Climate Compatible Growth

RESOURCE EFFICIENCY IN LAO PDR INDUSTRY: GUIDELINES FOR A SUSTAINABLE INDUSTRIAL DEVELOPMENT

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List of Abbreviations

BAU	Business-as-usual
CCG	Climate Compatible Growth programme
GDP	Gross Domestic Product
GGGI	Global Green Growth Institute
GHG	Greenhouse Gas Emissions
GWP	Global warming potential
HCFC	Hydrochlorofluorocarbon
ICT	Information and communication technology
LAK	Lao Kip
Lao	The People's Democratic Republic of Lao
LDC	Least developed country
MoIC	Ministry of Industry and Commerce
MVA	Manufacturing value added
NDC	Nationally Determined Contributions
NSEDP	National Socioeconomic Development Plan
NUOL	National University of Laos
ODOP	One District One Product
SEC	Specific Energy Consumption
SME	Small- and medium-sized enterprise
USD	United States dollars

Unit Abbreviations

GW	Gigawatt
kt	kilotonnes
kWh	kilo-Watt-hour
ML	Megalitre
Mt	million tonnes
T	tonnes
TJ	Terajoule

Executive Summary

The People's Democratic Republic of Lao (hereafter Lao) is a landlocked Southeast Asian country which borders Thailand, China, Myanmar, Cambodia, and Viet Nam. The economy in Lao had been steadily increasing since the early 2000s, but declined during the COVID-19 pandemic. Lao depends on natural resources for economic growth and exports, especially agriculture and forestry products, mining and quarrying, and hydroelectricity. The actions taken as the country recovers from the economic slowdown and creates industrial and economic strategies will be crucial in determining whether the economy can recover sustainably in the coming decades.

Industrial activity in Lao, particularly the power and construction sectors, is a key driver of economic growth. Since 2018, Lao has pursued a National Green Growth Strategy. This, in turn, has led to creating the 2022 Green Industry Policy for sustainable economic development in combination with industrial modernization and green growth to graduate from the least-developed country category.

Industrialization has depended on both national and foreign actors, finance mechanisms, and equipment imports, with industries being mainly small and medium enterprises. If Lao is to keep relying on industry to drive growth, while limiting greenhouse gas (GHG) emissions to achieve its green growth goals, increasing energy and material efficiency in industry will be integral to creating a national response. This report explores the current status of Lao's industrial sector and the potential for introducing material and energy efficiency measures. The key industries explored include Construction, Agro-processing, Food and Beverage, Garment, Chemicals, and other cross-cutting sectors.

The report identifies resource efficiency potentials in industries and actions to increase productivity, create jobs, and reduce emissions. Alongside these actions, there will be a requirement for investments, financial measures, infrastructure, and information campaigns, as well as carefully coordinating stakeholders.

The industry trends observed showcase a transition to an economy that relies on more and more specialized industry over time. Different factors—such as company location, size, capital available, or type of company— influence material acquisition and makes it difficult for sector-wide analyses to be conducted. Coal seems to be the hardest-to-acquire material among different sectors. The most common trade barriers identified by the companies are inflation, high exchange rates, costs, material, and transport challenges. Thus, Lao requires financial measures and improvements in transport provision alongside industrial efficiency measures.

The perceptions of government officials on material acquisition and trade barriers for material provision showed that there is a degree of disconnect between policy initiatives and their influence on the challenges faced by industry and the trade barriers identified. Policymakers focus more on bureaucratic, skills, and policy related barriers, while industry responses focus on material, economic, or transport barriers.

Material provision for the **Construction** sector is varied, some companies find it easier than others. Maintenance tends to be reactive rather than preventive. National knowledge of local-level activity seems to be lacking in some cases. For example, one cement company produces electricity with an on-site coal thermal power plant, yet the power plant is not included in national electricity generation accounts.

Products from the **Agro-processing** sector in Lao are destined for both the domestic and international markets, with products such as cassava or rice having global importance. Yet, raw material availability is hindering the ability of industries such as corn or cassava to meet demand. Trade of agro-processing products with Lao's neighbours is common and forms part of the value chain of products such as meat. The sector relies on small-scale enterprises which hinder efficient and standardised processes, as reflected by the 92–99% of livestock small holders or the 80% of rice milled in non-industrial facilities. Given local manufacturing constraints, the sector requires equipment imported from abroad. Some growth was shown in the sector a decade ago, given the plant capacity expansions, and maintenance was shown to be reactive.

Garment factories have varied levels of energy efficiency, size, sophistication, and age. Lao's garment factories mainly supply international markets, with 64% of companies producing to export. The specific energy consumption of clothing factories does not seem to reflect economies of scale.

Cross-cutting sectors rely on material imports, which are becoming hard to acquire, for example, for rubber production. Company profit margins are affected by material costs in foreign currencies and transport costs. Some of these sectors reflect growth due to investments in capacity extensions, for example, the Chemicals sector. Reactive maintenance is common, but some of it may be increasing the efficiency of the factories by virtue of replacing outdated equipment in the Mining and Energy sectors. Waste management is becoming difficult given the increased use of plastics, which requires mechanical recycling plants and a recycling network.

Improved operating practices could generate immediate energy savings at no cost. If investment are made, equipment that should be replaced to increase efficiency was identified. This includes motors, lights, dryers, boilers, and steam traps. Actions that increase productivity include changing to a semi-continuous process of brick-making, improving drying spaces for salt production, replacing clothes dryers, improving wood drying and storage, improving thermal insulation, or implementing predictive maintenance. The level of awareness about potential productivity gains from energy efficiency must be raised among small and medium enterprises.

Heat and electric machinery are two key areas for Lao to focus on to achieve greater emission reductions. The cost and emission savings quantified showed that the garment industry has almost double the opportunities for reducing costs than the rice milling industry. Steam-related equipment and motor replacements for garments and heat recovery in paddy dryers save 88% and 96% of the total yearly cost savings of the garment and rice milling industries respectively. The garment industry also has the potential to reduce emissions 26 times more than rice milling. Garment industry emissions can be reduced mainly through motor replacements and implementing heat-related measures, all of which would account for 83% of emission reductions in the garment industry. Air compressors and V-belt replacements are key for the rice milling industry, which would account for 79% of emission reductions in the industry. Additional emission savings opportunities include introducing material efficiency measures for infrastructure, and regulating ozone-damaging hydrochlorofluorocarbon (HCFC) refrigerants.

This report is a collaboration between the Climate Compatible Growth programme (CCG) and the Global Green Growth Institute (GGGI).

Summary of Policy Recommendations

The policy recommendations stemming from this report cover resource, infrastructure, financial, and supporting measures.

Resource measures can increase the energy and material efficiency in industry. Suggested measures include promoting the use of more efficient appliances such as improved motors and boilers, focusing on equipment that brings the highest emission and cost reductions such as heat and electrical equipment, regulating damaging compounds such as HCFC refrigerants, and putting material substitution at the heart of resource efficiency policies so that changing practices can be embraced shortly after regulations are created.

Infrastructure measures can ensure reduced emissions are locked into infrastructure that supports Lao industry. Measures include upgrading transport infrastructure to benefit company logistics—with care taken to ensure the materials used in building infrastructures benefit from resource measures to limit environmental impact—and using local materials, where possible, to favour the local economy.

Financial measures can create a favourable investment environment for industry to be able to conduct replacements, repairs, and expansions. Measures include limiting the impact of high exchange rates on businesses, controlling inflation to increase stability for raw material acquisition, and creating financial measures to lessen the burden of upgrading equipment.

Supporting measures can ensure the other measures are well-received and widespread to maximize their impact. Measures include inspecting and monitoring practices in industry, linking the information monitored to Nationally Determined Contributions (NDC) reporting, setting industry-specific and equipment efficiency standards, promoting training for industries and their workforce on resource efficiency, and disseminating information at different levels of industry and government so local knowledge on industry-specific practices is increased and goals are aligned. The regulatory framework should also be strengthened including, but not limited to, supporting the development of specialized energy savings companies.

ບົດສະຫຼຸບຫຍໍ້

ສປປ ລາວ ມີທີ່ຕັ້ງຢູ່ໃນເຂດອາຊີຕາເວັນອອກສ່ຽງໃຕ້ ບໍ່ມີທາງອອກສູ່ທະເລ, ມີຊາຍແດນຕິດຈອກກັບ ປະເທດໄທ, ຈີນ, ມຽນມາ, ກຳປູເຈຍ ແລະ ຫວຽດນາມ. ເສດຖະກິດຂອງລາວມີທ່າອ່ຽງຂະຫຍາຍໂຕຢ່າງຕໍ່ເນື່ອງ ນັບແຕ່ປີ 2000 ເປັນຕົ້ນມາ ແຕ່ທົດຖອຍລົງໃນຊ່ວງການລະບາດຂອງພະຍາດໂຄວິດ-19. ສປປ ລາວ ອີງໃສ່ແຫຼ່ງຊັບພະຍາກອນ ທຳມະຊາດ ເພື່ອການເຕີບໂຕທາງເສດຖະກິດ ແລະ ການສົ່ງອອກ, ໂດຍສະເພາະ ຜະລິດຕະພັນທາງດ້ານກະສິກຳ ແລະ ປ່າໄມ້, ການຂຸດຄົ້ນບໍ່ແຮ່ ແລະ ໄຟຟ້ານ້ຳຕົກ. ການດຳເນີນການໃນຂະນະທີ່ປະເທດພວມຟື້ນໂຕຈາກການທົດຖອຍທາງເສດຖະກິດ ແລະ ການວາງຍຸດທະສາດທາງເສດຖະກິດ ແລະ ອຸດສາຫະກຳ, ແມ່ນມີຄວາມສຳຄັນໃນການພິຈາລະນາວ່າ ເສດຖະກິດສາມາດຟື້ນໂຕຢ່າງຍືນຍົງໃນຊ່ວງບັນດາທົດສະຫວັດຕໍ່ໜ້າໄດ້ ຫຼື ບໍ.

ກິດຈະກຳທາງອຸດສາຫະກຳ ຢູ່ໃນ ສປປ ລາວ, ໂດຍສະເພາະ ຂະແໜງການໄຟຟ້າ ແລະ ກໍ່ສ້າງ, ເປັນຕົວຂັບເຄື່ອນຫຼັກ ໃນການເຕີບໂຕທາງເສດຖະກິດ. ນັບແຕ່ປີ 2018 ເປັນຕົ້ນມາ, ສປປ ລາວ ໄດ້ວາງຍຸດຖະສາດການເຕີບໂຕສີຂຽວແຫ່ງຊາດ (National Green Growth Strategy). ໂດຍສືບເນື່ອງຈາກຍຸດທະສາດດັ່ງກ່າວ, ມາຮອດປີ 2022 ໄດ້ມີການພັດທະນານະໂຍບາຍອຸດສາຫະກຳສີຂຽວ (Green Industry Policy) ເພື່ອໃຫ້ເກີດການພັດທະນາທາງເສດຖະກິດແບບຍືນຍົງ ໂດຍປະສານສົມທົບກັບການຫັນອຸດສາຫະກຳເປັນທັນສະໄໝ ແລະ ເຕີບໂຕຕາມທິດສີຂຽວ ເພື່ອຮັດໃຫ້ປະເທດຫຼຸດພົ້ນຈາກຄວາມດ້ອຍພັດທະນາທີ່ອລະກ້າວ.

ການຫັນເປັນອຸດສາຫະກຳ ໄດ້ຕິດພັນກັບ ຜູ້ມີສ່ວນກ່ຽວຂ້ອງທັງຢູ່ພາຍໃນ ແລະ ຈາກຕ່າງປະເທດ, ບັນດາກົນໄກດ້ານການເງິນ, ແລະ ການນຳເຂົ້າອຸປະກອນ, ໃນຂະນະທີ່ ໂຮງງານອຸດສາຫະກຳສ່ວນຫຼາຍ ຍັງເປັນແບບຂະໜາດກາງ ແລະ ນ້ອຍ. ຖ້າຫາກວ່າ ສປປ ລາວ ຍັງຢາກອີງໃສ່ອຸດສາຫະກຳເພື່ອຂັບເຄື່ອນການເຕີບໂຕ, ໃນຂະນະທີ່ຈຳກັດການປ່ອຍທາດອາຍເຮືອນແກ້ວ (GHG) ເພື່ອໃຫ້ບັນລຸບັນດາຄາດໝາຍການເຕີບໂຕຕາມທິດສີຂຽວ, ການຍົກສູງປະສິດທິພາບໃນການນຳໃຊ້ພະລັງ ງານ ແລະ ວັດສະດຸ ຢູ່ໃນອຸດສາຫະກຳ ຈະເປັນສິ່ງທີ່ຫຼີກລ້ຽງບໍ່ໄດ້ ເພື່ອໃຫ້ເກີດການຕອບສະໜອງແຫ່ງຊາດ. ບົດລາຍງານນີ້ ສຳຫຼວດກ່ຽວກັບສະຖານະການປະຈຸບັນໃນຂະແໜງອຸດສາຫະກຳຂອງລາວ ແລະ ທ່າແຮງບົ່ມຊ້ອນ ສຳລັບການແນະນຳໃຊ້ບັນດາມາດຕະການປະຢັດພະລັງງານ ແລະ ວັດສະດຸ. ອຸດສາຫະກຳສຳຄັນ ທີ່ໄດ້ຮັບການສຳຫຼວດ ລວມມີ ອຸດສະຫະກຳການກໍ່ສ້າງ, ປຸງແຕ່ງກະສິກຳ, ອາຫານ ແລະ ເຄື່ອງດື່ມ, ຕັດຫຍິບ, ເຄມີພັນ, ແລະ ບັນດາພາກສ່ວນຂ້າມຂະແໜງການຕ່າງໆ.

ບົດລາຍງານນີ້ ກຳນົດທ່າແຮງບົ່ມຊ້ອນໃນການປະຢັດຊັບພະຍາກອນ ຢູ່ໃນຂະແໜງອຸດສາຫະກຳຕ່າງໆ ແລະ ກຳນົດບັນດາມາດຕະການ ເພື່ອເພີ່ມຜົນຜະລິດ, ສ້າງວຽກເຮັດງານທຳ, ແລະ ຫຼຸດຜ່ອນການປ່ອຍທາດອາຍເຮືອນແກ້ວ. ຄວບຄູ່ກັບບັນດາມາດຕະການເຫຼົ່ານັ້ນ ອາດມີຄວາມຕ້ອງການໃນການລົງທຶນ, ການພັດທະນາດ້ານໂຄງລ່າງພື້ນຖານ, ແລະ ການເຜີຍແຜ່ຂໍ້ມູນຂ່າວສານ, ຕະຫຼອດເຖິງການປະສານງານຢ່າງລະມັດລະວັງລະຫວ່າງບັນດາຜູ້ມີສ່ວນກ່ຽວຂ້ອງທັງຫຼາຍ.

ທ່າອ່ຽງຂອງຂະແໜງອຸດສາຫະກຳສະແດງໃຫ້ເຫັນ ການຂ້າມຜ່ານໄປສູ່ ເສດຖະກິດ ທີ່ອີງໃສ່ຂະແໜງອຸດສາຫະກຳສະເພາະທາງນັບມື້ນັບຫຼາຍ. ບັນດາປັດໃຈຕ່າງໆ, ເຊັ່ນວ່າ ທີ່ຕັ້ງ, ຂະໜາດ, ຄວາມພ້ອມເລື່ອງທຶນ, ຫຼື ປະເພດຂອງບໍລິສັດ ຈະສົ່ງຜົນກະທົບຕໍ່ການຊອກຫາວັດຖຸ ແລະ ເຮັດໃຫ້ມີຄວາມຫຍຸ້ງຍາກທີ່ຈະດຳເນີນການວິເຄາະທົ່ວທັງຂະແໜງການ. ປະກົດວ່າ ຖ່ານຫີນເປັນວັດຖຸທີ່ຫາຍາກທີ່ສຸດ ສຳລັບບັນດາຂະແໜງການທີ່ຕ່າງກັນ. ບັນດາບໍລິສັດບອກວ່າ ອຸປະສັກທ້ອໄປສຳລັບທຸກຂະແໜງການ ແມ່ນໄພເງິນເຟີ້, ຄວາມທ້າທາຍໃນເລື່ອງອັດຕາແລກປ່ຽນ, ຕົ້ນທຶນ, ວັດຖຸ ແລະ ຄ່າການຂົນສົ່ງ ທີ່ສູງຂຶ້ນ. ເພາະສະນັ້ນ, ສປປ ລາວ ຈະຕ້ອງມີມາດຕະການທາງດ້ານການເງິນ ແລະ ການຍົກລະດັບການບໍລິການໃນການຂົນສົ່ງ ຄຽງຄູ່ກັບບັນດາມາດຕະການທາງດ້ານປະສິດທິພາບຂອງອຸດສາຫະກຳ.

ຄວາມຮັບຮູ້ຂອງເຈົ້າໜ້າທີ່ລັດ ກ່ຽວກັບ ການໄດ້ມາຂອງວັດສະດຸ ແລະ ອຸປະສັກທາງການຄ້າ ໃນການສະໜອງວັດຖຸ ໄດ້ສະແດງໃຫ້ເຫັນ ລະດັບຂອງຄວາມບໍ່ເຊື່ອມຕໍ່ລະຫວ່າງ ການລິເລີ່ມດ້ານນະໂຍບາຍ ແລະ ຜົນກະທົບຂອງບັນດາຄວາມລິເລີ່ມນັ້ນ ຕໍ່ສິ່ງທ້າທາຍຕ່າງໆ ທີ່ອຸດສາຫະກຳພວມປະເຊີນ ແລະ ບັນດາອຸປະສັກທາງການຄ້າທີ່ບອກມານັ້ນ. ຜູ້ວາງນະໂຍບາຍສຸມໃສ່ຫຼາຍ ໃນເລື່ອງລະບອບການປົກຄອງ, ທັກສະ ແລະ ອຸປະສັກທາງການເມືອງ, ໃນຂະນະທີ່ການຕອບໂຕ້ຂອງອຸດສາຫະກຳແມ່ນສຸມໃສ່ອຸປະສັກທາງດ້ານວັດສະດຸ, ເສດຖະ ກິດ ຫຼື ການຂົນສົ່ງ.

ການສະໜອງວັດຖຸສຳລັບຂະແໜງການກໍ່ສ້າງ ແມ່ນແຕກຕ່າງກັນ, ເຊັ່ນວ່າ ບາງບໍລິສັດຊອກຫາວັດຖຸໄດ້ງ່າຍກວ່າບໍລິສັດ ອື່ນໆ. ການບຳລຸງຮັກສາມີທ່າອ່ຽງແບບຕາມແກ້ບັນຫາ ແທນທີ່ຈະເປັນການປ້ອງກັນໄວ້ກ່ອນ. ຄວາມຮູ້ແຫ່ງຊາດກ່ຽວກັບກົດຈະກຳລະດັບທ້ອງຖິ່ນເບິ່ງຄືວ່າຍັງຂາດແຄນໃນບາງກໍລະນີ. ຍົກຕົວຢ່າງ, ບໍລິສັດຊີມັງແຫ່ງໜຶ່ງ ຜະລິດໄຟຟ້າໃຊ້ເອງດ້ວຍໂຮງງານໄຟຟ້າຄວາມຮ້ອນຖ່ານຫີນ ແລະ ໂຮງງານໄຟຟ້ານີ້ບໍ່ທັນຖືກຈັດເຂົ້າສະຖິຕິການຜະລິດໄຟແຫ່ງຊາດ.

ຜະລິດຕະພັນຈາກຂະແໜງປຸງແຕ່ງກະສິກຳຢູ່ ສປປ ລາວ ເຊັ່ນຜະລິດຕະພັນທີ່ເປັນມັນຕົ້ນ ຫຼື ເຂົ້າ, ແມ່ນມີຄວາມສຳຄັນ ທັງສຳລັບຕະຫຼາຍພາຍໃນ ແລະ ຕະຫຼາດສາກົນ. ແຕ່ຄວາມພ້ອມດ້ານວັດຖຸດິບ ເຊັ່ນສາລີ ຫຼື ມັນຕົ້ນ ຍັງເປັນອັນກີດຂວາງຄວາມສາມາດຂອງອຸດສາຫະກຳ ເພື່ອຈະບັນລຸ

ຕາມຄວາມຕ້ອງການ. ການຄ້າຂາຍຜະລິຕະພັນປຸງແຕ່ງກະສິກຳຂອງລາວ ກັບບັນດາປະເທດອ້ອມ ຂ້າງ ແມ່ນເປັນເລື່ອງທຳມະດາ ແລະ ປະກອບເປັນຕ່ອງໂສ້ເພີ່ມມູນຄ່າ ສຳລັບຜະລິດຕະພັນ ເຊັ່ນ ຊີ້ນ. ຂະແໜງ ປຸງແຕ່ງກະສິກຳ ອີງໃສ່ບັນດາວິສາຫະກິດຂະໜາດນ້ອຍ ທີ່ຂາດຂະບວນການຜະລິດທີ່ມີ ປະສິດທິພາບ ແລະ ທີ່ເປັນມາດຕະຖານ, ເຊິ່ງສະແດງອອກໃນຕົວເລກ 92–99% ຂອງຜູ້ລ້ຽງສັດຂະໜ າດນ້ອຍ ຫຼື 80% ຂອງການສີເຂົ້າ ທີ່ບໍ່ແມ່ນລະດັບອຸດສາຫະກຳ. ເນື່ອງຈາກຂໍ້ຈຳກັດດ້ານການຜະລິດໃນ ທ້ອງຖິ່ນ, ຂະແໜງປຸງແຕ່ງກະສິກຳຈຳເປັນຕ້ອງນຳເຂົ້າອຸປະກອນຈາກຕ່າງປະເທດ. ສັງເກດເຫັນທ່າ ອ່ຽງເພີ່ມຂຶ້ນຂອງການນຳເຂົ້າໃນທົດສະຫວັດທີ່ຜ່ານມາ ເນື່ອງຈາກການຂະຫຍາຍໂຕດ້ານໂຮງງານ ແລະ ການບຳລຸງຮັກສາທີ່ເປັນເປັນແບບປະຕິກິລິຍາຕາມແກ້ບັນຫາ.

ບັນດາໂຮງງານຕັດຫຍິບ ມີຄວາມແຕກຕ່າງກັນ ໃນເລື່ອງລະດັບປະສິດທິພາບດ້ານພະລັງງານ, ຂະໜາດ, ຄວາມສັບຊ້ອນ ແລະ ອາຍຸການໃຊ້ງານຂອງໂຮງງານ. ບັນດາໂຮງງານຕັດຫຍິບຢູ່ ສປປ ລາວ ສ່ວນໃຫຍ່ແມ່ນສະໜອງໃຫ້ຕະຫຼາດສາກົນ, ເຊິ່ງມີ 64% ຂອງບັນດາບໍລິສັດທີ່ຜະລິດເພື່ອການສົ່ງ ອອກ. ການຊົມໃຊ້ພະລັງງານຈຳເພາະຂອງບັນດາໂຮງງານຕັດຫຍິບ ເບິ່ງຄືຈັ່ງວ່າ ບໍ່ສະທ້ອນໃຫ້ເຫັນ ຕາມຂະໜາດຂອງຂະແໜງເສດຖະກິດນີ້..

ບັນດາພາກສ່ວນຂ້າມຂະແໜງການ (**Cross-cutting sectors**) ອີງໃສ່ການນຳເຂົ້າອັດສະດຸ, ເຊິ່ງກາຍເປັນການຍາກທີ່ຈະໄດ້ມາ, ຍົກຕົວຢ່າງ, ສຳລັບການຜະລິດຢາງພາລາ. ອັດຕາຜົນກຳໄລຂອງ ບໍລິສັດ ໄດ້ຮັບຜົນກະທົບຈາກຕົ້ນທຶນຂອງອັດສະດຸ ທີ່ໄຫ່ຕາມເງື່ອນຕາຕ່າງປະເທດ ແລະ ຕົ້ນທຶນການ ຂົນສົ່ງ. ບາງຂະແໜງການ ສະແດງໃຫ້ເຫັນວ່າການເຕີບໂຕ ແມ່ນເນື່ອງຈາກການຂະຫຍາຍໂຕທາງ ດ້ານກຳລັງການຜະລິດ, ເຊັ່ນ, ຂະແໜງເຄມີພັນ. ການບຳລຸງຮັກສາແບບປະຕິກິລິຍາແມ່ນເປັນເລື່ອງ ທຳມະດາ, ແຕ່ການປ່ຽນອຸປະກອນທີ່ລ້າສະໄໝໃນຂະແໜງບໍ່ແຮ່ ແລະ ພະລັງງານ ອາດຈະເປັນການ ເພີ່ມປະສິດທິພາບຂອງໂຮງງານໄດ້. ການບໍລິຫານຄຸ້ມຄອງນ້ຳເສຍຈະກາຍເປັນເລື່ອງຍາກ ເນື່ອງຈາກ ວ່າ ການນຳໃຊ້ປຫຼາສະຕິກເພີ່ມຂຶ້ນ, ເຊິ່ງຈຳເປັນຕ້ອງມີໂຮງງານກຳຈັດ ແລະ ເຄືອຂ່າຍຂອງການຣີໄຊ ເຄິ ນ.

ການປັບປຸງການປະຕິບັດດ້ານການດຳເນີນການສາມາດກໍ່ໃຫ້ເກີດການປະຢັດພະລັງງານແບບ ບໍ່ມີຄ່າໃຊ້ຈ່າຍ. ຖ້າມີການລົງທຶນ, ເຫັນວ່າ ຄວນຕ້ອງປ່ຽນແທນບັນດາອຸປະກອນ ເພື່ອຍົກສູງ ປະສິດທິພາບ. ໃນບັນດາອຸປະກອນນີ້ ຈະລວມມີ ມໍເຕີ, ລະບົບແສງສະຫວ່າງ, ເຄື່ອງອົບແຫ້ງ, ໝໍ້ ອາຍນ້ຳ, ແລະ ເຄື່ອງດັກອາຍ. ບັນດາມາດຕະການ ທີ່ຈະຊ່ວຍເພີ່ມຜະລິດຕະພາບ (productivity) ຈະລວມມີ ການປ່ຽນໄປໃຊ້ຂະບວນການເຄິ່ງຕໍ່ເນື່ອງ ໃນໂຮງງານດິນຈີ່, ຍົກລະດັບບໍລິມາດຂອງການ ອົບແຫ້ງໃນໂຮງງານຜະລິດເກືອ, ການປ່ຽນຖ່າຍເຄື່ອງອົບເສື້ອຜ້າ, ປັບປຸງການອົບໄມ້ ແລະ ສາງເກັບ

ມ້ຽນໄມ້, ປັບປຸງສະ ໜອນກັນຄວາມຮ້ອນ, ຫຼື ຈັດຕັ້ງປະຕິບັດການບຳລຸງຮັກສາແບບຄາດຄະເນໄວ້ກ່ອນ. ຄວນຕ້ອງຍົກລະດັບຈິດສຳນຶກກ່ຽວກັບທ່າແຮງບໍ່ມຊ້ອນໃນເລື່ອງຍົກສູງຜະລິດຕະພາບຈາກການປະຢັດພະລັງງານ ສຳລັບບັນດາໂຮງງານຂະໜາດກາງ ແລະ ນ້ອຍ.

ເຄື່ອງຈັກຄວາມຮ້ອນ ແລະ ໄຟຟ້າ ເປັນສອງຂົງເຂດຫຼັກ ສຳລັບ ສປປ ລາວ ທີ່ຄວນຕ້ອງສຸມໃສ່ ເພື່ອໃຫ້ບັນລຸການຫຼຸດຜ່ອນໃນການປ່ອຍທາດອາຍເຮືອນແກ້ວ. ການປະເມີນການປະຢັດຕົ້ນທຶນ ແລະ ການປ່ອຍທາດອາຍເຮືອນແກ້ວ ສະແດງໃຫ້ເຫັນວ່າ ອຸດສາຫະກຳຕັດຫຍິບ ມີໂອກາດສຳລັບການຫຼຸດຜ່ອນຕົ້ນທຶນ ເຖິງສອງເທົ່າ ເມື່ອທຽບກັບ ອຸດສາຫະກຳຜະລິດນ້ຳກ້ອນ. ການປ່ຽນແທນອຸປະກອນກ່ຽວກັບອາຍນ້ຳ ແລະ ມໍເຕີ ສຳລັບໂຮງງານຕັດຫຍິບ ແລະ ການເກັບກູ້ຄວາມຮ້ອນໃນເຄື່ອງອົບເຂົ້າ ຈະຊ່ວຍປະຢັດພະລັງງານໄດ້ 88% ແລະ 96% ຂອງມູນຄ່າການປະຢັດທັງໝົດຕໍ່ປີ ຂອງອຸດສາຫະກຳຕັດຫຍິບ ແລະ ສີເຂົ້າຕາມລຳດັບ. ອຸດສາຫະກຳຕັດຫຍິບຍັງມີທ່າແຮງບໍ່ມຊ້ອນ ເພື່ອຫຼຸດຜ່ອນການປ່ອຍທາດອາຍເຮືອນແກ້ວໄດ້ສູງເຖິງ 26 ເທົ່າ ທຽບໃສ່ໂຮງສີເຂົ້າ. ການປ່ອຍທາດອາຍເຮືອນແກ້ວຂອງອຸດສາຫະກຳຕັດຫຍິບ ສາມາດຫຼຸດຜ່ອນລົງໄດ້ ໂດຍຕົ້ນຕໍແມ່ນການປ່ຽນຖ່າຍມໍເຕີ ແລະ ຈັດຕັ້ງປະຕິບັດມາດຕະການກ່ຽວກັບຄວາມຮ້ອນ, ເຊິ່ງລວມກັນແລ້ວ ຈະກວມເອົາເຖິງ 83% ຂອງການປ່ອຍທາດອາຍເຮືອນແກ້ວທັງໝົດຂອງອຸດສາຫະກຳຕັດຫຍິບ. ການປ່ຽນຖ່າຍເຄື່ອງອັດອາກາດ ແລະ ສາຍພານຮູບຕົວ V ແມ່ນບັດໃຈສຳຄັນ ສຳລັບອຸດສາຫະກຳສີເຂົ້າ, ເຊິ່ງຈະກວມເຖິງ 79% ຂອງການປ່ອຍທາດອາຍເຮືອນແກ້ວທັງໝົດຂອງອຸດສາຫະກຳນີ້. ໂອກາດໃນການປະຢັດຕົ້ນທຶນຈາກການປ່ອຍທາດອາຍເຮືອນແກ້ວ ຈະລວມເອົາບັນດາມາດຕະການປະຢັດອັດສະດຸ ສຳລັບໂຄງລ່າງພື້ນຖານ, ແລະ ການຄວບຄຸມການນຳໃຊ້ ສານທຳຄວາມເຢັນທີ່ທຳລາຍໂອໂຊນ (hydrochloro-fluorocarbon ຫຼື HCFC).

ບົດລາຍງານນີ້ ແມ່ນຜົນຂອງການຮ່ວມມື ລະຫວ່າງ ແຜນງານວ່າດ້ວຍການເຕີບໂຕທີ່ປັບເຂົ້າກັນໄດ້ກັບການປ່ຽນແປງດິນຟ້າອາກາດ (Climate Compatible Growth programme, ຫຼື CCG) ແລະ ສະຖາບັນການເຕີບໂຕສີຂຽວສາກົນ (Global Green Growth Institute, ຫຼື GGGI).

ບົດສະຫຼຸບຂໍ້ແນະນຳທາງນະໂຍບາຍສຳລັບ ສປປ ລາວ

ຄຳແນະນຳດ້ານະໂຍບາຍ ທີ່ເກີດຈາກບົດລາຍງານນີ້ ຈະກວມເອົາບັນດາມາດຕະການດ້ານ ຊັບພະຍາກອນ, ໂຄງລ່າງພື້ນຖານ, ການເງິນ ແລະ ການສະໜັບສະໜູນ.

ມາດຕະການດ້ານຊັບພະຍາກອນ (Resource measures) ສາມາດຊ່ວຍເພີ່ມປະສິດທິພາບດ້ານ ພະລັງງານ ແລະ ວັດສະດຸໃນອຸດສາຫະກຳ. ມາດຕະການທີ່ແນະນຳມານີ້ ລວມມີ ການສົ່ງເສີມການນຳໃຊ້ ເຄື່ອງໃຊ້ພະລັງງານທີ່ມີປະສິດທິພາບກວ່າ ເຊັ່ນ ມໍເຕີ ແລະ ໝໍ້ອາຍນ້ຳທີ່ຜ່ານການປັບປຸງແລ້ວ, ໂດຍສຸມໃສ່ ອຸປະກອນ ທີ່ໃຫ້ປະໂຫຍດສູງສຸດໃນການຫຼຸດຜ່ອນການປ່ອຍທາດອາຍເຮືອນແກ້ວ ແລະ ຕົ້ນທຶນ ເຊັ່ນ ອຸປະກອນທາງຄວາມຮ້ອນ ແລະ ໄຟຟ້າ, ການຄວບຄຸມສານທຳລາຍຊັ້ນໂອໂຊນ ເຊັ່ນ ສານທຳຄວາມເຢັນ ປະເພດ HCFC, ແລະ ວາງແຜນການປ່ຽນແທນວັດສະດຸ ເຊິ່ງເປັນຫົວໃຈຂອງນະໂຍບາຍໃນການນຳໃຊ້ ຊັບພະຍາກອນຢ່າງມີປະສິດທິພາບ ໂດຍທີ່ການປ່ຽນແປງໃນການປະຕິບັດ ຈະເກີດຂຶ້ນຕາມມາ ຫຼັງຈາກ ການສ້າງກົດລະບຽບ.

ມາດຕະການດ້ານໂຄງລ່າງພື້ນຖານ (Infrastructure measures) ສາມາດໝັ້ນໃຈໄດ້ວ່າ ການ ປ່ອຍທາດອາຍເຮືອນແກ້ວທີ່ຫຼຸດລົງໄດ້ນັ້ນ ຈະຖືກລວມເຂົ້າກັບໂຄງລ່າງພື້ນຖານ ທີ່ສະໜັບສະໜູນ ອຸດສາຫະກຳຂອງລາວ. ບັນດາມາດຕະການ ລວມມີ ການຍົກລະດັບໂຄງລ່າງດ້ານຄົມມະນາຄົມຂົນສົ່ງ ເພື່ອ ເອື້ອປະໂຫຍດແກ່ໂລຈິຊະຕິກຂອງບໍລິສັດ—ດ້ວຍຄວາມເອົາໃຈໃສ່ ເພື່ອຮັບປະກັນວ່າ ວັດສະດຸທີ່ຖືກໃຊ້ໃນ ການກໍ່ສ້າງໂຄງລ່າງພື້ນຖານ ຈະໄດ້ປະໂຫຍດຈາກມາດຕະການດ້ານຊັບພະຍາກອນ ເພື່ອຈຳກັດຜົນກະທົບ ດ້ານສິ່ງແວດລ້ອມ ແລະ ໂດຍການນຳໃຊ້ວັດສະດຸຂອງທ້ອງຖິ່ນ, ບ່ອນໃດທີ່ເປັນໄປໄດ້, ເພື່ອລຸກຍູ້ເສດຖະກິດ ຂອງທ້ອງຖິ່ນ.

ມາດຕະການດ້ານການເງິນ (Financial measures) ຈະສາມາດສ້າງສະພາບແວດລ້ອມ ທີ່ເອື້ອ ອຳນວຍແກ່ການລົງທຶນ ສຳລັບອຸດສາຫະກຳ ເພື່ອໃຫ້ສາມາດດຳເນີນການປ່ຽນຖ່າຍ, ສ້ອມແປງ, ແລະ ຂະຫຍາຍ. ບັນດາມາດຕະການລວມມີ ການຈຳກັດຜົນກະທົບຈາກອັດຕາແລກປ່ຽນທີ່ສູງຕໍ່ພາກທຸລະກິດ, ຄວບຄຸມໄພເງິນເຟີ້ ເພື່ອເພີ່ມທະວີຄວາມໝັ້ນຄົງສຳລັບການຈັດຫາວັດສະດຸ, ແລະ ວາງບັນດາມາດຕະການ ທາງການເງິນ ເພື່ອຜ່ອນຜັນພາລະໃຫ້ແກ່ການຍົກລະດັບອຸປະກອນ.

ບັນດາມາດຕະການສະໜັບສະໜູນ (Supporting measures) ສາມາດເຮັດໃຫ້ແນ່ໃຈໄດ້ວ່າ ບັນດາມາດຕະການອື່ນໆໄດ້ຮັບການຍອມຮັບທີ່ດີ ແລະ ແຜ່ກວ້າງອອກໄປ ເພື່ອໃຫ້ໄດ້ຮັບຜົນກະທົບສູງສຸດ. ບັນດາມາດຕະການລວມມີ ການກວດກາ ແລະ ຕິດຕາມ ການປະຕິບັດໃນພາກອຸດສາຫະກຳ, ເຊື່ອມໂຍງຂໍ້ ມູນທີ່ຕິດຕາມໄດ້ ໃຫ້ແກ່ບົດລາຍງານການປະກອບສ່ວນແຫ່ງຊາດທີ່ກຳນົດ (Nationally Determined Contributions, NDC), ສ້າງມາດຕະຖານການປະຢັດພະລັງງານ ສະເພາະອຸດສາຫະກຳ ແລະ ອຸປະກອນ, ສົ່ງເສີມການຝຶກອົບຮົມສຳລັບອຸດສາຫະກຳ ແລະ ກຳລັງແຮງງານຂອງເຂົາເຈົ້າກ່ຽວກັບປະສິດທິພາບໃນ ການໃຊ້ຊັບພະຍາກອນ, ແລະ ເຜີຍແຜ່ຂໍ້ມູນຂ່າວສານໃນລະດັບແຕກຕ່າງກັນ ຂອງພາກອຸດສາຫະກຳ ແລະ ລັດຖະບານ ເພື່ອໃຫ້ຄວາມຮູ້ທ້ອງຖິ່ນກ່ຽວກັບການປະຕິບັດສະເພາະອຸດສາຫະກຳ ເພີ່ມຂຶ້ນ ແລະ ຄາດ ໝາຍກຳສອດຄ່ອງກັນ. ຂອບດ້ານລະບຽບການຄວນຕ້ອງເຂັ້ມແຂງຂຶ້ນ ລວມມີ, ຕົວຢ່າງ, ໃຫ້ການສະໜັບສະ ໜູນການພັດທະນາບັນດາບໍລິສັດບໍລິການດ້ານພະລັງງານໂດຍສະເພາະ.

1 Introduction

The People's Democratic Republic of Lao (hereafter Lao) is a landlocked Southeast Asian country with borders with Thailand, China, Myanmar, Cambodia, and Vietnam. The World Bank categorizes Lao as a least developed country (LDC). The population in Lao reached 7.4 million in 2021 [1] with a Gross Domestic Product (GDP) of 2,551.3 current USD per capita [2]. GDP had been steadily increasing since the early 2000s with an average growth rate of 5.5% from 2000 to 2018 [2]; however, a decline has been observed during the COVID-19 pandemic, reaching -1% in 2020. Lao depends on natural resources for economic growth and exports, especially agriculture and forestry products, mining and quarrying, and hydroelectricity [3]. The actions taken as the country recovers from the GDP decline and creates industrial and economic strategies will be crucial in determining whether the economy will recover sustainably in the coming decades.

Just before the pandemic, Lao had set in motion a strategy for sustainable economic development, as reflected by the launch of the 2018 National Green Growth Strategy [4]. Ministerial work towards this strategy included the creation of a comprehensive development plan by the Ministry of Industry and Commerce (MoIC). This was designed to support export-oriented, non-resource-based industries to hasten industrialization, modernization, green growth, inclusiveness, and sustainability. These actions should help to achieve the ultimate objective set by the latest five-year National Socioeconomic Development Plan (NSEDP) [5], which is to achieve industrial modernization and green growth in order to graduate from the LDC category by 2025.

Industrial activity in Lao, particularly the power and construction sectors, has been a driver of GDP growth between 2016 and 2020 [5]. Other types of industries in Lao are agricultural produce-processing, and specialized finished products. Industrialization has depended on both national and foreign actors, finance mechanisms, and varying levels of efficiency in equipment used (e.g., motors, boilers, chillers). If Lao is to keep relying on industry to drive its growth while limiting greenhouse gas (GHG) emissions to achieve its green growth goals, knowledge of ways to increase energy and material efficiency in industry is needed so a national response may be formed. In response, this report explores the current status of Lao industry and the potential for introducing material and energy efficiency measures. More specifically, this report will explore the case for investing in efficiency in industry in Lao, mapping energy and material flows and showcasing findings from surveys conducted in Lao with ministries and companies on energy and material efficiency. The key industries explored include construction, agro-processing, garment, chemicals, food and beverage, among others. The report shows the need to strengthen resource efficiency actions and investments in Lao to deliver productivity gains, create jobs, and reduce emissions.

This report is a collaboration between the Climate Compatible Growth programme (CCG) and the Global Green Growth Institute (GGGI)

2 Energy, materials, and emissions in Lao's industry

This section introduces the industrial context of Lao, explores the industrial energy and material flows, and discusses national emissions by sector and the commitments made to reduce emissions.

2.1 Industrial context of Lao

The key industries driving economic growth in Lao are hydropower, mining and quarrying, wood products, and agricultural products [6], thus showing that Lao continues to heavily rely on natural resources as a driver of growth.

Lao exports intermediate goods (44.4%), raw materials (35.3%), consumer goods (16.1%), and capital goods (4.2%) in 2020 [6]. In turn, Lao imports mostly consumer goods (38.8%), capital goods (26.5%), intermediate goods (22%), and raw materials (12.7%). With regards to products, in 2020 Lao mostly exported electricity, followed by gold, copper, and live bovine animals, and imported mainly oil products, bovine animals, beverages, and diesel trucks and parts [6]. The monetary value of exports (5,088 million USD) is only slightly higher than that of imports (5,014 million USD) [6]. The types of industry and technology levels that supply the domestic market and the international markets are different, with food processing, beverage, and construction materials being for domestic supply, while industry for export includes clothing and footwear and electrical and telecommunication equipment [5]. Industries for exports have benefits related to special economic zones. Current trade flows depend on neighbouring countries, mainly Thailand and China.

Table 1 shows that the top manufactured exports from Lao mainly depend on natural resources (in this case, basic metals). Out of the 22 manufactured exports, nine are low-tech (such as food and beverage and apparel), five are medium-tech (such as basic metals), and eight are high-tech [7]. Despite having a small proportion of high-tech manufactured goods, overall export concentration of medium- and low-tech manufactured goods was around 67%. Manufacturing of these products relies on companies that are small- and medium-sized enterprises (SMEs), which are the main type of company in Lao [5].

Table 1 Industry share of total manufactured exports (%), 2020. Source: 2016 - UNIDO Industrial Analytics Platform, country profiles [7].

Industry	Share %	Industry	Share %
Basic metals	33.2	Scientific instruments	1.8
Telecommunications	14.1	Glass, ceramics, & cement	1.7
Paper products	9.9	Furniture & other	1.7
Chemicals	8.6	Machinery & appliances	0.2
Apparel	8.3	Rubber & plastics	0.2
Food & beverages	8.1	Tobacco	0.2
Leather & footwear	3.8	Automotive	0.1
Wood products	3.6	Office equipment	0.1
Electrical apparatus	2.3	Metal products	0.1
Textiles	1.8		

The industrial sector in Lao had been growing until the pandemic; however, a push to reinvigorate the sector is expected. Between 2016 and 2020, the value of industrial and handicrafts production reached 3.136 million USD (LAK 52,728 billion) with an average annual increase of 9.2%. The national target is 15% per year, which has not been fulfilled since 2018 when growth of this sector started to slow down, reaching only 3% in 2020 [5]. The government recognizes that, despite the progress in local development, economic progress has not been sufficiently systematic, leading to incoherent value chains between different local actors, mainly for agricultural products [5].

Box 1 shows more information on regional industries and the economic activities that directly influence them and regional economic development.

Box 1 Lao regional industries and related economic activities. Source: [5]

Northern region: Agricultural production is prevalent including rice, tea, banana, cassava, and maize cultivation. Large livestock is raised. The power sector includes the completion of the Hongsa lignite-fired power plant and a hydropower project. Agro-processing is growing and includes tea processing plants, rubber processing plants, wood processing plants; and the so-called "One District One Product" (ODOP) items (an initiative which aims to improve local economic development based on improving unique products in given districts), which include buttered banana chips, turmeric compounds, and salted and dried buffalo skin. Infrastructure renovations include roads, expressways, and the Lao–China railway.

Central region: Agricultural production includes the cultivation of rice, sweet corn, sugarcane, cassava, and other crops and vegetables. Agro-processing plants include tapioca factories and rice mills. Other industries include garments, beverages, construction materials, mineral mining, including iron, tin, lead, limestone, potash-magnesium salt, barite, gypsum, zinc, bismuth, tellurium, and others for domestic supply and export. Infrastructure renovations include irrigation systems and road and highway construction.

Southern region: Agricultural production includes mainly coffee, cassava, cashew nuts, passion fruit, and contract farming, such as planting cabbage, bananas, maize, sugarcane, chilli, bamboo shoots, and rice. The most prominent manufacturing industries are food and beverage processing, wood processing, minerals, chemicals, construction materials, and office supplies. Infrastructure renovations or construction include bridges, roads, and a river embankment construction.

Lao recognized that green growth needs to be implemented as a strategy for the country to keep growing without worsening environmental degradation [5]. In 2018, the Government of Lao adopted the National Green Growth Strategy to 2030, issuing laws and regulations related to climate change and the environment, including a forestry law and climate change decree [8]. Linked to the Green Growth Strategy, a national Green Industry Policy was written in 2022, which is nearing endorsement [9]. The policy aims to increase productivity in the sector by "accelerating structural transformations" and shifting labour "from low to high productivity activities" while implementing "environmental conservation strategies". The topics covered by the policy include renewable energy, energy efficiency, waste minimization, water use efficiency, and greening supply chains. The policy highlights key challenges in Lao industries which include:

- The Lao domestic industry structure lacks awareness of green improvements that can be integrated in the manufacturing processes.
- Industries and investments lack diversification.
- Outdated technology and equipment are used and are often second-hand.
- Budgetary constraints restrict upgrades to increase efficiency.
- The availability of foreign investment is limited to improve the industrial sector.

Given the challenges highlighted for the industrial sector in Lao, recommendations from other reports include the need to increase productivity, transitioning the economy from an

agricultural to an industrial economy, diversifying industries of production, and expanding the service sector [3]. These activities are all needed if the industrial sector is to successfully—and sustainably—grow in the coming decade. Lao must also improve its performance in terms of manufacturing value added (MVA), diversification, competitiveness, and resilience. Changes needed include significant advancements in human capital, innovation, and cutting-edge technology, high-quality investments, business-friendliness, logistics, information and communication technology (ICT), data and statistics collection, technology standards and assurance, and private and public investment [3]. Such changes would foster inclusiveness, sustainability, higher and resilient competitiveness, and the expansion of the manufacturing sector.

This report directly addresses Lao's industrial needs and supports the 2022 Green Industry Policy by creating further evidence for actions that can be taken to increase the resource efficiency in different industries and tackle the constraints they face.

2.2 Mapping of energy and material flows

Statistical data on industrial flows and national energy use from source to sectors are available for Lao. In this section, these data are used to create Sankey diagrams for both industry and energy flows. Data on Lao industries include mainly primary materials and some finished products. Energy data include energy generation sources, and the sectors and sub-sectors that use such energy.

Figure 1 shows mineral manufacturing (i.e., primary materials) in Lao. Top soil and lignite have the highest production by mass, followed by limestone, iron, gypsum, and potash, which have uses for the Energy and Construction sectors.

Figure 2 shows the finished products manufactured in Lao in 2020. Leather, animal food, salt, ice, and tobacco have the highest production by mass. Drinking water and beer have the highest production by volume.

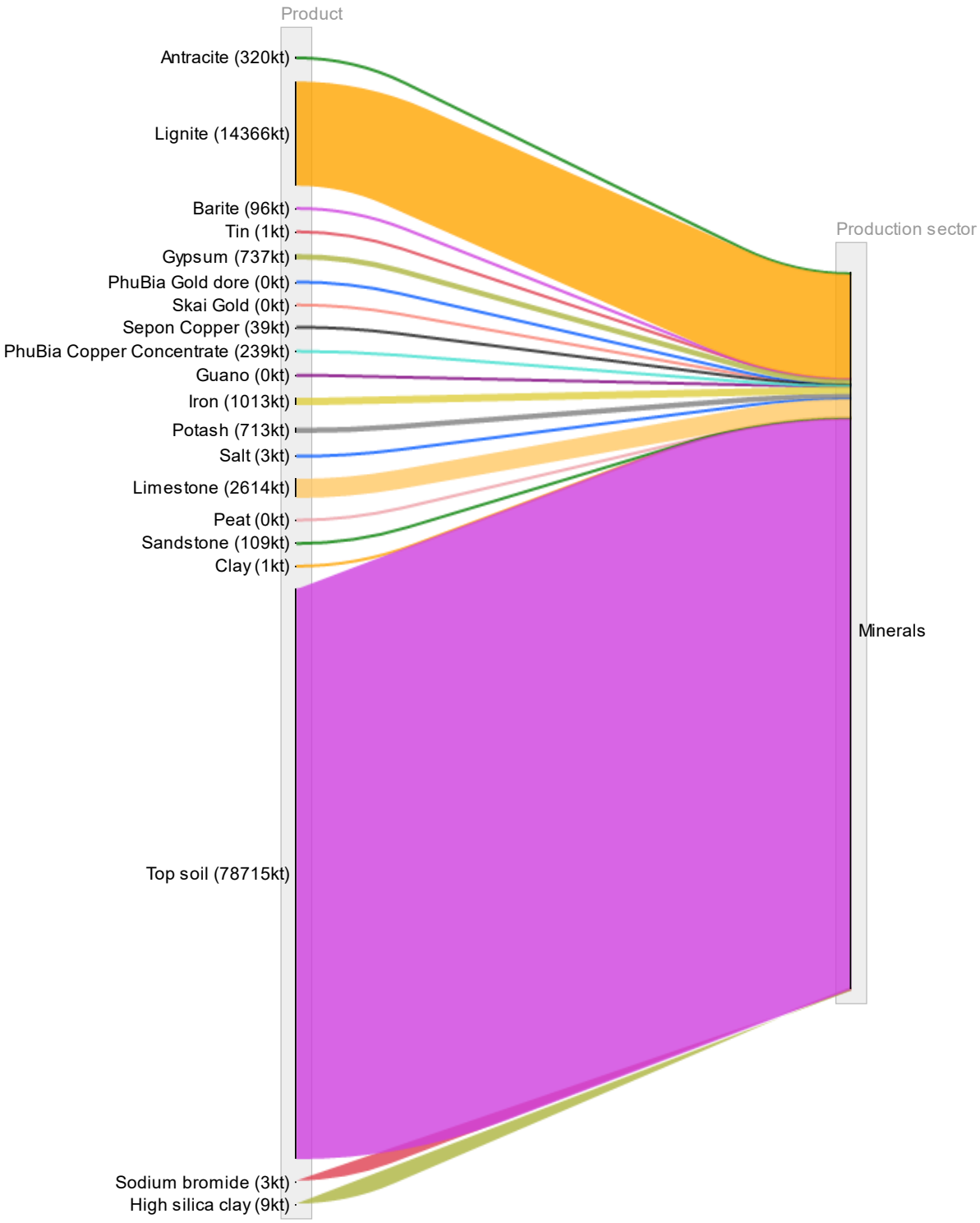

Figure 1 Manufacturing of minerals in Lao in 2020. Data source: [10]. Unit conversions and figure made by the authors of this report.[1] Units: kilotonnes (kt).

[1] The Zinc + Lead category was removed given the units.

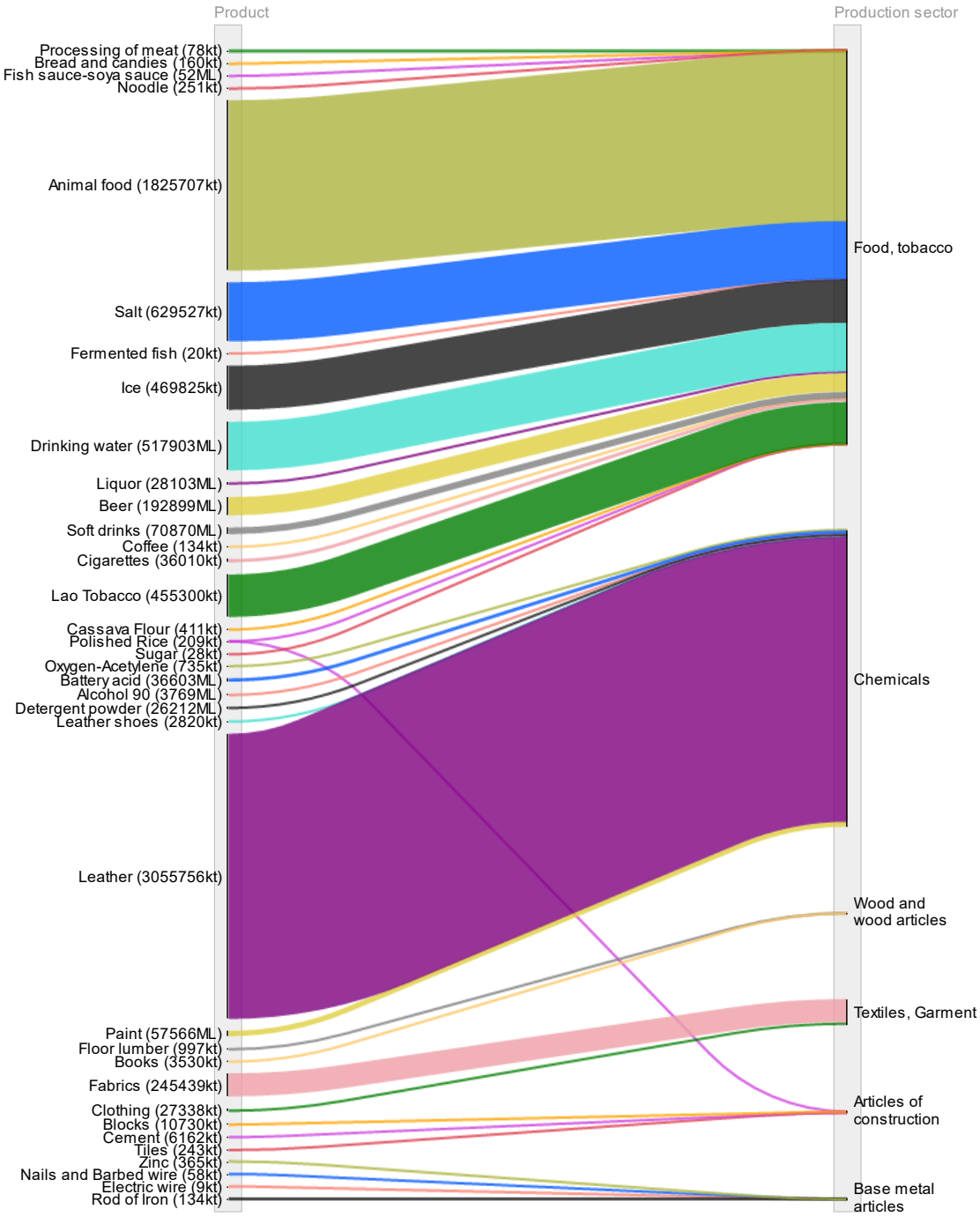

Figure 2 Finished product manufacturing in Lao in 2020. Data source: [10] – manufacturing and handicraft products. Unit conversions and figure made by the authors of this report.[2] Units: kilotonnes (kt) for solids and million litres (ML) for liquids.

[2] The products Medicine, Plastic goods, Wood furniture, Rattan furniture, and Agri tools were removed from this figure, since only monetary units were reported instead of mass or volume. In general, we would advise for the published statistics to undergo careful revisions before publishing to validate the results.

Energy flows for Lao as a whole are shown in **Figure 3**, which highlight the reliance on oil products for the road transport sector, biofuels and waste are mostly used for the residential sector, and electricity is used mainly by industry. Currently, Lao's economic prospects are being affected by high oil prices, given the dependency on oil for transport and Lao's landlocked position [11].

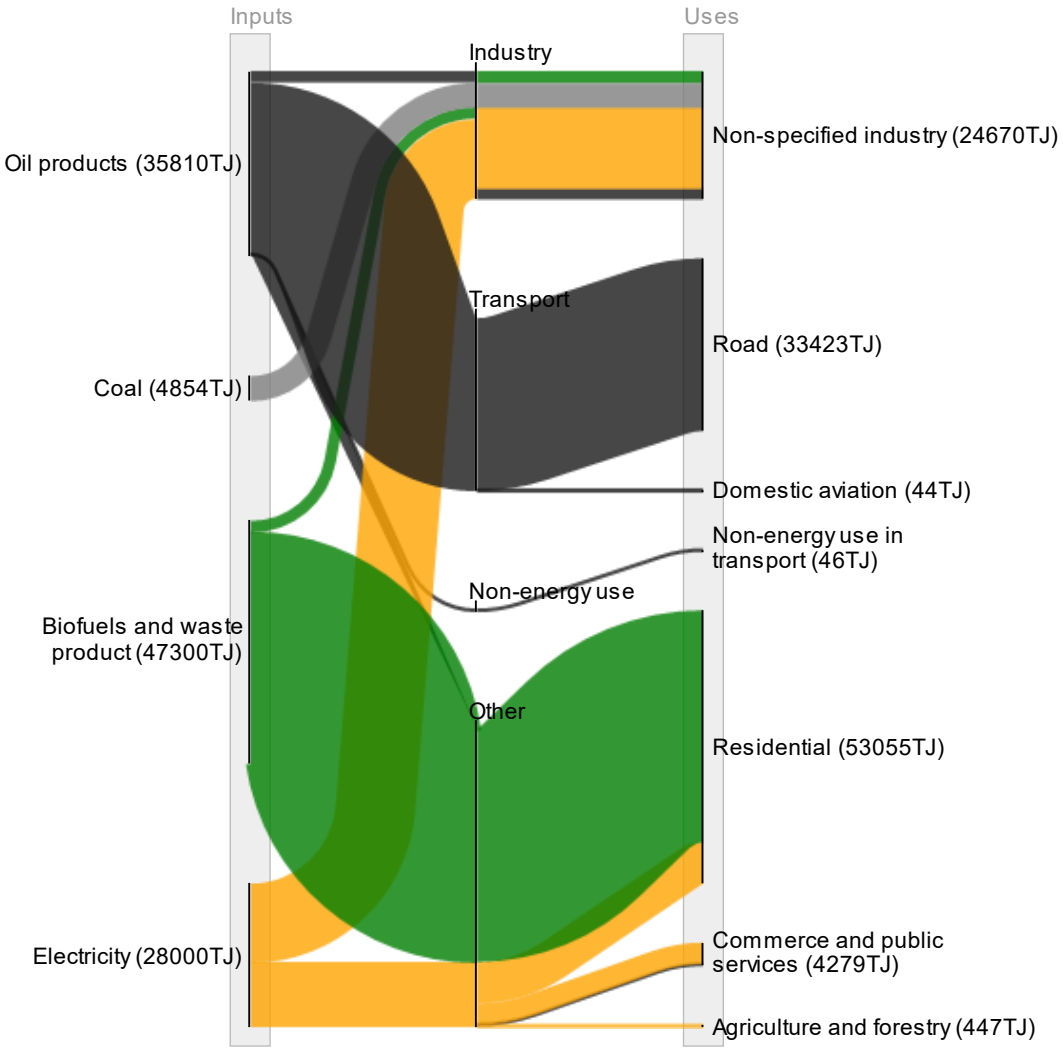

Figure 3 Energy flows of Lao in 2020. Data source: [12]

2.3 Lao CO_2 emissions and reduction pathways

In the 2021 Nationally Determined Contributions (NDCs), Lao committed unconditionally to reducing its greenhouse gas emissions (GHG) in 2030 by 60% compared to a business-as-usual (BAU) scenario [13]. The actions taken by Lao to reach the NDCs include reductions in land-related emissions by reducing deforestation and increasing hydropower capacity up to 13 GW. Further plans are conditional on international support and include developing electricity capacity equal to 1 GW of wind and solar, and 300 MW of biomass, and reducing final energy consumption by 10% compared to a BAU scenario.

Total emissions in Lao are estimated to be 41.8 million tonnes (Mt) of CO_2 in 2020, with 65.4% produced by the power industry, 22.0% other industrial combustion, 5.1% buildings, 4.2% other sectors, and 3.3% the transport sector [14]. This represents a total of 5.84 tonnes CO_2 per capita. Emissions in Lao have usually been thought of as low; however, there has been an increase in emissions over time with almost a doubling of emissions for both the power industry (14.3 to 27.4 Mt of CO_2) and other industrial combustion (4.9 to 9.2 Mt of CO_2) between 2018 and 2019 [14]. These increases highlight the need to pay attention to the power sector and industry evolution, so industrial development is done hand-in-hand with measures to limit industrial emissions, thereby increasing process efficiencies and reducing locked-in emissions.

The Lao government plans for emission reduction, from 2015 to 2030, include action in forestry, renewable energy, rural electrification, transport, large-scale hydropower, and general climate change [8]. Yet, growing industrial emissions have taken much longer to be considered in plans. In 2022, the emissions from industry are finally being considered by the Green Industry Policy. The policy offers opportunities for renewable energy, energy efficiency, waste minimization, water use efficiency, greening supply chains, and introduces financial considerations so that the plans can succeed.

2.4 Research design

This report explores the application of material and energy efficiency interventions in Lao industry. Material and energy surveys have been conducted, and these results were then analysed and compared against the literature and national statistics to complement the findings.

Material efficiency surveys were conducted by CCG in collaboration with the National University of Laos (NUOL). Two separate surveys were conducted. The first surveyed 69 companies, across 10 provinces, the second surveyed 23 government employees. The industries interviewed during the material efficiency surveys were split into seven main sectors (Agro-processing, Chemicals, Construction, Food and Beverage, Energy, Mining, and a category called Other). The interviews covered the following topics: background of the company and interviewee, perceptions of material provision challenges, materials used and produced, replacement of equipment parts or buildings, and knowledge of efficiency and emissions terms. The government officials interviewed included 12 officials from the Department of Industry and Commerce, six from the Ministry of Energy and Mine, two from the Ministry of Natural Resources and the rest from other organisations. The responses were conducted in Lao language and translated to English. Then, they were cleaned and aggregated to, for example, identify percentages or frequency of using terms.

Energy efficiency surveys were conducted by GGGI in late 2021 and included 25 site visits to different factories. The industries interviewed during the energy efficiency surveys are divided into four main sectors (Agro-processing, Construction, Garment, and Other). The topics covered include: background of the company and sector, energy equipment review, and investment opportunities identified for increasing energy efficiency.

Table 2 presents a breakdown of the types of industry included in each type of survey.
Table 3 Presents a breakdown of the affiliation of the government officials interviewed.
Detailed information about the methodology of each type of survey can be found in Section 5.

Table 2 Breakdown of industry types by type of survey.

Industry type	Number of energy efficiency survey responses	Number of material efficiency survey responses
Construction materials	9	41
Agro-processing	7	2
Garment	7	0
Chemicals	0	11
Food and beverage	0	6
Mining	0	1
Energy	0	1
Other	2	7
Total	25	69

Table 3 Breakdown of government officials interviewed during the material efficiency surveys.

Institution	Number of respondents
Ministry of Energy and Mine	6
Ministry of Natural Resource and Environment	2
Department of Industry and Handicraft	1
Department of Industry and Commerce	12
Department of Planning and Cooperation	1
United Nations Industrial Development Organization	1

3 Opportunities and challenges to increase energy and material efficiency in Lao industry

This section discusses the survey responses and presents general findings and material provision perceptions at the national level for company and government employees. These are followed by sub-sections which cover the key sectors of Construction, Agro-processing, Garments and cross-cutting industries which include Chemicals, Mining, Energy, Food and Beverage and Other. Each sector sub-section introduces the industries covered and whether they were included in the surveys of energy, materials or both.These sub-sections expand on the context of each sector in Lao and material and energy survey responses. In particular, the sub-sections cover the background of each industry and their national relevance, the material provision challenges they face, their energy consumption, and their equipment or part replacement practices.

3.1 General material provision perceptions of company employees

The industries interviewed reflect some of the evolution of the industrial sector in Lao, since the information gathered includes the foundation year, location, and whether the companies are national or international.

Figure 4 shows the foundation year of each company interviewed as part of the material survey, split by sector for both national and international companies. Nationally-owned companies interviewed represented 51% of respondents, and international companies 49%, mainly Chinese and Thai (29% and 9% of the 69 companies interviewed respectively).

Among the companies interviewed, the Construction sector and a Chemical company are those recorded to have the earliest presence in Lao, from 1994. The Construction sector has grown steadily throughout the 2000s, for both national and international companies, while companies in the sectors of Food and Beverage, Agro-processing, and Mining were founded between 2007 and 2013. International companies covering the sectors included in the surveys are prevalent after 2005, with the Construction sector being the only exception to this starting year. The industry trends observed showcase the transition to an economy that relies on more and more specialized industry over time.

The companies interviewed reflect the large number of small and medium-size enterprises in Lao, with 20% of the companies interviewed having less than 10 employees, 33% having 10 to 50 employees, 17% having between 51 and 100 employees, 23% between 101 and 500 employees, and only 6% having more than 500 employees.

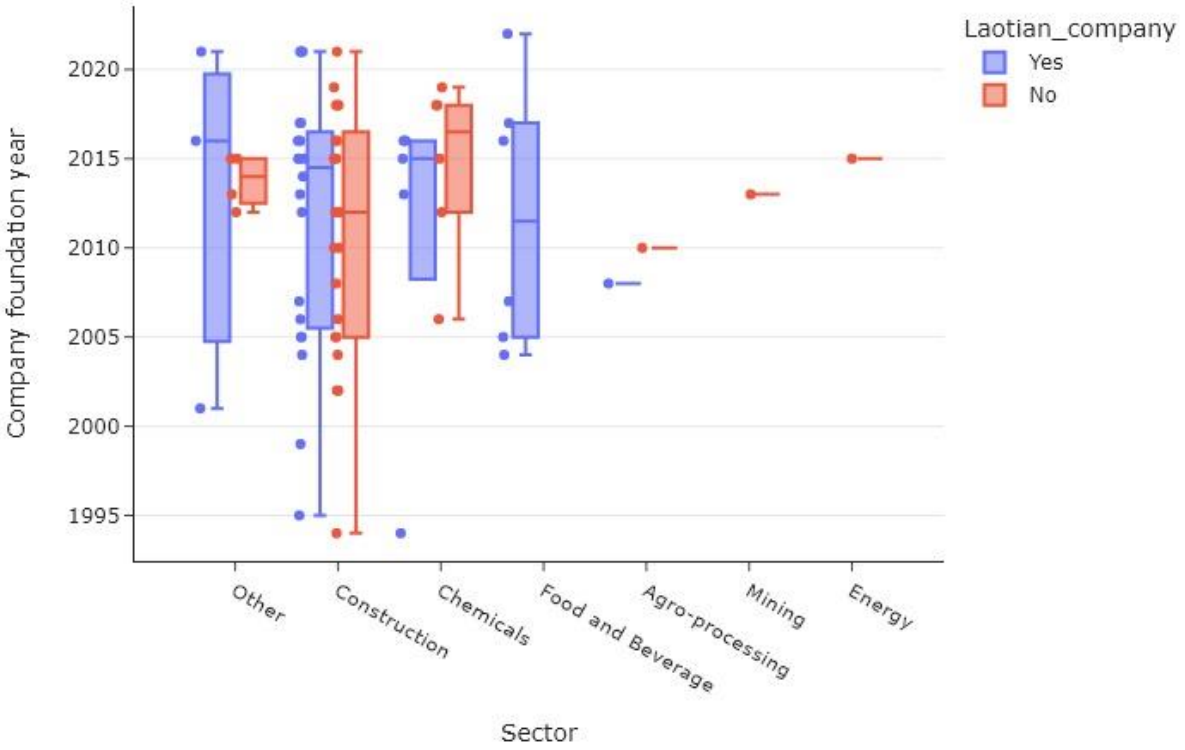

Figure 4 Distribution of the company foundation year by its type of sector coloured depending on whether it is a nationally-owned (blue) or international (red) company. The value indicated by a horizontal line in the middle of the box refers to the median value.

The perceptions of material provision included in the material surveys done in industry considered the ease of material acquisition, changes in material access, the identification of materials that are hard-to-acquire, and trade barriers affecting each sector. In questions such as changes in material access or hard-to-acquire materials, the interviewees also had the opportunity to give more detailed responses, which are quoted in the findings where relevant.

Figure 5 shows the perception of the ease of material acquisition by sector for the companies interviewed during the material surveys. For most companies, material acquisition seems easy (32%), for a further 28% it is neither easy nor hard, while 20% report that material acquisition is hard. The sectors with easy and neither easy nor hard material acquisition are mostly Construction, Chemicals, and Other. As companies from the Construction sector were the most frequently surveyed, they dominate the breakdown. However, there is a disparity between companies within the same industries that suggests that other factors influence their the ease of acquiring materials, which could be their location, size, capital available, type of company, among others.

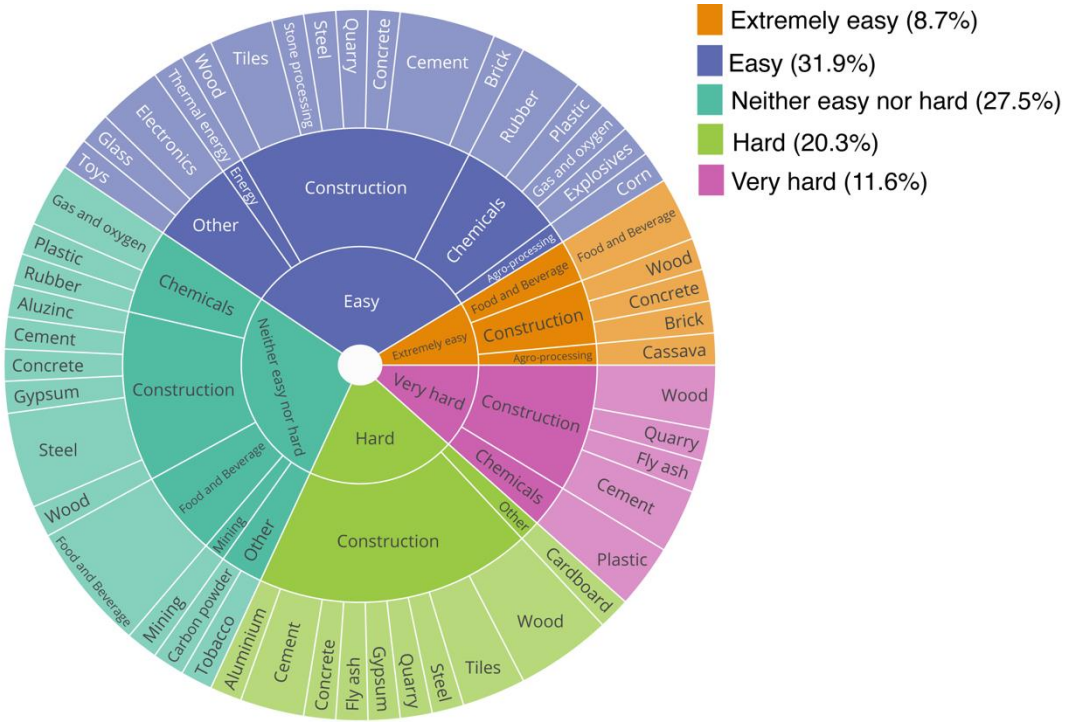

Figure 5 Perception of ease of material acquisition as a share of the total companies surveyed split by sector and industry.

Figure 6 shows the perception of changes in material access as a share of the companies surveyed and by sector. The perception of material access is that it has mostly remained unchanged (32%) or has become easier than in the past and easier than during COVID (adding both, 32%); however, 26% of the companies reported it had gotten harder than in the past. As with the question of ease of material acquisition, these responses present enough disparities that it is hard to have a clear picture of the situation for each industry. However, the responses show that the COVID pandemic had a negative effect on material access for some companies. Pandemic-related difficulties in material provision cited during the surveys include that “the nation of origin, which sources and manufactures the substance, is closing down owing to COVID prevention efforts”.

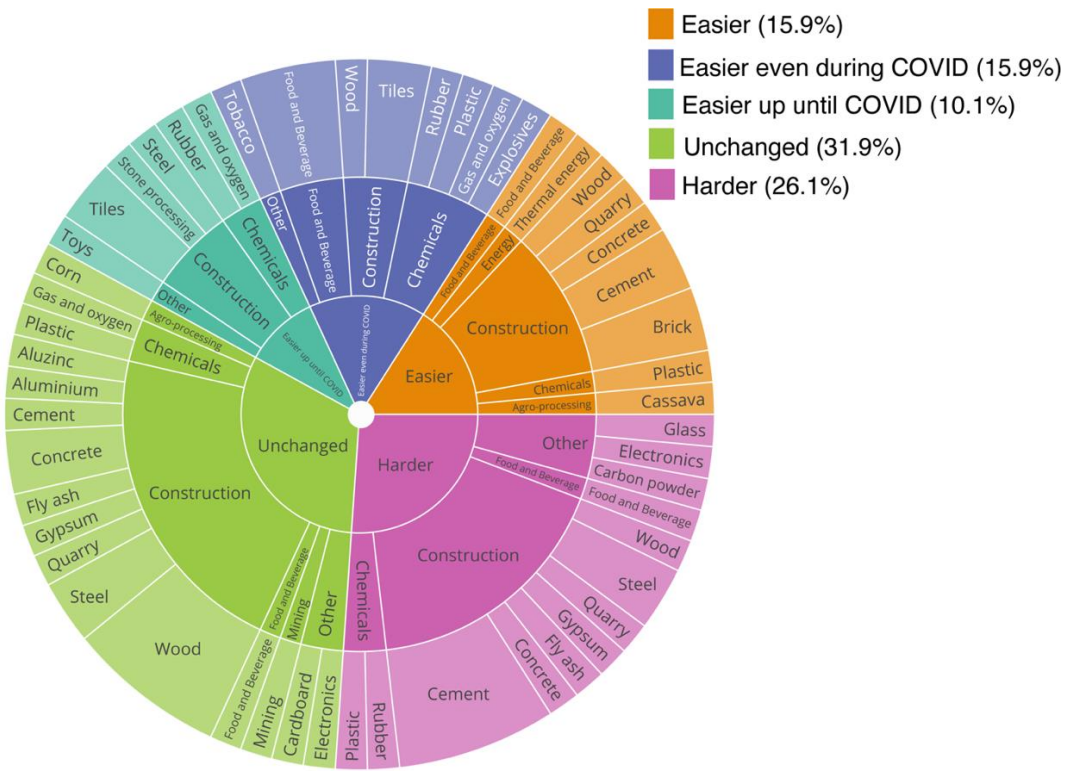

Figure 6 Perception of changes in material access as a share of the total companies surveyed split by industry and sector.

Table 4 shows the materials that were reported as hard-to-acquire in each sector, where coal was the material most commonly mentioned overall. Given the large number of companies from the Construction sector included in the surveys, several materials are cited, mainly coal (five times), fibre stone and fibre glass (twice), and wood materials (e.g., logs, chips).

Table 4 Materials cited as hard-to-acquire by sector during the material surveys for companies. Note that not all respondents reported these materials and that responses have been aggregated by sector.

Sector	Hard-to-acquire materials cited
Chemicals	Raw rubber, rubber, coal, plastics
Construction	Iron, sand, explosives and bombs, manganese, coal (x5), raw material, wood logs, stone, limestone powder, rice husk, wood chip, fibre stone and fibre glass (x2), chemicals
Food and Beverage	Fruit juice
Mining	Coal, fuel oil
Other	Charcoal, microchips, diesel for diesel engine, corrugated boxes, and printing materials

Figure 7 shows the trade barriers identified in the industry surveys, with the size of each word representing the frequency in which each term is mentioned. Detailed responses by industry can be found in **Table 6** in Section 3.3. Overall, inflation (36), exchange rate (29), cost (19), material (10) and transport-related terms (transportation, shipping and logistic adding up to 18 occurrences) were the most common trade barriers identified. Thus, Lao requires financial measures and improvements in transport provision alongside industrial efficiency measures.

Figure 7 Most common trade barriers identified. The size of the words refers to the frequency of citing each term.

Figure 8 shows the material provision considerations to make new projects or business expansions that the companies interviewed have to make, with 71% of the companies saying that considering material provision is very important, while only 20% say it is not important. Examples were gathered on how material provision affects business decisions, which will be discussed in the context of each type of sector in the remaining sub-sections.

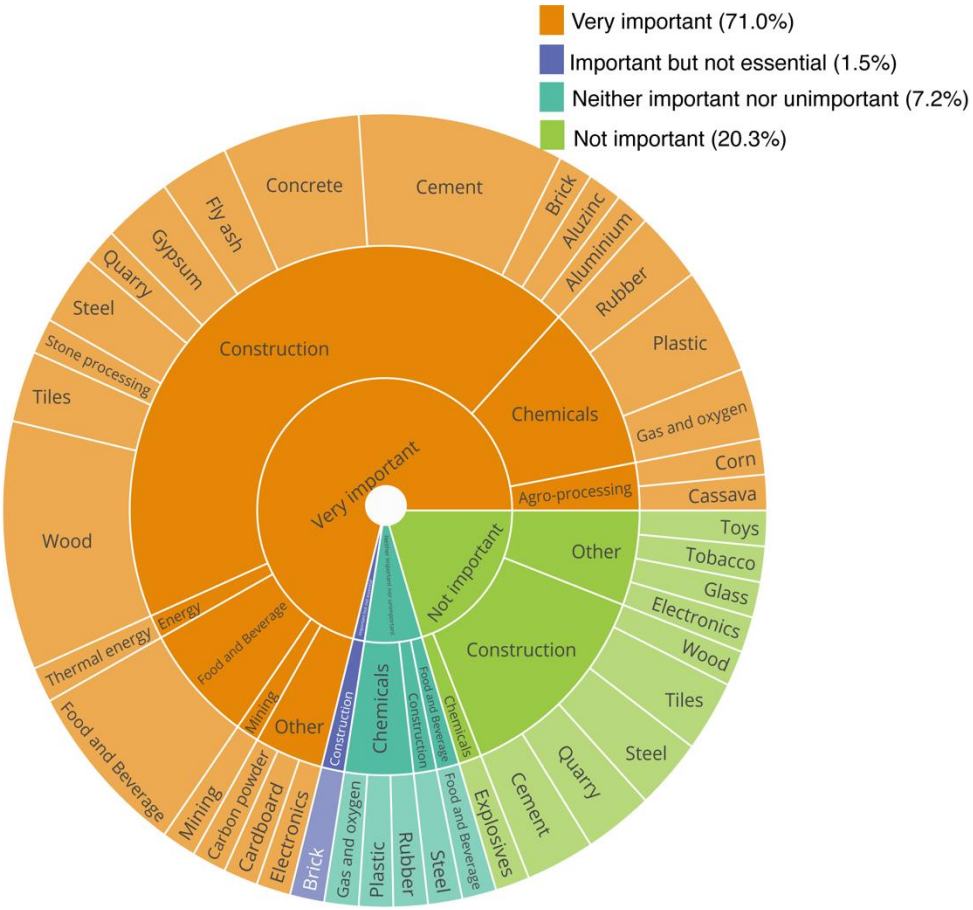

Figure 8 Importance of material provision considerations for new projects or expansions in the business split by industry and sector.

Key general material findings within companies

The industry trends observed showcase the transition to an economy that relies on more and more specialized industry over time. The companies interviewed reflect the large number of small and medium-size enterprises in Lao. There is a disparity between responses on the ease of acquiring materials and how this changes over time within the same industries. This suggests that different factors influence material acquisition. These could include the company location, size, capital available, or type of company. The material cited as the hardest to acquire was coal. Apart from coal, the Construction sector cited several other materials such as fibre stone, fibre glass, and wood materials. The most common trade barriers identified by the companies are inflation, high exchange rates, costs, material, and transport challenges. Thus, Lao requires financial measures and improvements in transport provision alongside industrial efficiency measures.

3.2 General material provision perceptions of government officials

Material surveys conducted for government officials also included the barriers for trade and local production that they were aware of. Their responses on trade barriers illustrate that there are varying levels of knowledge at government level. Responses range from detailed knowledge of the barriers, to saying there were “no barriers” because the ministries “promoted” initiatives or that it was “easy to export and import”, to also saying they did not know. These shows a disconnect between government initiatives and how they trickle down to industry.

A response by a member of the Ministry of Energy and Mines with detailed knowledge gave the following response regarding the ease of acquiring materials:

> *"According to the current mechanism of international trade, Lao's import and export of goods is relatively easy. In particular, the import of construction materials is very convenient as most of the power projects are private investments with direct foreign exchange and therefore are not affected by domestic inflation as much as they should be, but may be affected by changes in global market prices. In addition, the import of project materials is also exempted from import duties in accordance with the government's investment promotion policy. The export sector is also somewhat convenient as Lao has new options for the export of goods, such as rail transport and the prioritization of Lao by the parties to the treaty."*

It is evident that there is a disparity in perceptions, since not all construction companies reported it was easy to acquire materials.

Other government official responses hinted at the regulations and inspections that need to be conducted which are a barrier for trade, for example, one respondent mentioned "an extensive documentation process with regular checks". As with industry surveys, the exchange rate and inflation were mentioned, but only twice out of 23 interviews. The stark contrast between responses from industry and government officials regarding the perceptions of trade barriers shows some degree of disconnect between practical activities in industry and policy application.

Selected responses of government officials on local manufacturing barriers revealed bureaucratic barriers such as "document processing", high production costs, lack of resources such as "machinery" or "raw materials", lack of "skills" and "technical expertise", and "production methods not advanced enough". A detailed response mentioned that Lao:

> *"still relies heavily on imports, such as goods and materials from industrial plants, due to the lack of sufficient production bases, low skills, and the [small] size of the domestic market, but production for export has to be competitive. In addition, the limited infrastructure of roads, and transportation is also a factor that hinders the production and logistic of goods".*

Overall, seven survey responses (i.e., 30%) alluded to both the lack of resources- specifically raw materials- and skills as key local manufacturing barriers, while two responses (9%) alluded to transport.

During the material surveys, government officials were asked broadly about their perceptions on the ease of acquiring certain materials both locally and through trade**. Figure 9** shows the share of such responses by type of material. Natural bulk materials are perceived as the easiest to obtain, with 13% of respondents saying it is "extremely easy" to acquire them. In general, all materials are reported as relatively easy to acquire, especially heavy machinery, vehicles, and specialized or non-natural bulk materials. The materials that are reported as not easy to acquire are mostly those identified as trade-dependent. Trade-dependent materials identified are mainly those in vehicles (30%), specialized materials (26%), and bulk materials (22%). The two types of materials reported as hard to obtain locally are bulk

materials (with 22% and 13% of responses for natural and non-natural materials respectively). Specialized materials were most frequently identified as those “extremely hard” to obtain (13%).

Comparing the industry and government official responses, there is a degree of similarity in their perceptions of material acquisition. For example, the industry reports that it was hard to acquire wood locally, while officials identify natural bulk materials as having barriers to obtain both locally and through trade. However, there are also slightly contradictory responses. For example, in some cases, heavy machinery or specialized manufacturing materials are mostly identified as relatively easy to obtain at government level, but responses on trade barriers expressed that microchips or specialized machinery were hard to get.

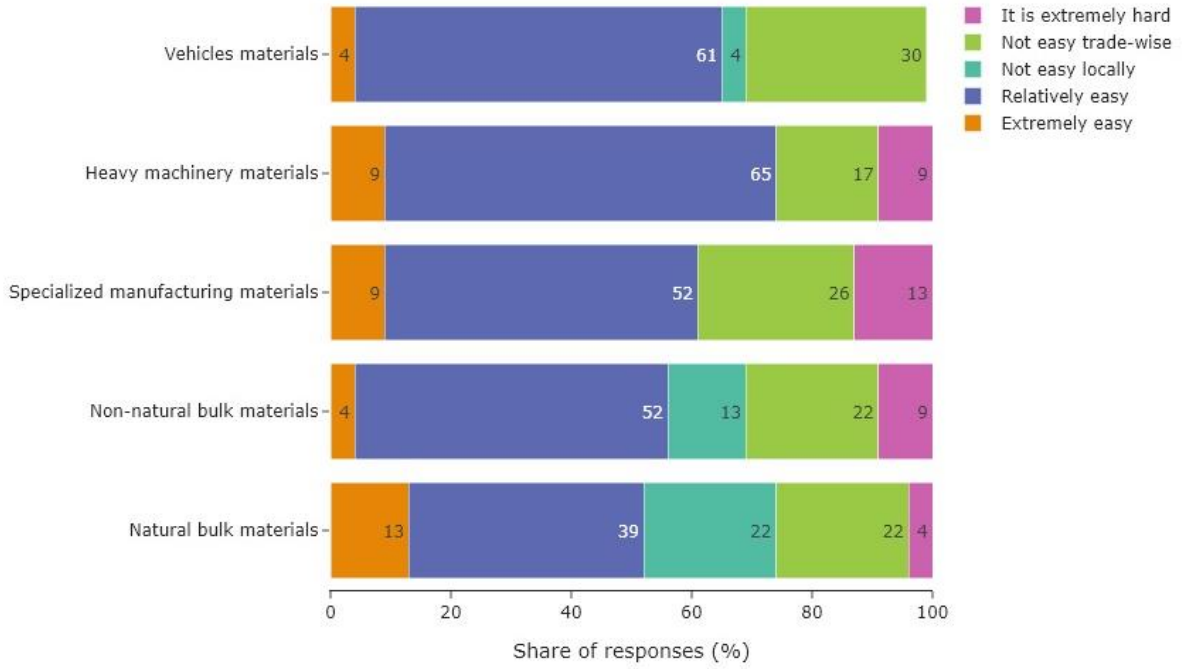

Figure 9 Government official perceptions on acquisition of given materials in Lao. The share of responses refers to the share of responses over the total number of government surveys.

Key general material findings within government officials

The government officials perceptions on material acquisition and trade barriers for material provision showed that there is a degree of disconnect between policy initiatives and their influence on the challenges faced by industry and the trade barriers identified. Policymakers focus more on bureaucratic, skills- and policy-related barriers, while industry responses focus on material, economic or transport barriers.

3.3 Construction

The Construction sector in Lao includes the production of materials for construction such as steel, cement, rebar, PVC pipes, paints, plastics, and bricks as well as the treatment of wood to make it fit for use in buildings.

On average, the Construction sector companies interviewed in the material and energy surveys use 8,034,405 kWh of electricity annually. **Table 5** shows the energy use by industry interviewed during the surveys. One cement company was found to produce electricity with

an on-site coal thermal power plant, with the company having a concession for coal supply, but the power plant is not included in any national electricity generation accounts.

Table 5 Average annual energy use of selected industries in the Construction sector included in material and energy surveys. In cases where only one factory is included, its value is reported in the average column. Otherwise, the range of values is presented as minimum and maximum.

Survey type	Industry	Energy source	Average energy source use (kwh/year)	Minimum energy use (kwh/ year)	Maximum energy use (kwh/ year)
Material	Aluminium	Electricity	15,588		
Material	Aluzinc	Electricity	6,240		
Material	Brick	Electricity	713,640	179,280	1,248,000
Material	Cement	Electricity	39,726,030	3,317,268	83,637,180
Material	Concrete	Electricity	25,092	13,440	42,804
Material	Fly ash	Electricity	2,738,634	2,160,000	3,317,268
Material	Gypsum	Electricity	770,466	255,828	1,285,104
Material	Quarry	Electricity	185,106	133,519	271,692
Material	Steel	Electricity	18,182,400	360,000	48,000,000
Material	Stone processing	Electricity	900,000		
Material	Tiles	Electricity	148,136	45,283	297,600
Energy	Brick	Wood	2,533,300		
Energy	Cement	Electricity	46,641,314		
Energy	Cement	Coal	460,506,447		
Energy	Cement	Diesel	1,974,000		
Energy	Steel	Electricity	1,504,567	1,370,448	1,638,686

Generally, the Construction sector is diverse regarding the ease of material acquisition.

Table 6 shows the material provision considerations that different companies in the Construction sector make. Material provision considerations show that some raw materials and equipment can be hard to find since they need to be imported, and the high exchange rate affects purchases and the cost to consumers.

Table 6 Selected responses of material provision considerations for the construction sector and specific industries. These responses were selected due to their level of detail. Different paragraphs per industry refer to different company responses.

Industry	Material provision considerations while planning new projects or expansions
Wood	Wood is the rarest raw material and is currently decreasing in quantity and increasing in price, including natural wood and plantation teak. There are not many timber resources with commercial worth. This affects production. Therefore, materials are imported from abroad to run businesses. Finding raw materials as inflows for the factory is not enough to meet the needs of customers and is an obstacle to increasing production capacity and growth.
Aluminium	Business expansion is a critical element that must be considered. Materials are a measure of the economy and product quality. The quality will be poor if the material is poor quality.
Aluzinc	Equipment bought from abroad. The price of Aluzinc sheet imports is still high because of the exchange rate, which makes the cost of production high.
Concrete	Equipment bought from abroad. Spring steel (PEY steel) must be imported from Thailand, so the cost of importing is higher due to the unstable exchange rate. Buying raw materials in foreign currency and selling them in Kip causes fluctuations in the price of products.
Steel	Procurement of raw materials is an important factor because if there is a lack of raw materials, steel cannot be produced. The exchange rate is very important because in the procurement of raw materials foreign currency is used.
Gypsum	Materials, such as limestone which is needed to make gypsum board and limestone powder, are the primary factors in business expansion. Thus, mining of limestone needs to be sufficiently focused to fulfil demand. Providing limestone involves putting together a crew to break ground, a unit to blast limestone to create limestone powder, and gypsum board.
Fly ash	This processing factory is involved in the processing of fly ash. Customer demand would decrease if the supply of materials is of poor quality and the pricing is unstable. Production will be tough to maintain if there is no distribution market. Because the railway has been constructed, there is no market to sustain. There is currently no distribution market.
Stone processing	Materials are an important aspect in determining profitability.
Cement	The material is essential when planning or growing a business because it serves as a gauge of its viability and quality. As an illustration, the […] Cement Factory makes cement. Cement is the only significant component. There will be distribution challenges if the material supply is insufficient, the quality is unstable, and the pricing is unstable. As a gauge of economy and quality, raw materials are crucial when developing a business plan or growing an existing one. Consider the activities in the cement industry, where coal and limestone are the primary raw resources. The factory's ability to meet its production needs and the growth of the company will be impacted by both the availability and quality of such resources.
Tiles	If there is no raw material, tiles cannot be produced.
Quarry	Machines and raw materials must be in the same place.
Brick	Importing raw materials is not an issue because domestic items are utilized. Indicators of materials and raw materials, machinery to raise the production capacity, [and] location of bricks burner. The exchange rate increase makes the price of oil expensive and, as a result, the factory has to raise the price of the product.

Replacement of equipment, parts, or buildings is common in any industry to repair malfunctions, replace outdated equipment, or to increase the efficiency of some devices. In Lao, the companies were asked about their replacement practices, including the parts, reason, and timeframe of replacement. **Figure 10** shows the reasons and timeframe of replacements and new builds done in the Construction sector for the material surveys. Most companies replace equipment that is damaged or faulty, while old or outdated equipment is a reason for replacement only 5% of the time, mainly in vehicles. Energy savings were only

reported as a reason in heavy machinery, while building extensions are done to increase the capacity of the factories. The timeframe for replacement showed that vehicles are the equipment most frequently replaced, followed by power and heat equipment and machinery. However, in all of the parts discussed, most companies said that it has been over 10 years since they last replaced anything. The responses suggest that maintenance tends to be reactive rather than preventive, with little consideration of energy or material efficiency.

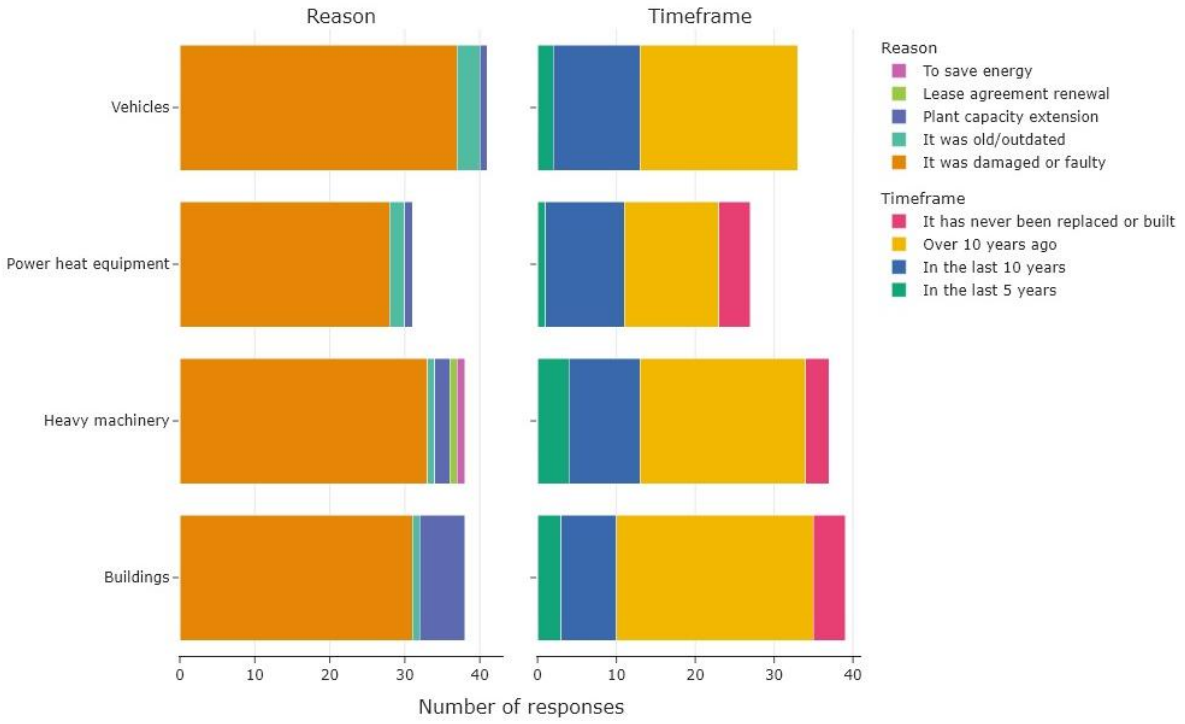

Figure 10 Cited reasons (left) and timeframe (right) for replacing given parts in the Construction sector. Number of responses refers to the number of surveys conducted.

Key Construction sector findings

Material provision for construction is varied; some companies find it easier than others. The challenges they face when acquiring materials include that raw materials and equipment can be hard to acquire since most need to be imported, with the high exchange rate affecting purchases and the cost to consumers. Replacements of parts and equipment occurred over 10 years ago for most companies. Thus, maintenance tends to be reactive rather than preventive. National knowledge of local-level challenges seems to be lacking in some cases. For example, there is a cement company which produces electricity with an on-site coal thermal power plant, yet the power plant is not included in national electricity generation accounts.

3.4 Agro-processing

The Agro-processing sector in Lao includes working with several type of staple crops and products including rice, maize, coffee, sugarcane, cassava, sweet potato, and industrial tree crops (for example, rubber, eucalyptus, and acacia). Generally, agriculture plays an

important role in the economy, with an estimated 72% of the total cultivated area being dedicated to rice [15].

The Agro-processing industries that were included in the surveys and this report are cassava, corn, feed, rice, salt, and abattoirs. From these industries, the material surveys focused on cassava and corn production, while the energy surveys focused on cassava, rice milling, salt production, animal feed, and abattoirs. In this sub-section, cassava and corn industries are discussed first, including material survey findings such as provision and machinery/equipment replacements, and the energy survey information on cassava. Then, the energy survey industries are introduced, explaining some processes for key industries such as rice milling in more detail.

On average, the companies interviewed in the material and energy surveys that belong to the Agro-processing sector use 1,183,859 kWh/year of electricity. **Table 7** shows the values for each industry type.

Table 7 Average annual energy use of selected industries in the Agro-processing sector included in material and energy surveys. In cases where only one factory is included, its value is reported in the average column. Otherwise, the range of values is presented as minimum and maximum.

Survey type	Industry	Energy source	Average energy source use (kwh/year)	Minimum electricity use (kwh/year)	Maximum electricity use (kwh/year)
Material	Cassava	Electricity	3,600,000		
Material	Corn	Electricity	29,376		
Energy	Rice mills	Electricity	338,796	53,000	755,000
Energy	Cassava	Electricity	1,382,924		
Energy	Cassava	Wood	2,500,000		
Energy	Abattoir	Electricity	1,226,300		
Energy	Animal feed	Electricity	525,758		

Corn and cassava

Corn and cassava are important crops in Lao. Corn is the second-most important crop after rice in Lao [16], while cassava production has increased more than five-fold between 2010 and 2020, reaching over 100,000 hectares. Lao and its neighbours (Thailand, Cambodia and Viet Nam) belong to the top five global cassava exporting countries [17].

One cassava flour factory that was visited during the energy surveys had an annual production of 5,579 tonne. Its Specific Energy Consumption (SEC) was estimated to be 240 kWh/tonne of electricity and 434 kWh/ton of wood.

Table 8 shows responses of material provision considerations for the Agro-processing sector. The corn and cassava industries rely heavily on raw materials, but material procurement is insufficient, thereby hindering the ability of these industries to meet customer demand.

Table 8 Selected responses of material provision considerations for the Agro-processing sector and specific industries.

Industry	Material provision considerations while planning new projects or expansions
Corn	The purchase of raw materials for the firm is insufficient to satisfy the demands of the clients. Because there isn't much maize growing in Xayaburi, there isn't enough to suit the factory's demands.
Cassava	The procurement of raw materials for production is insufficient to fulfil demand, and the firm will be unable to meet the demands of the consumers. For example, we have a market to supply 15,000 to consumers every year, but our raw materials are insufficient to satisfy the market's expectations, which has a significant impact on our choice.

Figure 11 shows the reasons and timeframe of replacements and new builds done in the Agro-processing sector. This is a section from the material surveys. Equipment is replaced mostly due to it being damaged or faulty. Only in the case of plant capacity extension do companies report replacing vehicles and heavy machinery. The two Agro-processing companies surveyed said that it has been over 10 years since they last replaced any parts. These responses suggest that maintenance is reactive and that there was some growth in the sector a decade ago, but no consideration of energy or material efficiency.

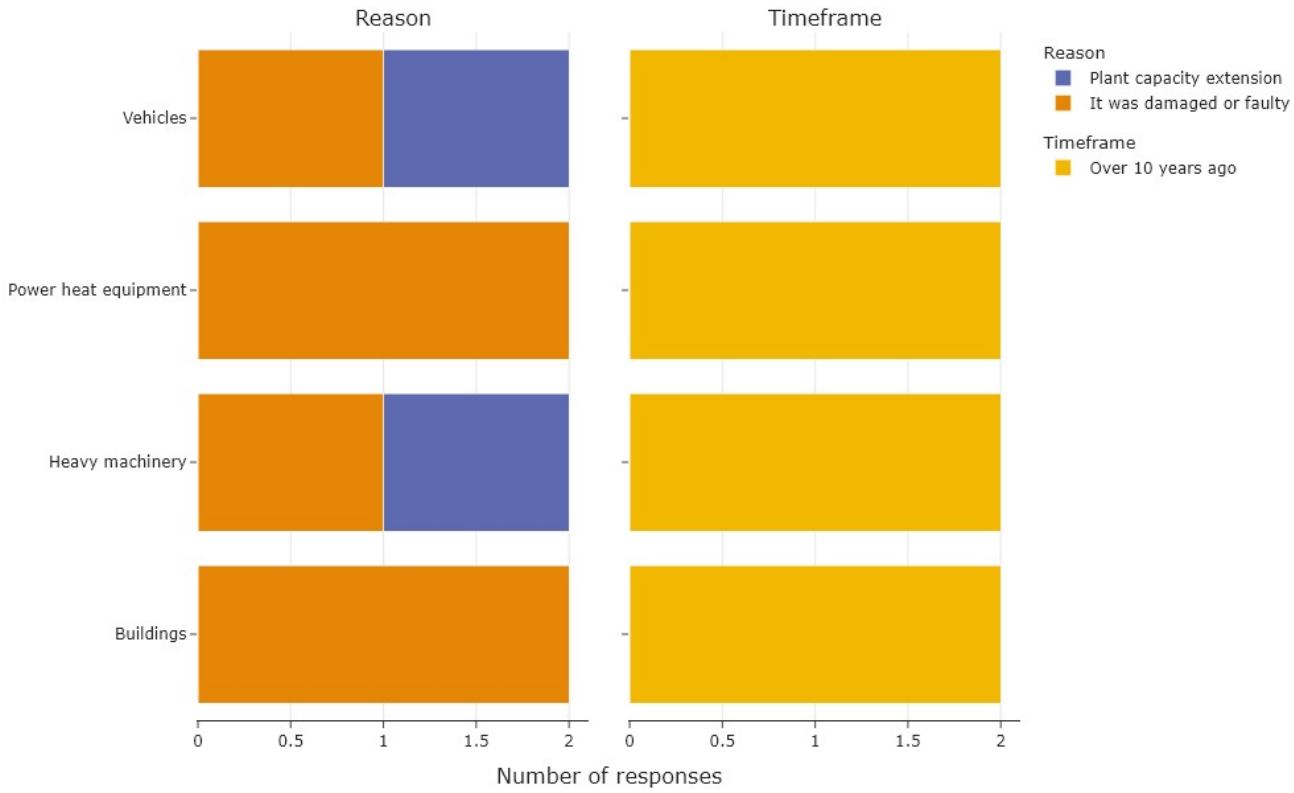

Figure 11 Cited reasons (left) and timeframe (right) for replacing given parts in the Agro-processing sector. Number of responses refers to the number of surveys conducted.

Rice

Rice is the staple food of most of the population of Lao, and its supply guarantee and quality are of utmost importance for the food security of the whole of the country. The steps needed for rice milling include paddy cleaning, de-husking, separating the components, polishing the rice, grading, colour sorting, and finally, packing. To produce one tonne of polished rice, 1.6 tonne of paddy rice needs to be harvested. This is due to the removal of husk, bran, dust, and the waste produced. The Lao production of paddy rice reached 3.5 Mt in 2019, including all types (inundated and dry cultivation). These were milled in three types of milling facilities depending on the scale of the operation. This corresponds to about 2.2 Mt of polished rice produced in Lao annually.

The three categories of rice mill facilities are:

- **Local level:** very small operations found in villages for milling the production of local rice farmers, with an important share of self-consumption of their harvest. Machinery is often very basic and old, many operations are manual, and the quality of the milling is rather poor. The annual tonnage per milling facility is small and milling often happens on demand, as farmers bring their own harvested rice.
- **Intermediate level:** in or near small towns for consumption by the growing urban population.
- **Industrial level:** in or near larger urban centres. Most of the operation is automated and the quality of the milling is higher, even if some equipment is sometimes outdated. Several thousands of tonnes can be produced annually in these facilities. Part of the production is often exported as the quality of the milling reaches international standards.

This report focuses on the industrial level with an annual production of 1 kt/year or more.

The Lao Rice Milling Association encompasses ten industrial rice mills, based in the Vientiane region, producing a total of 192 kt/year of polished rice. The precise number of industrial rice mills in Lao is unknown, but it can be estimated that a total of 20% of the entire rice production of Lao is milled in industrial-level facilities (capacity ≥ 1 kt/year), that is, about 706.9 kt/year of paddy rice, corresponding to 441.8 kt of polished rice.

Three rice mills have been visited during the GGGI project on energy efficiency (**Table 9**), all situated in Vientiane Capital, to assess the energy use in the rice milling industrial sub-sector.

Table 9 Annual production of rice milling factories interviewed in the energy surveys.

Rice milling factory	Production (tonne/year)
1	10,000
2	7,000
3	2,500

The three rice mills have different levels of energy efficiency, sophistication, and age, hence giving a good view of the industrial rice milling landscape in Lao. The factories produce polished rice which is mainly destined for the domestic market with some exports to surrounding countries, namely Thailand, China, and Viet Nam, among others.

Nearly all the processing equipment used at the mills is imported, especially from China and Vietnam, since Lao does not produce industrial equipment. To reduce capital expenses, most of the equipment has been purchased second hand, leading to lower energy efficiency associated with the somewhat worn-out machinery.

The energy consumption ranges from 53,000 to 755,000 kWh/year. The SEC ranges from 61 to 302 kWh/tonne of polished rice, which is high to very high according to international benchmark figures on rice milling.

Salt

Salt production in Lao was estimated to have reached 390 Mt in 2021, which is only 62% of the 2020 production [10]. This reflects the slowdown of the sector with respect to the three years prior. The sector has been a focus of energy efficiency audits in the past which focused on reducing the use of fossil fuels, improving the production efficiency, and conducting equipment checks [18].

During the energy surveys in this project, one salt factory was visited. However, no data on salt production or energy consumption was provided by the company. Thus, its SEC is not estimated in this section.

Animal Feed and Abattoirs

The production of feedstock for animal feed is an attractive business since one of the main exports in Lao is live bovine animals, as shown in the Introduction. Pigs (3.4 million heads in 2017), cattle (1.9 million heads), buffalo (1.2 million heads), and goats (0.5 million heads) are the main livestock species in Lao, with between 92–99% of each being bred at small holder level and the rest in farms [19]. Feed for these animals requires the use of crop residues and agro-industrial by-products. For example, ruminant diets use rice straw, cassava pulp, and wet brewers' grains as roughage, energy and protein sources respectively [20].

The value chain of animals consumed as meat includes slaughterhouses at an industrial level and small-scale slaughtering at markets. For pigs, sheep and goats, an estimated half of the heads from small holders ends up in abattoirs [19]. Animal imports from neighbouring countries which end up being consumed in Lao is common for animals such as pigs, sheep or goats [19].

Currently, challenges faced by the livestock sector include surging prices of livestock inputs (such as animal vaccines) and food items, leading to distress sales of animals that have long-term impacts for small holder livestock production [21]. Food items in turn are influence by the high prices of fuel and other inputs.

During the energy surveys conducted for this report, one animal feed and one abattoir were included. Their electricity use was 525,758 kWh/year for the animal feed factory and 1,226,300 kWh/year for the abattoir. The SEC was 49.6 kWh/ton for animal feed and 8.46 kWh/head for the abattoir.

Key Agro-processing sector findings

Products from the Agro-processing sector in Lao are destined for both the domestic and international markets, with products such as cassava or rice having global importance. Yet, raw material availability is hindering the ability of industries such as corn or cassava to meet demand. Trade of agro-processing products with Lao's neighbours is common and forms

part of the value chain of products such as meat. The sector relies on small-scale enterprises which hinder efficient and standardised processes, as reflected by the 92–99% of livestock small holders or the 80% of rice milled in non-industrial facilities. Given local manufacturing constraints, the sector requires equipment imported from abroad. Some growth was shown in the sector a decade ago, given the plant capacity expansions, and maintenance was shown to be reactive.

3.5 Textiles/garments

The textiles/garment sector is only covered by the energy surveys and not by the material surveys. Thus, there is no data regarding equipment replacement plans and this sub-section focuses on summarising the Garment sector in Lao and the energy use obtained during the energy surveys.

Garments

There are 78 industrial garment factories in Lao. Of these, 50 are export oriented and 28 are sub-contractors. There is a Lao Garment Association comprised of 48 factories. These figures do not include local production of textile (silk, cotton) which is handled by smaller factories, family run workshops, and artisanal home production. The focus of this report is only on industrial-scale garment production.

The national energy consumption of the industrial garment sector in Lao is not known. Hence, data provided by the factories visited and the observations done during the energy audits were used to estimate the energy consumption at sectoral level. Some information given by the Lao Garment Association has also been used for this estimate.

Six garment factories have been visited during the GGGI project on energy efficiency (**Table 10**), all situated in the Vientiane area, to assess the SEC in the Garment sector.

Table 10 Annual production of garment factories interviewed in the energy surveys.

Garment factory	Production (pieces/year)
1	1,260,000
2	6,770,000
3	824,635
4	2,279,732
5	3,405,870
6	1,260,000

Those six garment factories have different levels of energy efficiency, size, sophistication, and age, hence giving a good overview of the garment landscape in Lao. A large part of the production is destined for export.

The energy surveys reflect that energy consumption ranges from 135,000 to 3,471,318 kWh/year for garment factories. The cost of electricity in the six garment factories is 765 LAK/kWh on average, taxes included. The SEC ranges from 0.16 to 1.52 kWh/piece of

clothing produced, which is close to the average according to international benchmark figures on garment fabrication.

Shoe factories

Only one shoe factory was included in the energy surveys. The factory had an annual production of 200,000 pairs of shoes. The electricity use was 538,768 kWh/year, therefore the SEC is 2.69 kWh/pair of shoes.

Key Textile/Garment sector findings

Garment factories have varied levels of energy efficiency, size, sophistication, and age. Lao's garment factories mainly supply international markets, with 64% of companies producing to export. The SECs range from 0.16 to 1.52 kWh/piece of clothing produced, a variation that does not seem to reflect economies of scale, and 2.69 kWh/pair of shoes.

3.6 Cross-cutting technologies including waste management

Other industries that supply materials to others and thus have a cross-cutting component were aggregated in this section. The sectors include Chemicals, Energy, Food and Beverage, Mining, Plastics, and others, which in turn have specific industries, for example, plastics or rubber for Chemicals. The industries in this section were mainly covered by the material efficiency surveys. Only the plastics industry is included in the energy surveys. Thus, this section presents the findings of the material surveys, including material provision considerations and equipment/part replacements without detailing each industry. Then, the plastic industry is covered in more detail, discussing the energy survey results.

Cross-cutting sectors play an important role in Lao's economy. This is showcased by mineral production, where gold and copper are among the top five main exports of Lao [6]. Mineral production reached USD 7.53 billion and the export value of minerals was estimated at USD 6.66 billion in 2020 [5]. The sector is, however, being affected by low mineral prices which have led to a production decline. The government has temporarily suspended mining concessions to improve policies and regulations which favour national interests and manage environmental impacts [5].

Table 11 shows the average monthly electricity use of the factories included in the material and energy surveys of cross-cutting sectors. It should be noted that the Chemicals sector has a high average, which is linked to the maximum value of electricity use reported by the explosives industry.

Table 11 Average annual electricity use of selected sectors included in material and energy surveys. In cases where only one factory is included, its value is reported in the average column. Otherwise, the range of values is presented as minimum and maximum.

Survey type	Sector	Average electricity use (kwh/year)	Minimum electricity use (kwh/ year)	Maximum electricity use (kwh/ year)
Material	Chemicals	39,499,910	4,200	423,860,800
Material	Energy	1,292,595		
Material	Food and Beverage	759,642	18,468	4,118,400
Material	Mining	14,736,040		
Material	Other	2,516,865	20,580	7,200,000
Energy	Electronics	2,127,760		
Energy	Plastics	1,863,600		

Table 12 shows material survey responses on material provision considerations for various cross-cutting sectors. Several industries rely on material imports, and their costs in foreign currencies affect the profit margin of the companies. Thus, high material prices or high exchange rate may impact the quality of the final products. Transport costs are an important consideration given their impact on final product costs.

Table 12 Survey responses of material provision considerations for the Chemicals, Energy, Food and Beverage, Mining, and other sectors and their specific industries. Each paragraph in a sector refers to a unique response. When companies used the same response, the number of times are indicated.

Sector	Industry	Material provision considerations while planning new projects or expansions
Chemicals	Gas and oxygen	Materials are imported from abroad to run businesses. Planning, for instance, is challenging when purchasing items from abroad and selling them later in Lao Kip. The requirement for labour is vital for business expansion because the internal raw materials cannot satisfy client demand. For instance, the direct importation of gas, gas containers, and other equipment for the cooking gas industry creates decision-making challenges.
Chemicals	Plastic	In the process of planning or expanding a business, every element is important, but indispensable is the material because it is an indicator of the business and quality. In order for a factory to produce completed plastic granules, rubber must be imported in appropriate quantities, and if the imports are insufficient or of low quality, the plant's production will not reach the requirements required by the market. If you buy materials that are not of good quality for production, the quality of the product will be low.

Chemicals	Rubber	Procurement of raw materials is difficult because there are many parts of the procurement business that cut prices, due to the fact that the factory has promoted the cultivation of rubber as the company's own. We need more raw materials.
Energy	Thermal energy	Provide quality materials, meet the needs, and find materials that can be easily purchased in Lao and imported from abroad. Steel can be obtained from sellers in Lao or imported from abroad.
Food and Beverage	Food and Beverage	Because materials are important components that must be imported from overseas, they are a crucial consideration. For example, equipment for producing drinking water bottles must be purchased in foreign currency. Supply of materials is an indispensable factor. Produce enough drinking water to meet customer needs (x2). Equipment bought from abroad. The factory's new product expansion plan is based on consumer need.
Mining	Mining	The exchange rate must be stable, and supply and demand must be sufficient. The price of production will rise and will have an impact on sales if the cost of transportation and raw materials is high.
Other	Cardboard	Business expansion is a critical element that must be considered. Materials are a measure of the economy and product quality. The quality will be poor if the material is poor quality.
Other	Electronics	Material provision will have an impact on production planning because if it is not viable to produce in the long term, the plant will have to close or cut the workforce.
Other	Carbon powder	An important factor in business expansion is the material. The manufacture of carbon powder will be easier if there are enough raw materials available, and in order to obtain enough raw materials to supply the factory, it will be necessary to find the location nearest to the plant to save on transport costs.

Figure 12 shows the reasons and timeframe of replacements and new builds done in the cross-cutting sectors. As with Construction or Agro-processing sectors, equipment is replaced mostly due to it being damaged or faulty. Plant capacity extension replacements were reported in the sectors of Chemicals, Energy, and Other, mainly replacing heavy machinery and buildings. Most companies said that it has been over 10 years since they last replaced any parts. However, the Chemicals sector is the one where parts have been replaced as recently as the last year, and most replacements were conducted in the last ten years, reflecting growth in the sector. The sector classified as Other also shows replacements in the last five and ten years. These responses suggest that there is investment in some of these sectors, mainly the Chemicals sector. Reactive maintenance is still reflected in the responses, but some of it may be increasing the efficiency of the factories by virtue of replacing outdated equipment. Mining and Energy are the sectors where the least replacements were reported in recent years.

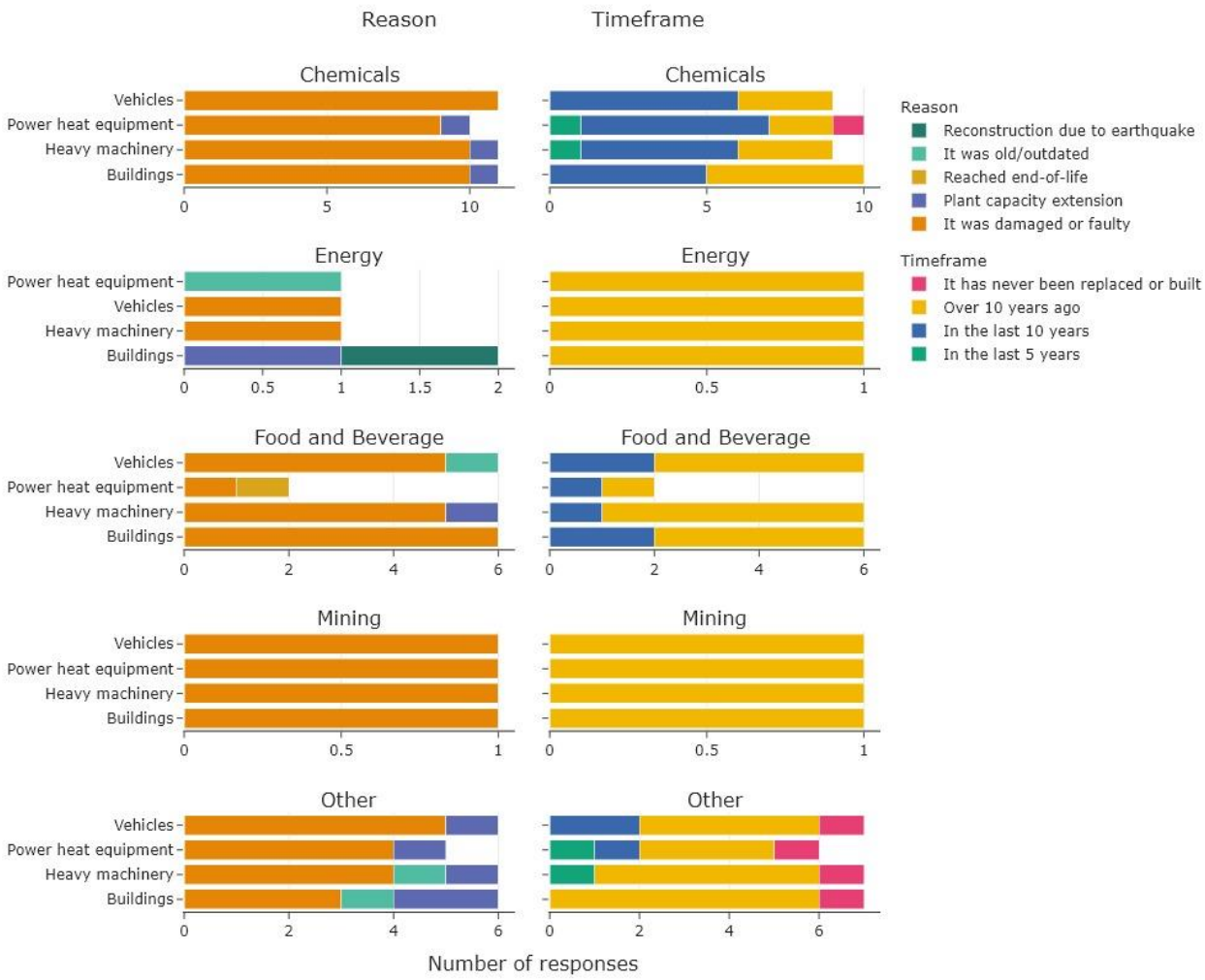

Figure 12 Cited reasons for replacing given parts in cross-cutting industrial sectors. Please note that the x-axis are different for each sector. Number of responses refers to the number of surveys conducted.

Plastics

An estimated total of 77 companies are involved in plastic goods manufacturing or recycling in Lao [22]. Although not all their products are fully identified, 17 out of the 77 companies are manufacturers of drinking bottles, carrier bags, other bags and sacks, furniture, baskets, ropes, and cups. These 17 companies have an annual production capacity of approximately 51,000 tonnes.

Only one plastic pipes factory was included in the energy surveys. The electricity use of the factory was 1,863,600 kWh/year. The SEC was 701 kWh/ton of raw plastic.

Box 2 shows a case study of Lao's plastic waste management, which affects many industries and other sectors of the economy and is becoming a pressing issue. The study presents opportunities for Lao to increase its waste management efforts. Studies such as these provide key methods so that Lao may evaluate options to better manage energy and material flows.

Box 2 Plastic waste: from challenge to opportunity

As Lao is undergoing rapid economic growth, the amount of plastic waste the country produces has similarly increased. Roughly 24% of all waste that ends up in landfill in Lao is plastic, and 95% of that is from single-use plastics. Currently, there are 17 landfills scattered across Lao's 18 provinces storing close to 40,000 tons of plastic waste per year. In the country's capital city, Vientiane, approximately 1,000 tonnes of waste are generated per day, of which 38% is collected and transported to landfill sites, 54% is self-disposed, only 8% is the waste generated is re-used or recycled.

Lao's Green Growth Strategy includes reducing waste and using resources more efficiently. Currently, however, it is mostly waste pickers from the informal sector that collect plastic waste at the landfills. However, there is potential to systematically address the waste issue and the associated emissions by transforming industry and managing the material flows from start to end-of-life. For example, by separating plastic waste from industry, plastic can either be recycled or reused as refuse-derived fuel, thus replacing high-carbon power sources.

In a study by the UK's Climate-Compatible Growth programme [26], different options and logistic networks for plastic recycling in Lao were analysed. The researchers developed an optimization model which maximizes the economic return of different CO_2 reduction options related to plastic waste management and used government data on waste as an input. The model chooses the best location for building new separation plants and different recycling and incineration options. While Lao has plans to incinerate plastic waste for electricity production, the results show that **building mechanical recycling plants**, placed in seven of the 18 provinces, and **establishing a recycling network across provinces**, may be better placed to maximize both economic and environmental returns. This implies further social benefits of local job creation and alleviated health risks. The solution also includes the waste streams from the landfill sites to waste separation plants, from the separation plants to the recycling facilities and from there to the demand centres, showing several logistical connections between the different provinces in the cost-optimal solution. While the results allow to draw several conclusions, it is key to note that these results are indicative. Additional data collection, especially in rural areas, is required to further refine them.

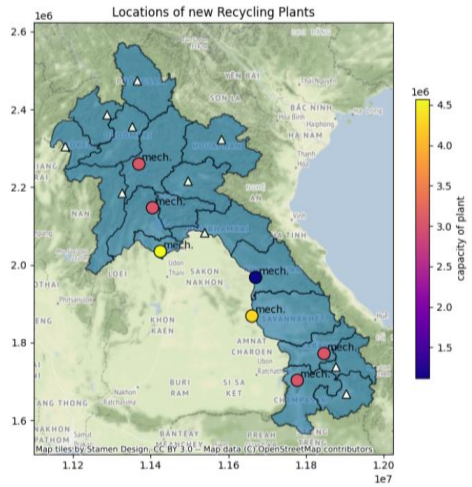

Figure B1: *Optimal location of mechanical recycling plants and their annual capacity in kilograms (all plants are located directly next to existing landfill sites; triangles denote landfill sites which are best served by transporting separated waste to recycling sites)*

Key Cross-cutting sector findings

Several industries in the cross-cutting sectors rely on material imports, which are becoming hard to acquire, for example, in industries such as rubber. Company profit margins are affected by material costs in foreign currencies and transport costs. Material costs also impact product quality, since high material prices or high exchange rates lead to compromising between quality and costs. There is investment in some of these sectors, mainly the Chemicals sector. Reactive maintenance is still reflected in the responses, but some of it may be increasing the efficiency of the factories by virtue of replacing outdated equipment. Mining and Energy are the sectors where the least replacements were reported in recent years. Waste management is becoming difficult given the increased use of plastics, which requires mechanical recycling plants and a recycling network.

3.7 Costs and potentials

The energy efficiency surveys revealed equipment that required upgrading and practices that can be changed. These actions are summarized in this section by industry, highlighting key findings from the energy surveys only. In the case of garment factories and rice mills, the actions identified were scaled up to quantify the investments required for each action at a national level, and the cost, energy savings, and payback period that such actions might bring. These two industries showcase how energy efficiency surveys can be used to conduct larger evaluations of improving Lao industries.

3.7.1 Construction

Bricks

The improvements proposed in the brick manufacturing sector include:

- Replace inefficient brick-moulding machine with more efficient ones.
- Replace inefficient V-belts with efficient V-belts in mechanical transmissions.
- Replace steel fan of forced draft by fibre reinforced plastic fan with efficient profile.
- Improve maintenance and housekeeping of the mechanical equipment and electrical motors to improve their performance and extend their lifetimes.
- Improve electrical installation to avoid overloading and overheating.
- Improve wood processes, including allowing time for the freshly cut wood to dry before using it as fuel in the kiln and wood storage to avoid moisture and pollution of wood fuel.
- Use existing and improved brick kilns as a model/pilot to inspire traditional brick kiln companies to switch to semi-continuous or continuous process instead of energy inefficient batch process. This will allow for:
    - Reduced heat losses through use of refractory bricks and proper insulant for kiln construction.
    - Heat recovery of heat losses and flue gas.

Figure 13 shows some of the inefficient machines and insulation, and leaks found.

Figure 13 Use of inefficient brick-moulding machines (left) and poor thermal insulation due to the use of ordinary earth construction materials (middle); and major oil leak on mechanical transmission gearbox (right) in the brick manufacturing industry.

Steel

The improvements proposed in the steelmaking sector include:

- Replace motors with more efficient ones (high efficiency ratio, high in-built power factor, and efficiency greater than 95%).
- Replace inefficient V-belts with efficient V-belts in mechanical transmissions.
- Install a capacitor bank at the factory power supply point to increase the power factor and avoid low power factor financial penalties from the utility company.
- Improve thermal insulation of all galvanization vats to reduce thermal losses while operating galvanization.
- Replace conventional welding machines using conventional copper windings transformer with welding equipment using electronic transformers.

Figure 14 shows examples of inefficient equipment in the steel factories.

Figure 14 Use of inefficient V-belt transmissions (left) and electrical motors in tube-rolling machines (middle); and welding machines with conventional transformers including copper windings and iron core to raise voltage (right) in the steel industry.

Cement

The improvements proposed in the cement manufacturing sector include:

- Recover heat from the thermal power plant to preheat process in cement production.
- Use refuse-derived fuel, a type of fuel made from selected waste and by-products which can replace the use of coal, i.e., reduce fossil fuel use in cement production and in the cement plant that uses coal for electricity generation.
- Replace ball crushers with vertical roller mill.
- Improve external insulation of cement kiln and the adjacent equipment.

- Put in place an energy management system like ISO 50001, which aims to measure and improve both energy efficiency and environmental management.
- Evaluate the feasibility of electricity production from heat recovery.
- Create equipment lists to evaluate energy efficiency proposals.

Figure 15 shows inefficiencies in cement plants in equipment and insulation.

Figure 15 Coal thermal plant in cement manufacturing company with no heat recovery (left); use of ball mills for crushing clinker instead of a vertical roller mill (middle); and cement kiln without thermal insulation (right).

3.7.2 Agro-processing

Rice milling

The improvements proposed in the rice milling industry include:

- Replace reciprocating piston air compressors with screw air compressors.
- Replace common drive systems with individual motors.
- Install heat recovery systems on paddy dryers.
- Replace inefficient V-belts with energy efficient cogged V-belts.

Figure 16 shows the energy saving potential of the measures identified in the rice milling industry. Overall, energy savings could lead to a reduction of 0.7% of annual energy use in this industry in Lao.

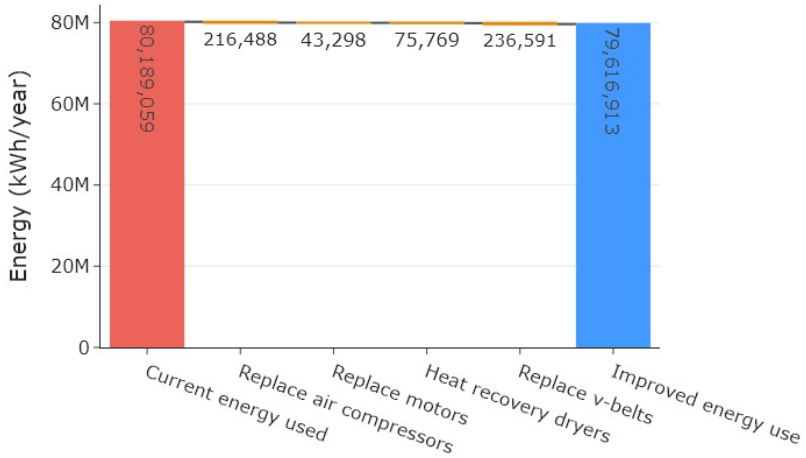

Figure 16 National energy savings with the measures evaluated compared to current energy use in the rice milling industry.

Salt

The improvements proposed in the salt production sector include:

- Fix the roofs of the brine tanks to prevent penetration of rain water with consequential dilution of the brine.
- Replace the reciprocating piston air compressor with screw technology air compressors.
- Replace the compressed air brine pumping with electric immersion pumps to avoid heat losses during the air compression process.
- Install ventilated greenhouses above the solar ponds to allow evaporation while preventing rain water from falling into the ponds and slowing down the evaporation process.
- Replace open air thermal evaporating systems with industrial salt boilers to reduce the energy losses and increase efficiency of the evaporating process. This will also reduce air pollution due to the combustion process, lowering impacts on the workers' health and on salt pollution.

Figure 17 shows inefficiencies in salt production.

Figure 17 Inefficient air compressors using reciprocating piston technology with heat losses are used to pump brine (left); solar evaporation happening in open-air, leading to salt contamination and slow evaporation due to rain (middle); and inefficient open-air thermal evaporation process using coal or saw dust, creating air pollution (right).

Cassava

The improvements proposed in the cassava production sector include:

- Replace inefficient electric motors with efficient ones.
- Replace inefficient V-belts with efficient cogged V-belts.
- Change reciprocating piston air compressor with screw air compressor.
- Replace old wood boilers for improved boilers with:
    - Proper thermal insulation, on both the boiler's body and the steam piping network.
    - Condensates recycling.
    - Proper storage of wood.
- Consider replacing the wood fuel used in the boiler with biogas produced with cassava production waste.

Figure 18 shows inefficient equipment and material storage in cassava processing.

Figure 18 Inefficient air compressor using reciprocating pistons with oil leak (top left); inefficient wood boiler with leaking combustion chamber and poor thermal insulation (top right); condensates from the wood boiler that are not recovered or recycled (bottom left); and poor wood storage (bottom right).

Abattoirs

The improvements proposed in the abattoir sector include:

- Use of waste to produce biogas.
- Replace inefficient motors and inefficient mechanical transmissions with efficient ones.
- Upgrade cold room chilling systems with efficient ones.

Figure 19 shows inefficient motors and chillers in abattoirs.

Figure 19 Inefficient AC motors (left); and inefficient chillers for cold rooms (right).

Animal feed

The animal feed production company visited showed good practices that can be followed by other Lao industries. This example reflects the ability of industries to increase their energy efficiency and maintain equipment adequately.

3.7.3 Textiles/garment

Garments

The improvements proposed in the garment production sector include:

- Replacing non energy efficient clutch motors with energy efficient servo-motors.
- Replacing non energy efficient fluorescent tubes with energy efficient LED tubes.
- Installing heat recovery on clothes dryers.
- Installing heat recovery on boilers.
- Fixing/replacing steam traps on steam distribution systems.
- Improving thermal insulation on steam distribution systems.
- Replacing non energy efficient reciprocating piston air compressors with energy efficient screw air compressors.

Figure 20 shows an example of inefficient equipment, at the top are servo motors, those like the top left need to be replaced for more efficient motors as shown on the top right. In some garment factories, sewing machines run with inefficient clutch asynchronous motors, working idle most of the time and resulting in excessive wearing of the motors and important heat losses. Improved servo motors can rotate only when the sewing machine is operating, thereby reducing electricity consumption and heat losses.

Figure 20 At the top: example of servo motors used in sewing machines in the Lao garment sector: inefficient clutch asynchronous motor currently used (top left) and improved motors that reduce energy consumption and minimize heat losses (top right). At the bottom: heat exchangers used by clothes dryers clogged with dust, thereby reducing the heat exchange efficiency (bottom left) and poor insulation of condensate tank (bottom right).

Figure 21 shows the energy saving potential of the measures identified in the garment sector. Overall, energy savings could lead to a reduction of 36.0% of annual energy use in this sector Lao.

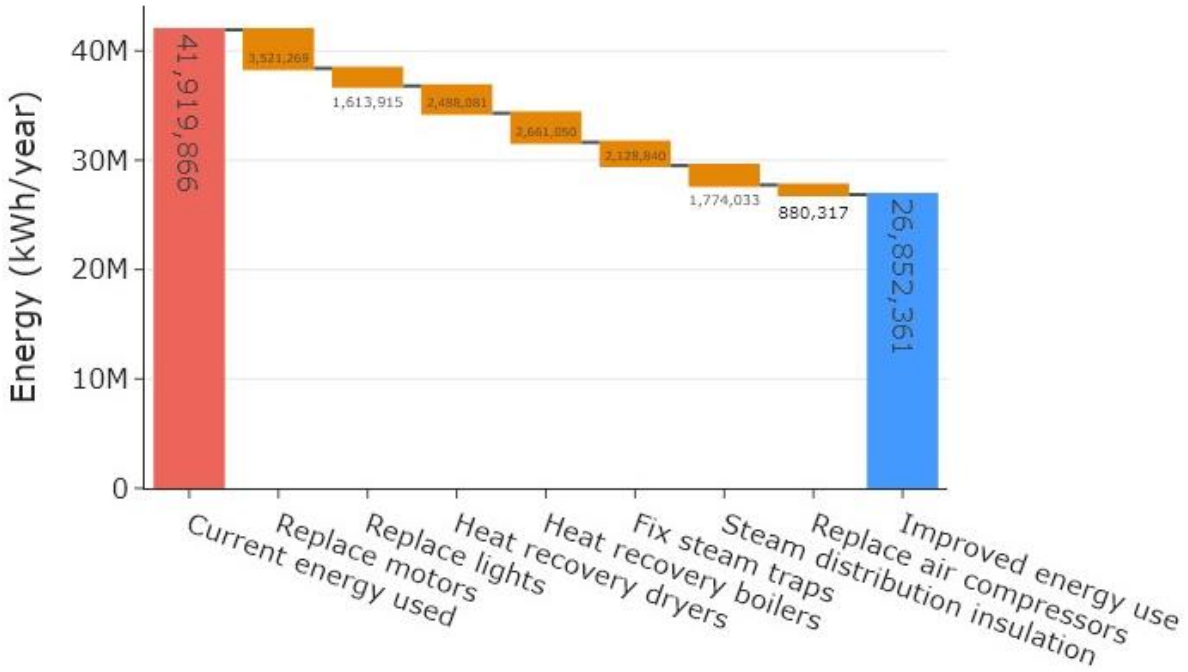

Figure 21 National energy savings with the measures evaluated compared to current energy use in the garment industry.

Shoe factory

The shoe factory visited showed good practices that can be taken forward by other companies.

3.7.4 Other

Plastics

The improvements proposed in the cement manufacturing sector include:

- Replace the steel fan of cooling towers with a fibre-reinforced fan with efficient profile.
- Replace R22 refrigerant in the chiller with R134A.
- Decrease rate of refused production to 2%, if possible, instead of the current 4.2%.
- Replace motors with efficient ones (high efficiency ratio, high in-built power factor, η>95%).

Figure 22 shows an example of environmentally damaging substances being used, in this case a hydrochlorofluorocarbon (HCFC) refrigerant (R22), that need to be replaced to avoid depleting the ozone layer. Replacing R22 refrigerant in the chiller should be replaced by less environmentally damaging refrigerants such as R134A.

Figure 22 Chiller in plastics production facility that uses refrigerant R22, which is a hydrochloro-fluorocarbon (HCFC) refrigerant with high ozone depletion potential that has been banned in other countries.

3.8 Knowledge of energy and material efficiency of industry and government employees

The knowledge of energy and material efficiency, and emission-related topics such as the Paris Agreement or the Nationally Determined Contributions (NDCs) was explored in both Lao industries and government employees as part of the material surveys. Interviewees were asked whether they had heard of certain terms and their level of familiarity with them.

Figure 23 and **Figure 24** show the responses, from company and ministry respondents respectively, concerning whether they have heard of various terms related to climate change and resource efficiency. Company employees reflect the lowest knowledge of the terms, particularly those related to emission reduction commitments with between 51 and 55% of the respondents saying they have not heard the terms before. In turn, industrial and material efficiency seems to be the terms most well-known with 87 and 88% of respondents having heard of the term. On the other hand, ministry employees were familiar with more of the terms generally, but both NDCs and carbon footprint were the terms they had heard of the least, with 13% of the respondents reported not to have heard the terms before. These responses suggest that, in the long-term, there needs to be awareness-raising campaigns, and, in the short-term, communication should revolve around energy efficiency and costs concerns, instead of on international agreements. These actions would help bridge the gap of knowledge and communication between government and industry employees.

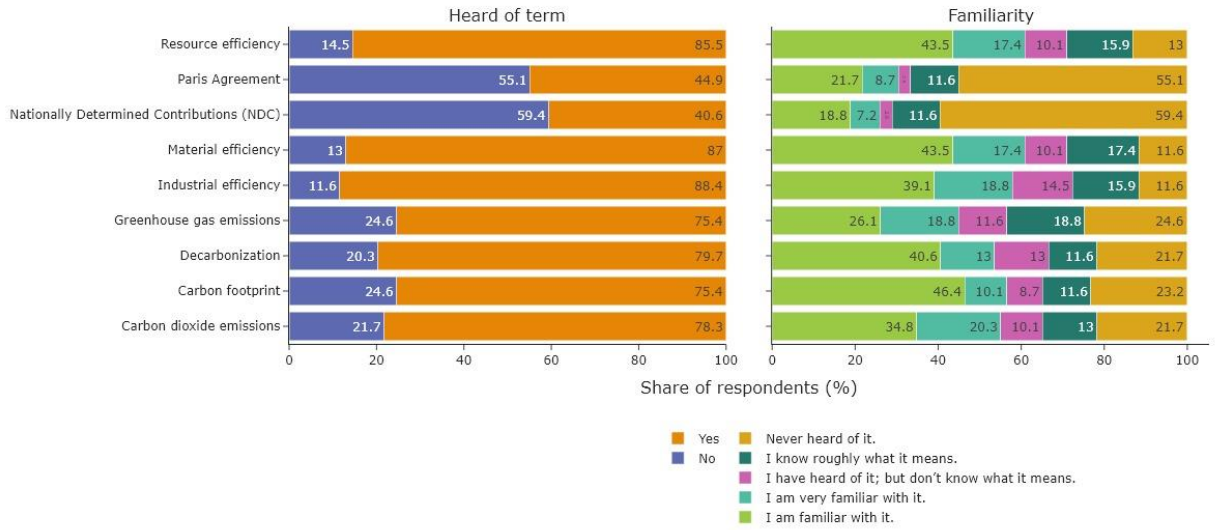

Figure 23 Company survey share of responses regarding having heard of efficiency and low-carbon terms (left) and their degree of familiarity with such terms (right).

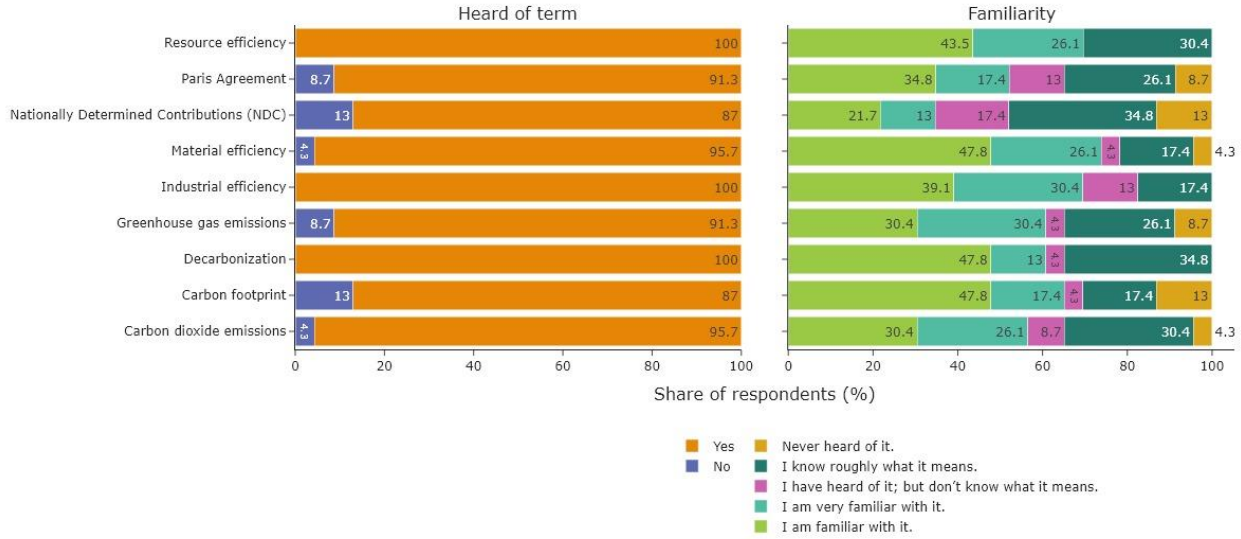

Figure 24 Ministry survey responses share of responses regarding having heard of efficiency and low-carbon terms (left) and their degree of familiarity with such terms (right).

4 Conclusions: the case for investing in resource efficiency

The findings of the energy and material surveys revealed the opportunities for Lao to encourage industrial efficiency; the current challenges faced by companies that are hindering their economic progress and limiting decisions surrounding materials; and the disconnect between different Lao actors that, if improved, could bring benefits for economic development. This section explores different benefits and considerations for increasing resource efficiency in Lao, from productivity improvements, to cost and emission reductions, additional challenges, and policy recommendations.

4.1 Productivity improvements

Measures identified in this report focused mainly on energy and material efficiency. Many of these measures also have the potential to increase the productivity of the industries visited. These improvements would increase production and earning potential of the companies. Examples of such improvements include changing brick-making to a semi-continuous process, speeding up the salt drying process by covering brine containers and solar drying spaces, replacing dust-clogged clothes dryers, improving wood drying and storage, installing capacitor banks at power supply points of steel factories to avoid low-power-factor penalties, improving thermal insulation of all galvanization vats to reduce thermal losses, or generally implementing predictive maintenance practices in industry. Other productivity improvements could be identified if the methodology presented in this report were used for other industries.

The measures identified can occur either if there is a push at national level to change practices or if local industries have the know-how and resources to make changes. Communication between the different actors will then prove essential to implement changes in an efficient manner.

4.2 Greenhouse gas emission reductions

Emission savings in a sector can be estimated using the emissions intensity of different energy sources used (e.g., electricity or heat). In 2019, the CO_2 emissions intensity of energy production was 0.22 kg CO_2/kWh [23]. **Table 13** shows the emission savings in the garment and rice milling industries where energy savings were quantified. The garment industry has large opportunities for reducing emissions, especially through replacing motors and implementing heat-related measures, all of which account for 83% of the emission reduction potential in the garment industry. Air compressors and V-belt replacements are key for the rice milling industry and account for 79% of the emission reduction potential in this industry. These results highlight that heat and electric machinery are two key areas for Lao to focus on to achieve greater emission reductions.

Table 13 CO_2 emission reductions by industry.

Sector	Industry	Co_2 emissions reduction (tonne co_2)
Garment	Garment	3,314
Agro-processing	Rice milling	126

Additional emission saving opportunities can be achieved with the introduction of material efficiency measures. For example, as transport networks are extended to address the transport barriers identified, if construction materials are used that come from industries that have introduced energy and material efficiency actions, the embodied emissions of the materials for transport projects will be reduced. This is important so that Lao does not lock in unnecessary emissions in its infrastructure.

The phase out of environmentally damaging greenhouse gas substances is needed. Examples of substances being used include refrigerant R22, an ozone-damaging hydrochlorofluorocarbon (HCFC) which has been banned in other countries. To put the use of R22 refrigerant into perspective, its global warming potential (GWP) is 1,810 [24], that is, a tonne of R22 produces 1,810 times more warming than a tonne of CO_2. Thus, Lao needs to identify these substances, implement bans, and spread knowledge on the use of alternatives.

4.3 Cost savings

The overall cost savings identified in this project are quantified for the two industries where investments and savings were projected: garment and rice milling. **Table 14** shows the total savings by sector, where the garment industry has almost double the opportunities for reducing costs than the rice milling industry. Steam-related equipment and motors save 88% of the total yearly costs of the industry, while heat recovery in clothes dryers represent 96% of the total savings.

Table 14 Cost savings by industry.

Sector	Industry	Cost saving of measure (usd/year)
Garment	Garment	1,047,211
Agro-processing	Rice milling	652,364

4.4 Challenges for energy and material efficiency implementation

The economy of Lao is relying on more and more specialized industries over time. This requires careful planning to upskill labour; increase material and machinery availability; introduce financial measures to increase investment and reduce the financial burden that hinders competitive local industry; and expand transport networks to support the growing local industries. The contrasts observed between the perceptions of government and industry employees also suggest that more coordination between different actors should be encouraged at different levels of government so that practical considerations can be included in local policies in a timely fashion.

Encouraging energy and material efficiency can have cascading benefits in the measures that have been identified in this report; yet, the same barriers for material acquisition will play a role in hindering immediate progress in efficiency. For example, purchasing more efficient equipment will be hindered by inflation and the exchange rates, which might make investments in such equipment less attractive. The government plans to have industry

supply the local market, such as with the recently announced measure in the garment sector [25], may benefit some local consumers, but it will not solve the trade barriers.

4.5 Policy implications

The findings of this report have shown that policies designed to benefit Lao industries should aim to:

- increase the energy and material efficiency in Lao industries;
- inspect and upgrade equipment and machinery in industry to ensure efficient equipment is in place;
- quantify efficiency actions and link them to NDC reporting;
- overcome key economic challenges that the industries face;
- encourage replacement of outdated or obsolete equipment where the financial burden of the replacement is lessened. This will benefit growing sectors, such as the Chemicals, or Energy sectors where plant capacity extensions were recently done;
- create standards for specific industries and equipment that may be followed;
- disseminate information on efficiency to increase local knowledge on best practices and regulations;
- promote training for industries and their workforces regarding resource efficiency and best practices;
- regulate and measure the use of harmful substances, for example, those that can produce wider environmental degradation such as the hydrofluorocarbon (HFCS) refrigerants, which damages the ozone layer;
- put material substitution at the heart of resource efficiency policies so that changing practices can be embraced shortly after regulations are created. This will address the difficulty in accessing materials such as coal or wood, which have had production be regulated without industry necessarily having found suitable alternatives;
- create key infrastructure to favour the distribution of raw materials and finished products to their respective markets; and
- deepen the relationship between industry and policy stakeholders to prevent the observed disconnect between goals, activities, and challenges.

4.6 Going forward

Future work stemming from this report that would help build evidence for energy and material efficiency practices in Lao include the following:

- Evaluation of material flows in each industry type from a bottom-up perspective, which can then be scaled up to the national context.
- Evaluation of additional energy efficiency actions in other industries in Lao following the research design from this report.

5 Detailed research design for this report

Material surveys – Climate Compatible Growth (CCG)

The surveys on material efficiency were conducted by CCG in collaboration with the National University of Laos (NUOL) between January and September 2022 and included 69 different companies and 24 government employees. The interviews for companies covered the following topics: background of the company and interviewee, perceptions of material provision challenges, materials used and produced, replacement of equipment parts or buildings, and knowledge of efficiency and emissions terms. The government interviews covered the following topics: background of the interviewee, perceptions of material provision challenges, and knowledge of efficiency and emissions terms. The responses were conducted in Lao language and translated to English. Then, they were cleaned and aggregated to, for example, identify percentages or frequently used terms.

Table 15 presents the number of interviewees for each position at the company in the material surveys. The majority of interviewees occupied top-level positions at the companies.

Table 15 Number of interviewees by position at the company.

Position	Count	Position	Count
Manager	26	Production manager	1
Director	13	Procurement manager	1
Vice director	6	Assistant manager	1
Owner	4	Deputy manager	1
Technician	3	Head of research unit	1
Vice production manager	2	General manager	1
Vice manager	2	Engineering supervisor	1
General assistant	2	Engineering manager	1
HR	2	Maintenance engineer	1

The full questionnaires detailing the questions asked to industry and government officials are available online on the Zenodo repository of this report (https://www.doi.org/10.5281/zenodo.7254366).

Energy audits – Global Green Growth Institute (GGGI)

The surveys on energy efficiency were conducted by GGGI in late 2021 and included 25 different companies. Descriptions that exemplify how the visits were conducted and how additional data were obtained are below:

Garment factories: A half day walkthrough energy audit was carried out in each garment factory, with observation of the operation and the equipment. Secondary data was collected from the management (energy bills, clothes production, list of equipment, interviews). No on-site energy measurements were conducted.

Rice mills: A half day walkthrough energy audit was carried out in each rice mill, with observation of the operation and the equipment. Secondary data was collected from the management (energy bills, rice production, list of equipment, interviews). No on-site energy measurements were conducted.

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