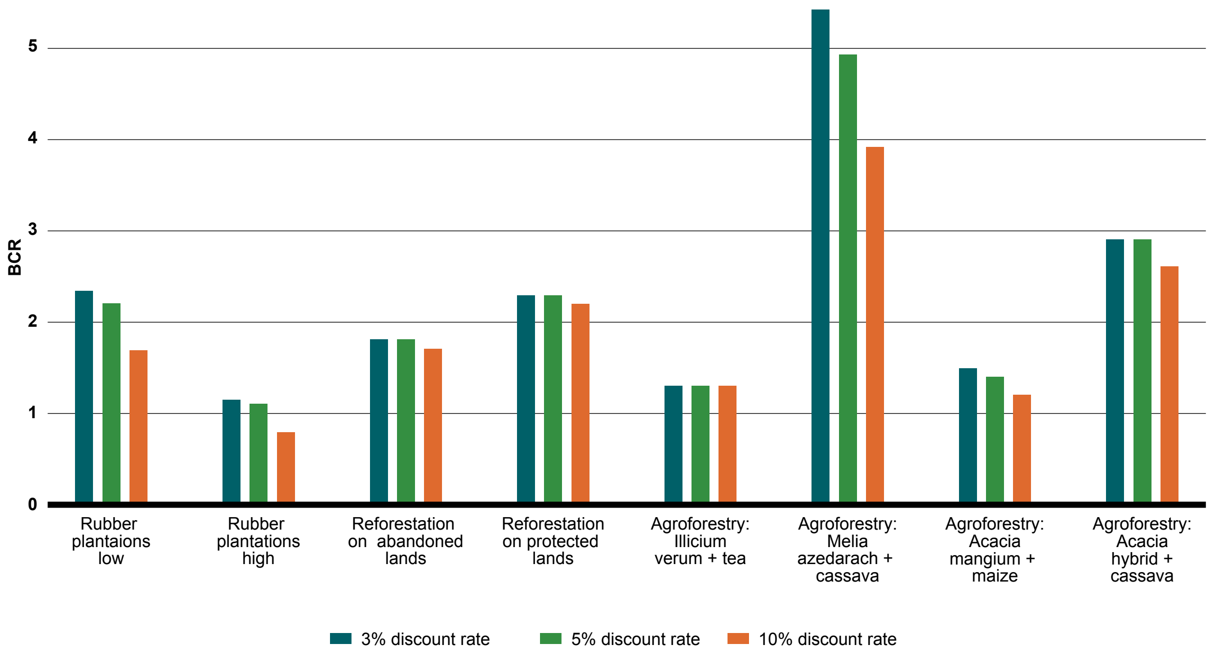
Figure 10.1 summarizes BCRs for forestry projects. Project benefits are higher than costs in all reforestation, forest conservation, and agroforestry projects. Most benefits in reforestation projects are intangible (regulating services of forest-ecosystems values). Benefits of agroforestry projects are presented by market values. Rubber plantations demonstrate lower BCRs; their benefits are uncertain, appear only in the seventh year of project implementation, and up-front costs are high.

Table 10.4 Benefits and Costs of Agroforestry Projects (US$/ha)

Agroforestry projects	Discount rate	PV costs	PV benefits	NPV	BCR
Illicium verum + tea	3%/yr	32,266	41,589	9,323	1.3
	5%/yr	27,893	35,743	7,851	1.3
	10%/yr	19,841	25,025	5,184	1.3
Melia azedarach +cassava	3%/yr	3,192	17,332	14,140	5.4
	5%/yr	3,062	15,149	12,087	4.9
	10%/yr	2,777	10,938	8,161	3.9
Acacia mangium + maize	3%/yr	3,227	4,895	1,668	1.5
	5%/yr	3,091	4,363	1,272	1.4
	10%/yr	2,797	3,303	506	1.2
Acacia hybrid +cassava	3%/yr	2,750	8,063	5,313	2.9
	5%/yr	2,643	7,664	5,022	2.9
	10%/yr	2,404	6,362	3,957	2.6

Source: Estimated using Van Thang et al. 2015.
Note: Project cycle varies.

Figure 10.1 Benefit-Cost Ratios for Forestry Projects



Note: Estimated values.

10.3 Interventions to Reduce Agricultural Land Degradation

The Lao PDR Agriculture Census 2010/2011 (Lao PDR MAF 2014) revealed that 20 percent of rural villages report that their land is lightly degraded, 8 percent—moderately degraded, and 1 percent—severely degraded. Most of the degradation is concentrated in uplands on deforested lands, where the reduced natural rotation cycle results in soil erosion and pesticide pollution in rubber plantations. Reforestation on the abandoned lands could restore fragile ecosystem, then agroforestry could develop as well. Reforestation and agroforestry projects require longer preparation times and benefits often appear later in the project cycle.

Another approach is to transform shifting low-productivity practices into more-efficient paddy production on terraces using better rice seeds. Upland rice swiddens are practiced on a rotational basis, moving from plot to plot within the same landscape after a certain fallow period, usually about 8 years. While generally considered to be environmentally sustainable, rotational swiddens require extensive land area. This is the predominant and low-productivity traditional farming system in the northern uplands of Lao PDR (Wong Darachanthara, and Soukkhamthat 2014). With declining upland rice yields, farmers must find alternative means of growing rice.

Linquist et al. (2007) compare traditional upland production systems with terrace-based paddy production in the uplands (Table 10.5). We assume a 30-year project cycle and adjusted cost and farmgate price of rice to 2017 with a GDP deflator.

Table 10.6 presents the BCRs for terrace construction for paddy rice compared to shifting upland rice cultivation. High initial costs make it difficult for the poor farmers to initiate such changes. However, significantly higher productivity of paddy on terraced slopes would justify support of small landholders and communities interested in this technology.

Table 10.5 Assumptions for Benefit-Cost Analysis of Terrace-Based Paddy Production

	2007	Adjusted to 2017
Yield upland rice t/ha	1.7	
Yield paddy rice t/ha	3.4	
Cost production upland rice, US$/ha	10	24
Cost production paddy rice, US$/ha	20	48
Farmgate price rice, US$/t	70	234
Cost construction terraces, weir, irrigation canals, US$/ha	300	720
Frequency rice cultivation upland	Once every 3 years	
Frequency rice cultivation paddy	1 per year	
Loss of rice area to terraces, %	10	
Lag for productivity increase after terrace construction	3	

Source: Linquist et al. 2007.

Table 10.6 Benefits and Costs of Terrace Construction for Paddy Rice Cultivation in Uplands (US$/ha)

Discount rate	PV Costs	PV Benefits	NPV	BCR
3%/yr	3,248	10,638	7,390	3.3
5%/yr	2,654	8,171	5,517	3.1
10%/yr	1,814	4,734	2,920	2.6

Source: Estimated based on Linquist et al. 2007.
Note: 30-year cycle.

Another way to increase the productivity of rice production on degraded soil would be the use of improved seeds. Eliste and Santos (2012) present a case for improved seed production in Lao PDR. To maintain high adoption rates of improved varieties, the purity or quality of the planting seed must be maintained over time. In Lao PDR, improved seeds named R3 are not widely used, and planting seed is being used in excess of the recommended three to four seasons before the seed stock is replenished. The use and availability of quality R3 planting seed inputs remain a significant constraint on improved rice productivity. Eliste and Santos (2012) estimate the costs and benefits of R3 production (rice yield growth by 20 percent over a 3-year period). In Table 10.7, we estimate the BCRs of utilizing R3 seeds.

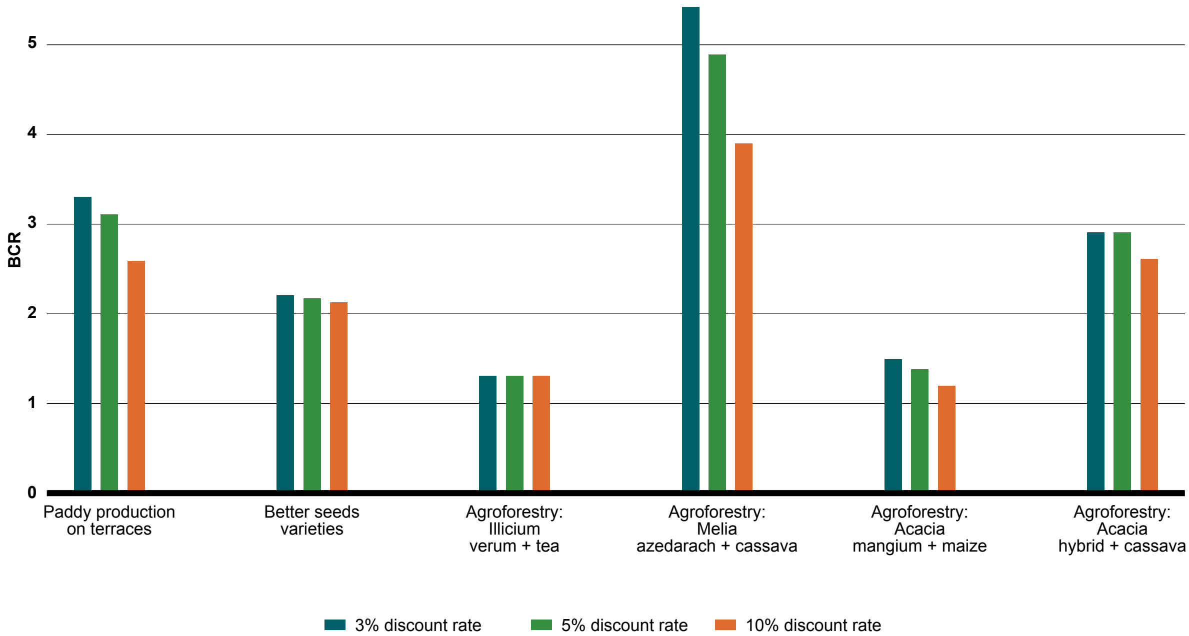
Figure 10.2 summarizes the BCRs of projects for mitigating soil degradation. The BCRs of agroforestry projects are included as well, because they allow increasing productivity on degraded lands. In all projects, project benefits are higher than costs and BCR is above 1. Terrace construction appears to be equally efficient compared to most agroforestry projects, but it requires a significant upfront investment.

Table 10.7 Benefits and Costs of Improved Seed Utilization (US$/ha)

Discount rate	PV Costs	PV Benefits	NPV	BCR
3%/yr	1,020	2,237	1,216	2.2
5%/yr	800	1,732	932	2.2
10%/yr	491	1,025	535	2.1

Source: Estimated based on Eliste and Santos 2012.
Note: 30-year cycle.

Figure 10.2 Benefit-Cost Ratios of Projects for Mitigating Soil Degradation



Note: Estimated values.

10.4 Interventions to Reduce the Impact of Large Dams on Fisheries

Large hydropower dams, especially a series of them, along the mainstream of major rivers inevitably damage or potentially eliminate native fisheries. This is due to a series of changes in the overall hydrologic system. Flows are completely changed. Large sections of flowing rivers are turned into large reservoirs. Vertical temperature profiles completely change. Habitats are completely different. Reduction or elimination of overbank flooding damages areas that are often important nursery grounds for various fish species. Moreover, the dams themselves are huge physical obstacles to fish passage along the river (Hortle and So Nam 2017; MRC 2015, 2017a, b).

There is one fundamental choice to be made in mitigating these losses of fisheries: To what extent should mitigation attempt to save and somewhat sustain at least a few (but not all) native species—or should most resources be devoted to developing reservoir-friendly, possibly commercially valuable, but nonnative fisheries?

More water from the reservoir can be released than would be the case if the dam were operated only to maximize power or water storage. Spills can benefit fish downstream but can sometimes be released in large *flushing flows* intended to wash away harmful accumulations of boulders and gravel. This will tend to increase downstream dissolved oxygen levels. Other measures can also be taken that increase oxygenation, such as artificially aerating the water passing through turbines. Increasing dissolved oxygen is generally the cheapest form of mitigation and appears to generally be effective. Another approach to improving downstream water quality is to regulate the temperature of releases by fitting the dam with intakes that can withdraw water from different levels of the reservoir. The use of hatcheries for artificially rearing fish whose natural habitat has been destroyed by dams is common in the United States for the Pacific salmon fishery in the northwestern United States. However, this can be quite an expensive annual operating cost (International Rivers 2019).

Fish passages—often referred to as fish ladders—are the main method of trying to overcome the physical barrier to fish migration that dams always cause. The following descriptions of the effort and range of estimates are for one large hydropower facility (169 MW) in the US Pacific Northwest, the Klamath Hydroelectric project (PacifiCorp 2004, 2012). The dam drains an approximate area of about 33,667 km^2 into flows of about 400 km and then empties into the Pacific Ocean.

The upstream fish-passage methods considered for this dam included ladders, and trap and haul. To account for differences in dam heights, we will also estimate costs for +/–50 percent compared to the quoted case for the Klamath (PacifiCorp 2004). Table 10.8 presents the costs.

Preventing fish from swimming into the turbines is often the problem involved with downstream passage. Screening is generally used to prevent this. The costs for the Klamath project (PacifiCorp. 2004) are shown in the next table, again with a +/–50 percent approach (see Table 10.9).

Five of the proposed nine dams will have installed capacities of over 1,000 MW, so we assumed that we should use the upper-bound estimates for those cases. Four were calculated at the lower bound. Table 10.10 summarizes these costs, based on Table 10.8 and Table 10.9 and on these assumptions about dam capacity and size. In addition, only one of the upstream interventions is applied at each dam, so we use the average of the two costs to include in the total. All estimates are adjusted to the Lao PDR with the GDP in PPP per capita differential (2017 GDP PPP/capita in Lao PDR to 2011 GDP PPP/capita in the United States, which is 0.14). Construction is assumed to last 15 years in parallel with dams.

Due to the difficulty of finding precise figures on the success of these mitigations, we assume that their success rate varies from as low as 30 percent to, at best, 80 percent. To estimate benefits of fish passages, this success rate is applied to the annual fish losses due to hydropower development estimated above. The benefit increases gradually during 15 years of dam construction.

We estimate BCR of fish passages construction in Table 10.11. In the low-end case with a low success rate, fish passages appear not an efficient option. However, with a higher success rate, all these projects become economically viable. That is why an adequate technology of fish passage for each dam—adapted to the Mekong River conditions—is a crucial prerequisite for project success (see MRC 2015).

Since the eventual success of fish-passage technologies is uncertain, it is imperative to provide critical food security to those who will be negatively affected by hydropower development. They are mostly poor households who depend on fishing for their daily protein intake. To substitute for lost migratory fish, aquaculture should be further developed in reservoirs formed by dams. Hambry (2002) describes prevailing aquaculture approaches in Lao PDR. We estimated costs and benefits for both the family and large-scale snakehead production in cages in Nam Ngum Reservoir, which would be characteristic for other reservoirs created by the dams. Table 10.12 describes specifics of each aquaculture type.

Table 10.8 Costs of Different Upstream Fish Passage Interventions in the United States

Passage type	Capital cost US$, thousands			O&M US$, thousands		
	−50%		+50%	−50%		+50%
Fish ladder	10,500	21,000	31,500	259	517	776
Trap and haul	2,100	4,200	6,300	775	1,550	2,325

Source: PacifiCorp 2004.

Table 10.9 Costs of Screening for Downstream Fish Passage in the United States

	Capital cost US$, thousands			O&M US$, thousands		
	−50%		+50%	−50%		+50%
Screening	7,755	15,100	22,650	323	646	969

Source: PacifiCorp 2004.

Table 10.10 Summary of Costs of Fish-Passage Interventions

Intervention	Capital cost US$, thousands	O&M US$, thousands
Fish ladder	1,481–4,443	36–109
Trap and haul	296–889	109–328
Screening	1,094–3,195	46–137
Total	37,233	2,250

Note: Adjusted with the GDP PPP/capita differential.

Table 10.11 Benefits and Costs of Fish Passage Construction (US$, Thousands)

	Discount rate	PV Costs	PV Benefits	NPV	BCR
Fish passages low-end	3%/yr	106,815	122,325	15,510	1.1
	5%/yr	85,140	89,136	3,995	1.0
	10%/yr	51,720	45,042	6,678	0.9
Fish passages high-end	3%/yr	106,815	445,808	338,993	4.2
	5%/yr	85,140	324,850	239,710	3.8
	10%/yr	51,720	164,154	112,434	3.2

Note: Estimated values.

The first type of aquaculture could form the basis of future development, since it could be scaled up in every reservoir. We estimate the BCRs of aquaculture in Table 10.13. All prices are adjusted to 2017 with a GDP deflator. Each production cycle is 0.75-year; annual costs, benefits, profits, and BCR are estimated for a 30-year cycle. Only Type 1 large-scale aquaculture is estimated to be economically viable. Low-productivity family farms are not efficient and are utilized for subsistence purposes.

Figure 10.3 summarizes the BCRs of projects for mitigating fishery loss. The BCRs of fishery-passages projects are high, assuming they are carefully crafted and have a high success rate; additionally, large-scale aquaculture with higher productivity is economically viable.

Table 10.12 Two Types of Aquaculture Analyzed in Lao PDR

Type 1	Large scale, 8 large cages from wood (US$540, each lasts 5 years), hired labor, and bought seed and food from hatcheries at a market price.
Type 2	Small scale, 5 small cages from bamboo (US$22, each lasts 2 years), family labor, and wild-caught seed and food.

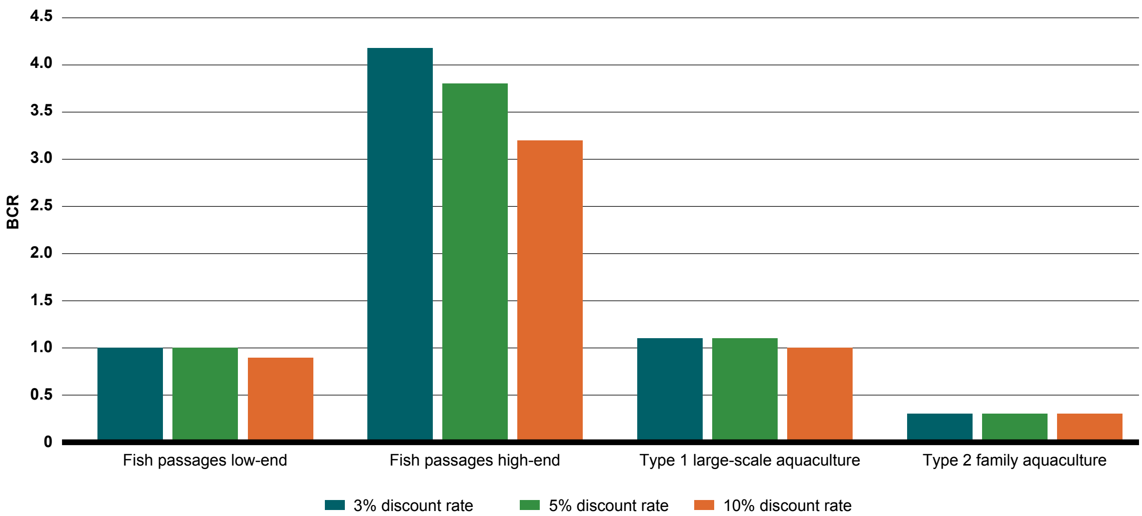
Source: Hambry 2002.

Table 10.13 Benefits and Costs of Aquaculture (US$)

	Discount rate	PV costs	PV benefits	NPV	BCR
Type 1	3%/yr	94,495	101,609	7,113	1.1
	5%/yr	74,819	79,691	4,872	1.1
	10%/yr	46,959	48,869	1,910	1.0
Type 2	3%/yr	26,834	7,938	-18,896	0.3
	5%/yr	21,057	6,226	-14,831	0.3
	10%/yr	12,928	3,818	-9,110	0.3

Note: Estimated values.

Figure 10.3 Benefit-Cost Ratios of Projects for Mitigating Fishery Loss



Note: Estimated values.

10.5 Interventions to Mitigate Flooding Disasters

Vientiane, like Lao PDR's other urban areas, is in the Mekong River floodplain and requires significant improvements to its urban water-management infrastructure to prepare for and manage disaster risks linked to floods (Lao PDR MAF 2012). Lao PDR faces mainstream flooding in the Vientiane plain, flash floods in the highlands, and flooding at the confluence of tributaries and the Mekong River. Floods generally result from high rainfall caused by typhoons combined with the occurrence of the southwest monsoon. Natural disasters, especially floods, resulting from climate abnormalities have been occurring more frequently. Since 1966, the country has experienced 25 floods of different magnitudes and duration. In the central part, the Vientiane plain was flooded 9 of the last 42 years (ADB 2011). Future flooding in this region is expected to worsen.

The Mekong River Commission has released a series of reports on sustainable management of the Mekong Basin. Their analysis of flooding risks identified four main flood issues (MRC 2018). Flood Damages could increase by a factor of 5 to 10 with development unless new forms of protection are developed. The trapping of sediments in the proposed dams is likely to increase erosion in the river, leading to the need for significant bank protection. The loss of floodplain storage will result in higher flood levels and increase flood frequency. Climate change is also highly likely to result in significant increases in floods. Damages are expected to be significant to urban and agricultural infrastructure including roads, banks, irrigation, and buildings of all types.

Mitigating infrastructure should include approaches of various types, both physical infrastructure and improved forecasting models. This would include upgrading and developing early warning systems with better flood forecasts and education programs on how people should respond to warnings. These should be people-centered early warnings, which would be easily and clearly understood. They need to be readily accessible through different technologies; timely; and tied to response actions to be taken by the people in advance of, during, and after the event (Flood Resilience Portal 2019).

Physical infrastructure could include flood walls, canals and pipes, pumps and pumping stations, and additional tunnels to carry rain and floodwaters. Flood-plain development should include areas for storage and conveyance for intense events. The physical infrastructure should work as a city-wide system to convey high floodwaters away from homes and businesses. Increase in surfaces that absorb water and slow down floods should be part of development plans.

The cost of mitigating infrastructure to manage floods in Vientiane was adjusted from examples in Bangkok and Ho Chi Minh City based on their relative populations. Under an ADB-funded project, Lao PDR plans to start building additional flood-control infrastructure (Lao PDR MAF 2012). Table 10.14 presents the total cost of infrastructure and the total cost on a per capita basis.

Table 10.14 Cost of Mitigation Infrastructure to Manage Flooding in Vientiane (Adapted from Examples in Bangkok and Ho Chi Minh City)

Description of Infrastructure Improvements	Total cost US$, millions		Cost per capita US$	
	Low End	High End	Low End	High End
Dredging of main drainage canals; construction and elevation of flood walls and dikes; construction of new drainage, culverts, and pumping systems	222	3,150	277	394

Source: Based on Bangkok Metropolitan Administration & Vietnam News 2018.

For the cost estimations, we assume 5 years construction time for the *Low-End* scenario and 10 years construction time for the *High-End* scenario, and 5 percent O&M cost.

It is assumed that mitigating interventions will increase flood protection of the urban population up to the 25-year event that has a 4 percent probability of occurrence each year. The Aqueduct Global Flood Analyzer estimates that increasing flood protection from mitigating a 2-year event to mitigating a 25-year event would avoid US$124 million (adjusted to 2017 with a GDP deflator) of urban damages for the total urban population. We assume 5 years construction time for the Low-End scenario and 10 years construction time for the High-End scenario. We attribute one-third to two-thirds of the total avoided urban damage to Vientiane, for several reasons. It is the country's largest city and has about one-third of the country's total urban population. Smaller cities will face similar flooding problems, but not to the same extent, since they have, proportionately, smaller amounts of impervious surfaces and are far less developed.

We estimate the BCRs of flood-mitigating interventions in Vientiane in Table 10.15. The BCRs are above 1 for the low-end scenario, and below 1 in the high-end scenario. This analysis reflects the high up-front costs of mitigating interventions that might be effective only in the case of low-probability events.

Another intervention that significantly reduces the risk of mortality in the case of extreme events is expansion of the early warning system and increasing the population's responsiveness to it. Early warning systems give people time to flee from a flash flood, enable local authorities to evacuate or shelter large numbers of people in advance of a cyclone, and enable a faster response to problems of water insecurity.

Warnings issued well before a natural disaster enable people to protect their property and infrastructure. For example, reservoir operators could reduce water level gradually to accommodate incoming flood waters, local authorities could position equipment for emergency response, people could shutter windows and reinforce roofs, and hospitals could prepare to take more patients. In general, the longer the lead time, the greater the amount of property and infrastructure that could be protected. However, with longer lead time comes greater risk of false alarms and incurred costs (Rogers and Tsirkunov 2011).

By 2017, a pilot early warning system had been created in Lao PDR for two river basins: Sebangfai and Sebanghiang (Lao PDR MoNRE 2017). The system should be expanded to other basins. In Golub and Golub (2017), the O&M unit cost of early warning system per capita in 2017 is estimated at US$2.3 per the exposed population or US$1.6 million annually (people affected by 2-year floods during 2 years from the Aqueduct Global Flood Analyzer). Based on the

Table 10.15 Benefits and Costs of Flood-Mitigating Interventions in Vientiane (US$, Millions)

	Discount rate	PV costs	PV benefits	NPV	BCR
Low-end scenario	3%/yr	455	710	255	1.6
	5%/yr	395	539	145	1.4
	10%/yr	301	302	1	1.0
High-end scenario	3%/yr	1,899	1,274	-625	0.7
	5%/yr	1,559	946	-613	0.6
	10%/yr	1,051	498	-553	0.5

Note: Estimated values.

estimated cost required to expand a pilot early warning system (Lao PDR MoNRE 2017), the capital costs of an early warning system are estimated at US$9.7 million. The benefits of the early warning system are estimated as the value of the mean preventable losses (100 percent dead, missing, injured, or lost cattle, and 10 percent of houses destroyed). The total value of the mean preventable losses is estimated at US$6 million.

We estimate the BCRs of increased population responsiveness and expansion of the early warning system below (Table 10.16). The BCRs are above 1 for all scenarios, reflecting the high efficiency of early warning systems in protecting life and property of Lao PDR's exposed population.

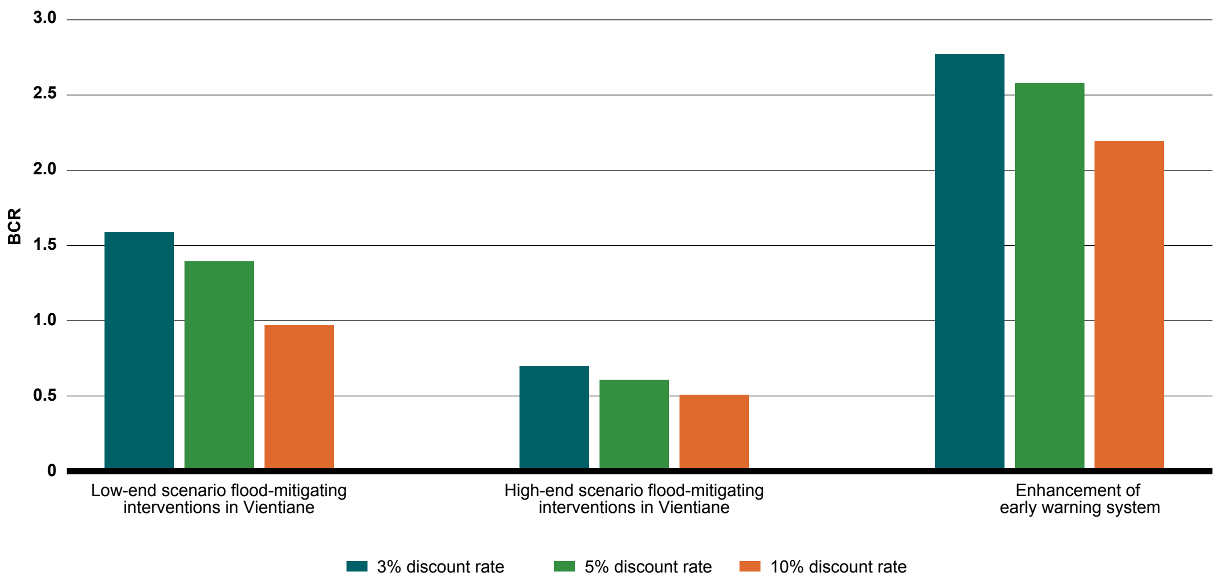
Figure 10.4 summarizes the BCRs of projects for mitigating flood damage. The BCRs of early warning system expansion are above 2. This reflects their efficiency in protecting the exposed population's lives and assets and corresponds to the global experience (Rogers and Tsirkunov 2011). *High-end* mitigating interventions in Vientiane may not be efficient in the average case, but they could be very useful in the case of rare catastrophic flood events.

Table 10.16 Benefits and Costs of Increased Population Responsiveness and Expansion of the Early Warning System (US$, Millions)

Discount rate	PV costs	PV benefits	NPV	BCR
3%/yr	40	111	71	2.8
5%/yr	33	86	53	2.6
10%/yr	23	51	28	2.2

Note: Estimated values.

Figure 10.4 Benefit-Cost Ratios of Projects for Mitigating Flood Damage



Note: Estimated values.

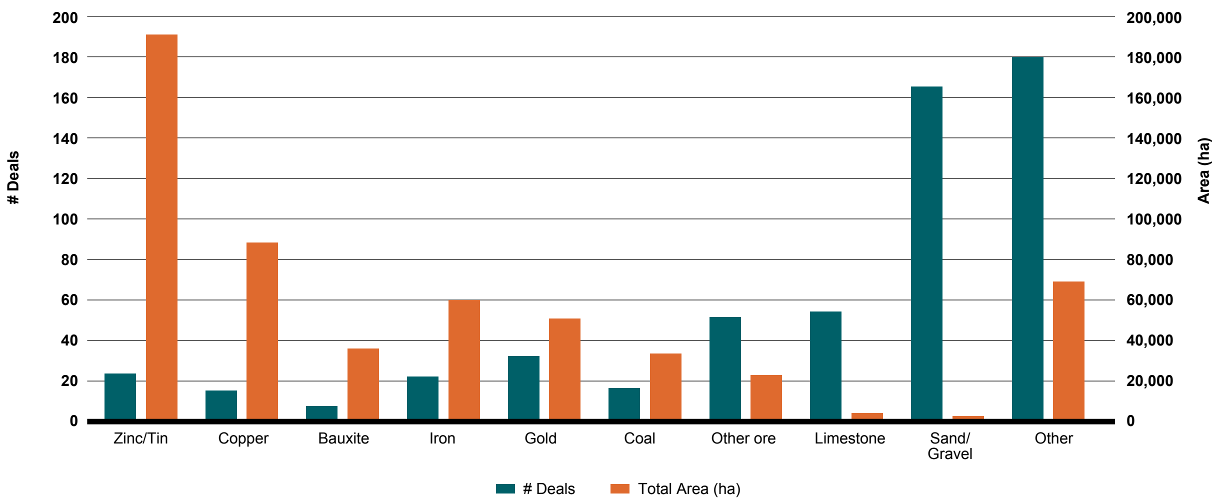
10.6 Interventions to Prevent Degradation of Water Quality from Mine Drainage

Constructed wetlands are artificial wastewater-treatment systems consisting of shallow ponds or channels that have been planted with aquatic plants, and that rely on natural microbial, biological, physical, and chemical processes to treat wastewater. They typically have impervious clay or synthetic liners, and engineered structures to control the flow direction, detention time, and water level. Constructed wetlands have been used to treat a variety of wastewaters including urban runoff, municipal, industrial, agricultural, and acid-mine drainage. They are wastewater-treatment systems composed of one or more treatment cells in a built and partially controlled environment. Primary functions of most constructed wetlands include water storage and water quality improvement. Ancillary functions include primary production of organic carbon by plants; oxygen production through photosynthesis; production of wetland herbivores, as well as predator species that range beyond the wetland boundaries; reduction of export of organic matter and nutrients to downstream ecosystems; and creation of cultural values in terms of educational and recreational resources (US EPA 1999).

Free water surface constructed wetlands resemble natural wetlands in appearance and function, with a combination of open-water areas, emergent vegetation, varying water depths, and other typical wetland features. These components include berms to enclose the treatment cells, inlet structures that regulate and distribute influent wastewater evenly for optimum treatment, various combinations of open-water areas and fully vegetated surface areas, and outlet structures that complement the even distribution provided by inlet structures and allow adjustment of water levels within the treatment cell. Shape, size, and complexity of design often are functions of the site.

The extent of mining concessions in Lao PDR is significant: during 2000–2008, it approached 550,000 ha (Schönweger et al. 2012). There are mines of various types spread across the country (Figure 10.5 Number and Area of Projects by Main Products in the Mining Subsector). The mining subsector contains 564 projects. Of all products within the mining subsector, sand and gravel excavation projects are the most common (165), followed by gravel and stone (106), limestone (54), gold (32), and copper (16). With respect to area, the three main products are zinc/tin with 189,900 ha, followed by copper with 86,888 ha and iron with 57,796 ha. The area covered by just those three types of mining projects alone covers 60 percent of the whole area within the mining subsector.

Figure 10.5 Number and Area of Projects by Main Products in the Mining Subsector



Source: Schönweger et al. 2012.

Table 10.17 Cost Range per Hectare for Constructed Wetlands to Treat Municipal Wastewater

	Construction cost/hectare Low End US$	Construction cost/hectare High End US$	Annual O&M costs Low End US$	Annual O&M costs High End US$
Cost range	145,050	255,012	2,510	4,045

Source: US EPA 1999.

Table 10.18 Estimated Costs to Treat 200 Mines of Various Ores with Constructed Wetlands

Cost Type	Low End US$, thousands		High End US$, thousands	
	200 ha	2,000 ha	200 ha	2,000 ha
Capital construction costs	5,802	58,020	10,200	102,005
Annual O&M Costs	100	1,004	162	1,618

Note: Estimated values.

Table 10.19 Benefits and Costs of Artificial Wetlands on the Abandoned Mining Sites (US$, Thousands)

Discount rate	PV costs low	PV costs high	PV benefits	NPV low	NPV high	BCR low	BCR high
				200 ha			
3%/yr	7,496	12,921	27,275	19,779	14,354	2.1	3.6
5%/yr	6,968	12,050	21,255	9,205	14,288	1.8	3.1
10%/yr	6,126	10,653	12,803	2,150	6,676	1.2	2.1
				2,000 ha			
3%/yr	75,034	129,177	272,752	197,718	143,575	2.1	3.6
5%/yr	69,735	120,479	212,555	92,075	142,820	1.8	3.0
10%/yr	61,297	106,514	128,027	21,513	66,729	1.2	2.1

Note: Estimated values.

Constructed wetlands should be used only for mines with a higher likelihood of serious chemical pollution. There are approximately 200 concessions related to metal ores in Lao PDR (Schönweger et al. 2012). Table 10.17 presents estimates of the cost to treat these 200 mines (of varying sizes) using constructed wetlands based on free water surface for the EPA municipal water treatment wetland.

The size of the constructed wetland is critical to the cost. Size estimations are typically based on areal loading rates of various constituents (US EPA 1999). It is beyond the scope of this chapter to estimate the size of wetland needed for specific mines. Therefore, two cases are presented: (i) small (200 hectares), and (ii) large (2,000 hectares). The cases are based on the US EPA guidance for the approximately 200 constructed wetlands for the concessions related to ores. All estimates in Table 10.18 are adjusted to 2017 with GDP in PPP per capita differential (from the United States, 1999, to Lao PDR, 2017, which is 0.2).

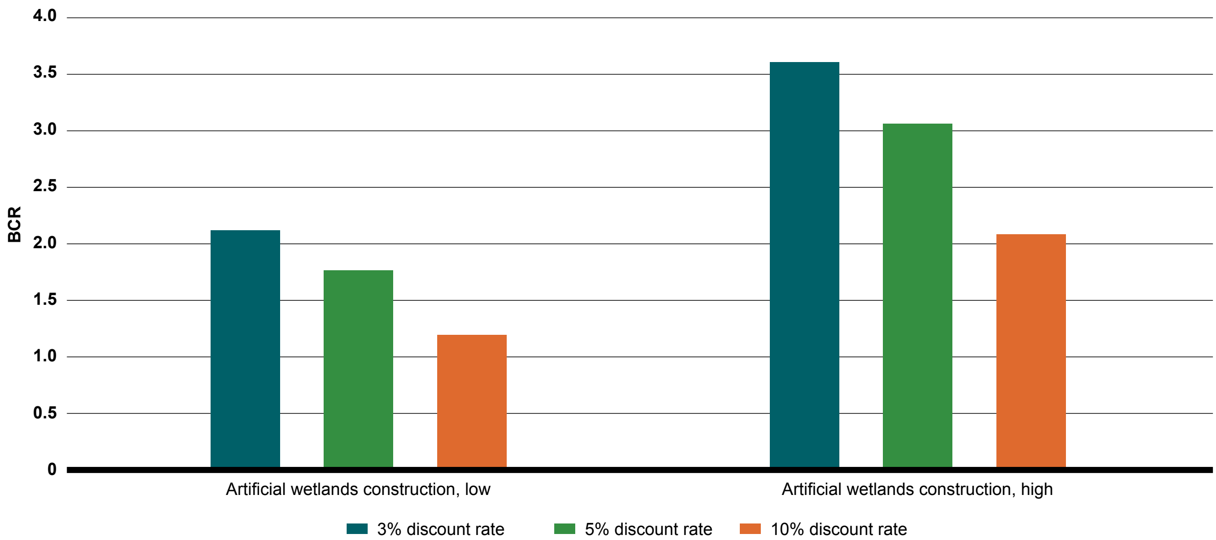
As previously noted, freshwater wetlands provide a wide range of ecosystem services. The average value of wetland ecosystem services in the Lower Mekong Basin is estimated at US$1,639–$12,630 ha/yr (Emerton 2013; US AID Mekong ARCC 2015). We use an average value of US$7,135 ha/yr for benefit-cost analysis of artificial wetland construction. The wetlands become fully operational in year 2.

We estimate the BCRs of artificial wetlands on the abandoned mining sites in Table 10.19 (see also Figure 10.6). All projects are economically viable due to the plethora of ecosystem services freshwater wetlands generate. However, a significant construction cost may jeopardize implementation of these projects. Furthermore, most of the ecosystem services that wetlands provide are intangible and the market does not internalize them.

It is not practical to treat individual artisanal mines with constructed wetlands. Perhaps people should be paid to not do individual artisanal mines. This would reduce their exposure to toxic metals and reduce pollution into the waterways.

Without the highest quality environmental management and controls, mining almost inevitably leads to water-quality degradation. Moreover, these waters

Figure 10.6 Benefit-Cost Ratios of Artificial Wetlands Construction on the Abandoned Mining Lands



Note: Estimated values.

are part of the critical support system and natural wealth of Lao PDR. In general, large-scale mining and hydropower developments can result in severe negative environmental and social effects, even with implementation of standard control measures. The environmental sustainability of natural resource production will depend on the effective implementation of existing regulations. Environmental sustainability must be an integral part of natural resource exploitation. While the legal framework is mostly adequate, there is a crucial need to strengthen the government's capacity for implementing and enforcing those laws (World Bank 2010). It is recommended that the Government of Lao PDR develop a comprehensive and accessible system for monitoring water quality.

10.7 Conclusions and Recommendations

Lao PDR is a country of great natural wealth, natural resources, and biodiversity. The majority of the people of Lao PDR base their livelihood on their homeland's natural capital. As the country modernizes and promotes economic development, there are serious problems of natural-resource degradation that have led to the quantifiable economic cost at US$822 million annually or 4.7 percent of GDP in 2017, as laid out in this report.

Holistic approaches suggest that sustainable forest management and conservation in Lao PDR is a foundation of the survival of ecosystems in the Lower Mekong Basin (LMB). Most forest-ecosystem benefits are intangible and not profit-generating. As the analyses reveal, interventions in agriculture exhibit the highest benefit-cost ratio. However, deforestation and forest-degradation costs constitute a larger fraction of the cost of natural-resource degradation (CoNRD), while the BCR of direct interventions in forestry is relatively lower. Application of a holistic approach to choose interventions for implementation reveals a connection between interventions in agriculture and reduction of deforestation and forest degradation, because increased agricultural productivity and new technologies like agroforestry alleviate pressure on forests that is partially explained by lower agricultural productivity. Therefore, increased productivity on agricultural lands helps prevent additional deforestation and forest degradation. Moreover, the adoption of new technologies (like agroforestry) in agriculture allows continuous growth of agricultural production, thereby increasing both food security and forest protection.

Strengthening the protection of forest areas should receive regulatory and management attention sufficient to maintain biodiversity and enhance tourism, but also to protect infrastructure and provide watershed services including flood-risk reduction. Lao PDR's 47 protection forest areas are the largest single land use designation in the country and host an estimated 1,896 villages. Because these areas are generally highly degraded, under the 2019 Forest Law there is a renewed opportunity to pursue village forest management. This opportunity includes the restoration and non-wood forest products, which would also reinforce the protective role of these forests—including biodiversity—while generating local livelihoods. In addition, biodiversity protection is closely linked to rehabilitation of forests and a corresponding increase in carbon sequestration.

Increased agricultural productivity may open some former agricultural lands for reforestation. In this context, interventions in agriculture are crucial to reduce the largest component of CoNRD attributed to deforestation and forest degradation. This agriculture-forestry coupling also serves as an important strategy for adaptation to climate change. The uncertainties associated with climate change require flexibility and responsiveness on the part of agriculture and continuous productivity growth to compensate for permanent and random productivity shocks attributable to climate change. Preventing forest degradation contributes to global mitigation efforts. Furthermore, preventing forest degradation has substantial local effects like watershed protection, which increases the resilience of local communities to climate change.

Ecosystem transformation, the adoption and use of new technologies, and economic growth contribute to overall poverty reduction. However, opportunities from agricultural expansion are limited for most of the rural population, given the combined effects of high inequality in land ownership, low employment potential, and higher rural non-farm incomes. Carefully selected interventions including agroforestry on the small farms can help reduce poverty. Reforestation and forest conservation projects on the riparian lands can also contribute to poverty reduction. In addition, biodiversity corridors are attractive for small and medium-sized farmers due to the lower opportunity cost of land.

Economically viable fisheries mitigation to counter the negative consequences of hydropower development should also be promoted. Hydropower development creates new challenges for ecosystems in LMB. The poor are those mostly affected by displacement and deterioration of their food security situation by the projected loss of migratory fish. Hydropower projects must include carefully designed fish passages. However, due to uncertainty regarding the rate of success, BCRs were relatively low. Thus, large-scale, highly productive aquaculture should be considered and promoted among local communities.

Mining has become a significant part of the Lao PDR economy, with a growing number of large concessions around the country. Large mining operations for metal ores frequently create long-term pollution problems, with mine wastes draining into watersheds and leading to poor water quality. This polluted water can become a source of serious health risks. Constructing wetlands to absorb these polluted flows can be an effective and efficient way to reduce these flows of contaminants into Lao PDR's various waterbodies. However, artisanal mining by the poor can be nearly impossible to regulate. This form of mining is also inefficient and often leads to serious exposures of neurotoxic compounds such as mercury. Perhaps the only practical approach to reduce this practice is to provide subsidies to the poor, so that they are no longer under such economic pressure for this income source.

Natural disasters (floods and droughts) are important climate hazards that are projected to intensify. Enhancement of early warning systems among exposed populations will practically eliminate property damage. We estimate that intervention in the early warning system would be highly effective. Capital-intensive mitigating interventions in urban areas exhibit a lower BCR. Such interventions should not be ruled out on this ground, since their implementation is vital during catastrophic events. This conclusion supports a Lao PDR adaptation strategy in urban areas that focuses on natural-disaster mitigation.

Future analyses would benefit from improved data collection associated with

> Better and more-accurate maps of forests, both type and extent;

> Better quantitative estimates of soil loss from erosion, not just in the uplands, but especially across all agricultural types of land, and at the catchment level and not just at the microplot level;

> Resolving different estimates of agricultural land uses, productivity, and yield;

> Providing better information about the use of agricultural inputs, specifically chemical pesticides and fertilizers; and

> Developing a comprehensive and accessible system for monitoring water quality, especially downstream from mining.

10.9 Notes

130 This chapter was prepared by Michael Brody and Elena Strukova Golub and draws upon additional material by the same authors presented in a background study (Brody and Golub 2019) containing additional information in support of the estimates, including an annex relating to the Aqueduct Global Flood Analyzer

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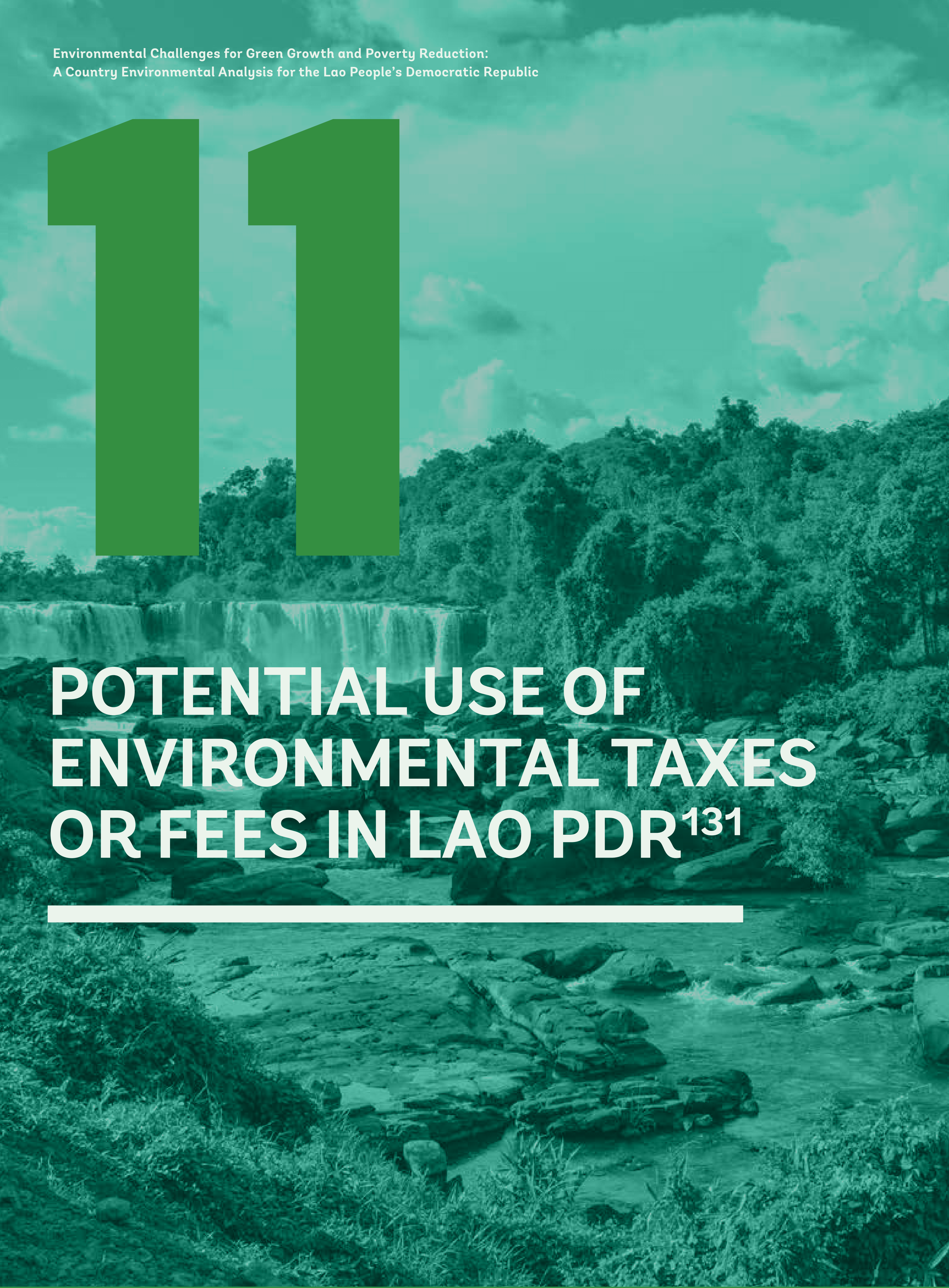


11

POTENTIAL USE OF ENVIRONMENTAL TAXES OR FEES IN LAO PDR[131]

Chapter Overview

Around the world, environmental taxes or fees are increasingly being used to improve health and the environment. Consistent with the polluter pays principle (PPP), such taxes and fees can correct for negative side effects associated with production or consumption and efficiently exploit diverse possibilities for reducing damaging discharges. The revenues generated by these taxes/fees can finance public expenditures while the taxes themselves may create incentives for the development and adoption of new technologies.

Two categories of PPP-consistent environmental taxes are often considered: individual-oriented revenue-based taxes, as exemplified by fuel taxes and vehicle taxes, and industrial pollution taxes—for example, water-discharge taxes/fees.

In developing an environmental tax scheme, three key design issues are (i) effectiveness (capacity to create incentives for pollution control), (ii) simplicity of design, and (iii) feasibility of implementation. A fourth important issue, fairness, is an appealing concept, although, in practice, it may mean different things to different people. Equitable treatment of different income groups is, perhaps, the easiest type of fairness to define and measure. Equitable treatment of different types of polluters can be more challenging because of the need to consider a firm's competitiveness position (domestically and internationally), and its ability to pass on the higher costs to customers or others.

Environmental taxes are currently in use in many countries. Such taxes make up more than 6 percent of the total tax revenues in the European Union (EU), with some EU countries' environmental taxes as high as 10 percent. The transport sector is the most heavily taxed, reflecting the long-standing tradition of this form of taxation and the fact that the transport sector is the main source of air pollution in most European countries. Water-pollution taxes represent the second-largest source of environmental tax revenues in the EU. In the developing world, there is also growing use of these tax instruments—for example, in China, Colombia, the Philippines, and Vietnam.

Three potential new environmental tax initiatives in the Lao People's Democratic Republic are considered in this chapter: (i) an environmental tax on road-transportation fuels; (ii) an environmental tax on diesel vehicles; and (iii) a new, two-part water-discharge fee on industrial polluters.

The environmental tax on transportation fuels would augment the existing revenue stream and result in long-run reductions in fuel use, yielding measurable health and environmental benefits. Such a tax would build on Lao PDR's existing administrative apparatus and consequently not pose significant implementation challenges.

The environmental tax on diesel vehicles is intended to reverse the dieselization among small vehicles that has taken place over the last two decades in Lao PDR. Dieselization has contributed to substantial $PM_{2.5}$ *ambient air pollution with severe health effects, especially in Vientiane Capital. The diesel tax would discourage the purchase of diesel vehicles, which contribute almost all of primary* $PM_{2.5}$ *air pollution from the consumption of road-transport fuel, especially in Vientiane Capital. Like the gasoline tax, an environmental tax on diesel fuels would not pose significant implementation challenges.*

Creation of a new fee for industrial water discharge is more challenging. The two-part fee design involves a basic tax obligation not dependent on discharge volumes and a second variable part directly tied to discharge amounts. Inasmuch as successful implementation of the second part is dependent on reliable facility-specific data not currently available, a phased approach might be the most practical way to develop the database and reporting mechanisms needed to implement the second phase.

The precise definitions of covered pollutants and polluters, as well as the amount of the discharge fees, are all difficult issues. The experiences of other countries can certainly inform these decisions. However, in the end, local considerations—both environmental and economic—are paramount. The practical barriers to implementing systems for environmental taxes/fees will be largely administrative in nature. Since industrial facilities in Lao PDR are not currently subjected to requirements for the self-monitoring and reporting of their pollution discharges, estimates of discharge volumes will have to be developed via enforceable requirements to provide these data. Clear guidance will be needed for this purpose, along with capacity building in both the public and private sectors.

Beyond the environmental tax options examined here, officials in Lao PDR may also want to consider other opportunities to add economic incentive mechanisms to their policy mix, either as complements to, or substitutes for, command-and-control approaches. Within a PPP framework that is either revenue neutral or revenue generating, other environmental taxes, deposit-refund schemes, or emissions trading are the clear options. It may be appropriate to drop the requirement for revenue neutrality. In all cases, careful thought should be given to the efficiency, effectiveness, fairness, and ease of implementation of any new proposals.

11.1 Introduction

Two laws in Lao PDR mandate the use of economic instruments for environmental protection—namely, the 2016 *Tax Law* and the 2017 *Law on Water and Water Resources.*

Article 59 of the *Tax Law* defines the scope of environmental tax and establishes that

> *Individuals, legal entities and organizations including Lao citizens, aliens, foreigners, stateless persons, authorized to operate businesses, [or] import or use natural resources that will pollute the environment in the Lao PDR are obliged to pay environmental tax in order to [generate a fund] to treat, remediate or clean up the pollution and waste to restore the land so it is suitable and safe for people to live there.*

Article 59 continues as follows:

> *The list of activities subject to or exempt from environmental tax, the objectives of the tax, taxable amount and the tax rates are defined in a separate regulation.*

As of April 2019, that regulation had yet to be developed and implemented.

Law on Water and Water Resources 2017: This law mandates that medium and large-scale water users are required to pay charges that are funneled into the Environmental Protection Fund (EPF), along with charges for wastewater discharges and fees for the restoration of water resources from investment projects and other activities. Article 63 and Article 34 of this law also establish sources that will be used to fund the Environmental Protection Fund (EPF): These include (i) fees for the restoration of water resources from investment projects and other activities, and (ii) service charges for water and water-resource use and for wastewater discharges.

The environmental taxes of the Tax Law and the charges and fees of the *Water Law* are examples of economic instruments for environmental protection. OECD defines economic instruments as fiscal and other economic incentives and disincentives to incorporate environmental costs and benefits into the budgets of households and enterprises.[132]

Economic instruments include taxes, charges, and fees on pollutants and waste; deposit-refund systems for recycling; tradable pollution permits; tax incentives, tax credits, subsidies, and reduced import taxes on clean industrial technologies and vehicles and other environmentally friendly goods and services; and accelerated depreciation for tax purposes and investment tax credits for enterprises to encourage the use of environmentally friendly technologies and equipment.

A principal goal of economic instruments is to correct for negative side effects or externalities associated with environmentally harmful production or consumption activities. A guiding principle in this respect is the *Polluter Pays Principle* (PPP) which aims to allocate or internalize the full cost of production and consumption to producers and consumers—including the cost of environmental damage.[133] Sometimes, however, when direct taxation of environmentally harmful activities and adherence to the PPP is not possible, is impractical, or is too costly to administer, incentives and subsidies may be the next-best solution. Incentives and subsidies may also be employed along with other economic instruments when environmental and poverty-alleviation objectives are jointly addressed.

This chapter focuses on environmental taxes and fees, and thus only on a subset of economic instruments for environmental protection. The chapter first provides background information on such taxes and fees and includes both a conceptual discussion of environmental taxation and a summary of recent international experience with these instruments, particularly in developing countries. The chapter then outlines the potential for three new environmental tax initiatives in Lao PDR for controlling pollution in the road-transport and industrial sectors:

- Environmental tax on road-transport diesel and gasoline to encourage less fuel consumption and air pollution.

- Environmental tax on diesel vehicles to reverse the rapid dieselization and increased air pollution from private vehicles that have taken place over the last two decades.
- Implementation of a new, two-part water discharge fee on industrial polluters that would provide incentives for recycling and reduced pollution.

The environmental tax on transportation fuel would augment the existing excise tax and revenue stream and lead to long-run reductions in fuel use, yielding measurable health and environmental benefits. Importantly, it would not pose significant administrative challenges, since it is based on the existing fuel-tax collection system and would build on the 4-percent rate increase of the excise tax imposed in January 2018.

The environmental tax on diesel vehicles would change the relative taxation of diesel vehicles versus gasoline vehicles to discourage the purchase of diesel vehicles, which contribute almost all primary $PM_{2.5}$ air pollution from the consumption of road-transport fuel.

Creation of a new fee for industrial water discharge presents both challenges and opportunities. The two-part design involves a basic tax obligation that is not dependent on discharge volumes and a second variable part that is directly tied to discharge amounts. Since successful implementation of the second part is dependent on facility-specific discharge information, a phased-in approach might be the most practical way to proceed.

11.2 Environmental Taxation

Environmental taxes or fees, also known as green taxes, pollution taxes, or eco-taxes, can be highly cost-effective tools for encouraging businesses and private individuals to reduce practices that cause damage to human health and the environment. Environmental taxes can also raise revenues to finance public expenditures, including environmentally related activities, compensation to low-income groups, and general government needs. Broader tax reform may also be possible.

A principal goal of environmental taxes is to correct for negative side effects or externalities associated with harmful discharges from production or consumption activities. Consistent with the polluter or user pays principles (PPP), the design of these taxes should reflect the nature and magnitude of the health, environmental, and other damages associated with these activities, as well as the basic principles of effectiveness, fairness, feasibility, and simplicity.

Another economic incentive mechanism—emissions trading[134]—can also price harmful externalities, although revenue generation is not assured, more elaborate institutional arrangements are required, and it is generally less popular in developing countries. Nonetheless, both these mechanisms are often preferred to traditional regulatory (command-and-control) instruments, since they can more efficiently exploit a broad set of options for reducing damaging emissions and can create incentives for the development and adoption of newer technologies.

11.2.1 Conceptual Case for Environmental Taxation

Many countries around the world, including developing nations, provide fuel, mining, timber, or other subsidies that increase emissions/discharges, resulting in damage to human health or the natural environment. Such subsidies can encourage overproduction and stifle incentives for the development or use of more efficient and/or cleaner technologies. Re-examination of existing or planned subsidies should be a priority in every country, especially one considering development of new environmental taxes.

Beyond the removal of environmentally harmful subsidies, two categories of PPP-consistent environmental taxes are often considered: individual-oriented revenue-based taxes, as exemplified by fuel taxes and vehicle taxes, and industrial pollution taxes—for example, water-discharge taxes/fees.

> *Individual-oriented revenue-based taxes* are aimed at changing private individuals' behavior and practices that can damage the environment. While some business will also pay these taxes, most of the revenues are derived from individuals. Ideally, these taxes should directly target the harmful externality—for example, vehicle emissions. In practice, eco-taxes are often placed on products or activities highly correlated with the externality—for example, motor fuels, vehicles, or congestion. Though they may not be popular in the short-term, history has shown that these taxes can provide long-term health and environmental benefits.

> *Industrial pollution taxes* aim to change the behavior of industrial companies that are often responsible for producing a significant amount of pollution but are not the principal ones harmed by it (the surrounding area and local environment are often the most damaged). For these industrial polluters, the taxes must be based on the amount of harmful emissions/discharges they produce.

Historically, most pollution-control activities involve a *command-and-control* mechanism, wherein

> Polluters are instructed what they can do and cannot do (command). This instruction most often takes the form of maximum-allowable concentrations of different pollutants that may be discharged into the environment (concentration standards);

> Behavior of the polluters is assessed to determine if they are complying with the command (monitoring); and

> Threats of fines and penalties are used to induce polluters to comply with the command (enforcement).

There are important limitations of command and control:[135]

> Since all polluters face the exact same requirements, command-and-control does not allow polluting units to exploit significant differences in marginal abatement costs. As a result, the overall pollution-control costs to achieve a given target level of aggregate pollution are not minimized.

> Once a polluter complies with the command, it has no incentive to continue reducing its discharges, since it can pollute freely for as long as it adheres to the standards.

> Fines and penalties are typically set at levels that are too low to generate incentives for polluters to pay serious attention to their pollution discharges. As a result, business may ignore the presence of such regulations; and

> Since a polluter can discharge pollution freely up to the regulatory standards, the approach fails to generate fiscal revenues from these polluters based on their use of the environment.

There is widespread agreement among experts that (i) environmental costs need to be internalized into the process of production and pricing; and (ii) environmental taxes, often in combination with traditional regulatory instruments, may be most effective in promoting this internalization.[136] Currently, the Ministry of Environment and Natural Resources (MoNRE) is examining the possibility of adopting some form of taxation on polluters to complement existing command-and-control approaches, consistent with Principle 16 of the *Rio Declaration on Environment and Development* (Earth Summit, Rio, 1992), which encourages "national authorities…to promote the internalization of environmental costs and the use of economic instruments…and that the polluter should, in general, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment."

Environmental taxation can alleviate some (but not all) of the difficulties experienced with command-and-control, since this mechanism

> Aims to *internalize* environmental costs by levying a tax or charge on pollution, or on the products or the processes that are responsible for pollution;

> Helps ensure that the overall cost to the country of achieving target levels of aggregate pollution are minimized;

> Provides continuous incentives to reduce pollution in order to avoid pollution payments; and

> Generates fiscal revenues that could be used in ways deemed appropriate by governmental authorities—for example, offsetting any undesirable impacts these instruments may have on trade, competitiveness, or overall fairness; and/or supporting environmental investments.

In developing an environmental tax scheme, a number of design issues should be considered: (i) effectiveness (capacity to create incentives for pollution control), (ii) fairness (equitable treatment of different income groups and different types of polluters), (iii) simplicity of design, and (iv) feasibility of implementation. Regarding effectiveness, it is critical that the overall scheme create incentives to reduce emissions/discharges. Over the long term, fees should be high enough to encourage environmentally favorable behavior change—for example, change in use patterns and/or the purchase of more-efficient vehicles or pollution-control equipment.

While fairness is an appealing concept, in practice it often means different things to different people. Equitable treatment of different income groups is, perhaps, the easiest type of fairness to define and measure. Equitable treatment of different types of polluters can be more challenging because of the need to consider a firm's competitiveness position (domestically and internationally), and its ability to pass on the higher costs to customers or others. The simplicity of an environmental tax implies that targeted facilities must be able to easily compute their total tax liabilities. For certain tax schemes, such as a transportation fuel tax, the procedures are straightforward. For others, implementation capacity and resources are likely to be limited, especially when the pollution fee system is initially introduced.

The feasibility of an environmental tax depends on many factors, including the administrative capacities of both the taxpayers and the government. At the outset, a new environmental fee system, especially one involving complex measurements and data collection, should not target a large number of polluters or pollutants. Over time, coverage can expand as experience and capacity increase.

By their very nature, environmental taxes encourage, but do not mandate, the use of specific pollution-control technologies. By establishing a system that allows all covered firms to equalize their marginal abatement costs, environmental taxes can be the most cost-effective method of achieving emission/discharge reductions. Environmental taxes also allow regulators flexibility in controlling future costs of pollution-reduction program, since they can adjust future tax rates up or down depending on actual pollution-control costs, international competition and other factors. Further, the tax revenues can be used to address the health or environmental problem by designating all or part of the funds for subsidizing new technologies or other investments.

On the negative side, there is the theoretical (but unlikely) possibility for the tax burden to exceed the abatement costs. If this does occur, the government can reduce tax rates or revert to a less ambitious command-and-control regulatory scheme. Accordingly, the preferred strategy is to begin with relatively low environmental taxes and be prepared to increase them over time as the tax-collection system improves and as evidence is collected on their effectiveness.

Regarding fairness, it is possible that environmental taxes may be regressive in nature—that is, they may impose disproportionate burdens on low-income populations. Interestingly, recent research refutes the belief that this is a common problem, especially in developing countries. A number of studies have found neutral or weak regressive results in richer countries, but quite strong evidence on the progressivity of fuel taxes in developing countries, such as China, Ethiopia, Ghana, India, Indonesian, Mali, Nairobi, and others (Sterner 2011). The intuition here is straightforward: In most developing countries, the very poorest households cannot afford to own a car. Cars are more of a *luxury* good and hence fuel taxes tend to have a disproportionate burden on upper- rather than lower-income populations. At the same time, fuel taxes may also increase the cost of public transportation because the poor typically use this mode more intensively. While reliance on public transportation might mitigate the progressivity of fuel taxes, the new research has found that the net effect is still progressive in practically all developing countries. As Sterner (2011) notes,

> *…it is quite often the middle (or upper-middle) classes that bear the brunt of the taxation. Maybe they help spread the myth that fuel taxes are regressive, for they compare themselves to the richest and not to the poor who are much less visible. This tendency is often reinforced by anecdotal evidence concerning some individual motorists…. It is inevitable that commuters who drive long distances will be negatively affected by higher fuel taxes. It would be wrong, however, to say that drivers in rural areas are negatively affected in general; in fact, many rural people have very low average mileage compared to drivers in urban or quasi-urban areas.*

There is also some recent research that compares the distributional aspects of economic incentive versus command-and-control approaches. For example, Deryugina, Fullerton, and Pizer (2019) and Fischer and Pizer (2019) find that environmental taxation and other types of economic-incentive programs can be *more progressive* or *less regressive* than traditional regulatory programs.

11.2.2 International Experience with Environmental Taxation

Currently, environmental taxes make up more than 6 percent of the total tax revenues in the European Union (EU), with some countries as high as 10 percent. The transport sector is the most heavily taxed, reflecting the long-standing tradition of this form of taxation and the fact that it is the main source of air pollution in most European countries. Water-pollution taxes represent the second-largest source of the environmental tax revenues in the EU. In the developing world, there is also growing use of these tax instruments, for example, in China, Colombia, the Philippines, and Vietnam.

China first introduced a small pollution levy on SO_2 emissions in 1979. Initially, this levy applied only to emissions above the standard. In 1998, the tax base was expanded to include all emissions, not just those in excess of the standard. More recently, the number of covered pollutants has expanded to include NO_x and certain toxics. Starting in 2006 the rate on SO_2 emissions was raised to about US$180/ton. Water discharges are also taxed in China. Monitoring and enforcement, which was initially weak, has improved dramatically over the years and the collection of revenues has shifted from local governments to the national-level Ministry of Finance.

In 1993, Colombia enacted Article 42 of *Law 99,* which provides

> *the direct or indirect use of air, water and soil…or throwing waste or agricultural, mining or industrial waste…or sewage from any source, fumes and noxious substances resulting from human…or economic activities…whether for profit or not, shall be subject to the payment of remuneration rates for the harmful consequences of the activities specified.*

Colombia's discharge fee system for water effluents, which began operation in 1997, is often held up as a model of a well-functioning, economic-incentive pollution-control program in a developing country. Based on a detailed study of the first five years of program operation, Blackman (2009) finds that despite a number of problems, including limited implementation in certain regions, noncompliance by numerous municipal sewerage authorities, and some confusion between discharge fees and emissions standards, pollution loads dropped significantly in many watersheds after the program was introduced. Blackman (2009) also finds evidence that the incentives created for regulatory authorities to improve permitting, monitoring, and enforcement supported improved watershed management.

Industrial pollution fees were first instituted in the Philippines in 1997. Recognizing the limited capacity of the local institutions to monitor heavy metals, the fees were implemented only for biological oxygen demand (BOD). In a 2003 revision, total suspended solids (TSS) were added. Currently, after more than 15 years of implementation, the program produces substantial revenues, although concerns remain about the capacity to effectively monitor heavy metals discharges in industrial effluent (Laplante 2015).

Vietnam's *Environmental Protection Tax Law* of 2012, which covers several pollutants, is also a good example of environmental taxation among non-OECD countries.[137] Cottrell and Falcão (2018) report on some evidence for behavioral responses resulting in reduced emissions/discharges as a result of the environmental taxes. However, Cottrell and Falcão also report some small negative impacts on GDP growth and employment compared to a business-as-usual scenario. The tax appears to have had a progressive impact on household welfare, with modelling indicating that the richest income quintiles lost a comparatively greater proportion of their income in tax payments—presumably because a large proportion of the environmental tax revenues are raised through transport taxes, which tend to be relatively progressive in Vietnam.

Political acceptability is often a consideration for possible use of environmental taxes. In fact, two aspects of these taxes can increase their general acceptability: (i) the clear connection between the taxes and damages to public health and the environment, and (ii) the possibility of returning some or all of the revenues to those adversely affected, or to the general public, or to support adoption of clean technologies. Inevitably, the entities from which taxes are collected will try to pass on the tax burdens, depending on their position in the market and the demand elasticities for their products. Clearly, the social or economic impacts of any potential pass-through should be considered before new taxes or fees are introduced.

Administrative issues of environmental taxes, especially new taxes, are potentially quite challenging. The precise definition of emission/discharge rates and current information on issues related to production can make it difficult to predict tax revenues. Further, there are often concerns about the creation of a new tax bureaucracy. Reliance on existing tax authorities for collecting environmentally related revenues can be a cost-effective strategy, since the integration of these taxes/fees into the overall tax regime can reduce administrative costs and increase collections.

Adverse competitiveness-effects can sometimes be a factor in the adoption of environmental taxes, as it can be for regulation via command and control. While the international evidence of actual competitiveness-harm resulting from environmental taxes is limited, tax opponents often raise the issue. Some analysis of the potential competitiveness effects should be conducted prior to adoption of new taxes.

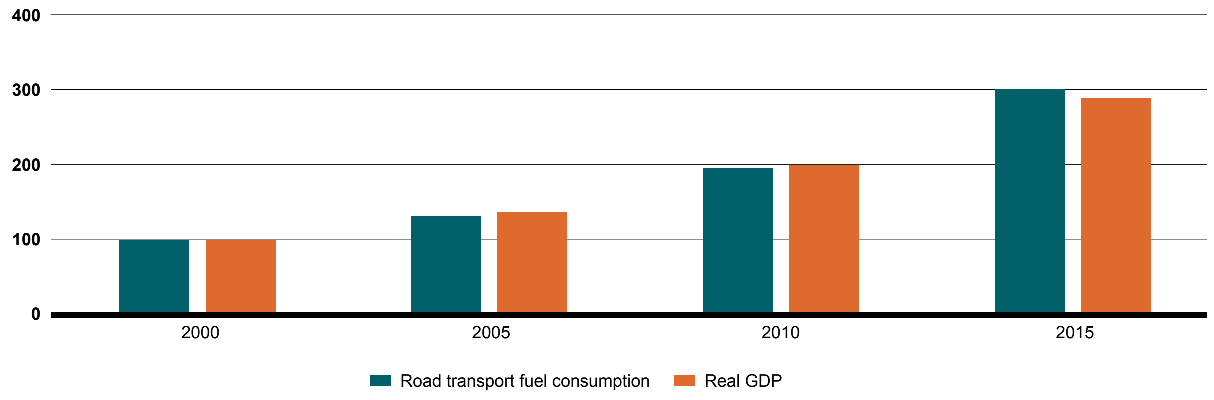
11.3 Environmental Tax on Fuels

The road-transport sector is a major contributor to $PM_{2.5}$ ambient air pollution in Lao PDR, especially in Vientiane Capital, causing severe health effects among the population. Fuel consumption in the sector nationwide tripled from 302 million liters in 2000 to 910 million liters in 2015 at an annual growth rate of 7.6 percent, slightly outpacing the growth of real GDP over the period (Figure 11.1).

Prior to 2018, excise taxes on transportation fuels in Lao PDR ranged from 20 percent above product costs for diesel to 35 percent above product costs for super gasoline. Aviation and other transportation fuels were taxed at lower rates.[138] Beginning in 2018, all transportation-fuel taxes were increased by 4 percentage points (Table 11.1).

While the primary goal of these excise taxes is to raise revenues, there is strong historical evidence that fuel taxes reduce long-term fuel demand by changing driving habits and/or by encouraging use of more fuel-efficient vehicles. Many studies have estimated demand elasticities for motor fuels.[139] Reduced fuel demand clearly improves air quality above baseline which, in turn, has a favorable impact on human health and the environment, including climate-related impacts. Specifically, a recent paper analyzed the effectiveness of environmental taxes by examining the environmental performance of 50 countries from all regions. Overall, the paper found that countries with higher revenues from environmental taxes also exhibit higher reductions in CO_2 and PM_{10} emissions (Miller and Vela 2013).

Figure 11.1 Growth in Road Transport Fuel Consumption and Real GDP in Lao PDR, Index 2000–2015



Source: Produced from MEM 2018 and World Bank 2019.

Table 11.1 Excise Tax Rates on Fuels in Lao PDR

	Gasoline (super) %	Gasoline (normal) %	Diesel %	Aviation %	Lubricants, hydraulic oils, and other %	Reference source
2011	25	20	10	10	5	Morgenstern chapter
2012	25	24	12	10	5	Tax Law 2012
2016–2017	35	30	20	10	5	Tax Law 2016
2018–current	39	34	24	14	9	Tax Law 2016

Further, and despite the concern that higher fuel taxes may discourage the purchase of larger, safer cars or cars versus motorcycles, the evidence is that reduced fuel demand also lessens road congestion, thereby saving time and cutting traffic accidents and road fatalities (for example, see IMF 2014).

This subsection considers the prospects for environmental taxes on transportation fuels. The proposed environmental taxes may be implemented by the development of the regulation mandated in Article 59 of the *Tax Law*. Since the administrative mechanisms for collecting fuel taxes are already in place, the new administrative burdens, if any, would be negligible. The key questions involve the estimation of the new revenues along with the health, environmental, congestion, and CO_2 benefits to be gained from a new tax hike. Arguably, the cost of air-pollution damage is much higher for diesel than for gasoline. As estimated by the IMF, a liter of diesel in Lao PDR imposes 2.5 times as much health damage as a liter of gasoline (IMF 2014). This suggests that any new fuel tax should be substantially higher for diesel. The higher damages associated with diesel could also support other policies unrelated to fuel—for example, higher vehicle taxes on diesel cars and light-duty trucks, and a ban on the importation of used light-duty diesel vehicles. For illustrative purposes, however, we consider here a simple hypothetical tax increase of 10 percentage points on all transportation fuels, to be imposed over a five-year period in equal increments of approximately 2 percentage points per year, starting in 2020.

The first step in understanding the multiple impacts of the new fuel tax is to calculate how the assumed 10 percentage point tax increase would affect demand for transportation fuels. Since the weighted average of current excise taxes on transportation fuels is approximately one-third of product costs, the assumed 10 percentage point increase in tax rates would increase end-use fuel prices by about 7.5 percent by the end of the fifth year (2024) (1.433/1.33 = 1.075).[140] Using a long-run demand elasticity estimate of *minus* 0.5 to *minus* 0.7 (IMF 2014; Sterner 2007) yields an estimated reduction in annual fuel use in Lao PDR of 3.85 percent to 5.39 percent below baseline starting in 2025. The five-year phase-in would result in roughly proportional fuel-use reductions in the earlier years.

Estimation of the additional revenues associated with the assumed tax hikes is relatively straightforward, as are the estimates of CO_2 reductions. A tax increase of 10 percentage points, which represents a 7.5 percent price increase at the pump, results in revenue increases ranging from 7.1 percent to 7.2 percent annually above baseline, depending on the demand-elasticity assumptions used.[141] Roughly proportional revenue increases would apply in the earlier years. CO_2 reductions in the transportation sector would be proportional to fuel-use reductions: 3.85 percent to 5.39 percent annually below baseline, starting in 2025.

Estimation of the multiple health, environmental, and congestion benefits associated with the tax hikes is more complicated, since detailed data and modeling capabilities generally available only in more-developed countries are required. However, two recent international studies about the health, environmental, and congestion benefits from transportation fuel-tax increases can help inform the benefits potentially attainable in Lao PDR from similar tax hikes.

The first of the two international studies reviewed here was developed by the US Environmental Protection Agency (EPA) in cooperation with the US National Highway Transportation Safety Administration (NHTSA). This study presents detailed model results on the domestic air quality benefits of a new regulation tightening fuel-efficiency requirements for new cars that would result in a 14 percent reduction in fuel use over a 34-year period (2017–2050). In addition to CO_2, the study estimates emissions of five major pollutants associated with the combustion of transportation fuels, including VOCs, CO, NOx, $PM_{2.5}$, and SOx. The US study also models the emissions of several toxic pollutants emitted by these fuels, including 1,3-butadiene, acetaldehyde, acrolein, benzene, and formaldehyde. Air-quality improvements associated with these improvements are estimated for different areas across the United States. In terms of human health impacts, the study estimates reductions in PM mortality and ozone-related health benefits, including both chronic and acute effects. Most of the major health effects are monetized using values from the literature. Since gasoline is the primary transportation fuel for light-duty vehicles in the United States, the more severe effects of diesel are under-represented versus the case of Lao PDR. (See Table 11.2 for selected results from this study.)

Table 11.2 displays the categories of human health and welfare effects associated with the fuel-use reductions, as developed in the US study.[142] As shown in Table 11.2, the effects are considered in two categories: (i) the quantified and monetized effects, and (ii) the unquantified effects. Premature mortality from $PM_{2.5}$ and from ozone are the two most important quantified/monetized health effects estimated by the US study. The myriad respiratory and cardiovascular impacts are also important from a health perspective. The total monetized value of the PM and ozone benefits estimated in the US study range up to US$2.6 billion for the year 2030 (2010 US$). The benefits from CO_2 reductions, estimated via the social cost of carbon, are in addition to those associated with PM and ozone.

Clearly, the value of fuel-use reductions in the United States are greater than those in Lao PDR because of the larger populations exposed, the differential nature of the control policies, the valuation of the health and environmental effects, and other factors. However, key factors weighting in the other direction are the greater use of diesel in Lao PDR and the stricter US fuel standards regarding sulfur, aromatics, and other contaminants. Both these factors increase the health and environmental benefits per million BTU of fuel-use

Table 11.2 Human Health and Welfare Effects of Pollutants Affected by Reduction in Fuel Use

	Quantified and monetized in primary estimate
PM: healtha	Premature mortality based on cohort study estimatesb and expert elicitation estimates. Hospital admissions: respiratory and cardiovascular. Emergency room visits for asthma. Nonfatal heart attacks (myocardial infarctions). Lower and upper respiratory illness. Minor restricted activity days. Work loss days. Asthma exacerbations (among asthmatic populations. Respiratory symptoms (among asthmatic populations). Infant mortality.
Ozone: health	Premature mortality based on short-term study estimates. Hospital admissions: respiratory. Emergency room visits for asthma. Minor restricted activity days. School-loss days.
Ozone: welfare	Decreased outdoor worker productivity.
	Unquantified benefits
PM: healtha	Low birth weight, pre-term birth, and other reproductive outcomes. Pulmonary function. Chronic respiratory diseases other than chronic bronchitis. Non-asthma respiratory emergency room visits. UVb exposure (+/-)c.
PM: welfare	Visibility in Class 1 areas in SE, SW, and CA regions. Household soiling. Visibility in residential areas. Visibility in non-class 1 areas and class 1 areas in NW, NE, and Central regions. UVb exposure (+/-)c. Global climate impactsc.
Ozone: health	Chronic respiratory damage. Premature aging of the lungs. Non-asthma respiratory emergency room visits. UVb exposure (+/-)c.
Ozone: welfare	Yields for commercial forests, fruits and vegetables, and other crops. Damage to urban ornamental plants. Recreational demand from damaged forest aesthetics. Ecosystem functions UVb exposure (+/-)c . Climate impacts.
CO: health	Behavioral effects.
Nitrate deposition: welfare	Commercial fishing and forestry from acidic deposition effects. Commercial fishing, agriculture and forestry from nutrient deposition effects. Recreation in terrestrial and estuarine ecosystems from nutrient deposition effects. Other ecosystem services and existence values for currently healthy ecosystems. Coastal eutrophication from nitrogen deposition effects.
Sulfate deposition: welfare	Commercial fishing and forestry from acidic deposition effects. Recreation in terrestrial and aquatic ecosystems from acid deposition effects. Increased mercury methylation.
HC/Toxics: healthd	Cancer (benzene, 1,3-butadiene, formaldehyde, acetaldehyde). Anemia (benzene). Disruption of production of blood components (benzene). Reduction in the number of blood platelets (benzene). Excessive bone marrow formation (benzene). Depression of lymphocyte counts (benzene). Reproductive and developmental effects (1,3-butadiene). Irritation of eyes and mucus membranes (formaldehyde). Respiratory irritation (formaldehyde) Asthma attacks in asthmatics (formaldehyde). Asthma-like symptoms in non-asthmatics (formaldehyde). Irritation of the eyes, skin, and respiratory tract (acetaldehyde). Upper respiratory tract irritation and congestion (acrolein).
HC/Toxics: welfare	Direct toxic effects to animals. Bioaccumulation in the food chain. Damage to ecosystem function. Odor.

Source: US EPA 2012.

Note: [a] In addition to primary economic endpoints, there are a number of biological responses that have been associated with PM health effects including morphological changes and altered host-defense mechanisms. The public health impact of these biological responses may be partly represented by our quantified endpoints. [b] Cohort estimates are designed to examine the effects of long-term exposures to ambient pollution, but relative risk estimates may also incorporate some effects due to shorter-term exposures (see Kunzli et al. 2001 for a discussion of this issue). While some of the effects of short-term exposure are likely to be captured by the cohort estimates, there may be additional premature mortality from short-term PM exposure not captured in the cohort estimates included in the primary analysis. [c] May result in benefits or dis-benefits. [d] Many of the key hydrocarbons related to this action are also hazardous air pollutants listed in the CAA.

reductions in Lao PDR relative to the United States. Due to the many uncertainties involved in comparing the situations in the two countries, no attempt is made to develop quantitative estimates of the health, environmental, and traffic congestion benefits in Lao PDR associated with the hypothetical transportation fuel-tax increases. However, even this qualitative review suggests they would be substantial.

The second study, *Getting Energy Prices Right,* was conducted by the International Monetary Fund (IMF 2014). It examined the benefits to 188 countries of adopting new fees or taxes on transportation fuels, labeled as *corrective taxes*. The focus in the following is strictly on the IMF estimates of the damages associated with liquid transportation fuels, including the categories of local air pollution, traffic congestion, road accidents, and global climate change. The IMF methodologies for estimating damages associated with local air pollution and road accidents are roughly like those used by the US EPA and NHTSA. An important contribution of the IMF analysis is that it integrates information from numerous databases compiled by international agencies and others and uses a consistent methodology to estimate the size of the required corrective taxes across all countries.

Within the overall framework of a global benefit-cost analysis, the IMF focuses on the single largest component of damages, namely the mortality risk from particulate matter with diameter up to 2.5 micrometers ($PM_{2.5}$). The IMF uses a technique known as *intake fractions*, which circumvents the need to use data and computationally intensive air-quality models, to estimate how much pollution is inhaled by exposed populations in different countries. Intake fractions depend on the height at which emissions are released (generally ground level for transportation fuels), the size of the exposed population, and the meteorological and topological conditions. Ambient ammonia concentrations are also considered. These pollution-damage estimates are then combined with information on local emission factors for different fuels to derive environmental damages from fuel use. Emission rates can vary considerably depending on the control technologies in use. When data are insufficient for specific countries, extrapolations are made from other areas.[143]

A final step values mortality risks—more precisely, the value per premature death avoided—across all 188 nations. Based on a widely reviewed OECD study (OECD 2012), which recommends starting international valuation of mortality risk reduction at US$3 million per life saved (2005 US$), the IMF adjusts the estimates for per capita income levels in different countries. As the IMF authors note, the implied mortality-risk values used in their cross-country calculations may differ substantially from the actual values used by decision-makers in the individual countries.

Congestion costs are based on the cost of reduced travel speeds for other road users per mile driven. There are two main components of the calculations: the amount of travel delay and the value of travel time, which is related to local wage rates. Delays are estimated via statistical models that include measures of GDP per capita, vehicle-miles traveled, road lengths, and the numbers of cars registered per capita. Trucks are assumed to contribute more heavily to congestion than cars.

The societal costs of road accidents include personal costs of both fatal and nonfatal injuries, medical costs, and property damages. Injury risks to pedestrians and cyclists, as well as to vehicle occupants involving multiple vehicles, are included in the IMF analysis of societal costs. Injuries to vehicle occupants in accidents involve single vehicles are excluded from the assessment, since those risks are assumed to be borne by the drivers rather than by society at large.

As the IMF notes (IMF 2014, 114–15),

> *higher income countries tend to have a lower incidence of injuries per mile driven because as countries develop vehicle and road safety tends to improve and the ratio of pedestrians and cyclists to motorists declines. The lower incidence of injuries is partially but not fully offset by higher valuations of fatality and injury risk in higher income countries*

The IMF also estimates road damage by attributing a portion of road maintenance to trucks, although these costs are relatively modest.

A summary of the IMF estimates of the corrective taxes are shown for the case of gasoline, in Table 11.3, for a sample of ten Asian countries, including Lao PDR.[144] The damages or corrective taxes are expressed in terms of 2010 US$ per liter of fuel consumed. Note that for all countries, carbon damages are estimated to be US$0.08 per liter, reflecting the global nature of the damages. In contrast, local air pollution damages vary by an order of magnitude across the Asian countries, from a low of US$0.007 per liter for Thailand to $0.06 per liter for Bangladesh. Lao PDR is below the average value for this category, at $0.02 per liter.

Congestion damages vary even more across the Asian countries, from US$0.006 per liter in Cambodia to US$0.21 per liter in China. The IMF did not estimate congestion damages for Lao PDR, presumably due to lack of data. Finally, to be noted is that accident damages differ by a particularly large amount. The lowest estimated damages are for the Philippines, at US$0.047 per liter. The highest damages are for Lao PDR, at US$1.699 per liter, probably due to the high use of motorcycles. The final column of Table 11.3 displays the total damages estimated for the Asian countries, which range from US$0.25 per liter in the Philippines to a high of US$1.80 per liter for Lao PDR, the latter almost entirely the result of the high damages associated with road accidents.

Results for diesel are displayed in Table 11.4. On average, local air pollution damages are nearly 4 times as high for diesel as they are for gasoline. In Lao PDR, local air pollution damages for diesel are 2.5 times as high as they are for gasoline. The total corrective tax on diesel is on average, however, slightly lower than on gasoline for the ten countries, albeit with large variation across the countries, with diesel to gasoline tax ratios ranging from 0.7 to 1.3.

There are several messages from this brief analysis of fuel-tax increases in Lao PDR based on the EPA/NHTSA and IMF studies:

- First, the long-term effect of raising fuel taxes is to reduce transportation-fuel use below baseline by changing driving habits and/or by encouraging use of vehicles that are more fuel-efficient.
- Second, the reduced fuel use for transportation will reduce local air pollution, traffic congestion, injuries, and fatalities. It will also reduce emissions of CO_2, which affects global climate change.

Table 11.3 Estimate of Corrective Tax on Gasoline, 2010 US$/liter

	Carbon	Local air pollution	Congestion	Accidents	Total
Bangladesh	0.08	0.067	0.011	0.287	0.45
Cambodia	0.08	0.022	0.006	0.623	0.73
China	0.08	0.039	0.210	0.217	0.55
India	0.08	0.036	0.029	0.632	0.78
Indonesia	0.08	0.021	0.075	0.145	0.32
Lao PDR	**0.08**	**0.020**	**NA**	**1.699**	**>1.80**
Malaysia	0.08	0.021	0.128	0.313	0.55
Philippines	0.08	0.012	0.111	0.047	0.25
Thailand	0.08	0.007	0.085	0.243	0.42
Vietnam	0.08	0.055	0.057	0.263	0.46

Source: Produced from IMF 2014.

Table 11.4 Estimate of Corrective Tax on Diesel, 2010 US$/liter

	Carbon	Local air pollution	Congestion	Accidents	Road damage	Total
Bangladesh	0.09	0.158	0.009	0.154	0.015	0.43
Cambodia	0.09	0.059	0.005	0.334	0.031	0.52
China	0.09	0.140	0.170	0.091	0.018	0.51
India	0.09	0.084	0.024	0.323	0.016	0.54
Indonesia	0.09	0.162	0.065	0.078	0.015	0.42
Lao PDR	**0.09**	**0.050**	**NA**	**NA**	**NA**	**NA**
Malaysia	0.09	0.191	0.111	0.168	0.015	0.58
Philippines	0.09	0.085	0.096	0.025	0.015	0.32
Thailand	0.09	0.077	0.074	0.130	0.015	0.39
Vietnam	0.09	0.13	0.050	0.141	0.015	0.43

Source: Produced from IMF 2014.

> Third, while the magnitude of the total benefits from reduced fuel use are difficult to calculate precisely in the case of Lao PDR, they are clearly significant, since they affect human health and the environment in a number of ways. Arguably, the case for higher taxes on diesel is greater than for gasoline.

> Fourth, the size of the *corrective taxes* appropriate to Lao PDR is substantially greater than current levels. The assumed 10 percentage point increase in taxes on transportation fuels over five years considered in this chapter is well below the IMF's estimated level of corrective taxes. Thus, such taxes carry virtually no risk of overshooting the IMF damage estimates.

11.4 Environmental Tax on Diesel Vehicles

Diesel vehicles are the main source of primary $PM_{2.5}$ emissions from road transport, with rapid dieselization having taken place over the last two decades in Lao PDR. This section discusses the possibility of implementing environmental taxes on diesel vehicles to reverse dieselization of light vehicles. The Lao PDR *Revised Tax Law 2016* mandates excise taxes on road-transport vehicles. Rates of taxation on vehicles are specified in Article 20 of the *Tax Law* and form the basis for the discussion in this section. The proposed environmental tax on diesel vehicles discussed here may be implemented by the development of the regulation mandated in Article 59 of the *Tax Law*.

11.4.1 Road-Transport Sector

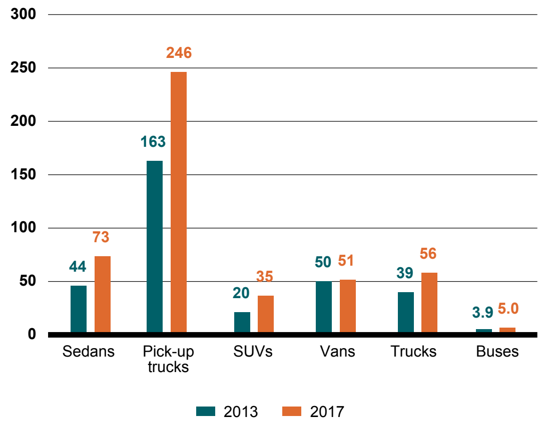
Lao PDR's rapid economic growth over the last three decades has created a surge in motorized transport and associated air pollution. As many as 33 percent to 38 percent of urban households now have at least one car, truck, or van, and 84 percent to 89 percent have at least one motorbike (LSB 2018a; 2018b).Nationwide, there were 465,000 registered sedans, pick-up trucks, SUVs, vans, trucks, and buses in 2017, up from 320,000 in 2013. The annual growth rate of these vehicles was 10 percent. The highest growth rates were for SUVs and sedans, but pick-ups still occupied the dominant share of vehicles with 246,000 in 2017, or 53 percent of all vehicles (Figure 11.2). Additionally, there were 1.5 million motorcycles in 2017, up from 1.1 million in 2013 (LSB 2015; 2018c).

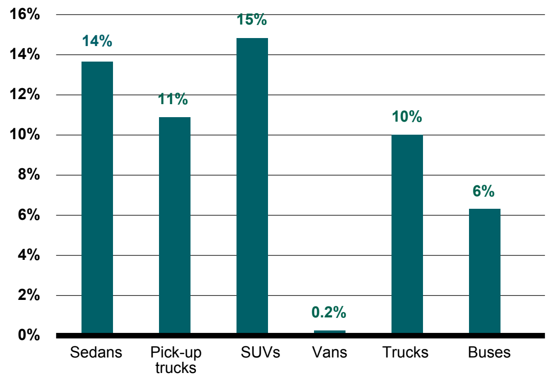
As many as 262,000 vehicles (4+ wheels) were registered in Vientiane Capital in 2017. Pick-ups constituted the largest category with 116,000 vehicles or 44 percent of total vehicles in the capital. Vehicles in the capital constituted 56 percent of vehicles in Lao PDR, although the population in Vientiane Capital is only 13 percent of the population in Lao PDR. The highest shares of vehicles in the capital were for sedans and SUVs with 79 percent and 70 percent of the nation's total, respectively (Figure 11.3). Additionally, there were 580,000 motorcycles, or 39 percent of the nation's total (LSB 2018c).

11.4.2 Dieselization in Road Transport

Transport fuel consumption has grown in tandem with the growth of the vehicle fleet. The recently prepared *Lao PDR Energy Statistics 2018* sheds light on this development (MEM 2018). Transport-fuel consumption increased from 303 million liters of gasoline and diesel in 2000 to 910 million liters in 2015. Diesel consumption more than tripled during this period, while gasoline consumption doubled. Annual growth in transport-diesel consumption was particularly high from 2005 to 2015 at 10 percent (Figure 11.4). This underscores the rapid dieselization of road transport that has taken place in Lao PDR.

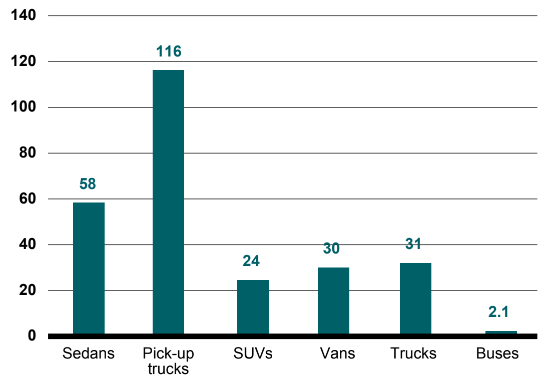
Figure 11.2 Registered Vehicles in Lao PDR, 2013–2017 (Left: ‘000; Right: % Annual Growth Rate)

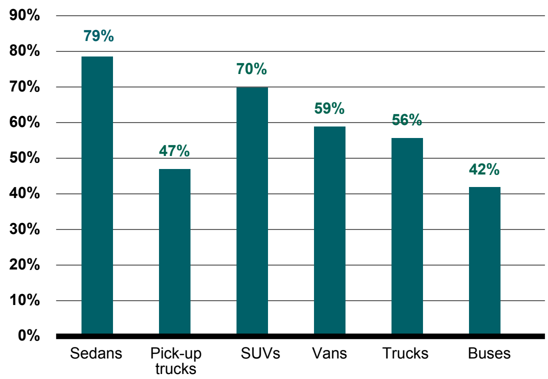




Sources: LSB 2015; 2018c.

Figure 11.3 Registered Vehicles in Vientiane Capital, 2017 (Left: ‘000; Right: % of Vehicles in Lao PDR)



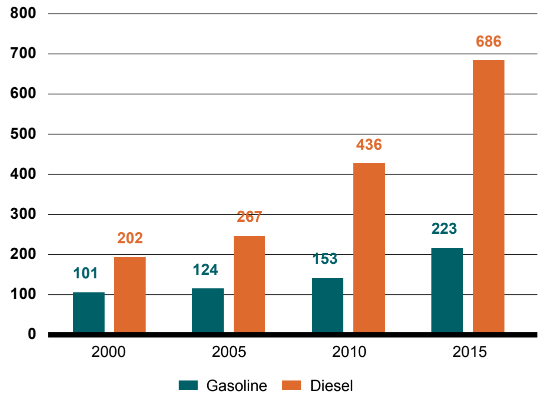


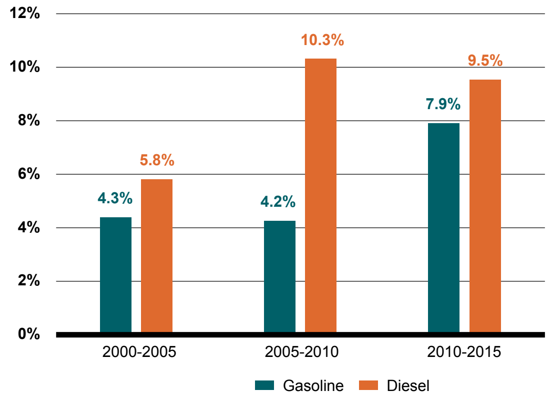
Sources: LSB 2015; 2018c.

The *Lao PDR Energy Statistics 2018* also provides estimates of transport-fuel consumption by vehicle category in 2015. First, the share of gasoline and diesel engines by vehicle category was estimated from a vehicle survey in Vientiane Capital. The survey found that 100 percent of pick-up trucks, vans, and buses, over 50 percent of SUVs and trucks, and 20 percent of sedans had diesel engines (Figure 11.5).

These estimates, along with the number of registered vehicles and with best judgements and assumptions about fuel efficiency (km/liter) and annual vehicle usage (km/year), resulted in estimates of gasoline and diesel consumption for each vehicle category. The estimates from MEM (2018) have been adapted here, with some modifications to fuel efficiency and annual vehicle usage, to provide fuel-consumption estimates that are consistent with the quantities of consumption presented in Figure 11.3. The results show that pick-up trucks are responsible for 53 percent of transport-diesel consumption in 2015, followed by trucks (19 percent), vans (16 percent), buses (6 percent), and SUVs and sedans (6 percent) (Figure 11.6). While these estimates are not precise, they do give a strong indication of the large share of diesel consumption by light vehicles (for example, pick-up trucks, vans, SUVs and sedans, and many smaller trucks) that could alternatively have been fueled by gasoline. The largest share of gasoline consumption is by motorcycles.

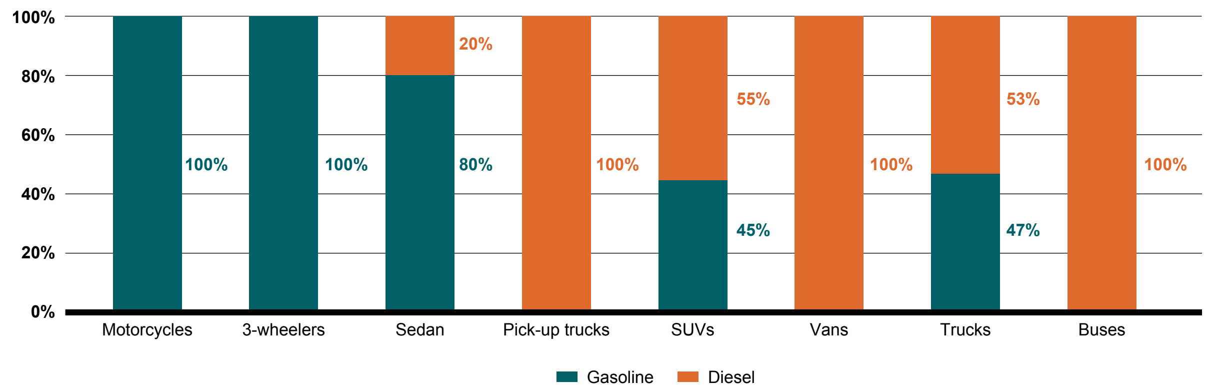
Figure 11.4 Transport Fuel Consumption in Lao PDR, 2000–2015 (Left: Million Liters; Right: % Annual Growth)





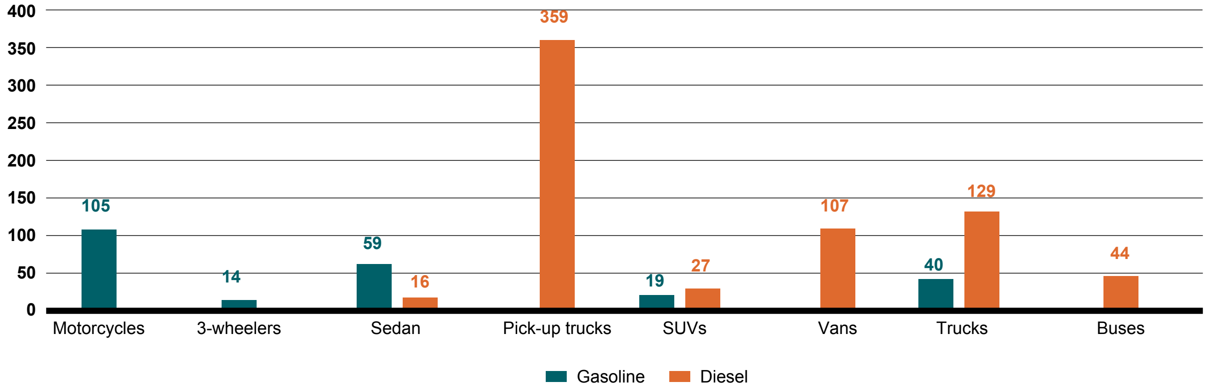
Source: MEM 2018.

Figure 11.5 Estimate of Vehicle Engine Fuel by Vehicle Category in Vientiane Capital



Source: MEM 2018.

Figure 11.6 Estimated Gasoline and Diesel Consumption by Vehicle Category in Lao PDR, 2015 (Million Liters)



11.4.3 Policy Options for Reversing Dieselization

Practically all primary $PM_{2.5}$ emissions from road vehicles (4+ wheelers) come from diesel engines.[145] Curtailing $PM_{2.5}$ pollution from road vehicles therefore requires interventions that reduce diesel-vehicle emissions. Several policy options are available, including (but not limited to) the following:

> Provision of low-sulfur diesel for road vehicles;

> Emissions standards on new vehicles (for example, EURO 4–6).

> Applying economic instruments or environmental taxes for managing transport-fuel demand—for example, taxes on fuels.

> Applying economic instruments to discourage road-transport dieselization—for example, differential taxes on gasoline versus diesel vehicles.

> Applying command-and-control instruments to prevent road-transport dieselization—for example, banning of light diesel vehicles.

Most countries implement a combination of two or more of these options to curtail air pollution from road transport.

The Decree on National Environmental Standards 2017 by MoNRE includes vehicle-emission standards equivalent to EURO 4. These vehicle-emission standards, for proper functioning of the technologies to control vehicle emission, necessitate road-vehicle diesel with a maximum of 50 ppm sulfur content, which is the maximum allowable limit in Thailand and Vietnam (the maximum limit in China is now 10 ppm for road-transport vehicles).

Lao PDR also has excise taxes on gasoline and diesel, which from 2018, according to the *Revised Tax Law 2016*, is 24 percent on diesel, 34 percent on regular gasoline, and 39 percent on super gasoline.

The *Tax Law 2016* also specifies excise taxes on *small*, *medium,* and *large* vehicles. The *Tax Law* defines *small* vehicles as passenger vehicles seating a maximum of 9 persons (for example, sedans, SUVs, pick-up trucks, and vans); *medium* vehicles as passenger vehicles seating 10–30 persons or trucks with weight of 3.5–15 tons; and *large* vehicles as passenger vehicles seating more than 30 persons or trucks weighing more than 15 tons.

For *small* gasoline and diesel vehicles, the tax rates are 25 percent to 90 percent depending on engine size. For two-door pick-ups/lorries with pick-up length longer than 50 percent of the length from front to rear wheels, however, the tax rate is 10 percent, since these vehicles are considered used mainly for commercial purposes. The tax rates for *medium* and *large* vehicles are 8 percent and

5 percent, respectively. For vehicles using *clean energy* such as electric, solar, and other forms of clean energy, the tax rate is 10 percent for *small* vehicles and 5 percent for *medium* and *large* vehicles (Table 11.5). The excise tax rates on the most common motorcycles (that is, 100–150 cc) are 20 percent to 30 percent.

The excise-tax regime on road transport in Lao PDR encourages vehicle-fuel efficiency and reduced vehicle usage from the tax on gasoline and diesel and encourages the purchase of passenger vehicles with smaller engine size (and greater fuel efficiency) from the vehicle-tax structure. This is good for the environment. However, the lower fuel tax on diesel (24 percent) than on gasoline (34 percent to 39 percent), coupled with the same vehicle tax rate on gasoline and diesel vehicles, has encouraged and is continuing to encourage rapid dieselization in road transport. The lower tax on diesel fuel may be intended to protect the commercial transport sector, but its environmental effect is severe unless coupled with counteracting measures.

One such counteracting measure is either an outright ban on small diesel vehicles, or an additional (environmental) tax on small diesel vehicles. This tax may be partially offset by a small or moderate reduction in the tax on gasoline vehicles so that the new tax regime will receive broader support among vehicle owners.

The advantage of an outright ban is total prevention of small diesel vehicles. The advantage of an environmental tax on small diesel vehicles is that it allows flexibility for vehicle owners. The advantage of a diesel vehicle is very minor for some owners, such as urban users with relatively low annual vehicle usage. These individuals would mostly purchase a gasoline vehicle if taxes are higher on diesel vehicles. Other owners may consider a diesel engine to have substantial advantages. This will mainly be owners with high annual vehicle usage who need the added durability of a diesel engine for substantial vehicle usage outside of urban areas, where the health impacts per unit of $PM_{2.5}$ emissions are lower than in urban areas due to low population density. Many of these

Table 11.5 Excise Tax Rates on Road Transport Vehicles in Lao PDR

Vehicle category	Gasoline, diesel fuel* (%)	Clean energy (%)
Small vehicles		
Engine size (cc)		
<= 1,000	25	10
1,001–1,600	30	10
1,601–2,000	35	10
2,001–2,500	40	10
2,501–3,000	45	10
3,001–4,000	70	10
4,001–5,000	80	10
> 5,000	90	5
Two-door pick-up/lorry**	10	5
Medium vehicles	8	5
Large vehicles	5	5

Source: Lao PDR Tax Law 2016.
Note: *Includes gas and other liquid fuels. ** With pick-up length longer than 50 percent of the length from front to rear wheels.

vehicle owners may continue to purchase a diesel vehicle even if taxes are higher, because they consider the value to be greater than the cost of the tax.

Therefore, to allow flexibility for various vehicle owners, an environmental tax on small diesel vehicles (along with a small or moderate reduction in the tax on gasoline vehicles) is considered here instead of an outright ban. One desirable option is to structure the environmental tax on diesel vehicles and reduction in the tax on gasoline vehicles such that tax revenues remain fairly similar to the current vehicle-tax regime. The lowering of the tax on gasoline vehicles will make the change in the tax regime more acceptable to vehicle owners, since it will compensate purchasers of gasoline vehicles instead of diesel vehicles for the higher tax on gasoline fuel. The increase in tax on small diesel vehicles needs to be large enough to achieve the desired objective of reversing dieselization—that is, to encourage most users to purchase gasoline vehicles.

Table 11.6 presents one scenario of change in the vehicle-tax regime. The proposed new tax rates continue to vary by engine size to encourage the purchase of vehicles that are smaller, more fuel efficient, and less polluting. The new tax rates on gasoline vehicles are 10 percentage points lower than the current tax rates and the new environmental tax on diesel vehicles bring taxes on diesel vehicles to twice the new rates on gasoline vehicles. If these differential tax rates result in a two-thirds reduction in the purchases of small diesel vehicles, and a corresponding increase in the purchases of small gasoline vehicles, then government revenues from vehicle taxes will remain unchanged. Moreover, government revenues from fuel taxes will increase because the tax on gasoline is higher than on diesel.

From the perspective of vehicle owners, the proposed new tax regime will save vehicle owners who purchase gasoline vehicles instead of diesel vehicles on the order of US$3,000 to US$14,000 depending on engine size. On the other hand, the increase in fuel cost from purchasing a gasoline vehicle amounts to approximately US$200 to US$550 per year as a result of the higher gasoline price and somewhat lower fuel efficiency of gasoline vehicles. The one-time vehicle cost saving is on the order of 15–30 times the increase in annual fuel cost, depending on type of vehicle. For pick-ups, which is the most important vehicle category for which to reverse dieselization, the saving is about 15 times the increase in annual fuel cost.

Table 11.6 Current and Proposed New Excise Tax Rates on Small Vehicles

	Current tax rate (%)	Proposed new tax rate (%)	
Engine size (cc)	Gasoline, diesel	Gasoline	Diesel
<= 1,000	25	15	30
1,001–1,600	30	20	40
1,601–2,000	35	25	50
2,001–2,500	40	30	60
2,501–3,000	45	35	70
3,001–4,000	70	60	120
4,001–5,000	80	70	140
> 5,000	90	80	160
Two-door pick-up/lorry	10	10	40

11.5 Industrial Water Effluent Fee

Discussions have been underway in Lao PDR for some time about the possibility of imposing a water-discharge tax or fee on industrial sources as a way to help stem the growing water-pollution problems, as described in the World Bank's *Lao PDR Environment Monitor 2005*.[146] This section, which draws on the work of Laplante (2015), outlines some of the key issues that need to be addressed in establishing a water-discharge fee. The preferred approach involves creation of a new, two-part fee: a basic tax obligation that does not depend on discharge volumes and a second part that is variable in that the more (or less) the firm pollutes, the more (or less) it pays. Because of the resources required to develop facility-specific discharge information to implement the second phase of the tax, the preferred approach might involve starting with the basic per facility charge. Then, using the revenues generated by the basic fee, build the necessary monitoring and reporting infrastructure needed to implement the second phase, including

> the measurement of wastewater discharges and requirements for the use of wastewater meters;

> clear instructions for the periodic self-monitoring and reporting of pollution discharges; and

> a system for verification and enforcement.

The main incentives for pollution control will come from the effective implementation of the PPP principle to create incentives for firms to reduce pollution. Notwithstanding monitoring and enforcement issues, this will be achieved if the fee per unit of pollution is sufficiently high to induce changes in firm behavior. Although not discussed here in detail, other (complementary) incentives could also be adopted—for example, tax incentives for clean production technology or water recycling, and incentives to relocate to less populous areas. There are several key issues to consider in the design of the industrial water-discharge fees:

> Which pollutant(s) to include?

> Which industrial polluters to include?

> What is the appropriate fee structure?

> How to account for different size of firms?

> How to estimate the fee base?

> What is the appropriate fee level?

11.5.1 Pollutant(s) to Include

Biological oxygen demand (BOD) or chemical oxygen demand (COD), and total suspended solids (TSS) are most commonly included in the list of targeted pollutants for industrial water discharges. Some countries also include selected heavy metals or other toxics in their pollution-fee schemes. While it seems logical to include toxics in any new tax scheme, monitoring of these substances can be challenging. Unsurprisingly, targeting a large number of pollutants has proved a very difficult task to implement in many countries. Based on past experiences, focusing on a limited number of water pollutants at first and then expanding the coverage as expertise and capacity increase are likely to yield better results.

11.5.2 Industrial Pollution Projection System (IPPS)

Most industrial water pollution in Lao PDR originates from the manufacturing and mining and quarrying sectors. Each sector requires its own specific interventions to minimize and control pollution. The focus of this chapter is the manufacturing sector.

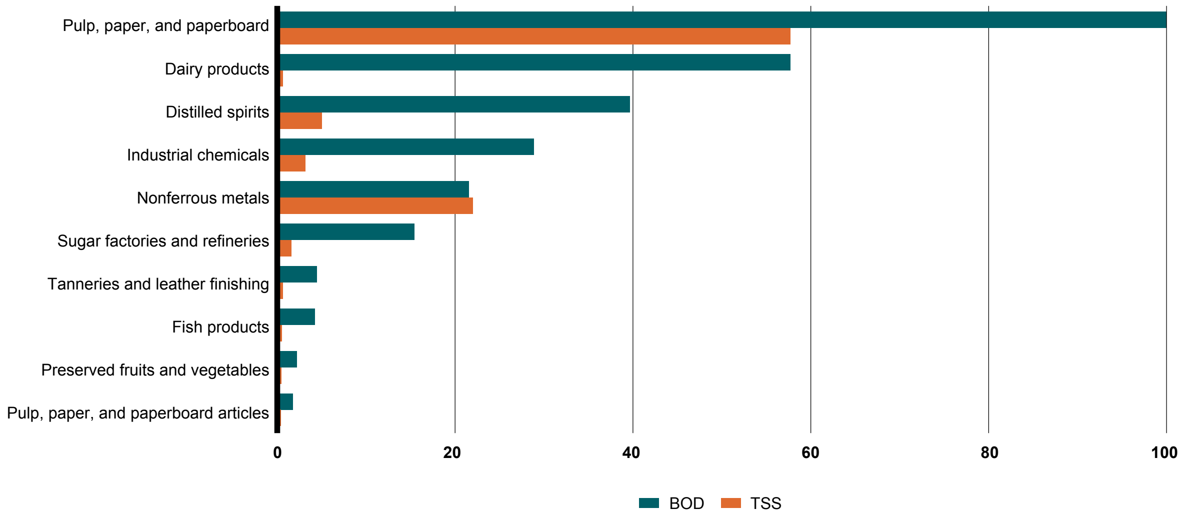
Quantitative information on water-pollution loads from the manufacturing sector in Lao PDR is very limited. Nevertheless, the GMS Core Environment Program administered by the Asian Development Bank undertook an estimation of pollution load based on the Industrial Pollution Projection System (IPPS) and the Lao PDR Enterprise Database of the Ministry of Industry and Commerce (ADB 2015).

The IPPS provides industrial pollution coefficients for pollution to water, air, and land from manufacturing sectors classified according to International Standard Industrial Classification (ISIC) 4-digit codes. The pollution coefficients are kg of pollutants per US dollar of output, value added, or employment in each sector. The water pollutants are BOD, TSS, a composite of toxic chemicals, and a composite of toxic metals including mercury, lead, arsenic, cadmium, chromium, nickel, copper, and zinc (Hettige et al. 1995).

The manufacturing sectors with the highest BOD and TSS water pollution per US dollar of output value according to IPPS are presented in Figure 11.7 and Figure 11.8. Only two of the sectors with high BOD also have high TSS, while several of the sectors with high TSS also have high BOD.

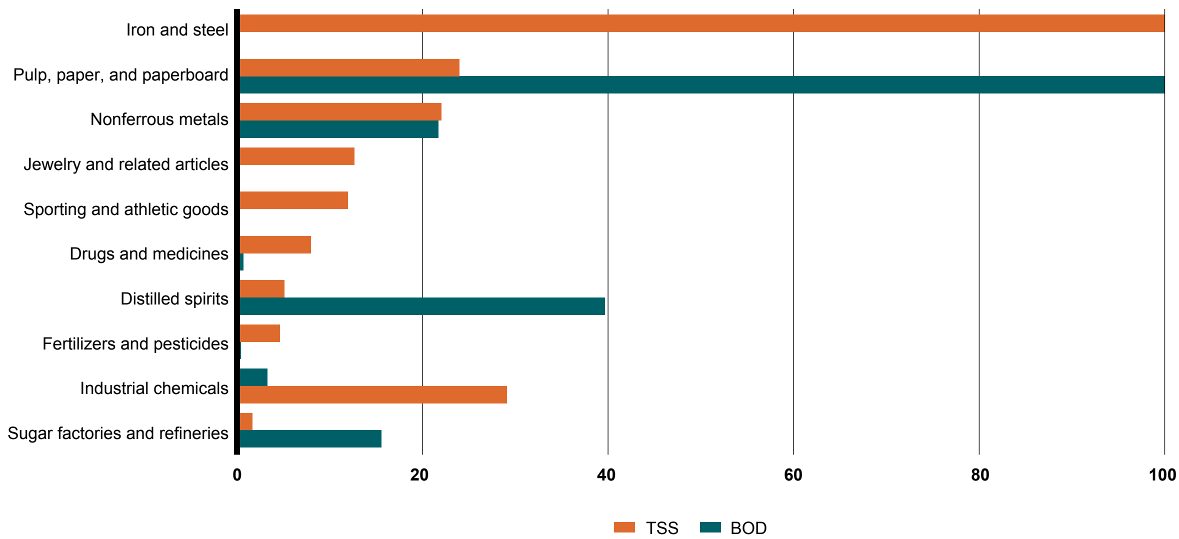
The manufacturing sectors with the highest intensity of toxic water pollution per US dollar of output value are mostly chemical and metal industries, along with

Figure 11.7 BOD Water Pollution Intensities from Manufacturing Industries, Index



Source: Produced from IPPS data in Hettige et al. (1995).

Figure 11.8 TSS Water Pollution Intensities from Manufacturing Industries, Index



Source: Produced from IPPS data in Hettige et al. 1995.

pulp and paper and a few other sectors (Figure 11.9). There is some overlap between these sectors and those with high BOD and/or TSS water pollution. These sectors are industrial chemicals (BOD), iron and steel (TSS), pulp and paper (BOD and TSS), and nonferrous metals (BOD and TSS), which are four of the five sectors with the highest intensity of toxic water pollution. Looking at all manufacturing sectors at the ISIC 4-digit level, there is some correlation between BOD and toxic chemical intensity, and between TSS and toxic metals intensity.[147]

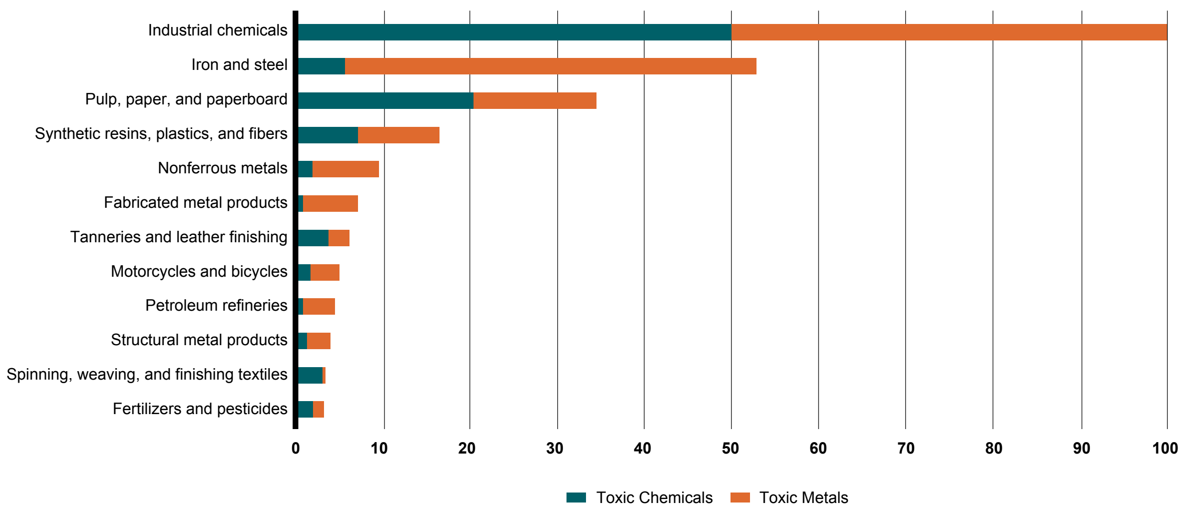
11.5.3 Manufacturing Sector in Lao PDR

The industrial sector share of GDP in Lao PDR reached 31 percent in 2017, up from 16.5 percent in 2000 (World Bank 2019). Electricity and construction contributed 54 percent of industrial value added, while mining and quarrying, manufacturing, and water supply and sewage contributed 46 percent (Figure 11.10).

The manufacturing sector's share of GDP stood at 7.5 percent of GDP in 2017, with the manufacturing sector's growth in value added at 8.6 percent per year since 2000. This has resulted in a quadrupling of the sector since 2000. Food; beverages and tobacco; and textiles, clothing, footwear, and leather goods stood at 53 percent of manufacturing value added in 2017 (Figure 11.11).

Other manufacturing, contributing 47 percent of value added, includes cement; other non-metallic mineral products; basic metals; chemicals; wood, wood products, and furniture; pulp and paper; rubber and plastic products; fabricated metal products; machinery, transport vehicles, and various equipment; and other manufacturing products.

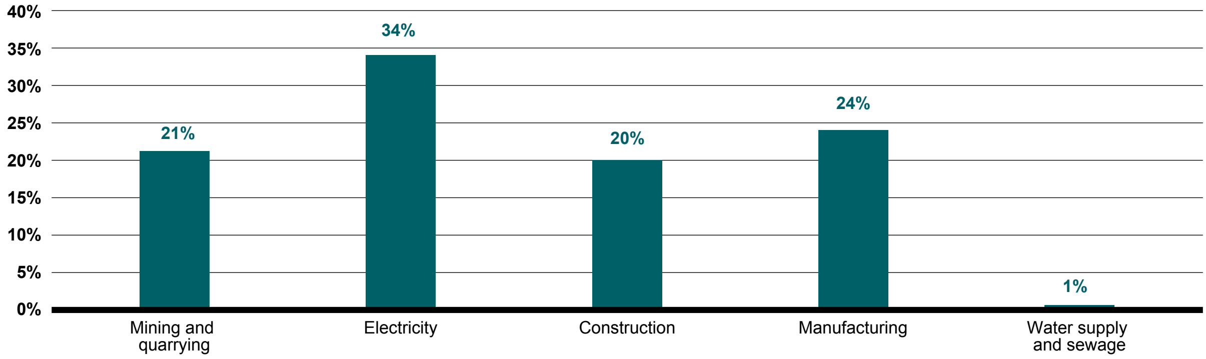
Figure 11.9 Manufacturing Sector Water-Pollution Intensities of Toxic Chemicals and Metals, Index



Source: Produced from IPPS data in Hettige et al. 1995.

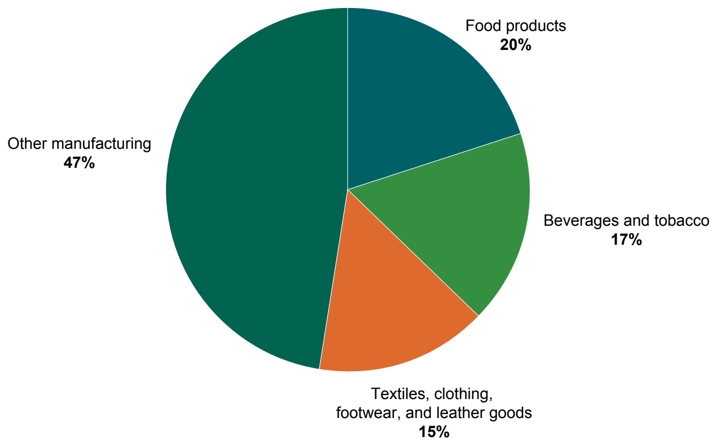
Note: Indexes were created separately for toxic chemicals and toxic metals pollution intensities in terms of kg of toxic pollution per US dollar of industrial output value, based on data in Hettige et al. (1995). A combined index, presented in this chart, was then created that gave equal weight to the toxic chemicals and toxic metals indexes.

Figure 11.10 Share of Industrial Value Added in Lao PDR, 2017



Source: LSB 2018c.

Figure 11.11 Share of Manufacturing Value Added in Lao PDR, 2017



Source: LSB 2018c.

11.5.4 Industrial Polluters to Include

The estimation of industrial pollution load undertaken by the GMS Core Environment Program was based on an analysis of approximately 12,000 enterprises contained in the Lao PDR Enterprise Database of the Ministry of Industry and Commerce in 2012 (ADB 2015). The current number is likely higher. Nearly 7,000 enterprises were excluded from the analysis, since these enterprises had only 1 or 2 employees, and they likely were not manufacturing enterprises. Some other enterprises were also excluded due to lack of data. The final number of enterprises analyzed was therefore nearly 4,900.

For administrative and other practical reasons, it may not be feasible to include all these enterprises in the initial tax scheme for water effluents. More importantly, it is not necessary to target all industrial polluters to achieve significant reductions in industrial pollution discharges, since a large share of industrial water is discharged by a relatively small number of industrial sectors and facilities.

With respect to the discharge of BOD and TSS, more than 65 percent of all industrial discharges from manufacturing originate from only 3 sectors. The iron and steel sector alone is estimated to produce more than 60 percent of total manufacturing sector emissions of TSS (Table 11.7).[148]

Table 11.7 Share of Effluent Discharges of TSS and BOD in Lao PDR

Industrial Sector	Share of Total Discharges of TSS
Iron and steel basic industries	61%
Non-ferrous metal basic industries	14%
Pulp, paper, and paperboard	8%%
	Share of Total Discharges of BOD
Basic industrial chemicals	23%
Pulp, paper, and paperboard	23%
Dairy products	20%

Source: ADB 2015.

Within each of these sectors, a limited number of enterprises contribute most of the discharges. As shown in Table 11.8, the largest 25 enterprises of the iron and steel basic industries and non-ferrous metal basic industries contribute to 77 percent and 87 percent, respectively, of all TSS emissions of their own sector.

Industrial water effluents of toxic chemicals and toxic metals from the manufacturing sector are also highly concentrated in a few sectors. The basic industrial chemicals and iron and steel sectors are responsible for 82 percent of toxic chemicals, and basic industrial chemicals is responsible for 75 percent of toxic metals (Table 11.9).

The analysis suggests that much can be achieved by initially targeting three sectors:

> Basic industrial chemicals;

> Iron and steel basic industries; and

> Pulp, paper, and paperboard industry.

According to IPPS and information from the Lao PDR Enterprise Database, these three industrial sectors are responsible for the following share of discharges:

> 86 percent of toxic chemicals;

> 84 percent of toxic metals;

> 69 percent of TSS; and

> 46 percent of BOD.

These percentages should be considered indicative and orders of magnitude, but nevertheless point to the concentration of water pollution from a few main manufacturing sectors. The analysis undertaken by the GMS Core Environment Program can be updated using more-recent information in the Lao PDR Enterprise Database. This can be combined with industrial pollution audits of the largest manufacturing enterprise in the most polluting sectors. Even in the absence of detailed and comprehensive measurements of water-effluent pollutants, such audits are useful for understanding likely pollution loads based on enterprise size, type of products and production volumes, industrial process and pollution abatement technologies, and environmental management practices.

Table 11.8 Share of Effluent Discharges of Largest Enterprises in Lao PDR

Industrial sector	Number of enterprises a	Contribution of largest 10 enterprises	Contribution of largest 25 enterprises
		TSS	
Iron and steel basic industries	103	49%	77%
Non-ferrous metal basic industries	60	71%	87%
Pulp, paper, and paperboard	8	100%	100%
		BOD	
Basic industrial chemicals	63	51%	76%
Pulp, paper, and paperboard	8	100%	100%
Dairy products	149	25%	40%

Source: ADB 2015. **Note:** a Registered with the Ministry of Industry and Handicraft in 2014.

Table 11.9 Share of Effluent Discharges of Toxic Chemicals and Metals in Lao PDR

Industrial sector	Share of total discharges of toxic chemicals
Basic industrial chemicals	54%
Iron and steel basic industries	28%
Non-ferrous metal basic industries	5%
Pulp, paper, and paperboard	4%
	Share of total discharges of toxic metals
Basic industrial chemicals	75%
Pulp, paper, and paperboard	9%
Iron and steel basic industries	5%

Source: ADB 2015.

11.5.5 Fee Structure

The fee structure should consider both the effectiveness of the environmental tax and the tax's ability to raise revenues. To address these potentially competing principles, a fee structure known as a two-part tariff could be adopted:

> A first part would be fixed in the sense that it does not depend on the level of pollution itself.

> A second part would be variable in that the more a firm pollutes, the more it pays. The less it pollutes, the less it pays. The variable component is simply the product of the per unit pollution fee and the quantity of pollution discharged.

The purpose of the fixed part of the fee structure is to generate revenues for the government to undertake the implementation of the pollution fee system. Regardless of the level of pollution, the fixed component of the discharge provides assurance that a given amount of revenues will be available for implementing the environmental tax program. The main purpose of the variable fee is to create incentives for pollution control. This two-part tariff system has been successfully applied in Canada—for example, British Columbia and Quebec—and in the Philippines. In the 2012 revision of its pollution fee system, Vietnam replaced the fee structure it had in place since 2005 with a two-part tariff. Of course, firms of different sizes may also be treated differently with respect to the level of the annual fixed payment. If so, the basic fee could be designed such that the level of the annual fixed payment is smaller (higher) for smaller (larger) firms. One plausible criterion is to group firms into different sizes depending on the quantity of wastewater discharged or, alternatively, based on water use.

11.5.6 Appropriate Fee Levels

As displayed in Morgenstern (2019: appendix), annual fixed payments in the Philippines vary between US$50 and US$100; in Vietnam, annual fixed payments vary between US$50 and US$500. Regarding the level of the fee per kilogram (or ton) of targeted pollutants, economic theory suggests the appropriate fee level should be set equal to the value of the marginal damages—a number that would be extremely difficult to estimate for Lao PDR based on the available data. In practice, the level of the pollution fee depends on several factors:

> The level of pollution fees in other countries,

> The amount of revenues estimated to be necessary to implement the pollution fee system; and, importantly

> Negotiated agreements with the targeted stakeholders.

Variable fees differ considerably across countries and over time. As Laplante (2015) notes, in the Philippines, in 1997 a fee of PHP 5/kg was implemented. The fee is the same today and would correspond to a fee of roughly US$110 per ton of BOD or per ton of TSS. In Vietnam, the 2012 revision introduced a fee of VND 1,000—3,000 per kilogram of COD and per kilogram of TSS, corresponding to approximately US$50 per ton. In the Philippines, firms must pay a fee on BOD or TSS (per criteria defined in the regulation) while in Vietnam, firms must pay a fee on COD *and* TSS.

In Lao PDR, industrial discharges of BOD, COD, and TSS have been subjected to regulatory standards and monitoring for more than a decade. Standards for toxics are much newer. Focusing on BOD, COD, and TSS also offers the distinct advantage that laboratory analysis to measure their concentrations in a given sample is relatively inexpensive (unlike other pollutants such as heavy metals or toxics). Further, in the process of abating BOD, COD, and TSS, some heavy metals and toxics may also be abated in significant proportion. Hence, these three pollutants would appear to be a reasonable starting point given the existing experience and capacity. At the same time, there are a number of reasons why both BOD and COD should not be targeted at the same time, and that COD could be a more reliable target than BOD:

> If there are traces of toxics or heavy metals in the firm's effluent, then the biological process may be impaired, and BOD may be an unreliable measure of pollution;

> The actual measurement of BOD can vary significantly from one laboratory to another depending on the equipment used and the handling of the sampling. BOD, unlike COD, is known to experience large margins of error;

> Information on COD concentrations can be obtained much faster than for BOD.

As noted, most industrial discharges of pollutants in Lao PDR originate from a small number of industrial sectors, at most 3 or 4. Within those sectors, a limited number of enterprises discharge most water pollutants. Thus, a strategy for targeting specific industrial sectors and/or specific enterprises may be the most appropriate way to start the system. Over time, as more experience is gained and better information is obtained on the nature of discharges from multiple industries and enterprises, the system can be expanded.

Three distinct but related approaches could guide the selection of polluters to include in the initial tax scheme:

> Approach 1: Select specific industrial sector(s) and apply the pollution fee to all firms within those sector(s);

> Approach 2: Select the largest sources of pollution discharges regardless of the sectors to which they belong and regardless of the areas where they are located;

> Approach 3: Select specific areas (such as provinces or districts) and apply the pollution fee to all or a subset of firms within those areas.

Each approach has its pros and cons. A disadvantage of both Approach 2 and Approach 3 is that they may violate the principle of fairness. The selection of the largest sources of pollution regardless of sectors will necessarily imply that within a given industrial sector, some enterprises will pay the pollution fee and others not. A similar outcome will arise with the selection of geographic areas to apply the pollution fee scheme. Furthermore, an approach based on geographic areas could potentially give rise to *leakage* whereby new industrial facilities would elect to locate in areas for which there is no pollution fee system. For these reasons, the selection of specific industrial sectors to include in the initial pollution fee scheme may be more appropriate.

As Lao PDR aims to implement pollution fees, it is important not to put its industries at a competitive disadvantage. Thus, pollution fees would best be set at levels like those of other countries in the region. With respect to the basic fixed fee, regional experience indicates a fee ranging between US$50 and US$500, depending on the size of the firm, may be suitable. Referring back to Table 11.8, which covers only five industries registered with the Ministry of Industry and Handicraft in 2014, this fee structure would yield annual revenues ranging from approximately US$20,000 to US$200,000 in the first year if applied equally to all enterprises in the five industries. Expansion to other industries would increase revenues based on the number of enterprises included. Annual revenues could rise to as much as US$6,000,000 if the basic fees were applied to all 12,000 enterprises registered in 2014. To avoid erosion of the value of the wastewater fees over time due to inflation, the fees should be adjusted annually to reflect the previous year's rate of inflation. If the decision is to collect more information on the nature of the discharges before deciding on the variable fee, no short-term decisions on the variable rate(s) are required.

11.6 Conclusions

Environmental taxes or fees, often used in tandem with other management approaches, are proving to be effective, efficient, and fair mechanisms for improving health and the environment around the world. They can also raise revenues to finance public expenditures, including environmentally related activities, compensation to low-income groups, and general government needs. Further, they create incentives for the development and adoption of new technologies.

In the broadest sense, environmental taxes can correct for negative side effects or externalities and efficiently exploit diverse possibilities for reducing damaging emissions associated with production or consumption activities. Consistent with the polluter pays principle, the specific tax design should reflect the magnitude of the health, environmental, and other damages. At the same time, some of the revenues could be used to support loans or grants for projects proposed by government agencies or the private sector for the purpose of pollution control or reduction.

Three potential new environmental tax initiatives in Lao PDR include (i) an environmental tax on road-transportation fuels; (ii) an environmental tax on diesel vehicles; and (iii) a new, two-part water-discharge fee on industrial polluters.

The environmental tax on transportation fuels would augment the existing revenue stream and result in long-run reductions in fuel use, yielding measurable health and environmental benefits. Since it builds on the existing administrative apparatus, it would not pose significant implementation challenges. At the same time, the relative tax increases to be imposed on gasoline versus diesel is a difficult issue. While the IMF study suggests diesel-fuel use results in 2.5 times as much health damages as gasoline, further research on this issue is warranted.

The environmental tax on diesel vehicles is intended to reverse the dieselization among small vehicles that has taken place over the last two decades in Lao PDR. The dieselization has contributed to substantial $PM_{2.5}$ ambient air pollution with severe health effects, especially in Vientiane Capital.

Creation of a new industrial water-discharge fee is more challenging. The two-part fee design involves a basic tax obligation not dependent on discharge volumes and a second variable part that is directly tied to discharge amounts. Inasmuch as successful implementation of the second part is dependent on reliable facility-specific data not currently available, a phased approach might be the most practical way to develop the database and reporting mechanisms needed to implement the second phase.

For the development of water discharge fees, several key challenges need to be addressed. The precise definition of covered pollutants and polluters, as well as the amount of the discharge fees, are all difficult issues. The experiences of other countries can certainly inform these decisions. In the end, however, local considerations, both environmental and economic, are paramount. The practical barriers to implementing systems for environmental taxes/fees will be largely administrative in nature. Since industrial facilities in Lao PDR are not currently subjected to requirements for the self-monitoring and reporting of their pollution discharges, estimates of discharge volumes will have to be developed via enforceable requirements to provide these data. Clear guidance will be needed for this purpose, along with capacity building in both the public and private sectors.

Beyond the environmental tax options examined here, officials in Lao PDR may also want to consider other opportunities to add economic incentive mechanisms to their policy mix, either as complements to, or substitutes for, command-and-control approaches. Within a PPP framework that is either revenue neutral or revenue generating, other environmental taxes, deposit refund schemes, or emissions trading are the clear options. It may be appropriate to drop the requirement for revenue neutrality, or for tax or financial subsidies for clean technologies or clean substitutes. In all cases, careful thought should be given to the efficiency, effectiveness, fairness, and ease of implementation of any new proposals.

In considering and designing environmental taxes and other economic incentives, the GoL can incorporate a number of lessons from energy-subsidy reforms undertaken by countries around the globe, including (1) adoption of taxes or elimination of subsidies that can result in price increases for consumers should be part of a comprehensive, long-term strategy, developed in consultations with stakeholders; (2) a clear and extensive communication strategy should be carried out, emphasizing how these measures will help to solve severe environmental and social problems; (3) establishment of new taxes or subsidy removals should be complemented with targeted measures to protect the poor; and (4) decisions on how to update and manage these economic instruments should be based on automatic and transparent pricing mechanisms, with the aim of depoliticizing the issue (IMF 2013b).

11.7 Notes

131 This chapter was prepared by Richard Morgenstern, with inputs from Bjorn Larsen, and draws upon additional material by the same author presented in a background study (Morgenstern 2019) containing additional information in support of the analyses, including an appendix relating to case studies outside of Lao PDR.

132 https://stats.oecd.org/glossary/detail.asp?ID=723

133 The OECD Council on Guiding Principles Concerning International Economic Aspects of Environmental Policies in 1972 describes this principle as follows: "The principle to be used for allocating costs of pollution prevention and control measures to encourage rational use of scarce environmental resources and to avoid distortions in international trade and investment is the so-called 'Polluter-Pays Principle'. This principle means that the polluter should bear the expenses of carrying out the above-mentioned measures decided by public authorities to ensure that the environment is in an acceptable state. In other words, the cost of these measures should be reflected in the cost of goods and services which cause pollution in production and/or consumption. Such measures should not be accompanied by subsidies that would create significant distortions in international trade and investment." (See www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=OCDE/GD(92)81&docLanguage=En)

134 Emissions trading systems are of two types: (i) the more common, mass-based system (sometimes known as cap and trade), which fixes total emissions (the cap); and (ii) a rate-based system, which fixes an emissions rate but not the total quantity of emissions. A rate-based approach is central to China's new CO2 emissions-trading system and has been used in a few US programs (see Goulder and Morgenstern 2018).

135 A more complete comparison between market-based and command-and-control policies can be found in Harrington, Morgenstern, and Sterner (2004).

136 Emissions trading and other PPP-compatible economic instruments have been used around the world in lieu of environmental taxes. While there are important differences between the various economic instruments, they all have the effect of pricing emissions/discharges taxes. Since environmental taxes generally involve less-demanding institutional arrangements than other economic instruments and are more commonly used in developing countries, they are the focus of this chapter.

137 Earlier efforts at environmental taxation were overly ambitious and had to be scaled back, due largely to difficulties in measuring and monitoring emissions/discharges. For example, the *Decree on Environmental Protection Charges for Wastewater* in June 2003 required both domestic and industrial sectors to pay a fee for discharging wastewater in the environment. The fee was first applied to 7 pollutants (including 4 heavy metals), although BOD was removed from the list because of monitoring concerns. Subsequently, the metals were also removed. Since 2012, industrial enterprises pay solely on their water discharges of chemical oxygen demand (COD) and TSS.

138 The excise tax is in addition to the small environmental tax already in place.

139 See, for example, Hughes et al. (2008); Levin, Lewis, and Wolak (2016); Park and Zhao (2010); Pock (2010); and Small and Van Dender (2007).

140 This calculation assumes the tax is fully passed forward to consumers without additional markups.

141 Specifically: 7.5 percent x (1.0 – 0.0385) = 7.2 percent; 7.7 percent x (1.0 – 0.0539) = 7.3 percent.

142 Clearly, the underlying policy proposals for tightened fuel-economy standards and the assumed transportation tax hikes differ dramatically from one another: The proposed US policy only affects new cars versus all vehicles in Lao PDR; the analysis covers a much longer time period in the United States: 34 years in the United States versus 5 years in Lao PDR. Other differences between the two situations involve population densities, GDP/capita, meteorology, and other related metrics, as well as differences in the underlying fuel quality. US transportation fuels have strict content standards regarding sulfur content, aromatics, and other characteristics, as compared to less-strict standards in Lao PDR. Notwithstanding all these differences, the same fuel-use metric applies in the case of the modeled US fuel-economy standards and the assumed transportation tax hikes in Lao PDR.

143 To establish baseline mortality rates for illnesses potentially aggravated by pollution, the IMF draws on the World Meteorological Organization's Global Burden of Disease project, which estimates the increased likelihood of mortality with the extra pollution and compares it to the baseline mortality rates.

144 Taken from IMF worksheets:
http://www.imf.org/external/np/fad/subsidies/data/subsidiestemplate.xlsx

145 Secondary $PM_{2.5}$ from vehicles formed in the atmosphere from gaseous vehicle emissions (that is, nitrogen oxides and sulfur dioxide) come from both gasoline and diesel vehicles.

146 Available at http://siteresources.worldbank.org/NEWS/Resources/report-en.pdf

147 Correlation coefficients of 0.48 and 0.68, respectively.

148 These data are from ADB (2015) "*Estimating Industrial Pollution in Lao PDR"*; they are available on the GMS website at www.gms-eoc.org.

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12

POLICY OPTIONS FOR STRENGTHENING LAO PDR'S INSTITUTIONAL FRAMEWORK FOR GREEN GROWTH[149]

Chapter Overview

The previous chapters of this report reveal strong linkages among environmental quality, economic growth, and social well-being of the 7 million inhabitants of the Lao People's Democratic Republic. The information presented in this report is a comprehensive assessment prepared after two years of targeted diagnostic research and analysis of issues and conditions within Lao PDR. The analysis was conducted by an international World Bank team in cooperation with counterparts in lead government agencies in Lao PDR. Information from the Ministry of Health, the Ministry of Natural Resources and Environment, and others provided an initial basis for the assessments, and this was complemented by other international information. The results can be regarded as a state-of-the-art contribution of information to decision-makers in Lao PDR having an interest in achieving sustainable growth consistent with the 2019 National Green Growth Strategy.

The scope of this report includes consideration of impacts on key economic sectors and on risk factors influencing the health of the population, which are discussed in detail in chapter 3. The assessments also encompassed the economic costs of degradation in the forestry, agriculture, fisheries, mining, and hydropower sectors, as presented in chapter 4. Within the context of the Mekong River and its watershed, chapter 4 also addresses climate-change impacts including increased risks of flooding. In chapter 6, the report identifies solid-waste management and plastics as an important priority to which the Government of Lao PDR has already pledged its support in regional and global initiatives.

The analytical work presented in this report clearly finds that the impacts of pollution on human health are among the most urgent priorities for Lao PDR. The assessments of pollution's impacts on human health in Lao PDR attribute some 10,000 deaths per year (or 21.6 percent of all deaths in the country) to four environmental health risk factors—household air pollution alone represents 44 percent of the 10,000 annual pollution-related deaths. These risk factors also caused nearly 100 million days of illness in 2017. Illness from these factors in turn decreases enjoyment of life, increases costs of treatment, and lowers economic productivity. All told, the costs of such deaths and illnesses were equivalent to 14.6 percent of national gross domestic product (GDP) in 2017 (Table 12.1).

The urgent message of this report is that all the identified issues must be, and can be, systematically addressed. The scope of recommendations is informed by benefit-cost analyses to help identify efficient interventions ranging from simple solutions already successfully adopted in other countries to more complex approaches targeted to improving household air quality. Innovative financial mechanisms associated with environmental taxes or fees are also considered.

All recommendations are considered carefully within the scope of the effectiveness of existing laws (including the Environmental Protection Law), the division of authority within the current institutional framework, and the role of environmental and social impact assessments (ESIA) in environmental planning. A number of reforms should be pursued to address priority challenges—all are realistically achievable if there is political will. All can contribute meaningfully to improved environmental quality, more-sustainable green economic growth, and alleviated poverty.

Table 12.1 Annual Cost of Environmental Degradation in Lao PDR (% GDP) in 2017

Household air pollution	5.68%
Ambient air pollution	3.50%
Water, sanitation, and hygiene	2.89%
Microbiological pollution	2.62%
Arsenic in groundwater	0.27%
Lead (Pb) exposure	2.52%
Lead (Pb) exposure—children	1.87%
Lead (Pb) exposure—adults	0.65%
Subtotal for environmental health costs	**14.6%**
Cost of deforestation	1.6%
Cost of forest degradation	1.1%
Cost of natural disasters	0.9%
Cost of soil degradation	0.6%
Cost of hydropower development and fish-habitat destruction	0.5%
Cost of artisanal gold mining exposure to mercury	<0.1%
Subtotal for natural resource degradation and natural disasters	**4.7%**
Total	**19.3%**

12.1 Context

Lao PDR has achieved rapid growth and poverty reduction since 2000. GDP has grown at an average annual rate of 8 percent since the beginning of the century. Lao PDR has been the second-fastest growing economy in ASEAN and among the world's 15 fastest-growing economies. Rapid economic development was associated with a fall in the percentage of the nation's population living in poverty, from 46 percent in 1992 to 23 percent in 2015.

However, income disparity is a persistent, and growing, challenge. The Gini index increased from 31 in the 1993 to 39 in the 2019. The top fifth of the population controls 44 percent of the country's wealth, while the bottom fifth controls only 8 percent. Income disparity is also evident from a geographic perspective: most of the wealth is concentrated in the Vientiane area, where only about 10 percent of the population lives.

Lao PDR's historical growth trajectory has also been associated with environmental degradation. Key economic activities underpinning Lao PDR's economic dynamism included uncontrolled mining, unregulated and illegal logging, hydropower-sector expansion, and inefficient agriculture. While these activities provided important economic gains, they have also resulted in significantly high rates of natural resource depletion and exposure to significant environmental health risks. The annual cost of environmental degradation is estimated at 19.3 percent of GDP in 2017.

12.2 Highlights of Diagnostic Analysis

Major environmental problems are associated with environmental health and represented an annual cost equivalent to 14.6 percent of GDP in 2017. The highest cost is due to household air pollution. Inadequate water supply, sanitation, and hygiene; outdoor ambient air pollution; and lead exposure also represent pressing challenges. In addition, problems associated with degradation of natural resources and losses from natural disasters have an annual cost that represented 4.7 percent of GDP in 2017.

Waste generation in Lao PDR stands at 0.15 kilograms daily per person, making it among the lowest in Asia. Nonetheless, the quantities generated are poorly managed and present risks to human health and the Mekong River watershed. Open dumps constitute 60 percent of waste-disposal sites. Plastics are currently recognized as a global issue and find their way into the Mekong watershed destined for global oceans. In Vientiane, plastics constitute 12 percent of the total waste stream.

As elsewhere in the world, the distribution of pollution impacts falls primarily on the vulnerable. Children bear the largest burden of lead pollution, suffering an estimated annual loss of 340,000 IQ points. The impairment of learning capacity from lead pollution has long-term implications such as lower incomes and compromised quality of life. Women suffer disproportionately from household air pollution, since they traditionally prepare the meals. Use of wood for cooking is the main cause of household air pollution. Almost 98 percent of the poorest households use wood for cooking, compared with 22 percent among the richest households. Income is also associated with other environmental health risks.

Only 58 percent of the poorest households use improved sources of drinking water and 25 percent have access to improved sanitation, compared with 100 percent and 99 percent, respectively, among the highest quintile. The incidence of diarrheal disease among children under 5 years of age is about 75 percent higher among children from the two poorest quintiles of the population than among children from the richest quintile. The degradation of natural landscapes and degradation of soils undermines the livelihoods of rural dwellers and pollution exposes them to diseases and heavy metals in regions where health services are unavailable or inadequate.

Climate-change hazards will exacerbate current human health issues and degradation of natural resources. The International Panel on Climate Change models suggest that maximum monthly flows in the Mekong Basin will increase by 35–41 percent, while minimum monthly flows will drop by 17–24 percent by 2100, further aggravating flood and drought risks. Rice production is also at risk to higher temperatures and shifts in rainfall.

12.3 Key Findings Informing Environmental Health Intervention Options

Benefit-cost analysis is used to help identify appropriate interventions for addressing environmental health and natural resource degradation issues. A wide number of interventions readily available to tackle Lao PDR's environmental health priorities have benefit-cost ratios (BCR) higher than 1, meaning that the social benefits from implementing them outweigh their costs (Table 12.2).

Table 12.2 Benefit-Cost Ratios of Interventions to Tackle Environmental Health Priority Challenges

Intervention	BCR (range)
Household air pollution control interventions	2.1–4.0
Interventions to reduce microbiological pollution in drinking water	1.5–7.5
Interventions to reduce arsenic in groundwater	8.5–17.0
Interventions to control ambient $PM_{2.5}$ in Vientiane Capital	0.4–6.6

One overriding priority is to achieve 50 percent clean energy use for cooking over the next 10 years by households increasing the use of gas (LPG) and electric stoves.

Four priorities emerge in the drinking-water and sanitation sector: (i) further investigation into the status of household drinking-water quality, (ii) a pilot promotion program for household point-of-use treatment of drinking water focusing on ceramic filtering and solar disinfection, (iii) addressing arsenic contamination of drinking water in the center and south of Lao PDR, and (iv) rural sanitation to end open defecation.

Three priorities are evident for combatting ambient air pollution: (i) implement ambient air quality monitoring first and foremost in Vientiane Capital; (ii) undertake $PM_{2.5}$ source-apportionment studies in Vientiane Capital to identify priority sectors for air pollution control, and design cost-effective interventions; and (iii) implement no-regret interventions including control of $PM_{2.5}$ emissions from household cooking and diesel vehicles, halting of household burning of waste/debris, and combatting street dust.

Two priorities are crucial regarding assessing the status of lead (Pb) exposure: (i) undertake a study to measure children's blood lead levels to determine exposure levels; and (ii) undertake a study to identify lead sources, including in the household environment, outdoor community environment, school environment, and specific sources such as lead-based paint, toys, ornaments and jewelry, traditional medicines, cosmetics, and utensils.

12.4 Key Findings Informing Natural Resource Degradation Options

The poor continue to depend on natural resources. A substantial share of their food is from the forest and local water resources. Own-caught fish and wild meat are important sources of protein for the poor, and forest food contributes substantially to dietary variation and nutrition. Non-timber forest products (NTFPs) are also an important source of income for the rural population and the poor, but some NTFPs are being over harvested and are on the decline in several provinces. While Lao PDR still has substantial forested lands, degradation and deforestation affect the poor disproportionately.

Economically viable means can be developed to address diverse issues, ranging from flood mitigation to adoption of new seed varieties. Agroforestry is an important potential intervention that mitigates degradation of forest quality and agricultural lands. The benefits of these interventions are generally higher than the costs of implementing them (Table 12.3).

Scale also plays a role in determining viability. Large-scale aquaculture provides opportunities for maintaining fishery productivity; family-scale aquaculture is not economic using standard criteria, but it would nonetheless provide a secure supply of nutrition to vulnerable populations in the event of emergencies.

For mitigating natural hazards, it may also be noted that investments in early warning systems are generally warranted. This would include development of improved flood forecasts and education programs on how people should respond to warnings.

12.5 Institutional Findings and Selected Policy Options

The Government of Lao PDR (GoL) has taken important steps to strengthen the institutional framework for environmental management and green growth. In June 2011, the National Assembly of Lao PDR endorsed the establishment of the Ministry of Natural Resources and Environment (MoNRE). MoNRE was established by combining departments and divisions related to natural resources and environment such as land, forest, geology-minerals, water resources, and environment from different ministries and agencies. The creation of MoNRE was based on the need to improve coordination, collaboration, and integration of natural resources and environment management. MoNRE has a mandate as a secretariat and key regulator for direct management of land, forest, water, air, and biodiversity and minerals. Its mandate also includes management of climate change, disaster, meteorology, and hydrology throughout the country.

Table 12.3 Summary of Benefit-Cost Ratios for Interventions to Mitigate Natural Resource Degradation

	BCR (range)
Forestry: Rubber plantations	0.8–2.2
Forestry: Reforestation	1.7–2.3
Forestry: Agroforestry	1.2–4.9
Soil erosion: Terraced production	2.6–3.1
Soil erosion: Improved seed varieties	2.1–2.2
Soil erosion: Agroforestry	1.2–4.9
Fishery management: Fish passages	0.9–3.8
Fishery management: Family aquaculture	0.3
Fishery management: Large aquaculture	1.0–1.1
Flood management: Infrastructure	0.4–1.7
Flood management: Early warning system	2.2–2.6
Mining mitigation: Artificial wetlands	1.2–3.1

The GoL has also adopted a number of policies and laws to mainstream green growth into long- and medium-term plans. Recent regulatory improvements, supported by the Green Growth Development Policy Operation (GGDPO) series, include the adoption of science-based, stringent standards for ambient air quality and key interventions to reduce exposure to lead and other harmful pollutants.

However, Lao PDR's legal, policy, and organizational framework has yet to set environmental health and pollution-management challenges as a priority, particularly with regard to specifically addressing the pollution challenges that result in the highest social and economic impacts.

Budget allocations for environmental protection in Lao PDR are insufficient to address severe pollution problems. Moreover, available resources are not used to tackle priority environmental health challenges, largely because there are no formal mechanisms in place to identify priorities using analytical work, assess interventions to tackle them, and allocate resources to implement such interventions as part of multiyear plans and programs.

Regarding the enforcement of the National Environmental Quality Standards (NEQS), environmental agencies are unable to monitor pollutant discharges, and regulatory actions are only undertaken in response to public complaints. As such, regulatory enforcement is selective and shallow. In addition, provinces are mired in administrative, funding, and staffing difficulties that prevent them from enforcing the NEQS.

Problems with ESIA in Lao PDR include inadequate screening, overly narrow scope for assessments that are conducted, poor quality of reports, inadequate capacity to evaluate ESIA documents, insufficient public participation, and a general lack of monitoring of projects' compliance with ESIAs' approval conditions. A better solution would be to create an environmental management system in which EIA is not the only conduit through which the productive sectors are required to deal with environmental considerations. Draft reforms are being developed with the aim of improving the efficiency and consistency of ESIAs, strengthening coordination among key agencies that participate in the various ESIA stages, and bolstering disclosure of information to the public and public participation in the ESIA review process.

Lao PDR has also taken steps to use SEAs to integrate environmental and social sustainability, as well as SDGs, into all policies, programs, and strategic plans. SEA regulations are now ready to be implemented for a variety of policy-level topics, including hydropower and the National Green Growth Strategy. The SEA regulations will guide public servants and practitioners on the best practices for designing and implementing SEAs, developing institutional capacity over time, and supporting better decision-making. Implementing ESIA and SEA reforms will call for dedicated efforts to build institutional capacity at MoNRE and other government agencies participating in them, phasing and piloting of improved procedures, and balancing the trade-offs between existing goals, such as reducing timeframes for approval of ESIAs, while also providing conditions for meaningful public participation.

Environmental taxes provide an opportunity for applying the polluter pays principle to change behavior and raise revenues. The 2012 *Tax Law* provides the legal framework to establish environmental taxes on individuals and organizations generating pollution and environmental degradation. The same law specifies that tax revenues will be used to treat, rehabilitate, or clean pollution. This report considers three realistic tax mechanisms that have proven successful in other jurisdictions and could be similarly applied in Lao PDR: (i) an increase in excise fuel taxes, (ii) a higher tax on small diesel vehicles that contribute significantly to ambient $PM_{2.5}$ pollution, and (iii) water-effluent charges. These mechanisms complement a green growth agenda that respects competitiveness of domestic industry and achieves other social goals such as reduced congestion and reduced traffic fatalities.

To address Lao PDR's environmental priorities effectively, a full range of environmental instruments could complement EIA regulations. These include (i) direct regulation by government—that is, so-called *command-and-control* measures; (ii) economic and market-based instruments; and (iii) others, including public disclosure, legal actions, and formal negotiation. The result would be a network of environmental regulations that would have fewer gaps and fewer bad incentives.

Policy options to accelerate Lao PDR's transition towards green growth include the following:

> **Supporting environmental institutions**. MoNRE was established in 2011 and is still in the process of consolidation. MoNRE's capacity should be expanded at the central and provincial levels by increasing the number of staff as well as their levels of professional education and experience. Funding will also be needed to augment MoNRE's capacity to conduct environmental monitoring and enforce compliance with environmental regulations.

> **Priority setting.** Currently, there are no formal mechanisms in place in Lao PDR that use analytical work to identify priorities and to incorporate priorities into multi-year planning processes. Also missing are mechanisms to incorporate the concerns of groups most severely affected by environmental degradation into Lao PDR's planning processes, as well as clear criteria to efficiently allocate scarce financial and human resources for environmental management at subnational levels. The creation of a group within MoNRE to conduct the analytical work to identify priorities would provide analytically sound foundations for setting environmental priorities across sectors and for budget allocation in response to those priorities. The budgetary allocation for environment should be informed by a priority-setting mechanism such as an analysis of the cost of environmental degradation.

> **Promoting coordination.** A necessary condition for improving coordination among environmental authorities and line departments is the establishment of a system for collecting credible data on the institutional performance of environmental agencies. These data are needed for planning coordinated activities and monitoring institutional performance. Disseminating and publicly disclosing such data can create strong incentives for compliance with coordinated plans and for improved institutional performance[150].

- **Strengthening the demand side of accountability and creating an enabling environment for social accountability.** It is crucial that a more systematic effort be made to raise awareness of environmental issues. Possible avenues for raising awareness include publication of data in support of key environmental indicators (including health statistics or pollution loads) and greater use of public forums to discuss environmental issues.

- **Developing and implementing alternative environmental policy instruments.** Gaps in environmental policies, weak enforcement, and deficient technical capacity have rendered Lao PDR's environmental management framework ineffective to reduce environmental degradation in the country. Environmental regulations only apply (or are only enforced) for a limited subset of activities, and some of the most polluting activities are systematically neglected by environmental regulation. Government regulators lack resources to enforce the regulatory framework. Because of this, enforcement is selective and compliance with regulations is extremely low.

12.6 Outlook and Policy-Action Matrix

A path forward requires setting priorities and selecting specific actions that address the various challenges and linkages identified in this report. A preliminary policy-action matrix has been developed that can serve as a basis for ongoing policy dialogues and discussions (Table 12.4). Priorities and timelines are indicative, intending to provide greater emphasis on immediate human health issues, with secondary priority normally placed on long-term natural resource degradation issues unless there exist strong immediate feedbacks to human health.

Within natural resource issues, highest priorities are placed on actions that can correct past externalities while still contributing to future *green growth.* Actions associated with mitigating natural hazards are prioritized based on cost effectiveness, but it may be noted that many of the cheapest—those associated with early warning systems—are very cost effective in protecting human lives and economic infrastructure. As a complement to all of these, ongoing institutional reforms and capacity building must be undertaken to ensure that other actions can be managed effectively. The policy-action matrix is deliberately not provided in geographic detail by province, although it may be noted that approaches and priorities may differ from one region to the next. An eventual target must be to continue a pace of poverty reduction that supports vulnerable individuals wherever they may be in the nation.

The World Bank support, through the GGDPOs, has contributed to design and adopt policy reforms that already represent important steps to confront Lao PDR's priority environmental challenges. Reforms adopted to date are aligned with key challenges identified in this report.

12.7 Notes

149 This chapter was prepared by Jack Ruitenbeek and Ernesto Sánchez-Triana.

150 The Vice Minister of Planning and Investment recommended that high-level officials should monitor and report the priority issues identified by this report at government meetings so that policies can be developed to address urgent environmental challenges that harm people and the environment.

Table 12.4 Lao PDR Environment and Green Growth Policy-Action Matrix—Priorities and Timeline

		Policy Action Period			Policy Action Target			
Core Area	Policy Intervention	Immediate Priority	Medium-Term	Long-Term	Environmental Health	Natural Resources Degradation	Disaster Mitigation	Institutional Strengthening
Institutions and Environment Planning (§2 §5)	Re-establish and augment historical budget allocations for environmental protection	■			■	■	■	■
	Enhance capacity to perform analytical work for priority-setting	■	■		■	■	■	■
	Enhance capacity to enforce National Environmental Quality Standards (all administrative levels)	■	■		■	■		■
	Continued reforms in environmental planning to introduce complementary instruments for EIA and ESIA	■			■	■		■
	Pilot selected reform options: procedural changes, reduced timeframes, new avenues for public participation	■	■		■	■		■
Environmental Health (§5 §9)	Household Air Pollution: Promote clean engergy use in cooking		■		■			■
	Household Air Pollution: Assess potential for promoting the use of electric stoves for cooking	■			■			■
	Drinking Water and Sanitation: Undertake pilot program on solar disinfection and ceramic filtering	■			■			
	Drinking Water and Sanitation: Address arsenic contamination (center and south Lao PDR)	■	■		■			
	Drinking Water and Sanitation: Invest in rural sanitation to end open defecation	■	■		■			
	Drinking Water and Sanitation: Continue assessments on household drinking water quality		■		■			■

		Policy Action Period			Policy Action Target			
Core Area	Policy Intervention	Immediate Priority	Medium-Term	Long-Term	Environmental Health	Natural Resources Degradation	Disaster Mitigation	Institutional Strengthening
Environmental Health (§5 §9)	Ambient Air Pollution: Implement ambient air quality monitoring in Vientiane Capital and other cities	■	■		■			
	Ambient Air Pollution: Undertake $PM_{2.5}$ source apportionment studies in Vientiane Capital	■			■			
	Ambient Air Pollution: Control of particulate emissions from household cooking and diesel vehicles	■			■			
	Ambient Air Pollution: Control street dust		■	■	■			■
	Lead Exposure: Undertake a blood lead level measurement study of children	■			■			
	Lead Exposure: Conduct a lead source identification study in households, communities, schools, and specific sources	■	■		■			
Natural Resources Degradation (§4 §10)	Improve analytical informtion base: Acquire better and more accurate maps of forests, both type and extent		■	■		■		■
	Improve analytical informtion base: Improve quantitative estimates of soil loss from erosion		■	■		■		■
	Improve information base on use of chemical pesticides and fertilizers		■		■	■		■
	Promote large-scale aquaculture to maintain fishery productivity		■	■		■		
	Increase adoption of agroforestry to mitigate land degradation and diversify income sources in poor areas	■	■			■		

Table 12.4 Lao PDR Environment and Green Growth Policy-Action Matrix—Priorities and Timeline (continued)

		Policy Action Period			Policy Action Target			
Core Area	**Policy Intervention**	**Immediate Priority**	**Medium-Term**	**Long-Term**	**Environmental Health**	**Natural Resources Degradation**	**Disaster Mitigation**	**Institutional Strengthening**
Natural Resources Degradation (§4 §10)	Adopt and develop new seed varieties that are resilient to climate-change hazards		■	■		■	■	■
	Consider protective defenses for flooding in high-population areas and critical agricultural assets		■	■	■	■		
	Implement early warning systems for flooding (forecasting, dissemination, public education)	■	■		■	■	■	■
	Develop a comprehensive and accessible system for monitoring water quality, especially downstream from mining		■		■	■		■
Solid Waste Management (§6)	Ambient Air Pollution: Ban open burning of household and other waste	■			■			
	Ban imports of plastics, e-waste, and other recyclables		■			■		
	Improve the institutional and regulatory framework for solid waste management	■						■
	Strengthen planning, information systems, and citizen engagement	■						■
	Promote elements of a circular economy to improve esource-use efficiency			■		■		
	Establish legal requirements for hazardous and medical waste management	■						■
	Establish standards for landfills in urban areas	■						■

		Policy Action Period			Policy Action Target			
Core Area	Policy Intervention	Immediate Priority	Medium-Term	Long-Term	Environmental Health	Natural Resources Degradation	Disaster Mitigation	Institutional Strengthening
Poverty Reduction and Economic Growth (§7 §8)	Integrate environmental health and natural resource degradation issues in investment and development planning		■	■	■	■		■
Poverty Reduction and Economic Growth (§7 §8)	Clear unexploded ordnance from poorest and most contaminated districts	■			■			
	Increase participation of vulnerable groups into new development initiatives		■	■				■
	Promotote family-scale aquaculture in vulnerable rural areas	■	■			■		
Environment Taxation (§11)	Develop and implement alternative envrionmental policy instruments		■	■				■
	Increase environment tax on road transportation fuels	■	■		■			■
	Consider a new environmental tax on diesel vehicles		■		■			■
	Consider a new, two-part water discharge fee on industrial polluters		■	■	■	■		■

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

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

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