Vientiane, Lao PDR

Green City Action Plan

An Investment Roadmap for Climate Action

DEVELOPED USING

Apex Advanced Practices for Environmental Excellence in Cities

AN INNOVATION OF IFC International Finance Corporation WORLD BANK GROUP

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About this Report

This report presents a summary of the Vientiane City Green City Action Plan (GCAP), focusing on prioritized climate investments and potential financing mechanisms. The GCAP was developed using Advanced Practices for Environmental Excellence in Cities (APEX), an innovation of the International Finance Corporation (IFC), a member of the World Bank Group.

Disclaimer notice

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Acknowledgments

This Vientiane Green City Action Plan – an Investment Roadmap for Climate Action, is the result of a strong collaboration between Ministry of Public Works and Transport, Vientiane Capital City officials, IFC, and the World Bank. The roadmap leverages a new IFC initiative, Advanced Practices for Environmental Excellence in Cities (APEX), which is supported by the APEX Online App, a tool that helps quantify and prioritize policy and investment solutions across four key sectors: built environment and energy, transportation, waste, and water.

IFC's team was led by Prashant Kapoor, working closely with, Lorraine Sugar, Kelvin Tagnipez, Khampao Nanthavong, and Amphavanh Sisouvanh. The Action Plan was part of a broader World Bank Group engagement on climate-smart city investments for Lao PDR. The team also wants to thank the following colleagues based in the World Bank Group's Lao PDR office who provided important suggestions, inputs, data, and information throughout the process: Maurice Andres Rawlins, Tanida Arayavechkit, and Viengsompasong Inthavong. The team is grateful to the IFC management teamfor its support: Thomas James Jacobs, Country Manager of Cambodia, Laos and Vietnam, and Phongsavanh Phomkong, Head of IFC Lao Office.

The Vientiane Green City Action Plan was supervised by Director General, Dr. Viengnam Douangphachanh, and coordinated by Deputy Director General, Mr. Nalongxay Myvapadith and Deputy Director General Mrs. Bannaseng Syphoxay, working together with the technical team which included Mr. Khamphonemisay Phommathat, Mr. Chenniphone Xaiyalath, Mr Saneha Panyasavath, Mr. Saynoy Santhavisouk and respective staff of the Department of Housing and Urban Planning, Ministry of Public Works and Transport (MPWT). Data and insights were provided by relevant government agencies, including the Department of Transport and Department of Water Supply of MPWT, Department of Energy Policies and Planning and Department of Energy Promotion and Saving of MEM—Ministry of Energy and Mines, Department of Climate Change of MoNRE—Ministry of Natural Resource and Environment, and Vientiane Capital's Departments, including Public Works and Transport, Natural Resources and Environment, Energy and Mine, Office of Management and Service, Nampapa Nakhoneluang State Enterprise, and Électricité du Laos.

Finally, the team wishes to thank all workshop participants and reviewers for their valuable feedback.

The draft Vientiane GCAP - an Investment Roadmap for Climate Action, was validated at Landmark Hotel on 5 March, 2024.

Image: Sakhone Phomsouvanh / IFC

About APEX

The APEX ("Advanced Practices for Environmental Excellence in Cities") Green Cities Program is a new IFC initiative that supports cities in emerging economies to accelerate the implementation of ambitious and transformative policy actions and investments that significantly contribute to transitioning to low-carbon and resource-efficient growth pathways. The program leverages the APEX Online App (*see Figure 1*), which helps cities to quickly assess the most cost-effective way to incorporate measures into their investment and policy pipelines, in order to achieve targets related to energy, transportation, waste, water, and greenhouse gas (GHG) emissions.

APEX uses information for the baseline year and projects forward to the target year using anticipated population growth rates. It evaluates actions relative to the business-as-usual (BAU) case, i.e., the scenario where the city government does not take any specific actions, and municipal operations and resident behaviors are the same as in the baseline year. The key assumptions for the BAU case can be adjusted in accordance with anticipated economic growth and initiatives of other spheres of government.

APEX helps quantify the impact of investment, planning, and policy solutions—referred to as *measures*—in the target year. There are over 100 measures preloaded into APEX, as well as the option to create custom measures. Each measure has an engine that quantifies its impacts and costs based on the specific situation in the city. The methodology behind each measure is based on prevailing engineering calculations, existing studies in the literature, and/or case studies from other cities.

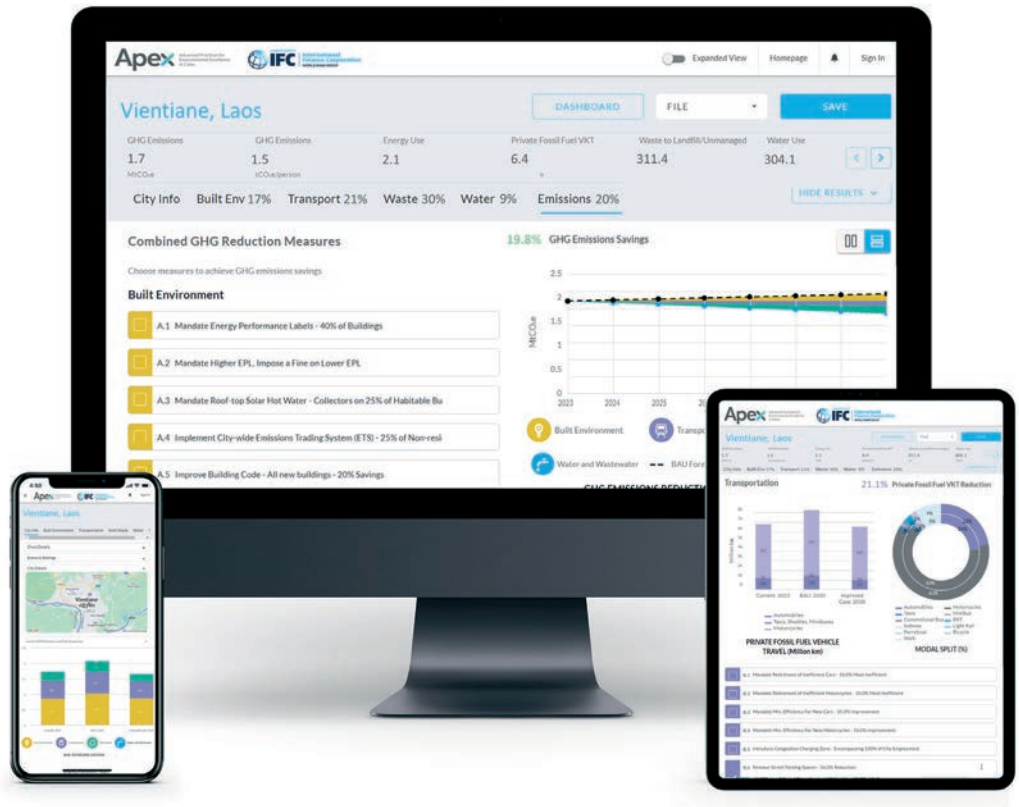

Figure 1: *The APEX Online Application (available at www.apexcities.com).*

Acronyms & Abbreviations

APEX	Advanced Practices for Environmental Excellence in Cities
BAU	Business-as-usual
BRT	Bus Rapid Transport
DOT	Department of Transportation
DHUP	Department of Housing and Urban Planning
DPI	Department of Planning and Investment
EaaS	Energy-as-a-Service
EDGE	Excellence in Design for Greater Efficiencies
EDL	Électricité du Laos
EE	Energy Efficiency
ESCO	Energy Service Company
EV	Electric Vehicles
FF	Fossil Fuel
GCAP	Green City Action Plan
GGGI	Global Green Growth Institute
GHG	Greenhouse Gas
GWh	Gigawatt hours
HVAC	Heating, Ventilation, and Air Conditioning
ICT	Information and Communication Technology
IFC	International Finance Corporation
JICA	Japan International Cooperation Agency
km²	Square kilometers
KPI	Key Performance Indicator
kt/year	Kilotonnes (thousand tonnes) per year
ktCO$_2$e	Kilotonnes of carbon dioxide equivalent
Lao PDR	Lao People's Democratic Republic
m²	Square meters
m³	Cubic meters
MEM	Ministry of Energy and Mines
MLD	Million Liters per Day
MONRE	Ministry of Natural Resource and Environment
MPWT	Ministry of Public Works and Transport
MRF	Materials Recovery Facility
MW	Megawatt
NSEDP	National Socio-Economic Development Plan
NUA	New Urban Agenda
OBF	On-bill Financing
O&M	Operation and Maintenance
PLF	Property-linked Finance
PPP	Public-Private Partnerships
PV	Photovoltaics
SUP	Single-Use Plastic
t/day	Tonnes per Day
USD	United States Dollar
VCOMS	Vientiane City Office of Management and Service
VKT	Vehicle Kilometers Travelled
VTMP	Vientiane Transport Master Plan

Executive Summary

Vientiane is the economic, cultural, and political capital of Lao PDR and is an important center for education, trade, and transportation in mainland Southeast Asia. The city is in the central region of the country, encompassing an area of 3,920 square kilometers (km^2) and a population of almost 1 million people. Vientiane's proximity to the Mekong River emphasizes cross-border commerce and connectivity, which is key to the city and country's green growth.

The Vientiane Green City Action Plan (GCAP) aims to help Vientiane Capital City and Lao PDR meet its climate mitigation and sustainability vision by identifying and prioritizing green city actions—including city-level policies, investments, and planning strategies—based on greenhouse gas (GHG) savings, sector benefits, indicative costing, and potential funding sources. It leverages a new platform developed by the International Finance Corporation (IFC) called APEX (Advanced Practices for Environmental Excellence in Cities), an online software tool that helps quantify and prioritize city-based policy and investment solutions in the energy, transport, waste, and water sectors. As such, it aims to increase the pipeline of public and private climate-related investments, which can be influenced by city-level policies and plans.

Using the year 2023 as its baseline and projecting to the year 2030, the Vientiane GCAP prioritizes and quantifies the impacts of 30 selected solutions, called *measures*, across the four sectors. Implementing these measures is expected to deliver a 22 percent GHG reduction, equivalent to 450 thousand tonnes of carbon dioxide equivalent ($ktCO_2e$) in GHG emissions. The GHG emissions reduction trajectory to 2030 is shown relative to the business-as-usual (BAU) scenario in *Figure 2*. The prioritized measures and corresponding sector benefits and GHG savings are shown in in *Table 1*.

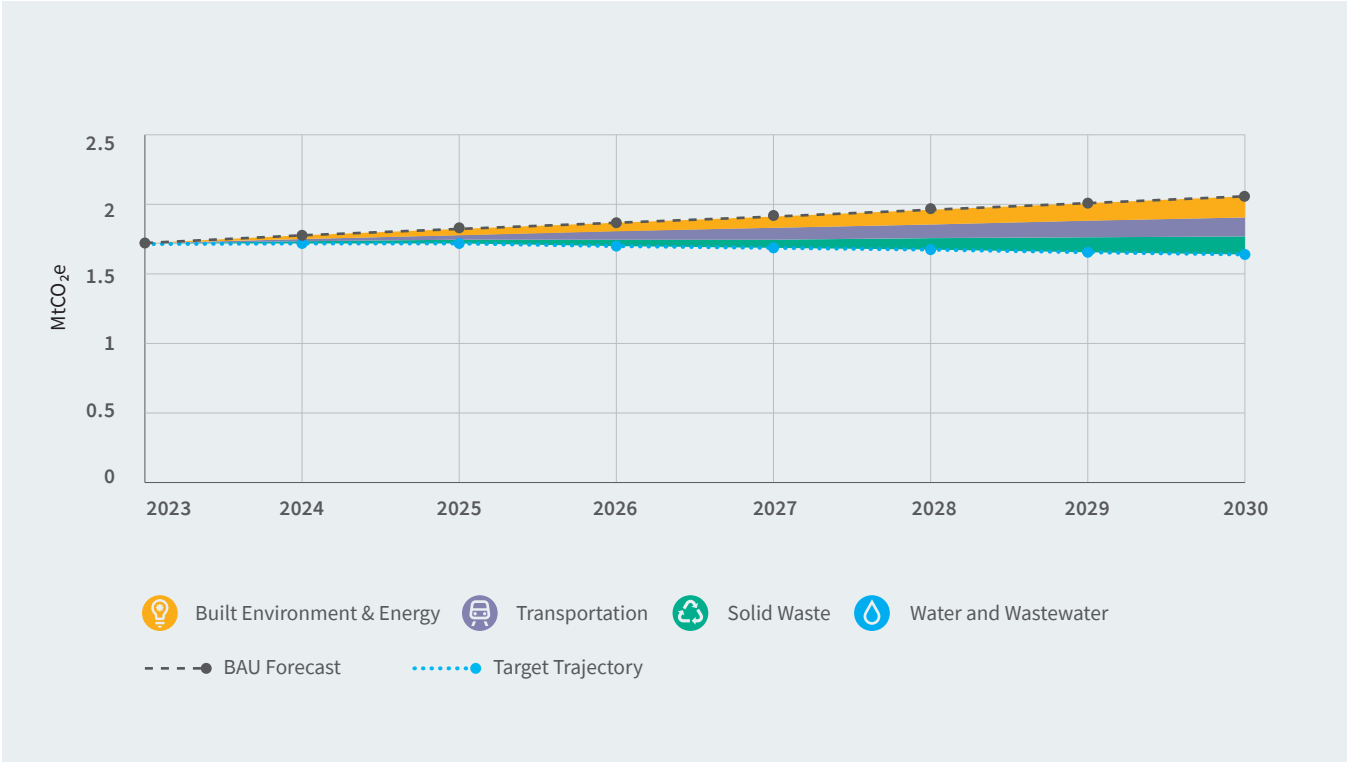

Figure 2: *Potential GHG reductions resulting from selected measures across the four APEX sectors. Implementing the 30 measures is expected to deliver a 22 percent GHG reduction, equivalent to 450 $ktCO_2e$ in GHG emissions.*

Note: $MtCO_2e$ = million tonnes of carbon dioxide equivalent; BAU = business-as-usual; GHG = greenhouse gas.

Table 1: Selected measures, benefits, and GHG savings across the four APEX sectors.

APEX Sectors	Measures	Sector Indicator	GHG Reduction Compared to Business-as-Usual (%)	GHG Reduction Compared to Business-as-Usual ($KtCO_2e$)
Built Environment & Energy	Mandate Rooftop Solar Hot Water	16% Fossil Fuel Energy Savings	8%	168
	Improve Building Code			
	Promote Cool Roofs			
	Increase Extent of Urban Forestry			
	Incentivize Green Building Certification (e.g. EDGE)			
	Finance for Private EE Refurbishment			
	Implement Rooftop Solar PV Program			
	Implement Green Certification for All Municipal Buildings			
	Implement EE Refurbishment for All Municipal Buildings			
	Upgrade All Streetlights with Energy Efficient Bulbs			
Transportation	Introduce Congestion Charging Zone	24% Less Private Fossil Fuel Vehicle Travel	8%	165
	Remove Street Parking Spaces			
	Provide EV Charging Infrastructure			
	Finance for Private EVs			
	Build Bicycle Lanes			
	Expand Electric Bus Fleet			
	Add BRT System and E-Buses			
	Add Park-and-Ride Lot to Transit Station			
	Introduce Smart Transit Fare Cards			
Solid Waste	Mandate Decentralized Composting	37% Less Waste Sent to Landfill	5%	111
	Mandate Decentralized Anaerobic Digestion			
	Ban Single Use Plastics			
	Improve Waste Collection			
	Add / Expand Materials Recovery Facilities			
	Add / Expand Waste-to-Energy Facilities			
Water & Wastewater	Develop Ponds / Lakes For Rainwater Storage	9% Water Security Improvement	0.3%	6.9
	Incentivize Local Water Retention in Lakes / Ponds			
	Reduce Unaccounted-for Water Losses			
	Add New Centralized Wastewater Treatment Facilities			
	Add Local Scale Wastewater Treatment Plant			
Total GHG Reduction			**22%**	**450 $KtCO_2e$**

Solutions in the GCAP can be converted into a pipeline for green investment in Vientiane, supported by both public and private sector funding. All 30 measures with their associated costs are listed in *Table 2*, which includes estimated total capital cost as well as the direct cost to the municipality and its agencies. Where the cost is for investment that falls within the city's mandate, the full cost is reflected as a direct cost. Direct costs total approximately USD 1,170 million and include actions where the city can leverage sources of finance, such as through municipal finance or public-private partnerships (PPPs) for capital investments. For indirect cost actions, the city can enable or incentivize the private sector to invest in green measures, by implementing policy, for example.

Image: © Phounsub Thepvongsa / World Bank

WBG Office, Vientiane. The GCAP recognizes building efficiency as one of the most impactful and affordable ways for the City to reduce GHG emissions.

Table 2: Green investment pipeline for Vientiane, including costs and potential funding sources.

APEX Sectors	Measures	Total Cost (USD Million)	Direct Cost (USD Million)	Potential Funding Sources			
				Own Revenue	Central Govt. Transfer / Loan	PPP	Private Finance
Built Environment & Energy	Mandate Rooftop Solar Hot Water	28					✓
	Improve Building Code	37					✓
	Promote Cool Roofs	72					✓
	Increase Extent of Urban Forestry	293	293	✓			
	Incentivize Green Building Certification (e.g. EDGE)	9					✓
	Finance for Private EE Refurbishment	300					✓
	Implement Rooftop Solar PV Program	135					✓
	Implement Green Certification for All Municipal Buildings	3	3	✓			✓
	Implement EE Refurbishment for All Municipal Buildings	32	32			✓	
	Upgrade All Streetlights with Energy Efficient Bulbs	14	14	✓			
Transportation	Introduce Congestion Charging Zone						
	Remove Street Parking Spaces						
	Provide EV Charging Infrastructure	1	1				✓
	Finance for Private EVs	1,625					✓
	Build Bicycle Lanes	0.2	0.2	✓			
	Expand Electric Bus Fleet	68	68		✓	✓	
	Add BRT System and E-Buses	441	441		✓	✓	
	Add Park-and-Ride Lot to Transit Station	12	12	✓	✓	✓	
	Introduce Smart Transit Fare Cards				✓	✓	
Solid Waste	Mandate Decentralized Composting	25	25		✓	✓	
	Mandate Decentralized Anaerobic Digestion	0.5	0.5		✓	✓	
	Ban Single Use Plastics						
	Improve Waste Collection	2	2		✓	✓	
	Add / Expand Materials Recovery Facilities	10	10		✓	✓	
	Add / Expand Waste-to-Energy Facilities	40	40		✓	✓	
Water & Wastewater	Develop Ponds / Lakes For Rainwater Storage	185	185	✓			
	Incentivize Local Water Retention in Lakes / Ponds						
	Reduce Unaccounted-for Water Losses	3	3		✓	✓	
	Add New Centralized Wastewater Treatment Facilities	7	7		✓	✓	
	Add Local Scale Wastewater Treatment Plant	33	33		✓	✓	
	Total	**3,376**	**1,170**				

The GCAP is one piece of the city's comprehensive approach to addressing climate change and promoting sustainable development. The GCAP focuses on climate change mitigation and resource efficiency in terms of energy consumption, private vehicle travel, waste reduction, and water security to the year 2030. The city has a net-zero emissions target for 2050, and there is work underway to develop sector-specific roadmaps that extend beyond 2030 as well.

Furthermore, strong private sector engagement could support the successful execution of the GCAP. Vientiane can bring together key ingredients to accelerate climate action by building a broad network of climate-smart businesses, industries, and financial institutions committed to achieving climate targets and a green city vision.

Avenue Lane Xang is Vientiane's primary boulevard, connecting important landmarks such as the Patuxai Victory Monument, the Presidential Palace, the Prime Minister's Office, Wat Si Sa Ket, and the UN House.

Image: © Phounsub Thepvongsa / World Bank

Introduction

Background and Objectives

Vientiane Capital, the largest city and the economic, cultural, and political heart of Lao PDR, is strategically situated in the country's central region, encompassing an area of 3,920 km^2. The city has a population of 968,991, growing at an annual rate of 3.1 percent. Its urban landscape has transformed dramatically, particularly in the four core urban districts of Chanthabouly, Sisattanark, Xaysettha, and Sikhottabong, where rapid urbanization has led to a concentration of the populace. In the last decade, the skyline has seen an increasing number of high-rise buildings, especially in the city center. Infrastructure development has not been limited to the urban core; semi-urban districts such as Xaythany, Hadxayfong, Sangthong, Naxaythong and Pakngum have also seen significant improvements in urban services and networks.

The economy of Vientiane Capital thrives on trade, services, and manufacturing, and is further bolstered by its proximity to the Mekong River border, which enhances cross-border trade and commerce. Additionally, the government's proactive approach to attracting foreign investment has spurred the creation of special economic zones, contributing to the city's economic dynamism.

Lao PDR's National Action Plan in Response to Climate Change for 2021-2030[1] stipulates a nation-wide GHG reduction target of 60 percent by 2030. The Lao PDR's New Urban Agenda (NUA), which was adopted in 2017[2] and is in-line with the above climate change strategy, sets out a transformative commitment for sustainable urban development and includes the following climate-smart agenda:

- Implement climate change mitigation and adaptation actions through (i) mainstreaming climate change into sectoral policies, strategies, and actions; (ii) enhancing information dissemination and technical support; (iii) improving cooperation mechanisms; and (iv) cutting the production of GHG emissions, such as methane and carbon dioxide (e.g., from the paddy fields, enteric fermentation, livestock manure) through the application of biogas digesters for electricity and bio-ethanol production.

- Build urban resilience through quality infrastructure and spatial planning, such as (i) considering climate-proofed alternative development options; (ii) adoption of climate-proofed policy and action plans; (iii) climate risk assessments before the approval of infrastructure construction projects; (iv) undertaking structural measures to prevent vulnerable infrastructure assets; and (v) adopting nonstationary hydrologic building codes for infrastructure and buildings, while actively promoting mitigation measures for service delivery and operation and maintenance (O&M) of infrastructure and facilities in existing urban areas.

- Adopt a smart-city approach that leverages digitization, clean energy, and technologies, such as (i) geospatial databases for monitoring and planning urban services and other aspects in the city; (ii) spatial data information systems; (iii) data analytics to support operations; (iv) securing city, national, and international connected ICT networks; (v) automation, and (vi) e-payment and digital platforms.

[1] National Climate Change Strategy 2030, Decree no. 98/PM, 24 February 2023.

[2] For more details, see National Progress Report on the Implementation of the New Urban Agenda published on September 2021 by MPWT; and related materials: The full VNR document is available at United Nation Lao PDR or from https://laopdr.un.org/en/13108-voluntarynational-review-implementation-2030-agenda-sustainable-development.

A draft climate action plan for Vientiane was prepared by Global Green Growth Institute (GGGI)[3] and is currently undergoing the approval process by Vientiane Capital Mayor. It identifies measures to reduce annual GHG emissions per capita from 2.6 to 2 tonnes per person per year, leverage economic opportunities from climate change, and increase disaster resilience. It has also set out the following ambitious vision:

> **"By 2030, Vientiane Capital will become livable, attractive and environmentally friendly, being the strategic hub for all development work, having quality economic growth in a green and sustainable manner through efficient use of resources and modern technologies, being resilient to natural and climate risks, social inclusive, equity and better quality of life for all Vientiane Citizens."**
>
> *GGGI Action Plan for Vientiane Capital 2023-2030.*

To realize the above vision, the following strategic objectives are also set for Vientiane Capital:

- Enhance quality economic growth through sustainable and efficient use of limited resources and environmentally friendly technologies.
- Protect urban environment in a systematic and sustainable manner, reduce air, water, noise, and soil pollution, as well as reduce GHG emissions into the atmosphere.
- Improve quality of life of all Vientiane Citizens through equal access to public services.

The Vientiane APEX GCAP, presented herein, aims to support the implementation of the New Urban Agenda (NUA), the GGGI Action Plan, and related sectoral strategies/master plans to respond to climate change. The GCAP identifies and prioritizes green city actions based on impact and cost. It identifies specific projects, policies, and planning strategies that can help the city achieve its GHG reduction goals, as well as gives indicative implementation costs. The actions are aligned with potential financing mechanisms that the city can consider to support implementation, including those engaging the private sector.

The Mekong Riverside Park is a popular destination for outdoor recreation activities with green spaces and night markets. It also serves as flood mitigation infrastructure and a bypass road during peak traffic hours.

Image: © Phounsub Thepvongsa / World Bank

[3] Green City Action Plan Vientiane Capital 2023-2030 was prepared in 2022 by GGGI, in partnership with Ministry of Public Work and Transport (MPWT) and Vientiane Capital, with financial support from Korea International Cooperation Agency (KOICA). Pending approval of Vientiane Capital's Mayor.

GCAP Development Process

The Vientiane APEX GCAP was developed between October 2023 and June 2024 in collaboration with the Ministry of Public Works and Transport (MPWT), led by the Department of Housing and Urban Planning (DHUP), and with input from sector representatives from technical departments. The objective was to develop a GHG reduction pathway by identifying and prioritizing measures across the built environment and energy, transportation, waste, and water sectors to help guide MPWT, Vientiane Capital authorities, and other concerned agencies towards meeting their green city ambitions.

The GCAP development process followed three main steps: 1) data collection and baseline setting, 2) selection and prioritization of measures, and 3) analysis using the APEX Online Tool. In addition, the writeup includes some ideas for business models and financing mechanisms to implement the GCAP.

The APEX software uses information for the baseline year and projects forward to the target year using anticipated population growth rates. It evaluates actions relative to the BAU case—that is, the scenario where the city government does not take any specific actions, and municipal operations and resident behaviors are the same as in the baseline year. APEX then helps quantify the impact of investment, planning, and policy solutions—referred to as measures—in the target year. There are over 100 measures preloaded into APEX, as well as the option to create custom measures. Each measure has an engine that quantifies its impacts and costs based on the specific situation in the city. The methodology behind each measure is based on prevailing engineering calculations, existing studies in literature, and/or case studies from other cities.

IFC collaborated with DHUP and MPWT officials to compile data, review current strategies and plans, and identify and prioritize solutions. Data were supplied by DHUP officials and concerned sector/line agencies, as well as retrieved from publicly available sources and key development partners (i.e., World Bank, GGGI, JICA, and others). For measures selection, the team first reviewed the Vientiane sectoral/departmental strategies and plans and the GGGI Action Plan for key measures that could be assessed using the APEX platform. Finally, workshops were held with sector representatives to verify data and discuss the context and priorities of different measures.

The workshops took place at the Landmark Hotel in Vientiane Capital on March 5, 2024. Participants included representatives of the DHUP, technical core teams corresponding to the four APEX sectors, including built environment and energy (Energy Department and Électricité du Laos of Vientiane Capital), transportation (DOT/MPWT and DPWT/Vientiane Capital), solid waste (VCOMS) and water and wastewater (Nampapa Nakhoneluang State Enterprise, Department of Water Supply/MPWT, Provincial/District Office of Natural Resource (PONRE/DONRE)) and others including Vientiane Statistic Center, GGGI, Department of Planning and Investment (DPI)/Vientiane Capital, and Faculty of Architect of National University of Laos (NUOL). The main objectives were to provide an overview of the APEX GCAP process, understand the content and priorities in existing plans, review and discuss actions aligned with APEX, and prioritize measures for further analysis.

The workshops were key to understanding the local context for the Vientiane Capital. Following the workshops, the APEX team developed the GCAP with the information received from the technical teams. Going forward, the DHUP will continue to have access to the APEX online software to conduct further analyses, monitor implementation, and track results.

Consultations with Vientiane stakeholders were facilitated to identify and prioritize measures during workshops hosted by MPWT.

Image: Sakhone Phomsouvanh / IFC

Introduction

City Context

This section presents a summary of the city data underlying the APEX analysis across the four main sectors: built environment and energy, transportation, waste, and water. Further details and data references are available in Appendix A.

Vientiane's BRT system will traverse National Road 13 South, connecting the National University of Laos, the Vientiane Railway Station and Lao PDR's southern provinces.

Image: © Phounsub Thepvongsa / World Bank

Built Environment & Energy

Vientiane Capital was established 450 years ago, but the built environment has undergone significant changes in land use over the past few decades. The urbanization of the city has been characterized as rapid and uncontrolled because of dynamic rural-urban migration. This has caused expansion and densification to accommodate the influx of population, especially younger generations seeking employment and a better quality of education and life in general. The built-up area has expanded and concentrated in four core urban districts: Chanthabouly, Sisattanark, Xaysettha, and Sikhottabong. The development also aligned with the recently approved Vientiane Master Plan 2030, which sub-divide the core urban into four major areas: core urban, sub-urban, periphery / outskirt, and expansion. The core urban area is reserved for old city squares, cultural heritage, administration, trade, and services. The sub-urban area includes areas surrounding the airport and along the Mekong riverbank. The periphery includes areas surrounding the airport, agricultural lands, the national university, conservation areas, and new developments, such as the 450-year road, highspeed railway, and border crossing. Expansion areas include land promoted as new city development, logistic hubs, and industrial and agricultural estates.

The result of the APEX analysis shows that 74 percent of Vientiane Capital's buildings are dedicated to residential use, which includes homes, apartments, and shop houses (*Figure 3*). Another 14 percent are commercial buildings. The remaining 12 percent is allocated for mixed-use properties, including government owned buildings.

Vientiane Capital relies exclusively on the Électricité du Laos (EDL) for their electricity distribution. Vientiane Capital has the highest consumption of electricity in the country, with a demand of 3.8 million GWh and average annual growth rate of 5 percent (2021-2030). The energy source in Lao PDR is predominantly hydropower (80.4 percent), followed by coal-power plants (18.6 percent), biomass (0.4 percent) and solar farms (0.6 percent). The total installed capacity is 10,091 MW (2020), of which about 70 percent is being exported. Nationally, the demand forecast for energy in 2030 is about 2,541 MW (with growth rate of 7 percent), with Vientiane Capital requiring the highest demand of 660 MW.

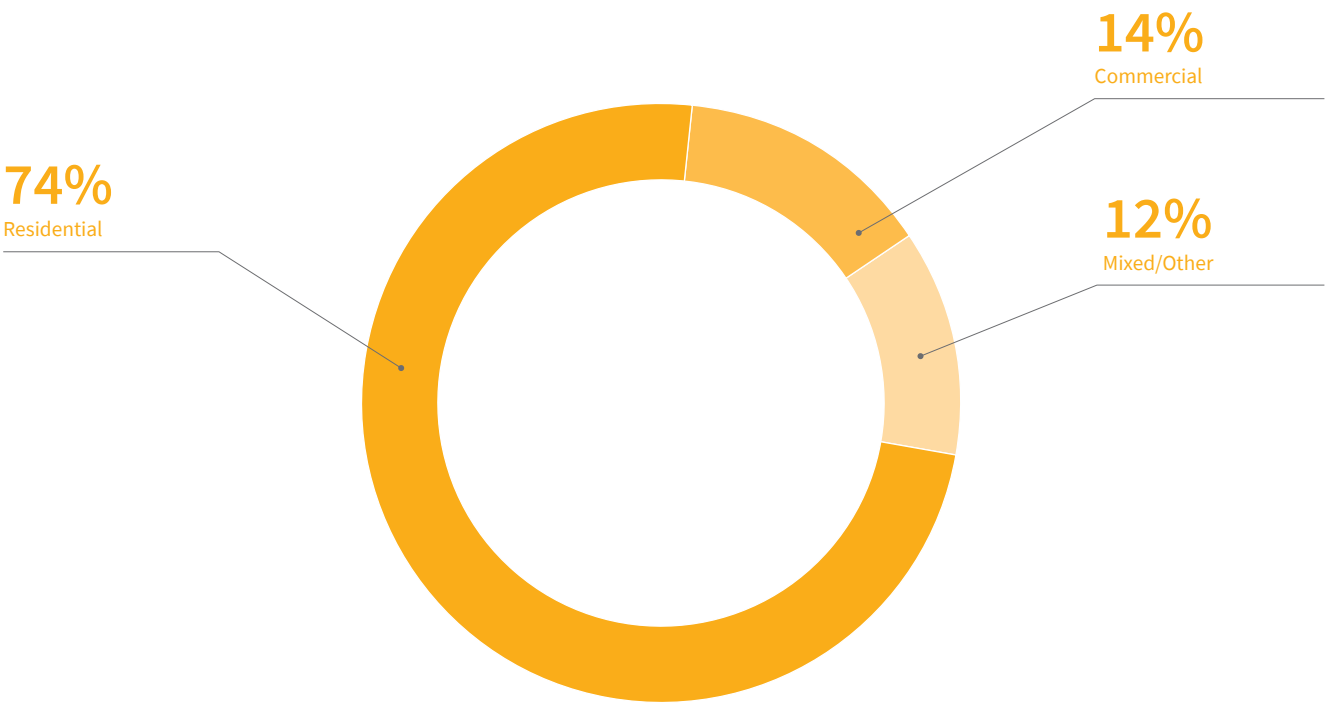

Figure 3: *Building area percentage by type.*

Transportation

Vientiane Capital is experiencing rapid motorization. Residents of Vientiane Capital predominantly rely on motorcycles (63 percent), followed by automobiles (24 percent), walking (9 percent), bicycles (2 percent) and public transport modes (2 percent) for their daily commuting needs, as shown in *Figure 4.* These figures align with the Vientiane Transport Urban Master Plan 2040, which shows that private vehicles, which heavily depend on combustion engines, have become the dominant mode of transport. The public transport share decreased from 4 percent in 2007 to a mere 1.4 percent in 2019, resulting in traffic congestion occurring throughout the city. The urban public transportation system includes buses and motor-taxi (i.e., car, Songteo, Tuk-tuk, Jumbo, and motorcycle). As part of the public transportation reform, a 27.6-km Bus Rapid Transport (BRT) system has been proposed and planned in three phases: short–term (2022-27, ongoing), medium–term (2028–32) and long–term (2033–40).

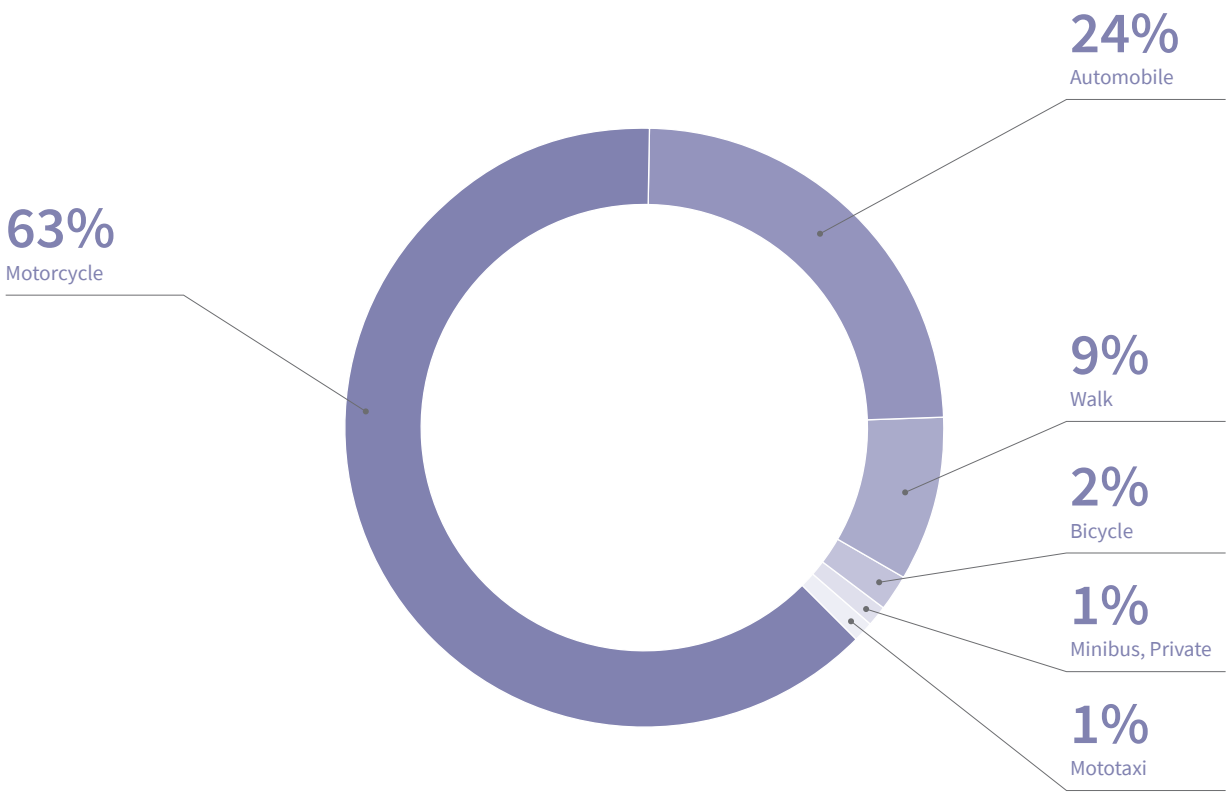

Figure 4: *Modal split by passenger kilometers travelled.*

Waste

On average, each resident of Vientiane Capital produces approximately 0.38 tonnes of waste per year, resulting in over 350 thousand tonnes annually. Over 60 percent of this waste consists of organic waste generated from food scraps. Unfortunately, only 31 percent of the total waste ends up in managed landfills, while 38 percent is disposed in open dumps, 26 percent is unaccounted, and 6 percent undergoes recycling (*see Figure 5*). Several challenges in waste management persist in Vientiane Capital. These include lack of a sanitary landfill and waste collection trucks, poor and narrowed access roads, and lack of public awareness and knowledge on recycling, leading to limited practices in waste separation. With an inadequate official waste collection network and inefficient services, this has prompted the residents to conduct illegal dumping and burning, as well as relying more on informal recycling methods.

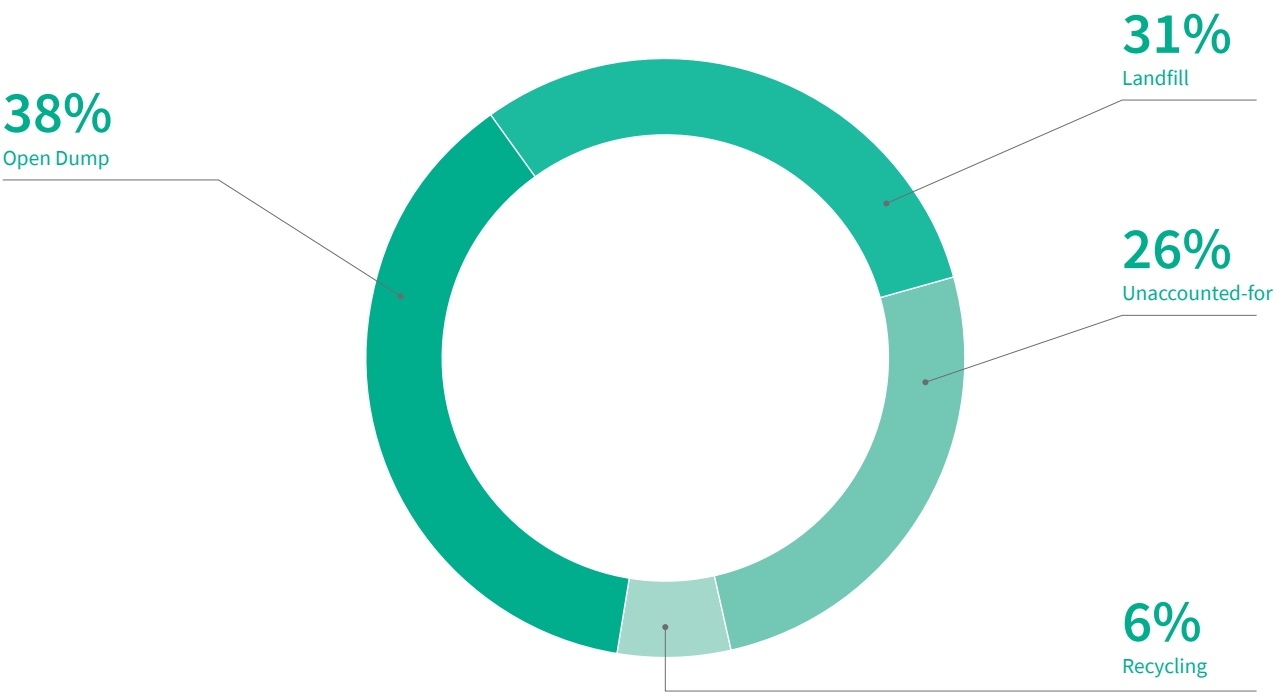

Figure 5: *Waste disposal by treatment type.*

Water

About 70 percent of residents of Vientiane Capital have access to safe and potable water, mostly in the core, semi-urban, and periphery areas. The Nampapa Nakhoneluang State-owned Enterprise develops, operates, and distributes potable water across Vientiane Capital. The company continues to expand, with 669,000 cubic meters (m^3) per day to be provided in the long-term (2016-2030), compared to the current estimated distribution of 449,000 m^3 per day (2024). For residents without access to safe and potable water, groundwater source is an alternative.

On average, Vientiane capital residents utilize 183 liters of water per person per day, which accumulates to a staggering 177 million liters per day (MLD) throughout the city. All this water goes through the treatment plants in different locations owned by the Nampapa Nakhoneluang State-owned Enterprise.

In terms of wastewater management and sewerage systems in Vientiane Capital, 95 percent of the wastewater is treated in septic tank systems, while 5 percent is untreated (*Figure 6*). There are inadequate wastewater treatment facilities for both households and businesses, which causes overflow of black water into drainage systems, public canals, and natural areas without proper treatment. Additionally, there is lack of regular de-sludging of septic tanks due to insufficient regulations and enforcement and low awareness of the communities. There are also issues with blockage of public canals, which have caused localized floods, stagnant water, and disease outbreak, primarily in rainy season.

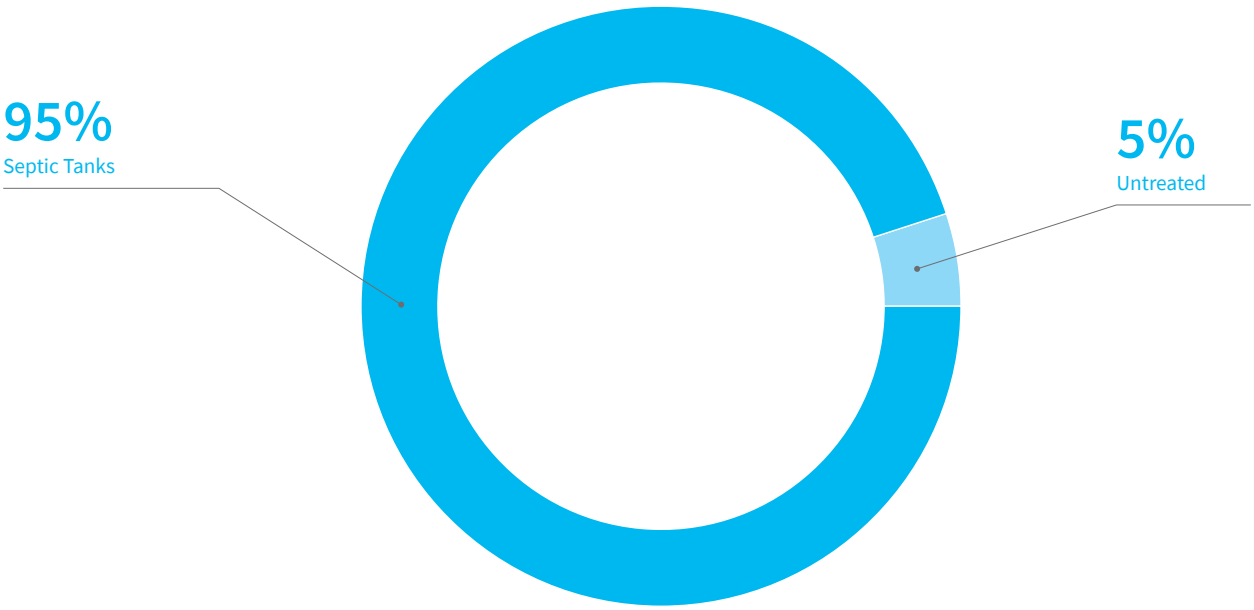

Figure 6: *Wastewater treatment methods.*

Greenhouse Gas Emissions

Using the APEX Online App to develop a GHG baseline for 2023, the GHG inventory showed that Vientiane produces over 1.74 million tonnes of carbon emissions across the energy, transportation, waste, and water sectors. As shown in *Figure 7*, half of the emissions (50 percent) is from the built environment and energy, and the other half is from transportation (33 percent), solid waste (16 percent), and water and wastewater (<1 percent).

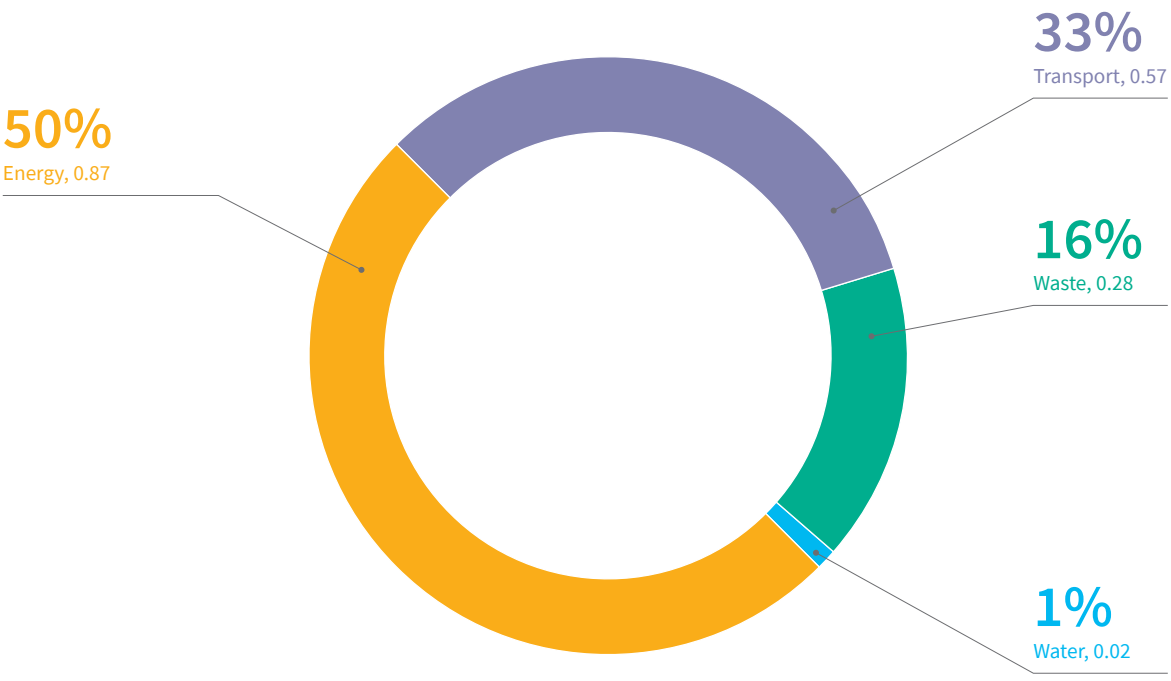

Figure 7: *GHG emissions for Vientiane Capital.*

Green City Actions and Savings

The 30 measures in the Vientiane GCAP are anticipated to result in a 22 percent reduction of the city's BAU GHG emissions across the built environment, transportation, solid waste, and water sectors. The current, BAU, and improved case emissions by sector are shown in *Figure 8*, and the savings in each sector is shown in *Figure 9*. Additional reductions may be achieved in sectors outside the scope of APEX (and outside the city's direct mandate), notably in industry and agriculture sectors.

The measures include a mix of direct-cost measures, where the cost is the responsibility of the city and its agencies, or indirect-cost measures that are mobilized by policies, regulation, and outreach programs (or the responsibility of other levels of government). This section provides an overview of the prioritized measures and results of the APEX analysis, including GHG emissions savings, cost, energy savings, and other indicators. Appendix B shows the full list of key assumptions for measures underlying the results calculations.

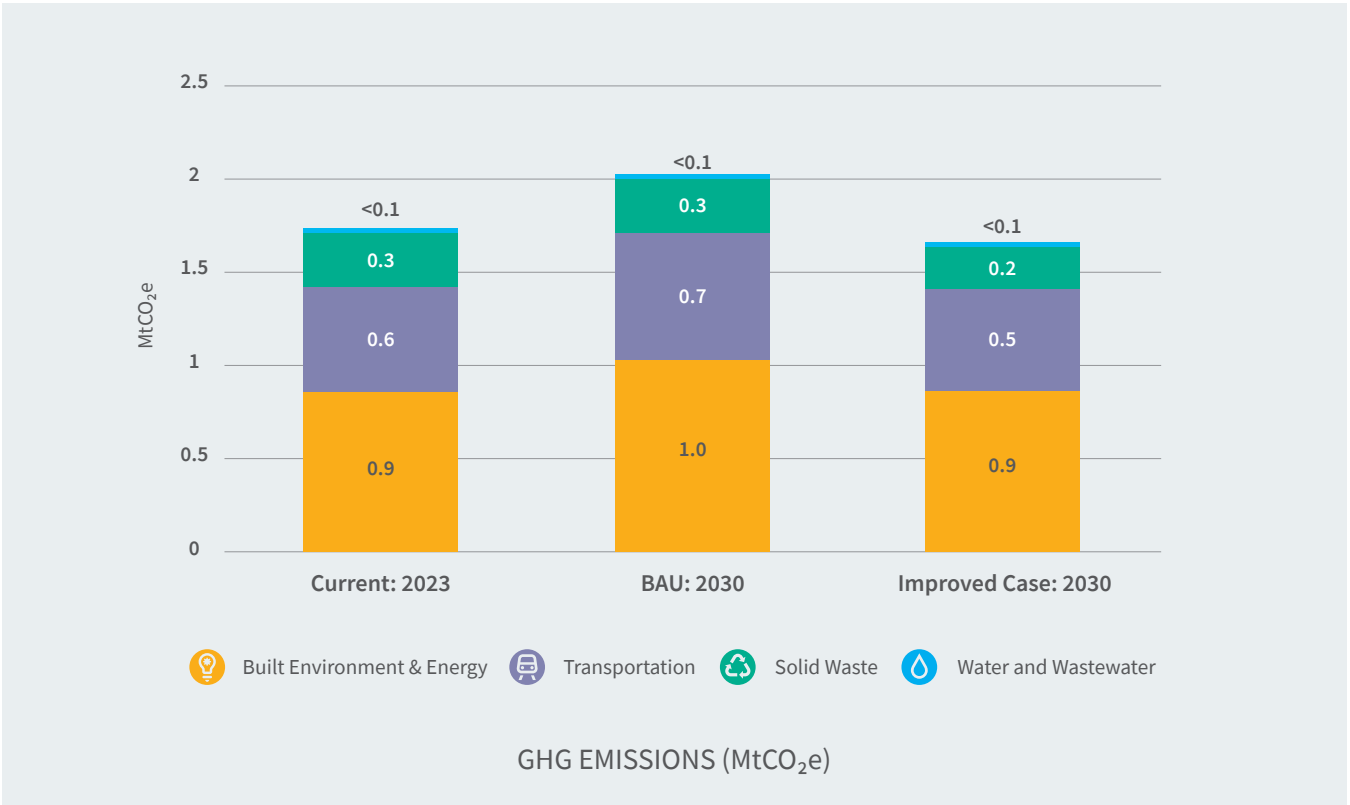

Figure 8: *Current, BAU, Improved Case for GHG emissions ($MtCO_2e$/year). Total GHG emissions in the BAU case is 2.1 $MtCO_2e$. Total GHG emissions savings in the improved case is 450 $ktCO_2e$, representing a savings of 22 percent.*

Note: $MtCO_2e$ = million tonnes of carbon dioxide equivalent; BAU = business-as-usual; GHG = greenhouse gas.

Image: © Phounsub Thepvongsa / World Bank

Public plazas along the Mekong River overlooking Thailand host local festivities such as Lai Hua Fai.

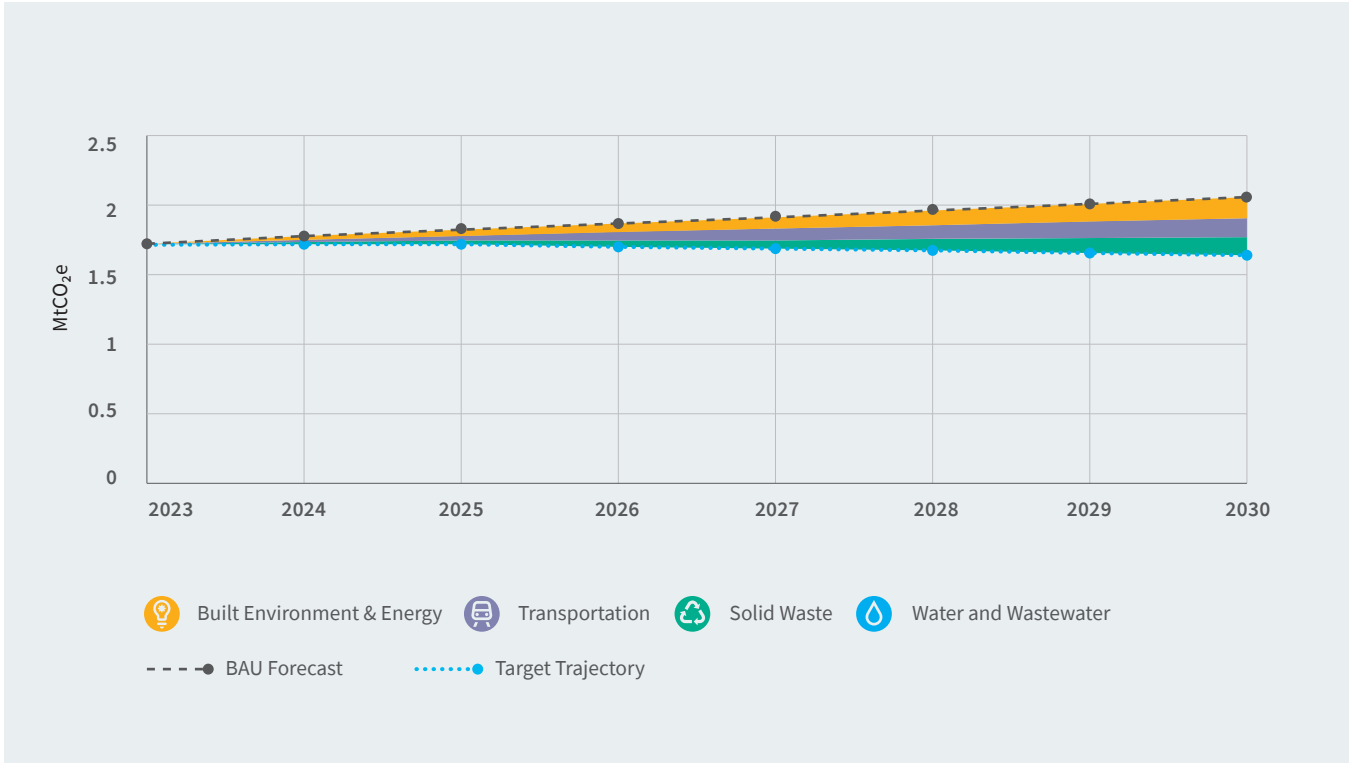

Figure 9: *Potential GHG reductions resulting from selected measures across the four APEX sectors. Implementing the 30 measures is expected to deliver a 22 percent GHG reduction, equivalent to 450 $ktCO_2e$ in GHG emissions.*

Note: $ktCO_2e$ = kilotonnes carbon dioxide equivalent; $MtCO_2e$ = million tonnes of carbon dioxide equivalent; BAU = business-as-usual; GHG = greenhouse gas.

Built Environment & Energy

Priorities in the built environment and energy sector include actions the city can implement within their own facilities, as well as indirect actions where the city can promote implementation among private homes and businesses. Actions within the city's operations and facilities include the expansion of urban forestry, the upgrading of streetlights to energy-efficient alternatives, the enhancement of energy efficiency in city-owned facilities, and the adoption of solar energy on city buildings.

The most significant cost savings are anticipated to arise from indirect measures. Such measures include the construction of energy-efficient buildings compliant with a green building code, the energy efficiency refurbishment of existing buildings, and the introduction of a rooftop solar and cool roofs program.

These initiatives are in line with Lao PDR's Renewable Energy Development Strategy 2011, the National Policy on Energy Saving and Conservation 2011, and the Energy Strategy for Lao PDR 2021-2030. Collectively, these strategies aim to promote energy conservation and the utilization of renewable electricity in households and communities.

16%
Fossil Fuel Energy Savings

8%
GHG Savings

356 GWh/year
Total Fossil Fuel Energy Savings

923
Total Cost (USD Million)

Total fossil fuel energy savings: 356 GWh/year

APEX Sector	Measures	Fossil Fuel Energy Savings (%)	GHG Savings (%)	Total Cost (USD Million)
Built Environment & Energy	1. Mandate Rooftop Solar Hot Water	0.2%	0.1%	28
	2. Improve Building Code	0.6%	0.3%	37
	3. Promote Cool Roofs	0.1%	<0.1%	72
	4. Increase Extent of Urban Forestry*	<0.1%	<0.1%	293
	5. + Incentivize Green Building Certification	1.2%	0.6%	9
	6. + Finance for Private EE Refurbishment	5.4%	2.8%	300
	7. + Implement Rooftop Solar PV Program	6.9%	3.5%	135
	8. Implement Green Certification for All Municipal Buildings*	0.6%	0.3%	3
	9. Implement EE Refurbishment for All Municipal Buildings*	0.7%	0.4%	32
	10. Upgrade All Streetlights with Energy Efficient Bulbs*	0.1%	<0.1%	14
	Total	**16%**	**8%**	**923**

**Direct cost item*
+ Measures with the highest impact in terms of GHG savings

Note: GWh = gigawatt-hour; GHG = greenhouse gas; EE = energy efficiency; PV = photovoltaics; USD = United States dollar

1. Implement Rooftop Solar Hot Water for Private-Owned Buildings

For this measure, the city requires solar hot water systems on rooftops of habitable buildings, including hotels, health, and residential buildings. Solar hot water systems work by using rooftop solar collectors to warm water that then flows through the building's plumbing system. Active solar hot water systems circulate water using pumps, while passive systems rely on gravity to circulate hot water. The results of this measure are based on a 25 percent uptake of solar hot water systems.

This is an indirect-cost measure because the costs of solar hot water systems are borne by private homes and businesses.

2. Implement Green Building Code

This measure includes the implementation of a Green Building Code applicable to the construction of new, non-residential buildings. While building codes are often set at the national level, cities with the regulatory authority can set more ambitious requirements. This measure targets a 20 percent energy and water savings beyond current code requirements.

While this is a policy that is implemented by the city, this measure is an indirect-cost measure because the costs of green building construction will fall on developers.

3. Promote Cool Roofs for both City-Owned and Private-Owned Buildings

The city promotes the adoption of cool roofs on buildings. Cool roofs reflect more sunlight and absorb less heat than conventional roofs, which can help reduce air conditioning loads and mitigate local urban heat islands. The results are based on 25 percent uptake of cool roofs, about 1.2 million square meters (m^2) of rooftop area.

This is an indirect-cost measure for private buildings because the costs of cool roofs are borne by the private sector. For city-owned buildings, cool roofs can be included in broader municipal building improvements and construction, for which the cost is direct to the city.

4. Increase Extent of Urban Forestry

This measure aims to increase the extent of the urban forest canopy, including forested areas of the city, street trees, and other parks and green spaces with trees. Trees in cities help reduce energy consumption in buildings, mitigate local urban heat islands, and sequester carbon from the air. The results are based on 10 percent increase in urban forestry, which is an additional 10 km^2 of canopy area. This is also aligned with 9th NSEDP of Vientiane Capital, Vientiane Master Plan III, and the draft climate action plan, which aims to develop and expand green spaces and incorporate green space concept into new developments (both public and private investment projects), with a target of 9 m^2 of green space area per person by 2030.

If the city government leads the tree planting program, this measure is considered a direct-cost measure. There are several economic benefits to urban trees, including increased property values and improved air quality. The city could also encourage the private sector and communities/household to undertake tree planting through planning regulations and/or instituting requirements for new developments, offices, schools, temples, and others.

5. Incentivize Green Building Certification

For this measure, the city incentivizes Green Building Certification for new buildings and developments. IFC's EDGE certification is well-suited to be tied into municipal policy due to its ease of use, low cost, and scalability. EDGE certification requires at least 20 percent savings in energy, water, and embodied energy in materials beyond current building code requirements. There are also two higher tiers of certification: EDGE Advanced (40 percent savings) and EDGE Zero Carbon. Incentives can include administrative incentives (e.g., expedited planning and approval processes), financial incentives (e.g., tax credits, funds, and rebates), and technical support (e.g., technical assistance and training for building green). The results are based on an improved scenario where 30 percent of new private residential buildings, or approximately 889,000 m^2 of building area, have Green Building Certifications equivalent to 20 percent building efficiency savings.

This is an indirect-cost measure because the costs of green building certification and construction are borne by the private sector.

6. Finance Private Energy Efficiency Refurbishment

This measure includes a financing program for energy efficiency refurbishment of private buildings, including efficient lighting/appliances, improved windows and building envelopes, upgraded heating, venting, and air conditioning (HVAC) systems, etc. The results are based on outfitting approximately 30 percent of existing building area with energy efficiency upgrades, about 7.85 million m^2 of building space.

This is an indirect-cost measure because the costs of energy efficiency refurbishment are borne by the private building owners. Private energy efficiency refurbishment is a key action to reduce GHG emissions for Vientiane. Examples of enabling policies and innovative financial products to scale refurbishments in other countries are property-linked finance (PLF) and on-bill financing (OBF). In PLF, the loan is attached to the property, not the individual or company that owns the building. Governments or private lenders provide financing to building owners, which helps pay for the upfront costs of energy efficiency improvements. Loans are paid back by increasing property taxes by a set rate for an agreed-upon term. Property owners begin saving on energy costs while paying for improvements, often resulting in net gains even with increased property tax. On the other hand, OBF allows utility customers to purchase equipment through their usual retailers—financed by the utility or a private lender—which is then paid back over time on electricity bills.

7. Implement Rooftop Solar PV Program

This measure is a city-wide rooftop solar PV program, where the city and its partners offer incentives and/or support to install PV panels on private buildings throughout the city. The results for the measure are based on an installation of 159 MWp of installed capacity, covering 50 percent of the estimated rooftop area in the city, though panels could also be ground mounted.

This is an indirect-cost measure because the costs of rooftop solar PV fall to the building owners. Rooftop solar PV is another key action to reduce GHG emissions for Vientiane. While currently there are no regulations to support the program, rooftop solar could also be included in PLF or OBF programs described above. Other mechanisms to improve its viability include: net-metering, which is a utility billing practice that allows homeowners and businesses with solar panels to receive credit for the excess energy they generate and send back to the electric grid feed-in-tariff targets; and feed-in tariff, which is a policy designed to support the development of renewable energy sources by providing a guaranteed, above-market price for producers.

8. Implement Green Certification for Municipal Buildings

For this measure, the city commits to constructing all new municipal buildings according to Green Building standards. As noted above, if the certification program EDGE is used, the green buildings would see a 20 percent reduction in energy and water consumption, as well as 20 percent less embodied energy in materials, relative to local conventional construction. By pursuing green certification for their own buildings, the city will lead by example and help support the development of technical capacity for green building certification in the private sector as well.

This is a direct-cost measure involving uplift costs for green building construction, which Vientiane can finance through its own budget or central government transfers.

9. Implement Energy Efficiency Refurbishment Program for Municipal Buildings

This measure is an energy efficiency refurbishment program, where Vientiane's existing municipal buildings are upgraded to reduce their energy consumption. By making their own facilities energy efficient, the city is leading by example and can lower building operating costs. The results for the measure are based on an energy efficiency refurbishment program that upgrades all city-owned buildings or approximately 820,800 m^2 of building area. Implementing this measure will require an inventory of city-owned buildings and their energy consumption. A comprehensive energy audit will enable professional recommendations to reduce energy consumption, such as upgrades to lighting, appliances, windows, and HVAC systems, for some examples.

The measure is a direct-cost measure with energy savings revenue that may make it attractive for leveraging private sector financing where enabling policies exist. For example, energy-as-a-service (EaaS) or leasing are ways the city could work with private financers to implement energy efficient improvements, particularly for energy efficiency equipment such as efficient appliances and HVAC system components. EaaS is a business model whereby customers pay for an energy service without having to make any upfront capital investment. The EaaS company installs energy efficiency solutions in public buildings selected by the city, retains ownership of the equipment, and receives service fees. In a lease arrangement, the lending party (e.g., financial institution, a vendor, leasing company) provides the use of the equipment to the city for a specified time in exchange for periodic payments, which can be covered by savings in energy expenditures.

10. Upgrade All Streetlights with Energy Efficient Bulbs

This measure aims to upgrade over 6,000 streetlights with energy efficient bulbs, which use 80 percent less energy than existing bulbs. This measure is a direct-cost measure with energy savings revenue. In cities around the world, various forms of PPPs have been used successfully to upgrade lighting, such as energy performance contracts, where an energy service company (ESCO) implements the project and receives payments based on energy savings performance.

Solar-powered streetlights have been installed along new roads as Vientiane continues to expand.

Image: © Philippe Aramburu / World Bank

Transportation

Priorities within the transportation sector are centered on expanding public transport and developing bike lanes, alongside the electrification of buses and private vehicles. To further advance these goals, the introduction of a smart transit fare system is proposed, coupled with policies designed to manage and avoid private vehicles driving into the city. Such policies may include congestion charging, park-and-ride lots next to transit stations, and removing street parking spaces. These initiatives align with the objectives of the Vientiane Capital Urban Transport Master Plan (VTMP 2040)[4], which envisions an accessible, livable, and sustainable city for all by the year 2040.

Achieving this vision necessitates a comprehensive restructuring of public transportation, encompassing the development of road networks and traffic management, and fostering a shift in transportation behaviors. Without a concerted effort to change current habits, the share of public transport will remain low at 14.2 percent by 2040, falling short of the ambitious 30 percent target. Efforts to improve public transport should also consider the transition to electric vehicles, with the most significant GHG savings coming from private EVs, e-buses, and e-BRTs.

24% Reduction in Private FF Vehicle Travel

8% GHG Savings

1,999 million VKT/year Total Private FF VKT Reduction

2,147 Total Cost (USD Million)

Total Private Fossil Fuel (FF) VKT Reduction: 1,999 million VKT/year

APEX Sector	Measures	Reduction in Private FF Vehicle Travel (%)	GHG Savings (%)	Total Cost (USD Million)
Transportation	1. Introduce Congestion Charging Zone**	1.3%	0.4%	--
	2. Remove Street Parking Spaces**	0.4%	0.4%	--
	3. Provide EV Charging Infrastructure*	<0.1%	<0.1%	1
	4. + Finance for Private EVs	16.7%	5.4%	1,625
	5. Build Bicycle Lanes*	<0.1%	<0.1%	0.2
	6. + Expand Electric Bus Fleet*	2.8%	0.8%	68
	7. + Add BRT System and E-Buses*	2.7%	0.8%	441
	8. Add Park-and-Ride Lot to Transit Station*	0.2%	0.1%	12
	9. Introduce Smart Transit Fare Cards**	<0.1%	<0.1%	--
	Total	**24%**	**8%**	**2,147**

**Direct cost item*
***Policy-based measure that is currently not costed in APEX*
+ Measures with the highest impact in terms of GHG savings

Note: EV = electric vehicles; BRT = bus rapid transit; E-buses = electric buses; FF = fossil fuel; GHG = greenhouse gas; USD = United States dollar

[4] Prepared and approved in March 2023, with support from JICA – through the Project for Institutional Capacity Building for Sustainable Urban Transport System in Lao PDR.

1. Introduce Congestion Charging Zone

This measure introduces a congestion charging zone in an area of the city with heavy traffic congestion, most often the central business district. Vehicles that enter the zone during operating times—typically peak congestion hours—are charged a fee. The fee should be set in a manner that effectively deters personal fossil fuel vehicle travel and makes public transportation options more desirable.

Vientiane's central business district and Mekong river-side areas have been identified as important areas for business and tourism. This measure assumes that 20 percent of all vehicles enter this central zone, which necessitates environment- and heritage-sensitive public transport and sidewalk infrastructure to shift passengers away from private vehicle travel. The results are based on a congestion charging system that deters about 30,200 vehicles per day.

This measure is considered a policy measure and is not currently costed in APEX.

2. Remove Street Parking Spaces

In this policy measure, the city removes approximately 10 percent of street parking spaces to deter private vehicle travel on city streets. The road space can instead be used to expand sidewalks or create outdoor cafe seating, for some examples. By restricting facilities for private cars, the city can help promote active and public transport modes.

This measure is considered a policy measure and is not currently costed in APEX.

3. Provide EV Charging Infrastructure

This measure aims to create a charging network for EVs with the installation of an initial batch of 100 publicly owned EV charging stations. Stations would be available to the public at locations throughout the city, providing recharging opportunities in addition to at-home charge points. As EV adoption grows, this measure will require working with partners to create a broader charging network for EVs.

EV charging infrastructure is a relatively new area of infrastructure planning for Vientiane, and a framework for detailed planning for EVs and EV charging stations is to be established. In Vientiane, the private sector is already constructing charging stations on their own, in support of their own privately-operated fleet of EV taxis or rideshare services.

From the perspective of power generation and distribution state-owned enterprises, EV charging is a potential driver of additional demand for energy, as well as a potential future revenue source. From a transport perspective, electric vehicles are seen as an opportunity to reduce carbon emissions and improve local air quality. The Energy Strategy for Lao PDR 2030 has set out a policy to "create a mechanism to reduce the importation of fuel and gas by changing and promoting the use of electric vehicles in the transportation sector." A 2030 energy demand scenario has been prepared including EV promotion, with the demand for electricity in Vientiane projected to be 1,322 GWh (equivalent to 219 MW). Nationally, a total of 16,787 GWh is needed. This represents an average annual growth rate of 7.6 percent, which is 0.8 percent higher than the BAU case.

This measure is a direct-cost measure where the city can easily work with private sector partners. There are various options for PPPs. For example, the city could allow companies to construct, own, and operate public charging stations on city-owned property. This measure would also be well-suited to the product-as-a-service or leasing-of-assets model, where the city leases the chargers and then makes payments using revenue from energy sales. If the city wanted to retain ownership of the charging infrastructure, it could also be funded through government transfers or loans.

4. Incentivize EV for Private Owners

This measure aims to incentivize and facilitate the transition to EVs through municipal policy and financial intermediaries. Banks can offer car buyers financing to purchase EVs which can be paired with other incentives offered by the city and partners, such as access to public charge points, expedited or discounted vehicle registration, discounts on electricity at private charge points, and others. The results are based on replacing 325,000 conventional automobiles and two-wheelers in the city's fleet with electricity-powered alternatives.

This is an indirect-cost measure because the costs of buying electric vehicles are borne by the private vehicle owners. Transition to EVs is a key action to reduce GHG emissions for Vientiane, which private financing and enabling policies can help accelerate.

5. Build Bicycle Lanes

This measure includes building 30 km of bicycle lanes and other bicycle infrastructure (i.e., bicycle parking). Bicycle infrastructure helps promote the shift to active transportation by improving conditions for cyclists, including improved safety while riding, property security when the bicycle is not in use, and ease of routing.

This measure is a direct-cost measure, where the bicycle lane infrastructure is considered a public good provided by the city. A more comprehensive bicycle and active transport infrastructure plan can be financed by the government through its own budget or a central government loan/transfer. Non-motorized transport could also be part of a bigger package of climate-smart municipal infrastructure projects that could align with climate financing.

6. Expand Electric Bus Fleet

This measure aims to expand and electrify the fleet of city buses to support more bus ridership. Electric buses have fewer tail-pipe emissions and require less maintenance compared to diesel buses. Additional electric buses should be combined with other actions to incentivize public transport ridership, such as rationalization of bus routes, bus frequency, and location of bus stops. On the operational side, electrification of the bus fleet will also require bus depots and service stations to be upgraded with charging infrastructure.

This measure is a direct-cost measure for which there are several innovative PPP approaches that have worked in other markets to leverage private sector financing. For example, creation of a public asset corporation that purchases and maintains the e-buses, batteries, and charging infrastructure. The e-buses and batteries could potentially be considered separately and individually procured through a product-as-a-service or leasing model. If the city wishes to maintain ownership of the buses, funding could be pursued through the city's budget or central government loan, including sustainability- or climate-linked financing.

7. Add Electric BRT System

This measure adds a new Bus Rapid Transit (BRT) system. BRT systems are bus networks that operate on purposely constructed, dedicated lanes, similar to rail networks. This measure includes purchasing electric BRT buses for the new BRT system, as well as outfitting depots and service stations with charging infrastructure. The BRT Project[5] phase 1 under the VTMP 2040 has started and is expected to be in operation by 2024, with 12.9 km of BRT corridors and 27 stations. The project will also provide a fleet of 55 12-meter, low-floor battery electric buses, as well as a driving training program for 140 drivers.

This is a direct-cost measure currently co-financed by the Asian Development Bank, European Union's Asia Investment Facility, European Investment Bank, Global Environment Facility, and the Organization of the Petroleum Exporting Countries Fund for International Development.

8. Add Park and Ride at Transit Stations

This measure includes park-and-ride lots next to transit stations with 1,000 spaces for automobiles and 2,000 spaces for two-wheelers. A park-and-ride lot is a parking facility for public transport riders, where they can leave their private vehicles to avoid driving into the city. Park-and-ride lots can help increase public transport ridership in areas without adequate feeder buses, such as suburban and peri-urban areas.

This measure is a direct-cost measure for which the funding can be allocated within transport infrastructure projects, such as the BRT and city bus projects above. Funding through the city's own budget is an option if the city wishes to utilize city-owned land for the park-and-ride facilities.

9. Introduce Smart Transit Fare System

In this measure, the city introduces smart transit fare cards, which allow riders to load money onto their cards and pay for trips by simply tapping or swiping their smart card. This can increase public transport ridership by making payment faster and more convenient, as well as improving security by eliminating the need to carry cash.

This measure is considered a policy measure and is not currently costed in APEX.

[5] Under Vientiane Sustainable Transport Project (VSUTP) co-financed by ADB, EIB, OPEC Fund, EU-AIF, GEF, and Higher Technology Fund.

Waste

Priorities within the waste sector are focused on enhancing recycling facilities, optimizing waste collection services, and promoting waste-to-energy practices, composting, and anaerobic digestion. These efforts are in line with the Sustainable Solid Waste Management Strategy and Action Plan for Vientiane Capital 2021-2030, which aims to foster a clean, green, and livable city. To realize this vision, it is essential to ensure that every citizen has access to adequate waste collection services. Furthermore, the success of this strategy depends on the effective recovery of waste through resource initiatives and facilities, as well as the promotion of source separation at the household level to decrease per capita waste generation rates[6].

37%
Waste Diverted from Landfill

5%
GHG Savings

95 kt/year
Landfilled Waste Reduction

77
Total Cost (USD Million)

Landfilled Waste Reduction: 95 kt/year

APEX Sector	Measures	Waste Diverted from Landfill (%)	GHG Savings (%)	Total Cost (USD Million)
Waste	1. Mandate Decentralized Composting*	8.4%	1.0%	25
	2. Mandate Decentralized Anaerobic Digestion*	5.0%	0.7%	0.5
	3. Ban Single Use Plastics**	0.2%	<0.1%	--
	4. Improve Waste Collection*	2.5%	1.0%	2
	6. + Add/Expand Materials Recovery Facilities*	6.4%	1.4%	10
	7. + Add/Expand Waste-to-Energy Facilities*	14.0%	1.3%	40
	Total	**37%**	**5%**	**77**

**Direct cost item*
***Policy-based measure that is currently not costed in APEX*
+ Measures with the highest impact in terms of GHG savings

Note: kt = kilotonnes; GHG = greenhouse gas; USD = United States dollar

[6] According to the survey conducted by GGGI in 2020, the waste generation per capita in Vientiane is 750 grams per day, while the total household waste generation was calculated as 711 tonnes per day according to the Vientiane Capital population data from Lao Statistics Bureau. With waste generated from other sources, such as business entities and public buildings counted, the total waste generation in Vientiane amounted to approximately 970 tonnes per day in 2020.

1. Mandate Decentralized Composting

With this measure, the city aims to compost 15 percent of domestic and commercial organic waste by requiring homes, businesses, and/or neighborhoods to manage their waste locally. This measure will involve a decentralized, community-scale composting approach that uses small or medium-sized composting facilities, where collection and treatment are locally managed. Composting involves the decomposition of organic materials by microorganisms in the presence of oxygen. Decentralized composting can help reduce waste transportation costs and divert organic waste from landfills. The results are based on diverting 60 tonnes per day (t/day) food and organic waste from landfill and composting it instead.

This measure is a direct-cost measure which can be financed through the city's budget/central government transfers or through various PPP contract modalities. There is the potential for revenue from compost material, albeit modest and unlikely to exceed operating costs.

2. Mandate Decentralized Anaerobic Digestion

This measure aims to process 20 percent of domestic and commercial food waste using anaerobic digestion. The measure needs small-scale digestion plants to convert food waste (i.e., biomass) to biogas, which can be used to generate electricity and/or heat. Anaerobic digestion involves the decomposition of organic materials by microorganisms without oxygen. Contamination of food waste, including food packaging and utensils, can interfere with both mechanical and biochemical aspects of the digestion process; therefore, this method is best suited to be used with food and beverage manufacturing and pre-consumer food waste sources, which tend to have lower levels of contamination. The results are based on diverting 36 t/day of food waste from landfill, with the collected biogas that can be used locally for fuel.

As with composting, this measure is a direct-cost measure with potential revenue from collected biogas, though likely modest. It could be financed through the city's budget/central government transfers or using a PPP approach.

3. Ban Single Use Plastics

This measure introduces a ban on single-use plastics (SUPs) which are approximately 2 percent of all plastic waste in Vientiane. SUPs can include plastic carryout bags, plastic utensils, plastic straws, plastic packaging, and other single-use items designed for immediate disposal. Bans on SUPs can help reduce the amount of waste sent to landfill and reduce plastic litter in the environment, including in rivers, lakes, and oceans. The city can also incentivize private sector to develop alternative products to SUPs that use locally available materials.

This measure is considered a policy measure and is not currently costed in APEX.

4. Improve Waste Collection

In this measure, the city introduces efforts to improve the collection of solid waste, which would otherwise go uncollected and untreated. The city can implement or expand a curbside waste pickup program, and/or work with communities and the informal sector on waste collection. Improving waste collection can help reduce illegal dumping of waste on land and in waterways. This measure is based on achieving 100 percent waste collection across the city. For costing, the analysis estimates an additional 10,000 waste bins, a 247 t/day waste transfer station, and 5 waste collection vehicles; however, a comprehensive feasibility would be required.

This measure is a direct-cost measure which can be financed through the city's budget/central government transfers, or through various PPP contract modalities for waste management services.

5. Add/Expand Materials Recovery Facilities

The city aims for 40 percent of recyclable waste ready to be recycled or reused. This measure adds a new Material Recovery Facility (MRF), which is a specialized plant that receives, separates, and prepares recyclable materials for recycling industries and end-use manufacturers. There are two types of MRFs: clean MRFs that receive source-separated recyclables, and dirty MRFs that receive mixed waste where recyclables are co-mingled with other waste. Smaller MRFs that are manual or semi-automated process less than 15 t/day of recyclables. Larger facilities that are mechanized and fully automated can process 100 t/day or more. The results are based on increasing the recycling rate to 40 percent of recyclable waste in the city, which adds a new MRF facility with approximately 100 t/day of additional capacity.

This measure is a direct-cost measure financed through the city's budget/central government transfers or engaging the private sector through a PPP. There are various potential contract modalities, which would also depend on the pricing and market viability for recyclable materials.

6. Add/Expand Waste-to-Energy Facilities

This measure adds a new waste-to-energy plant or expands existing waste-to-energy facilities. Waste-to-energy is thermal treatment of waste involving the combustion of waste materials into heat, gas, and ash. Waste-to-energy is primarily a waste management solution that, at the same time, can deliver base load electricity to the grid (and is able to also supply heat). The results are based on a 100 t/day facility.

This measure is a direct-cost measure that could be funded through the city's budget/central government transfers or through a PPP. Typically, waste-to-energy relies on a combination of tipping or gate fees and electricity tariffs for financial viability. This measure is complex and will require a comprehensive feasibility study and institutional arrangements.

SUPs are approximately 2 percent of all plastic waste in Vientiane. A ban on SUPs can reduce the amount of waste sent to landfill and plastic litter in the environment

Water

Priorities in the water sector include water efficiency and security through reducing system-wide losses, as well as developing alternative sources of water supply with development/expansion of rainwater storage and retention areas. With more rainwater storage/retention areas, this can also help reduce water stress during the drought periods and alleviate flooding during the monsoon season. The city has also prioritized adding new central and local wastewater treatment facilities to provide treatment capacity to specific areas of the city (e.g., new developments, industrial areas, or communities).

9%
Water Security Improvement

0.3%
GHG Savings

27 MLD
Total Water Security Improvement

228
Total Cost (USD Million)

Total Water Security Improvement: 27 MLD

APEX Sector	Measures	Water Security Improvement (%)	GHG Savings (%)	Total Cost (USD Million)
Water & Wastewater	Water Savings from Green Building Certification	1.4%		
	1. Develop Ponds/Lakes for Rainwater Storage*	4.6%	<0.1%	185
	2. Incentivize Local Water Retention in Lakes/Ponds**	<0.1%	<0.1%	--
	3. Reduce Unaccounted-for Water Losses*	2.6%	<0.1%	3
	4. Add New Centralized Wastewater Treatment Facilities*	--	0.1%	7
	5. Add Local Scale Wastewater Treatment Plant*	--	0.3%	33
	Total	**9%**	**0.3%**	**228**

**Direct cost item*
***Policy-based measure that is currently not costed in APEX*

Note: MLD = million liters per day; GHG = greenhouse gas; USD = United States dollar

1. Develop Ponds/Lakes for Rainwater Storage

In this measure, the city develops ponds/lakes for rainwater storage, where rainfall water is captured and stored for future use. This can also help with flood mitigation by preventing rainwater from entering the stormwater drainage system. The results are based on increasing the available volume of lakes for rainwater storage by 10 percent or approximately 670,000 m^3.

This measure is a direct-cost measure which can be financed through the city's own budget or bundled together with other projects for a government loan.

2. Incentivize Local Water Retention in Lakes/Ponds

This policy measure includes incentives for developers and community groups to construct local water retention ponds, lakes, and/or reservoirs in undeveloped, open spaces. Retention systems slow stormwater drainage and capture surface water runoff for future use, which can help increase water supply and reduce water stress during drought periods. The retention systems can also help reduce flooding. The results are based on increasing the available open space used for local water retention by 10 percent, equivalent to 1,960,000 m^2 in catchment area.

This measure is considered a policy measure and is not currently costed in APEX.

3. Reduce Unaccounted-for Water Losses

This measure includes upgrading the water supply network to reduce unaccounted-for water losses in the system. Unaccounted-for water losses are calculated as the bulk system input less the authorized consumption. Unaccounted-for water losses include apparent losses (i.e., unauthorized consumption, metering inaccuracies) and real losses (i.e., leakage on transmission and/or distribution mains, leakage and overflows of utility storage tanks, and leakage on service connections up to the point of customer metering). Strategies to reduce water losses include repairing and replacing leaking water pipes and tanks, improvements to metering systems, removal of unauthorized connections, and controlling of water use through fire hydrants. The results are based on system improvements to reach Nampapa's target water loss percentage of 25 percent, equivalent of 8.4 MLD of additional water security.

This measure is a direct-cost measure with potential revenue from avoided water losses—both in terms of reducing apparent losses through more accurate billing, as well as real losses through fixing network leakage. This measure can be financed through the city's budget or central government loan. Alternatively, various types of PPPs have worked successfully to reduce water losses in cities around the world. One example is where a private company is tasked with water metering and billing, while water treatment and distribution functions remain with the city water utility. Large scale water network and metering upgrades could also be funded through a government loan.

4. Add New Centralized Wastewater Treatment Facilities

This measure includes the addition of a new, centralized wastewater treatment plant to provide additional capacity to the wastewater treatment system. The results are based on increasing formalized wastewater treatment with about 20 MLD in new treatment capacity.

This measure is a direct-cost measure that could be funded through the city's budget or central government loan. There are also various PPP contract modalities where the private sector can participate in the construction and/or operation of the wastewater treatment facilities.

5. Add Local Wastewater Treatment Facilities

This measure includes new, localized wastewater treatment plant to provide treatment capacity to a specific area of the city. This can be used for new developments, industrial areas, or communities previously unserved by the existing wastewater treatment network. The results are based on increasing local wastewater treatment with about 60 MLD in new treatment capacity.

As with centralized wastewater treatment facilities, this is a direct-cost measure that could be funded through the city's budget, a central government loan, or through a PPP approach where the private sector participates in the facilities' construction and/or operation.

Green Investment Pipeline

Solutions in the Green City Action Plan can be converted into a pipeline for green investment in Vientiane, supported by both public and private sector funding. In *Table 3*, potential financing approaches that city could consider in the future are provided for the 30 investments, which includes a mix of both direct-cost and indirect-cost measures. Where the cost falls within the city's mandate, the full cost is reflected as a direct cost. However, the city can leverage other funding sources, including private sources of financing for these investments, such as through PPPs and other business models. The investment pipeline is anticipated to reduce 22 percent of the city's GHG emissions across all sectors under analysis.

As shown in *Figure 10*, the potential financing volumes for these 30 measures can be visualized by dividing them into three groups, categorized based on shared characteristics and financing opportunities:

1. **Investing in Climate-Smart Infrastructure and Public Services** includes measures that enhance transport options, improve waste management, and increase water security.
2. **Investing in Green Municipal Buildings** will help reduce energy consumption in both new and existing public buildings through energy efficiency upgrades and renewable energy.
3. **Mobilizing Financing Towards Private Green Buildings and Electric Vehicles** through implementing climate-smart building policies, facilitating private financing for alternative energy, climate-smart upgrades and greening of both existing and new private buildings, and incentivizing the e-vehicle transition.

The total investment cost for all measures is approximately USD 3,376 million. Direct cost measures add up to USD 1,170 million. The list of investments includes actions where the city can nudge behaviors through policy implementation such as green building codes, through pilot projects such as EV charging stations, or through leveraging the private sector to invest in green measures through mechanisms such as EaaS, PPPs, etc.

Loca Taxi, a local private mobility company with the largest EV fleet in the country, has set up charging stations across Vientiane and Lao PDR.

Image: Kelvin Tagnipez / IFC

Table 3: Summary of the 30 measures in the green investment pipeline, including costs, GHG savings, and potential financing options the city could consider in the future. The pipeline has both direct-cost and indirect-cost measures, including actions where the city can nudge (i.e., implement policy, pilot investments, etc.) or leverage (i.e., through PPP, etc.) the private sector to invest in green measures. The measures with the highest impact in terms of GHG savings are shown in green. Costs are indicative only; all would need further feasibility work.

Vientiane Green Investment Pipeline

APEX Sectors	Measures	Total Cost (USD Million)	Direct Cost (USD Million)	Indirect Cost (USD Million)	GHG Savings (%)	Potential Funding Sources			
						Own Revenue	Central Govt. Loan / Transfer	PPP	Private Finance
Built Environment & Energy	Mandate Rooftop Solar Hot Water	28		28	0.1%				✓
	Improve Building Code	37		37	0.3%				✓
	Promote Cool Roofs	72		72	<0.1%				✓
	Increase Extent of Urban Forestry	293	293		<0.1%	✓			
	Incentivize Green Building Certification	9		9	0.6%				✓
	Finance for Private EE Refurbishment	300		300	2.8%				✓
	Implement Rooftop Solar PV Program	135		135	3.5%				✓
	Implement Green Certification for All Municipal Buildings	3	3		0.3%	✓			✓
	Implement EE Refurbishment for All Municipal Buildings	32	32		0.4%			✓	
	Upgrade All Streetlights with Energy Efficient Bulbs	14	14		<0.1%	✓			
Transportation	Introduce Congestion Charging Zone				0.4%				
	Remove Street Parking Spaces				0.4%				
	Provide EV Charging Infrastructure	1	1		<0.1%				✓
	Finance for Private Electric Vehicles	1,625		1,625	5.4%				✓
	Build Bicycle Lanes	0.2	0.2		<0.1%	✓			
	Expand Electric Bus Fleet	68	68		0.8%		✓	✓	
	Add BRT System and E-Buses	441	441		0.8%		✓	✓	
	Add Park-and-Ride Lot to Transit Station	12	12		0.1%	✓	✓	✓	
	Introduce Smart Transit Fare Cards				<0.1%		✓	✓	
Solid Waste	Mandate Decentralized Composting	25	25		1.0%		✓	✓	
	Mandate Decentralized Anaerobic Digestion	0.5	0.5		0.7%		✓	✓	
	Ban Single Use Plastics				<0.1%				
	Improve Waste Collection	2	2		1.0%		✓	✓	
	Add / Expand Materials Recovery Facilities	10	10		1.4%		✓	✓	
	Add / Expand Waste-to-Energy Facilities	40	40		1.3%		✓	✓	
Water & Wastewater	Develop Ponds / Lakes For Rainwater Storage	185	185		<0.1%	✓			
	Incentivize Local Water Retention in Lakes / Ponds				<0.1%				
	Reduce Unaccounted-for Water Losses	3	3		<0.1%		✓	✓	
	Add New Centralized Wastewater Treatment Facilities	7	7		0.1%		✓	✓	
	Add Local Scale Wastewater Treatment Plant	33	33		0.3%		✓	✓	
	Total	**3,376**	**1,170**	**2,206**	**22%**				

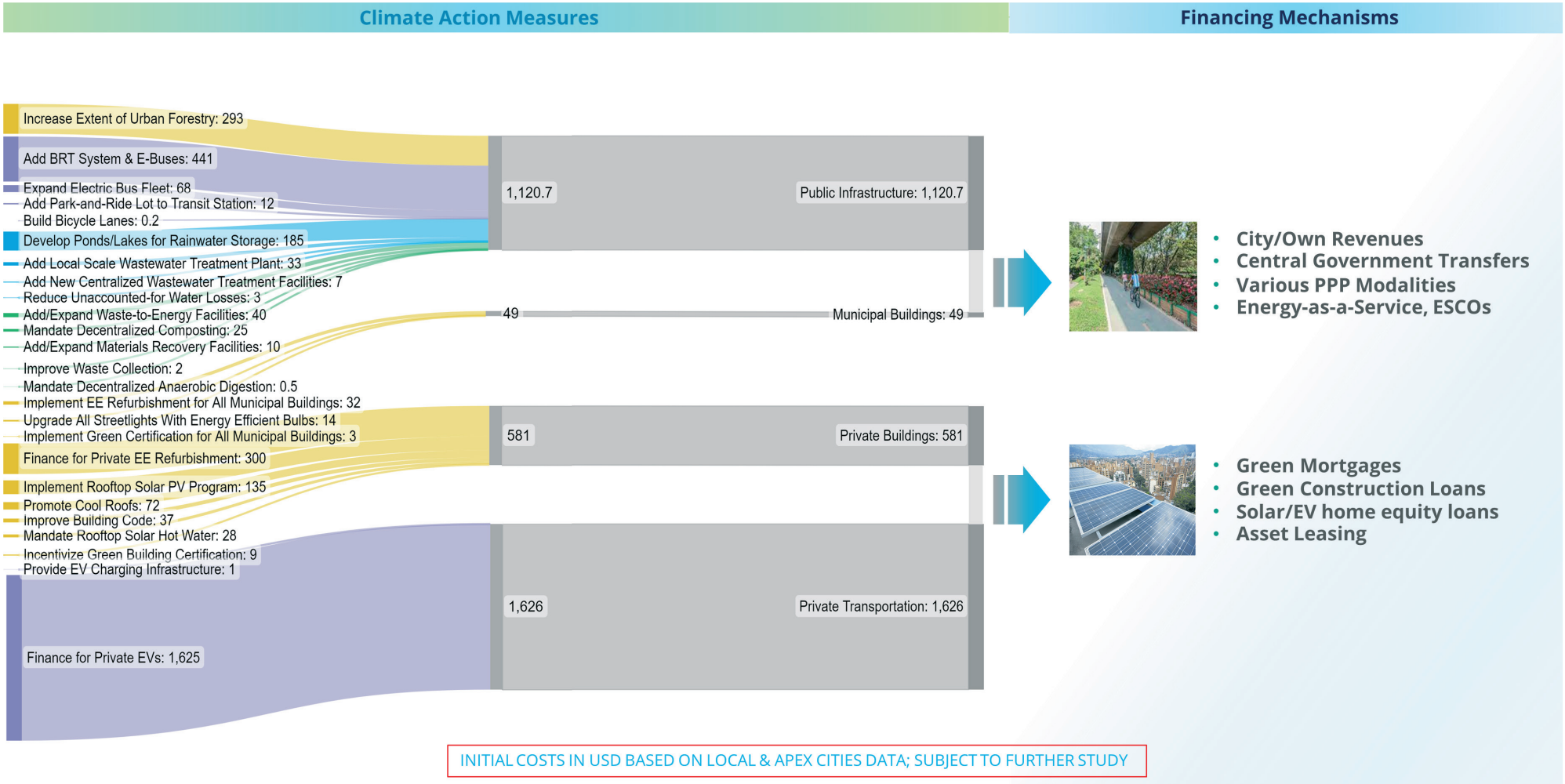

Figure 10: *Investment flow diagram showing the potential financing volumes aligned to measures in the green investment pipeline (shown in USD million).*

Summary and Conclusion

The Vientiane GCAP identifies 30 measures spanning four sectors of analysis: built environment and energy, transport, solid waste, and water and wastewater. These solutions also represent a green investment pipeline for Vientiane totaling USD 3,376 million. If fully implemented, these measures could collectively contribute 22 percent GHG reduction for Vientiane in 2030, equivalent to 450 $ktCO_2e$ in GHG emissions.

In terms of GHG impact, there are about 7 measures that stand out with the highest contributions. High impact items on the built environment and energy side include a city-wide solar PV program and greening of private buildings with energy efficiency upgrades, which can be accelerated through private sector financing. In the transport sector, financing and incentives for EVs can encourage the transition towards electric mobility and reduce emissions. Finally, improved waste collection and new waste management technologies, including composting for organic waste and waste-to-energy, will help avoid the GHG emissions associated with landfills. Taken together, these measures will contribute to 75 percent of the emissions reduction potential and can be considered priorities for future implementation.

The GCAP explores possible options to finance the measures, which can be grouped based on implementing agencies or enabling policies. These three clusters are Climate-Smart Infrastructure and Public Services, Green Municipal Buildings, and Private Green Buildings and EVs. The private sector will play an essential role in ensuring Vientiane Capital reaches its climate targets. Several of the highest impact measures are indirect-cost measures, where the cost falls with private building and vehicle owners. The GCAP also discusses implementation models where the private sector can help the city reduce its financial risk and free up its precious financial resources. Given the importance of mobilizing private investment towards green city actions, Vientiane Capital will play an important role in convening stakeholders, providing incentives, and educating residents and businesses about green city actions and financing opportunities.

The Boten-Vientiane line was opened in December 2021, and is the Lao PDR section of the Laos-China Railway.

Image: © Phounsub Thepvongsa / World Bank

Appendix A: APEX City Data

This appendix shows the city data and assumptions underlying the GCAP analysis. Most data were provided to IFC by MPWT & DHUP, as specified. The full list of data references is provided in Appendix C.

General City Information

Data	Value	Notes and Reference
Resident population	968,991	Lao Statistics Bureau 2020, MPI
Annual growth rate (%)	3.1%	Lao Statistics Bureau 2020, MPI
Population at working age, 15-74 years old (%)	79.6%	Lao Statistics Bureau, Labor Force Survey 2022, MPI
Persons per household in urban areas	4.40	Lao Statistics Bureau, Labor Force Survey 2022, MPI

Built Environment & Energy

Data	Value	Notes and Reference
City area (km^2)	3,920	Vientiane Capital Statistic Center 2021
Length of streets (km)	2,707	Department of Public Works and Transport, Vientiane Capital 2023
Number of streetlights	6,219	Vientiane City Office of Management and Service 2022
Number of traffic light sets	84	Vientiane Times news article 2020
Area of parks and green spaces (km^2)	0.40	Vientiane City Office of Management and Service 2023
Area of forest canopy (km^2)	108.15	Urban Transport Master Plan of Vientiane Capital 2023
Total building area (million m^2)		
Retail	1.22	Estimated using Lao PDR, Vientiane Land Use and Zoning Maps
Office	1.96	
Hotel	0.74	
Health	0.30	
Education	1.06	
Institutional/Assembly	0.56	
Warehouse	0.06	
Transport	0.04	
Residential		
Apartments	8.85	Estimated by IFC team based on 5 times national per-capita average
Homes	8.22	
Average building area per person (m^2)	31.6	Calculated with 2019 population
Building energy consumption (kWh/m^2/year)		
Retail	100	Adapted from IFC's EDGE tool and calibrated using energy consumption data from Vientiane Capital
Office	90	
Hotel	150	
Health	200	
Education	90	
Institutional/Assembly	80	
Warehouse	80	
Transport	80	
Residential		
Apartments	70	
Homes	75	
Energy Source (%)		
Grid Electricity	95.00%	Energy Strategy for Lao PDR 2030
Local electricity generation	0.00%	
District heating	0.00%	
District cooling	0.00%	
Local heat sources	5.00%	
Energy emissions factors kgCO_2e/kWh)		
Grid electricity	0.472	Country estimates, APEX defaults
Local heat sources	0.110	

Transportation

Data	Value	Notes and Reference
Average trips per day per resident	3.5	Estimated with data provided in the Urban Transport Master Plan of Vientiane Capital 2023.
Average trip distance (km)	17.94	Estimated based on national/regional averages
Working days per year	303	Estimated based on national/regional averages
Modal split by passenger-kilometers (%)		
Automobile	24%	Urban Transport Master Plan of Vientiane Capital 2023.
Motorcycle	63%	
Moto-Taxi	1%	
Minibus, private	1%	
Bicycle	2%	
Walk	9%	
Transit ridership (passengers/day)		
Bus, standard	1,643	Estimated with data provided in Urban Transport Master Plan of Vientiane Capital 2023.
Transit infrastructure		
Length of bus lanes (km)	339	Urban Transport Master Plan of Vientiane Capital 2023.
Number of conventional buses in fleet	88	
Average occupancy rate (passengers)		
Automobile	2.5	Estimated based on national/regional averages
Motorcycle	1.4	
Taxi	2.5	
Moto-taxi	1.4	
Microbus	8.38	
Minibus	20.11	
Bus, standard	47.49	
Number of vehicles in fleet		
Automobile	298,843	Data provided by MPWT. Annual vehicle registration nation-wide 2020 -2023.
Motorcycle	775,790	Data provided by MPWT. Annual vehicle registration nation-wide 2020 -2023.
Taxi	86	Technical Capacity Enhancement for Planning Urban Public Transport System in Vientiane, Lao PDR
Moto-taxi	648	
Minibus	28,131	Data provided by MPWT. Annual vehicle registration nation-wide 2020 -2023.
Annual growth in private vehicle ownership (%)		
Automobiles	12.8%	Technical Capacity Enhancement for Planning Urban Public Transport System In Vientiane, Lao PDR.
Motorcycles		
Annual rate of vehicle retirement/obsolescence (%)		
Automobiles	5.0%	Estimated based on the global average
Motorcycles	5.0%	

Waste

Data	Value	Notes and Reference
Municipal solid waste (MSW) generation (t/person/year)	0.29	Sustainable Solid Waste Management: Strategy and Action plan for Vientiane Capital 2021-2030
MSW composition (%)		
Organic waste	67.0%	Sustainable Solid Waste Management: Strategy and Action plan for Vientiane Capital 2021-2030
Paper and cardboard	8.8%	
Wood		
Textiles	0.3%	
Rubber and leather		
Plastics	12.1%	
Metal	0.1%	
Glass	3.3%	
Other	8.4%	
Organic waste composition (%)		
Food waste	44.3%	Sustainable Solid Waste Management: Strategy and Action plan for Vientiane Capital 2021-2030
Organic waste	55.7%	
Waste treatment (%)		
Landfill	31%	Sustainable Solid Waste Management: Strategy and Action plan for Vientiane Capital 2021-2030.
Open Dump	38%	Estimated based on country averages
Recycling	6%	
Unaccounted-for	26%	

Water

Data	Value	Notes and Reference
Municipal water consumption (MLD) - system input/bulk	177	Calculated based on data by Nampapa Nakhoneluang state enterprise
Potable water (%)	100%	
Non-potable water (%)	0%	
Average consumption per person (L/day) - bulk/population	183	2020. Vientiane Capital for Water Treatment Project WWTP & WTP: WWTP and canalization – Feasibility Study rev 6.
Industrial water consumption (MLD)		
Unaccounted-for water losses (%)	28%	Nampapa Nakhoneluang state enterprise Annual Report 2022.
Water source (%)		
Groundwater	0.2%	Nampapa Nakhoneluang state enterprise Annual Report 2022.
Surface water	99.8%	Nampapa Nakhoneluang state enterprise Annual Report 2022.
Desalination	0%	
Recycled wastewater	0%	
Rainwater capture	0%	
Wastewater treatment		
Wastewater flow (MLD)	127.7	Vientiane Capital for Water Treatment Project WWTP & WTP: WWTP and canalization – Feasibility Study rev 6, 2020
Treatment type (%)		
Septic Tanks	95%	Vientiane Capital for Water Treatment Project WWTP & WTP: WWTP and canalization – Feasibility Study rev 6, 2020
Untreated	5%	Country Estimate / APEX Default

Appendix B: APEX Key Assumption for Measures

This appendix shows the key assumptions for measures underlying the GCAP analysis.

Built Environment & Energy

Measure	Key Assumptions	Corresponding APEX Measures
1. Mandate Rooftop Solar Hot Water	• Collectors on 25% of Habitable Buildings • Cost is USD 8 per kWh savings	A.3 Mandate Rooftop Solar Hot Water
2. Improve Building Code	• New non-residential only, 20% savings • Cost is USD 34 per m^2 green building (non-residential uplift cost)	A.5 Improve Building Code
3. Promote Cool Roofs	• 25% of All Rooftops, 1.2 million m^2 • Cost is USD 60 per m^2 cool roof	A.7 Promote Cool Roofs
4. Increase Extent of Urban Forestry	• 10% increase, 10 million m^2 of new canopy area • Cost is USD 29 per m^2 tree planting	A.8 Increase Extent of Urban Forestry - 10% Increase
5. Incentivize Green Building Certification	• Residential only, 30% of new private buildings, 0.89 million m^2 • Cost is USD 10 per m^2 green building (residential uplift cost)	A.9 Incentivize Green Building Certification (e.g., EDGE)
6. Finance for Private EE Refurbishment	• 30% of existing buildings, 7.85 million m^2 • Cost is USD 38 per m^2 of retrofitted building area	A.10 Finance for private energy efficiency refurbishment
7. Implement Rooftop Solar PV Program	• 159 MWp installed, 37% of building rooftops • Cost is USD 850 per kWp installed	A.14 Implement Rooftop Solar PV Program
8. Implement Green Certification for All Municipal Buildings	• 100% of new municipal buildings, 154,000 m^2 • Cost is USD 20 per m^2 green building (uplift cost)	A.16 Implement Green Certification/Labelling for All Municipal Buildings
9. Implement EE Refurbishment for All Municipal Buildings	• 100% of existing municipal buildings, 843,000 m^2 • Cost is USD 38 per m^2 of retrofitted building area	A.17 Implement EE Refurbishment Program for All Municipal Buildings
10. Upgrade All Streetlights with Energy Efficient Bulbs	• All streetlights upgraded, 6,219 streetlights • Cost is USD 2,222 per streetlight upgraded	A.19 Upgrade All Streetlights with Energy Efficient Bulbs

Transportation

Measure	Key Assumptions	Corresponding APEX Measures
1. Introduce Congestion Charging Zone	• Encompasses 20% of city employment • No cost, policy measure	B.5 Introduce Congestion Charging Zone
2. Remove Street Parking Spaces	• 10% reduction in street parking spaces • No cost, policy measure	B.6 Remove Street Parking Spaces
3. Provide EV Charging Infrastructure	• 100 public EV chargers • Cost is USD 11,480 per public EV charger	B.15 Provide EV Charging Infrastructure
4. Finance for Private EVs	• 325,000 new electric vehicles, 50% automobiles and 50% two-wheelers • Average vehicle cost is USD 5,000 per vehicle (autos at about USD 10,000 each, 2-wheelers at USD 1,000 each)	B.16 Finance Electric Vehicles Through Banks
5. Build Bicycle Lanes	• 30 km of bicycle lanes • Cost is USD 8,133 per km of bicycle lane constructed	B.19 Build Bicycle Lanes
6. Expand Electric Bus Fleet	• 285 new electric buses • Cost is USD 238,215 per new electric bus	B.20 Expand Conventional Bus Fleet B.22 Electrify Conventional Bus Fleet
7. Add BRT System and E-Buses	• 27.6 km of BRT system constructed, 160 new electric BRT buses • Cost is USD 14,316,680 per km of BRT line, USD 286,062 per new electric BRT bus	B.23 Add / Extend BRT System B.25 Electrify BRT Bus Fleet
8. Add Park-and-Ride Lot to Transit Station	• 3,000 spaces added (autos and two-wheelers) • Cost is USD 4,030 per parking space	B.31 Add Park-and-ride Lot to Transit Station
9. Introduce Smart Transit Fare Cards	• Increases ridership in the transit system • No cost, policy measure	B.33 Introduce Smart Transit Fare Cards

Waste

Measure	Key Assumptions	Corresponding APEX Measures
1. Mandate Decentralized Composting	• 15% of food/organics, 60 t/day capacity • Cost is USD 408,657 per t/day capacity	C.1 Mandate Decentralized Composting
2. Mandate Decentralized Anaerobic Digestion	• 20% of food, 36 t/day capacity • Cost is USD 13,309 per t/day capacity	C.2 Mandate Decentralized Anaerobic Digestion
3. Ban Single Use Plastics	• 2% of plastics • Policy measure, no cost	C.5 Ban Single Use Plastics
4. Improve Waste Collection	• 100% collection rate, increase collection of 247 t/day • Cost is 8,086 per t/day collected, including 10,000 new bins at USD 120/bin, 247 t/day waste transfer station at USD 191.62/t/day, 5 waste collection vehicles at USD 150,000/vehicle	C.9 Improve Waste Collection
5. Add/Expand Materials Recovery Facilities	• 40% of recyclables, 100 t/day capacity • Cost is USD 101,031 per t/day capacity	C.11 Add / Expand Materials Recovery Facilities
6. Add/Expand Waste-to-Energy Facilities	• 100 t/day facility • Cost is USD 401,451 per t/day capacity	C.12 Add / Expand Incineration Facilities

Water

Measure	Key Assumptions	Corresponding APEX Measures
1. Develop Ponds / Lakes for Rainwater Storage	• 670,000 m^3 capacity added • Cost is USD 277 per m^3 capacity added	D.5 Develop Ponds / Lakes For Rainwater Storage
2. Incentivize Local Water Retention in Lakes/Ponds	• 10% of available open space • No cost	D.8 Incentivize Local Water Retention in Lakes / Ponds / Reservoirs
3. Reduce Unaccounted-for Water Losses	• 10% improvement to 25% losses, 8.4 MLD losses avoided • Cost is USD 341,524 per MLD loss avoided	D.14 Reduce Unaccounted-for Water Losses
4. Add New Centralized Wastewater Treatment Facilities	• 20 MLD additional capacity • Cost is USD 342,086 per MLD for a centralized facility	D.21 Add New Centralized Wastewater Treatment Facilities
5. Add Local Scale Wastewater Treatment Plant	• 60 MLD additional capacity • Cost is USD 546,753 per MLD for local facilities	D.24 Add Local Scale Wastewater Treatment Plant

Appendix C: Data References

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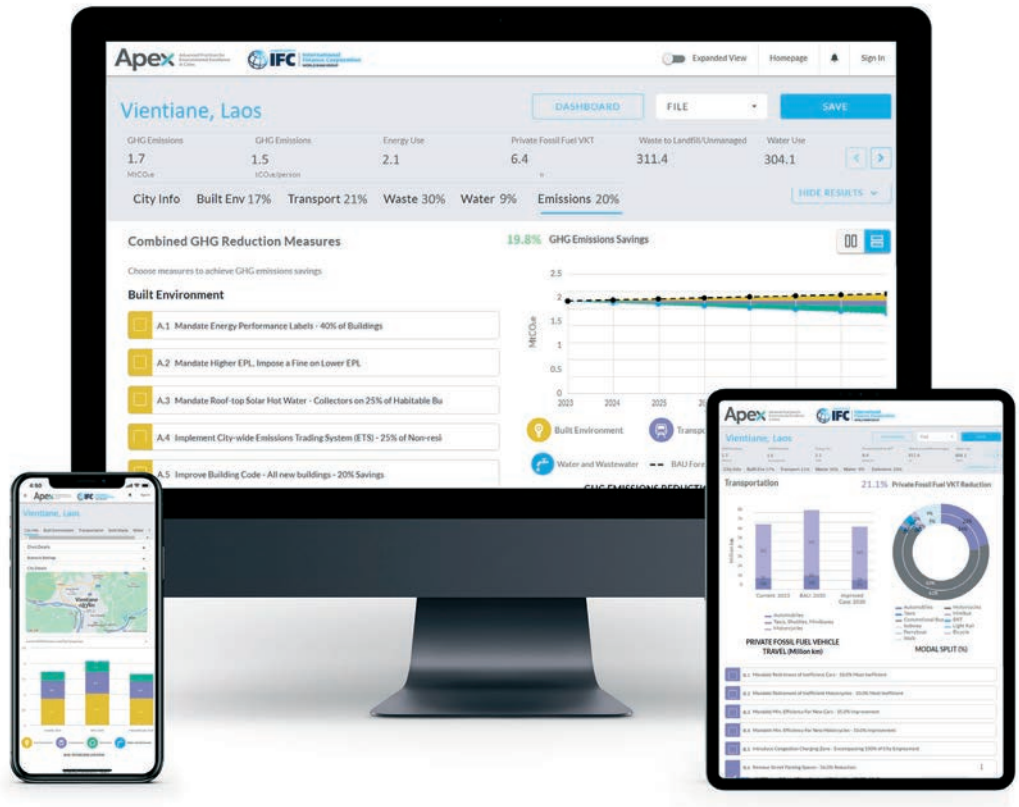

The APEX Online Application (available at www.apexcities.com).