

LPG Supply Master Plan for Cambodia

Edited by

Ministry of Mines and Energy, Government of Cambodia

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LPG Supply Master Plan for Cambodia

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Preface

In Cambodia, liquified petroleum gas (LPG) demand has been increasing rapidly, from 77,000 tonnes of oil equivalent (toe) in 2010 to 402,000 toe in 2019, an average annual growth rate of 20% per year over the last 9 years. LPG is used in the residential and commercial sectors for cooking and heating water, and in the road transport sector for fuelling 3-wheel tuk-tuks and 4-wheel vehicles. As Cambodia is expected to continue its remarkable economic growth, LPG demand is forecasted to increase continuously to 1,400,000 toe by 2050. Therefore, the Ministry of Mines and Energy must seek an economically appropriate LPG supply chain that supports delivery of 1,400,000 toe of LPG throughout Cambodia by 2050.

For an economically optimal LPG supply chain by 2050, the General Department of Petroleum requested that the Economic Research Institute for ASEAN and East Asia (ERIA) conduct a study to help find a cost minimum LPG supply route from LPG importation sites to final demand sites throughout Cambodia.

It is my hope that this study will support LPG companies in Cambodia to make appropriate business decisions regarding investing in a new LPG supply chain towards 2050.

Cheap Sour

Secretary of State

Ministry of Mines and Energy, Government of Cambodia

Acknowledgements

This report was prepared through a collaboration between the Economic Research Institute for ASEAN and East Asia (ERIA) and the General Department of Petroleum, Ministry of Mines and Energy, Government of Cambodia. The ERIA team consisted of Shigeru Kimura, special adviser on energy affairs; Han Phoumin, senior energy economist; and Citra Endah Nur Setyawati, research associate. It also included external experts: Takahisa Hiruma, vice president, ASIAM, who was in charge of the LPG supply side; and Nong Monin, Cambodia Development Research Institute, who was in charge of the LPG demand side. The General Department of Petroleum team was led by Cheap Sour, secretary of state, General Department of Petroleum, and consisted of Chea Channara, director general, General Department of Petroleum and many valuable staff members. Special thanks are extended to Shigeru Kimura for his strong leadership of this project.

Chea Channara

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Table of Contents

| | | |
|-----------|--|------|
| | Preface | iii |
| | Acknowledgements | iv |
| | List of Project Members | v |
| | List of Figures | vii |
| | List of Tables | viii |
| | List of Abbreviations | x |
| | Executive Summary | xi |
| Chapter 1 | Introduction | 1 |
| Chapter 2 | Existing LPG Supply Chain in Cambodia | 2 |
| Chapter 3 | LPG Consumption in Cambodia | 4 |
| Chapter 4 | Estimation of Current LPG Demand by Province in Cambodia | 22 |
| Chapter 5 | Forecast of Future LPG Demand in 2040 | 34 |
| Chapter 6 | Optimal Cambodia LPG Supply Chain in 2040 | 46 |
| Chapter 7 | Key Findings and Recommendations | 57 |
| | References | 60 |
| | Appendix | 61 |

List of Figures

| | | |
|------------|--|----|
| Figure 2.1 | LPG Supply Chain | 3 |
| Figure 3.1 | Types of Dwellings and Monthly LPG Consumption by Dwelling Type | 10 |
| Figure 3.2 | Main Uses of Biomass in the Household Sector | 14 |
| Figure 3.3 | Respondents Using Electricity for Cooking and Heating Water by Type of Establishment | 17 |
| Figure 3.4 | Study Participants by Business Size in the Industrial Sector | 19 |
| Figure 3.5 | Study Respondents Using Each Type of Fuel Source in the Industrial Sector | 19 |
| Figure 5.1 | Demand Estimation for LPG in Cambodia, 2040 | 34 |
| Figure 5.2 | LPG Service Stations, 2014–2040 | 35 |
| Figure 5.3 | LPG Demand by the Transport Sector, 2040 | 36 |
| Figure 5.4 | Gross Domestic Product and LPG Demand by the Industrial Sector in Viet Nam | 43 |
| Figure 6.1 | Structure of Logistics Optimisation LP Model | 46 |
| Figure 6.2 | Supply and Demand for LPG in Thailand, 2005–2020 | 47 |
| Figure 6.3 | Supply and Demand for LPG in Viet Nam, 2000–2020 | 48 |
| Figure 6.4 | LPG Transport Costs to Provincial Capitals by the Current Four LPG Supply Routes | 50 |
| Figure 6.5 | LPG Transport Costs to Provincial Capitals by All LPG Supply Routes | 56 |

List of Table

| | | |
|------------|--|----|
| Table 2.1 | Supply Volume by LPG Import Method or Place, 2021 | 2 |
| Table 3.1 | Site Selection, Sampling, and Sample Size for Study | 5 |
| Table 3.2 | Residential Sector Sample Distribution by Site Selection for Study | 6 |
| Table 3.3 | Monthly Average Driving Distances, LPG Consumption, and Fuel Economy of 3- and 4-Wheel Vehicles | 9 |
| Table 3.4 | Monthly LPG Consumption by Type of Container in the Residential Sector | 11 |
| Table 3.5 | Monthly LPG Consumption and LPG Intensity by Selected Area | 11 |
| Table 3.6 | Monthly LPG Consumption by Type of Container of Households with Non-Home-Based Small Businesses | 12 |
| Table 3.7 | Monthly LPG Consumption and LPG Intensity by Households with Non-Home-Based Small Businesses | 13 |
| Table 3.8 | Monthly Electricity Consumption for Cooking, Heating, Lighting, and Other Uses by Area in the Residential Sector | 14 |
| Table 3.9 | Average Floor Area and Number of Floors for Each Type of Establishment in the Commercial Sector | 15 |
| Table 3.10 | Monthly LPG Consumption by Type of Container in the Commercial Sector | 16 |
| Table 3.11 | Monthly LPG Consumption and LPG Intensity by Study Site in the Commercial Sector | 17 |
| Table 3.12 | Monthly Electricity Consumption for Cooking, Heating, Lighting, and Other Usage by Establishment Type in the Commercial Sector | 18 |
| Table 3.13 | Monthly LPG, Biomass, and Diesel Consumption by Sub-Industry in the Industrial Sector | 20 |
| Table 4.1 | LPG Demand for Transport by Province, 2021 | 23 |
| Table 4.2 | Distribution of Households by Type of Fuel Used for Cooking | 25 |
| Table 4.3 | LPG Demand for Residential Use by Province, 2021 | 27 |
| Table 4.4 | Residential LPG Demand and Gross Domestic Product per Capita of Neighbouring Countries | 29 |

| | | |
|-----------|---|----|
| Table 4.5 | Commercial LPG Demand and Gross Domestic Product per Capita of Neighbouring Countries | 30 |
| Table 4.6 | LPG Demand by the Commercial Sector by Province, 2021 | 30 |
| Table 4.7 | LPG Demand by Sector, 2021 | 32 |
| Table 4.8 | LPG Demand by Sector and by Province, 2021 | 32 |
| Table 5.1 | LPG Demand by the Transport Sector by Province, 2040 | 36 |
| Table 5.2 | Population in Cambodia, 2008–2040 | 38 |
| Table 5.3 | LPG Demand by the Residential Sector by Province, 2040 | 39 |
| Table 5.4 | LPG Demand by the Commercial Sectors of Neighbouring Countries, 2040 | 41 |
| Table 5.5 | LPG Demand by the Commercial Sector by Province, 2040 | 41 |
| Table 5.6 | LPG Demand by Sector in 2021 and 2040 | 43 |
| Table 5.7 | LPG Demand by Sector and by Province, 2040 | 44 |
| Table 6.1 | Unit Cost by Each Transport Mode | 47 |
| Table 6.2 | Business-as-Usual Case | 49 |
| Table 6.3 | Breakdown of LPG Supply Areas | 49 |
| Table 6.4 | Case 1 – Expanded Mekong Terminal | 51 |
| Table 6.5 | Case 2 – Utilisation of Domestic Rail | 52 |
| Table 6.6 | Case 3 – Utilisation of Large Tankers at Sihanoukville Terminal | 53 |
| Table 6.7 | Case 4 – Utilisation of New Canal Terminal | 54 |

List of Abbreviations

| | |
|------|---|
| BAU | business as usual |
| CDRI | Cambodia Development Resource Institute |
| ERIA | Economic Research Institute for ASEAN and East Asia |
| EV | electric vehicle |
| GDP | gross domestic product |
| LP | linear programming |
| LPG | liquified petroleum gas |

Measurements

| | |
|----------------|-------------------------|
| g | gram |
| kg | kilogram |
| km | kilometre |
| kWh | kilowatt-hour |
| m | metre |
| m ² | square metre |
| toe | tonne of oil equivalent |

Executive Summary

Liquified petroleum gas (LPG) consumption in Cambodia marked the highest growth amongst petroleum products in 2000–2019 due to its various uses across sectors. The residential and commercial sectors are shifting from biomass to LPG due to urbanisation, and the road transport sector has increased LPG consumption due to the rapid expansion of 3-wheel tuk-tuks imported from India. Cambodia's LPG use will continuously increase to 1,400 tonnes of oil equivalent (toe) by 2050 from 400 toe in 2019. Currently, LPG delivery from importation terminals to final destinations in Cambodia is fully dependent on small LPG tank trucks. To keep up with Cambodia's growing LPG use, this study recommends increasing LPG importation capacity at the Mekong River including via a new canal route, using rail transport for long distances from Sihanoukville, and using large-scale LPG tankers at Sihanoukville port.

Looking at future LPG demand by final users, the residential sector will dominate at 39% of the total in 2040, followed by the commercial sector at 37% and road transport sector at 20%. LPG demand will increase mainly in urban areas due to urbanisation, but about 7 million people will remain in rural areas to 2040. The government thus must continue to support rural households in using LPG instead of biomass for cooking for both health and time savings. It should set policies to encourage LPG companies to increase LPG supply to rural areas, maintaining an economic rationale for LPG business in rural areas.

An LPG consumption survey – covering the residential, commercial, road transport, and industry sectors – was conducted by a local consultant for this study. These unit consumptions were applied to forecast future LPG demand in each sector. To 2040, fossil fuels such as LPG must be increased. Thus, this study on seeking an optimal LPG supply chain using a cost minimisation approach model is indispensable for establishing appropriate LPG policies by the Ministry of Mines and Energy in Cambodia.

Chapter 1

Introduction

In Cambodia, liquified petroleum gas (LPG) demand has increased rapidly from 77,000 tonnes of oil equivalent (toe) in 2010 to 402,000 toe in 2019, resulting in an average annual growth rate of 20%. LPG is consumed widely across final sectors – i.e. residential, commercial, and transport – according to 2022 national energy statistics. Due to the forecasted increased gross domestic product (GDP) per capita in future, LPG demand should increase to 1,400,000 toe by 2050.¹ Therefore, an economically appropriate LPG supply chain is needed that covers all of Cambodia towards 2050.

Consequently, the General Department of Petroleum, Ministry of Mines and Energy requested that the Economic Research Institute for ASEAN and East Asia (ERIA) help inform such a supply chain for the future. Under this study, an LPG expert reviewed the current LPG supply chain in Cambodia by conducting interviews with representatives from LPG business entities in Cambodia. Then, an LPG consumption survey was conducted by a local consultant, which covered the residential, commercial, road transport, and industry sectors in Cambodia. Third, based on the review and survey, an LPG expert estimated current LPG demand by each province as well as forecasted provincial demand. Based on this future provincial LPG demand, the LPG expert investigated a low-cost LPG supply chain for the future by applying a liner programming (LP) method. Finally, referring to the optimum solutions, policy implications were extracted.

In this paper, Chapter 2 reviews the existing LPG supply chain in Cambodia, while Chapter 3 details the LPG consumption survey. Chapters 4 and 5 explain provincial LPG demand currently and in the future, Chapter 6 seeks an optimal solution for Cambodia's LPG supply chain in 2040, and Chapter 7 extracts associated policy implications.

¹ Note that both 2040 and 2050 are used throughout this paper; 2040 represents the target year, while 2050 represents the outlook.

Chapter 2

Existing LPG Supply Chain in Cambodia

1. LPG Import Volume

In cooperation with the General Department of Petroleum, a survey of import, storage, and delivery data of LPG and oil companies was conducted. Cambodia's LPG supply is entirely covered by imports. LPG imports in 2019 reached a record high of 340,958 tonnes but decreased to 322,136 tonnes in 2020 due to the COVID-19 pandemic. In 2021, there was a slight recovery to 325,618 tonnes.

According to the survey, there are four import routes:

- (i) **Import by tanker at the Sihanoukville terminal (21.3% of total).** The total storage capacity at the terminal is 6,500 tonnes. Imported LPG is transported to LPG service stations, bottling stations, second terminals, and final users nationwide by tank trucks. Cylinders filled at bottling stations are delivered to homes, hotels, and factories by retailers responsible for delivery.
- (ii) **Import by tanker at the Mekong terminal (7.5% of the total).** The total storage capacity at the Mekong terminal is 2,500 tonnes. The supply chain there is the same as that at Sihanoukville, but no company owns a second terminal.
- (iii) **Direct import by tank trucks from Viet Nam (65.4% of the total).** Land import companies do not have any import terminals or second terminals; they directly transport LPG to LPG service stations, bottling stations, second terminals, and final users nationwide by tank trucks. Therefore, they are competitive for their low costs.
- (iv) **Direct import by tank trucks from Thailand (5.8% of total).** Land import companies here do not have any import terminals or any second terminals; they directly transport LPG to LPG service stations, bottling stations, second terminals, and final users by tank trucks. Due to the long distance to the border, however, this import method is limited to parts of Cambodia's northern provinces.

Table 2.1. Supply Volume by LPG Import Method or Place, 2021

| Import Route | Total Delivery Volume | | Storage | |
|----------------------------|-----------------------|--------------|--------------|-----------------------|
| | (tonnes) | (%) | (tonnes) | (tanker size, tonnes) |
| Sihanoukville | 69,363 | 21.3 | 6,500 | 500–2,000 |
| Mekong | 24,281 | 7.5 | 2,500 | 500–1,000 |
| Land imports from Viet Nam | 213,097 | 65.4 | 0 | |
| Land imports from Thailand | 18,877 | 5.8 | 0 | |
| Total | 325,618 | 100.0 | 9,000 | |

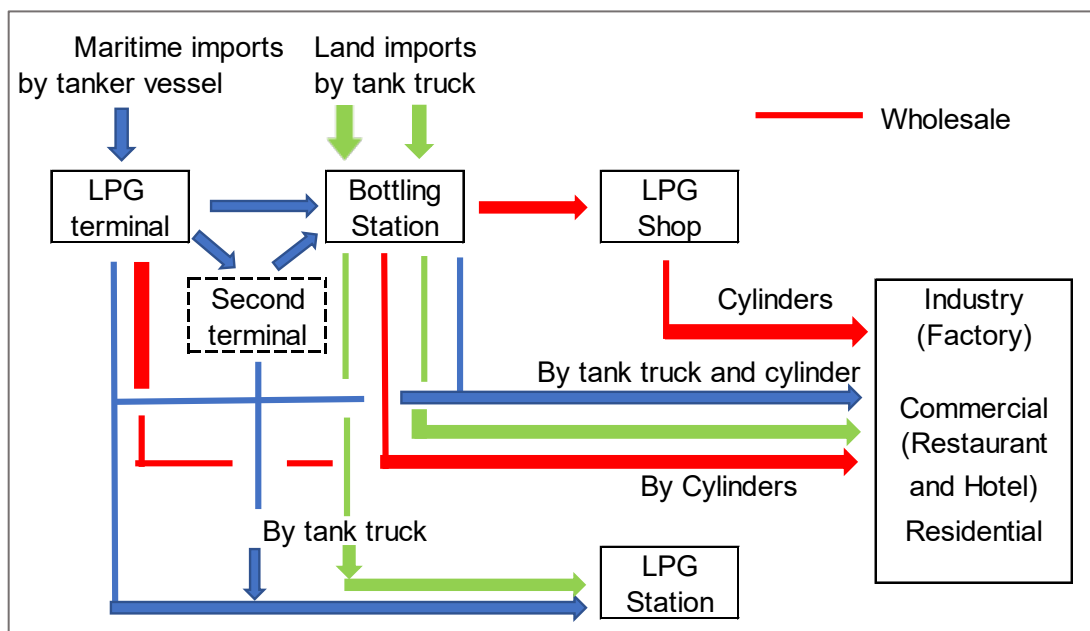
Source: General Department of Petroleum.

As mentioned above, land imports from Viet Nam accounted for the largest share at 65.4% of the total LPG imports, followed by maritime imports from the Sihanoukville terminal at 21.3%.

2. LPG Supply Chain

Figure 2.1 shows Cambodia's LPG supply chain. The supply base is the primary terminal, which is an import terminal as well as a second terminal, bottling station, and service station. Most of the supply to the final consumers of the industry, commercial, and residential sectors is in cylinders from bottling stations. Cylinder deliveries are primarily conducted by retailers. Supply to large users with storage tanks occurs by tank trucks from LPG terminals and bottling stations. In some cases, LPG is delivered by small tank trucks from LPG service stations, which have 740 locations across the country. Cylinders are also sometimes filled at service stations. There are many bottling stations and LPG shops across the country that are responsible for supplying cylinders, but understanding these details is a future challenge.

Figure 2.1 LPG Supply Chain



Source: Author.

Chapter 3

LPG Consumption in Cambodia

In Cambodia, LPG as fuel for cooking is used by 56% in urban settlements and 11% in rural, after firewood and charcoal (NIS, 2020). Only about 3% of all households use electricity for cooking (NIS, 2020). However, the demand for LPG consumption is predicted to increase due to urbanisation (at 4% per year) and a booming construction sector, along with the growth of transport and industrial and commercial activities.

LPG demand by different sectors has not been previously investigated; a study on the LPG consumption situation in specific sectors is needed to implement the findings of this study. ERIA requested that the Cambodia Development Resource Institute (CDRI) survey the LPG consumption situation in Cambodia to estimate LPG consumption by different users, including those in the residential, commercial, road transport, and industrial sectors.

1. Research Methodology

Data were collected by a CDRI research team from February to May 2023, using a digital questionnaire designed in consultation with an ERIA expert team. The total sample size was 591 respondents, distributed across different regions and sub-sectors.

The site selection and sampling methods varied depending on the sector and the availability of data sources (Table 3.1).

Table 3.1. Site Selection, Sampling, and Sample Size for Study

| Sector | Sub-sectors | Sample Size | Sampling | Site Selection |
|----------------|------------------------|-------------|-------------|-------------------------|
| Road Transport | 3-wheel (LPG tuk-tuks) | 100 | Snowball | Phnom Penh |
| | 4-wheel vehicles | 100 | Snowball | |
| Residential | Residences | 200 | Stratified | Phnom Penh, Kandal, |
| | | | Random | Siem Reap, Kampong Speu |
| Commercial | Large restaurants | 60 | Purposively | Phnom Penh |
| | 4–5-star hotels | 40 | | Siem Reap |
| | Malls/supermarkets | 21 | | |
| Industrial | Food production | 50 | Purposively | Phnom Penh or |
| | Beverages/breweries | 10 | | Kampong Speu/Kandal |
| | Wood products/paper | 10 | | |
| Total | | 591 | | |

Source: Author.

The road transport sector examined two types of vehicles: 3-wheel vehicles (i.e. LPG tuk-tuks) and 4-wheel vehicles. The sample size for this sector was 200 vehicles, with 100 vehicles for each type. The samples were selected using a snowball sampling method, where enumerators approached LPG vehicle drivers at gas stations or parking lots for the survey and then asked them to refer other LPG vehicle drivers. The data collection was conducted in all 14 districts in Phnom Penh.

The household sector included urban and rural households that use LPG for cooking or heating water. The survey classified communes as urban or rural according to the National Institute of Statistics definition, which considers an urban area based on three criteria: (i) more than 2,000 people living in a commune, (ii) a population density of higher than 200 people per square kilometre (km), and (iii) more than 50% of workers employed in non-agriculture sectors. The sample size for this sector was 200 households, with 100 households in each area. The sampling method used was stratified random sampling. For urban households, the data collection was conducted in four districts in Phnom Penh: Boeng Keng Kong, Chroy Chongvar, Mean Chey, and Russey Keo. For rural households, data collection was conducted in three provinces: Kampong Speu, Kandal, and Siem Reap. Table 3.2 shows the sample distribution in the residential sector by site selection.

Table 3.2. Residential Sector Sample Distribution by Site Selection for Study

| City/Province | District | Commune | Sample |
|---------------|----------------------|-------------------------|------------|
| Urban | | | 100 |
| Phnom Penh | Khan Mean Chey | Stueng Mean Chey 1 | 16 |
| | Khan Russey Keo | Tuol Sangke | 32 |
| | Khan Chroy Chongvar | Chroy Chang Va | 34 |
| | Khan Boeng Keng Kang | Boeng Keng Kang 3 | 18 |
| Rural | | | 100 |
| Kandal | Angk Snuol | Chongruk | 24 |
| Kampong Speu | Kong Pisei | Prey Puoch | 29 |
| Siem Reap | Krolanh | Kampong Thkov and Snuol | 47 |
| Total | | | 200 |

Source: Author.

The commercial sector comprised three types of buildings: large restaurants, 4- and 5-star hotels, and malls/supermarkets. The sample was selected using a purposive sampling method, which found subjects based on specific criteria or characteristics. The criteria for selecting commercial buildings were their sizes, locations, and LPG usage. The sample size was set at 121 buildings, with different allocations to Phnom Penh and Siem Reap based on the availability of data sources and potential LPG consumption. In Phnom Penh, the sample included 50 large restaurants, 25 4- and 5-star hotels, and 17 malls/supermarkets. In Siem Reap, the sample included 10 large restaurants, 15 4- and 5-star hotels, and 4 malls/supermarkets.

The industrial sector consisted of three sub-industries: food production, beverage/brewery, and wood/paper production. The sample size for this sector was 70 establishments: 50 food production respondents, 10 beverage/brewery respondents, and 10 wood/paper production respondents. The sampling method used was purposive sampling as well. The data collection was conducted in three sites: Phnom Penh, Kandal, and Kampong Speu.

The CDRI research team designed the questionnaire digitally using CSPro Version 7.7 based on consultation with the ERIA expert team. The questionnaire consisted of four modules corresponding to the four sectors. The contents of the questionnaire included:

- (i) **Road transport sector.** Type of vehicle (3- or 4-wheel), driving distance (km/month), LPG consumption (litre/month), and gasoline consumption if applicable (litre/month);

- (ii) **Residential sector.** Area (urban or rural), type of house (apartment or stand-alone), family size (number of persons), floor area (square metres [m²]), LPG consumption (kilograms [kg]/month) and usage (cooking and/or heating water), biomass consumption (cubic metres (m³)/month) and usage (cooking and/or heating water), and electricity consumption (kilowatt-hours [kWh]/month) and usage (cooking and/or heating water).
- (iii) **Commercial sector.** Type of building (hotel or restaurant), floor area (m²), LPG consumption (kg/month) and usage (cooking and/or heating water), biomass consumption (m³/month) and usage (cooking and/or heating water), and electricity consumption (kWh/month) and usage (cooking and/or heating water).
- (iv) **Industrial sector.** Sub-industry name (food or beverage/brewery), LPG consumption (kg/month) and usage (heating boiler or furnace), biomass consumption (m³/month) and usage (heating boiler or furnace), and diesel consumption (m³/month) and usage (heating boiler or furnace).

A team of seven enumerators, working under the supervision of one team leader and one fieldwork coordinator, used tablets to collect data digitally. The data collection process involved the following steps:

- (i) **Pre-testing.** The questionnaire was pre-tested with a few respondents from each sector to check the validity and reliability of the questions and functionality of the digital platform.
- (ii) **Training.** The enumerators were trained on the objectives, contents, and procedures of data collection. They were also familiarised with the use of tablets and software.
- (iii) **Fieldwork.** The enumerators visited the selected sites and interviewed the respondents face to face. They obtained informed consent verbally from the respondents before starting the interviews. They entered the data directly into the tablets using the CSPro software.
- (iv) **Data quality control.** The team leader and fieldwork coordinator monitored the data collection process and checked the data quality regularly. They also provided feedback and guidance to the enumerators.
- (v) **Data transmission.** The enumerators uploaded the data to a secure server at the end of each day. The CDRI research team downloaded and verified the data periodically.

2. Survey Results

2.1. Road Transport Sector

The survey collected data on monthly driving distances, LPG consumption, gasoline consumption, and fuel economy of vehicles in Phnom Penh.

The monthly driving distance was measured according to the distance that the respondents accrued with their vehicles per month. The average monthly driving distance for 3-wheel vehicles is 2,653 km, while for 4-wheel vehicles, it is 7,800 km. The difference between the two types of vehicles is significant, reflecting their different purposes and operational areas. Three-wheel vehicles are mainly used for services, such as transporting passengers or deliveries, within Phnom Penh. Four-wheel vehicles are also mainly used for services, but they cover more extensive distances from Phnom Penh to other provinces and vice versa.

The monthly LPG consumption was measured by asking the respondents the amount of LPG used per month for their vehicles. The average monthly LPG consumption for 3-wheel vehicles is 200 litres, while for 4-wheel vehicles, it is 1,200 litres. The differences in LPG consumption are mainly due to driving distances and vehicle sizes. Three-wheel vehicles have smaller engines and tanks than 4-wheel vehicles and drive fewer km per month.

The monthly gasoline consumption was measured by asking the respondents about the amount of gasoline used per month for their vehicles, if any. Most respondents reported that they either use tiny amounts or none at all; it is used mainly for situations when the LPG supply is depleted or for engine preheating purposes. The average monthly gasoline consumption for 3-wheel vehicles is only 2 litres, while for 4-wheel vehicles, it is 23 litres.

The fuel economy was calculated by dividing the monthly driving distance by the monthly LPG consumption for each vehicle. The average fuel economy for 3-wheel vehicles is 13.80 km/litre, while for 4-wheel vehicles, it is 6.25 km/litre. The differences in fuel economy are mainly due to vehicle sizes and engine efficiency. Three-wheel vehicles have smaller engines than 4-wheel vehicles and consume less LPG/km. The fuel economy of the vehicles in the survey is lower than the average fuel economy for vehicles that use LPG. This can be due to various factors such as vehicle condition, driving style, traffic congestion, road quality, or even the quality and purity of the LPG used.

Table 3.3 shows the monthly average driving distances, LPG consumption, and fuel economy of 3- and 4-wheel vehicles by district in Phnom Penh.

Table 3.3. Monthly Average Driving Distances, LPG Consumption, and Fuel Economy of 3- and 4-Wheel Vehicles

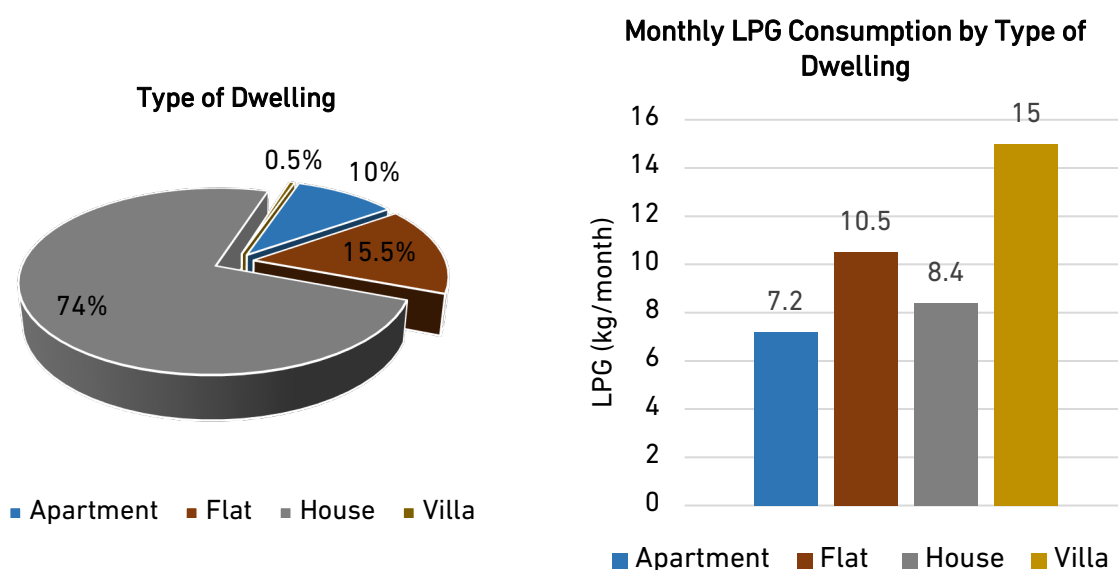
| Survey Site | 3-Wheel | | | 4-Wheel | | |
|---|-----------------------|-------------------------|-------------------------|-----------------------|-------------------------|-------------------------|
| | Driving Distance (km) | LPG Consumption (litre) | Fuel Economy (km/litre) | Driving Distance (km) | LPG Consumption (litre) | Fuel Economy (km/litre) |
| Khan Toul Kok and Russey Keo | 2,923 | 195 | 15 | 6,569 | 998 | 6.7 |
| Khan Sen Sok and Pur Senchey | 2,418 | 216 | 13 | 9,277 | 1,634 | 5.7 |
| Khan Daun Penh and Chroy Chongvar | 2,854 | 204 | 16 | 6,470 | 1,114 | 5.9 |
| Khan Prek Pnov and Kamboul | 2,931 | 211 | 14 | 12,729 | 1,982 | 6.1 |
| Khan BKK and 7 Makara | 3,093 | 147 | 19 | 10,479 | 1,490 | 6 |
| Khan Mean Chey and Dangkor | 2,539 | 215 | 11 | 6,975 | 1,200 | 6 |
| Khan Chamkar Mon and Khan Chabar Ampov | 1,885 | 205 | 10 | 7,969 | 1,124 | 7.3 |
| Average | 2,653 | 200 | 13.8 | 7,800 | 1,200 | 6.25 |

km = kilometre.
Source: Author.

2.2. Residential Sector

According to the survey, the average household size of the respondents is 4.5 persons, with a larger household size found in rural areas (4.7 persons) than in urban areas (4.3 persons).² Generally, the respondents live in four types of dwellings: houses, flats, apartments, and villas. The distribution of the respondents by type of dwelling and the average monthly LPG consumption by type of dwelling is shown in Figure 3.1. The majority of the respondents (74.0%) live in houses, followed by flats (15.5%), apartments (10.0%), and villas (0.5%). The average monthly LPG consumption varied by type of dwelling, with villas consuming the most (15.0 kg/month) and apartments consuming the least (7.2 kg/month). This could be related to the floor area, family size, and income level of each type of dwelling.

Figure 3.1. Types of Dwellings and Monthly LPG Consumption by Dwelling Type



kg = kilogram.
Source: Author

Five types of LPG containers are used by households: 250 grams (g), 5 kg, 15 kg, 25 kg, and 45 kg. The most popular type and size of LPG container is the 250-g can, which is used by 64.5% of all respondents, followed by the 15-kg cylinder, which is used by 30.0%. On the other hand, 45-kg cylinders are the least used by households, by only 0.5%. The survey also found that some households use 250-g cans together with cylinders (5-kg or 10-kg) for cooking. The average monthly LPG consumption for the 250-g can is 3.7 kg/month, which is higher for urban households (4.5 kg/month) than for rural households

² Phnom Penh household size is 4.4 in the population census (NIS, 2020), similar to the sample. The rural household size of the three provinces in the population census is 4.4, slightly smaller than the sample's 4.7.

(2.5 kg/month). On the other hand, the LPG consumption from cylinder containers (5-kg, 15-kg, 25-kg, and 45-kg) vary.

Table 3.4. Monthly LPG Consumption by Type of Container in the Residential Sector

| LPG Container Used | All | | Urban | | Rural | |
|--------------------|------|----------------------|-------|----------------------|-------|----------------------|
| | % | LPG Consumption (kg) | % | LPG Consumption (kg) | % | LPG Consumption (kg) |
| Can (250 g) | 64.5 | 3.7 | 70.0 | 4.5 | 59.0 | 2.5 |
| Cylinder (5 kg) | 13.5 | 5.0 | 11.0 | 5.0 | 16.0 | 2.8 |
| Cylinder (15 kg) | 30.0 | 8.8 | 23.0 | 11.0 | 37.0 | 7.5 |
| Cylinder (25 kg) | 5.5 | 18.0 | 4.0 | 12.2 | 7.0 | 21.3 |
| Cylinder (45 kg) | 0.5 | 30.0 | 1.0 | 30.0 | 0.0 | 0.0 |

g = gram, kg = kilogram.

Source: Author

LPG consumption can be influenced by the cooking frequency, cooking duration, cooking method, and cooking appliances of the households, particularly households that utilise LPG as part of their home-based small businesses. The home-based small businesses are usually food shops in both urban and rural areas that mainly serve clients in the morning. According to the survey, the average monthly LPG consumption of such households is 7.2 kg, with higher consumption for urban households (7.5 kg) than rural (5.0 kg). Meanwhile, the LPG fuel intensity is 1.50 kg on average, with a higher intensity for urban households (2.00 kg) than rural (1.24 kg) (Table 3.5).

Table 3.5. Monthly LPG Consumption and LPG Intensity by Selected Area

| | LPG Consumption (kg/month) | LPG Intensity (kg/person) |
|-------------------------------------|----------------------------|---------------------------|
| Urban | 7.5 | 2.0 |
| Stung Mean Chey 1 | 7.5 | 2.1 |
| Tuol Sangke | 5.0 | 1.3 |
| Chroy Chongvar | 13.4 | 2.8 |
| Boeng Keng Kang 3 | 10.0 | 2.3 |
| Rural | 5.0 | 1.2 |
| Chongruk (Kampong Speu) | 8.0 | 2.1 |
| Prey Puoch (Kandal) | 5.0 | 1.0 |
| Kampong Thkov and Snuol (Siem Reap) | 4.6 | 1.0 |
| Total | 7.2 | 1.5 |

kg = kilogram.

Source: Author.

LPG usage mainly for cooking purposes has increased dramatically since 2020, while firewood usage has decreased in rural Cambodia (NIS, 2023). One reason for this trend is the rising price of firewood, which is caused by the shortage of firewood in most regions across the country. Firewood is becoming scarce due to deforestation, illegal logging, and environmental degradation (Theangseng, 2023). Another possible reason is improved infrastructure in rural areas that have enabled people to access markets and an LPG supply more easily. Today, LPG is widely available in urban and rural areas owing to the expansion of distribution networks and the promotion of LPG by the private sector. Therefore, more people are switching to LPG as a cheaper, safer, and more convenient alternative to firewood.

Table 3.6. Monthly LPG Consumption by Type of Container of Households with Non-Home-Based Small Businesses

| LPG Container Used | All | | Urban | | Rural | |
|--------------------|------|----------------------|-------|----------------------|-------|----------------------|
| | % | LPG Consumption (kg) | % | LPG Consumption (kg) | % | LPG Consumption (kg) |
| Can (250 g) | 71.7 | 2.5 | 72.5 | 3.7 | 70.4 | 1.3 |
| Cylinder (5 kg) | 15.2 | 4.5 | 12.1 | 5.0 | 20.4 | 2.5 |
| Cylinder (15 kg) | 22.1 | 6.5 | 21.9 | 12.5 | 22.2 | 5.0 |
| Cylinder (25 kg) | 2.1 | 12.5 | 3.3 | 12.5 | 0.0 | 0.0 |
| Cylinder (45 kg) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

kg = kilogram.

Source: Author.

The average monthly LPG consumption of non-home-based small business households is 3.7 kg per month, with higher consumption for urban households (5.5 kg) than for rural (2.5 kg) (Table 3.6). The LPG fuel intensity is 1.4 kg on average, with a higher intensity for urban households (1.8 kg) than rural (0.6 kg).

The average monthly LPG consumption of non-home-based small business households for the 250-g can is 2.5 kg/month, which is lower than that of the ordinal household sample (3.7 kg/month). The consumption rate amongst urban households for the 250-g can is 2.5 kg/month, higher than that of rural households (1.3 kg/month) (Table 3.7). There were cases of rural households that consume up to 5.0 kg/month (i.e. 20 cans per month). They prefer using 250-g cans due to convenience, accessibility, and affordability. The typical stove used with LPG cylinders is much more expensive.

Table 3.7. Monthly LPG Consumption and LPG Intensity by Households with Non-Home-Based Small Businesses

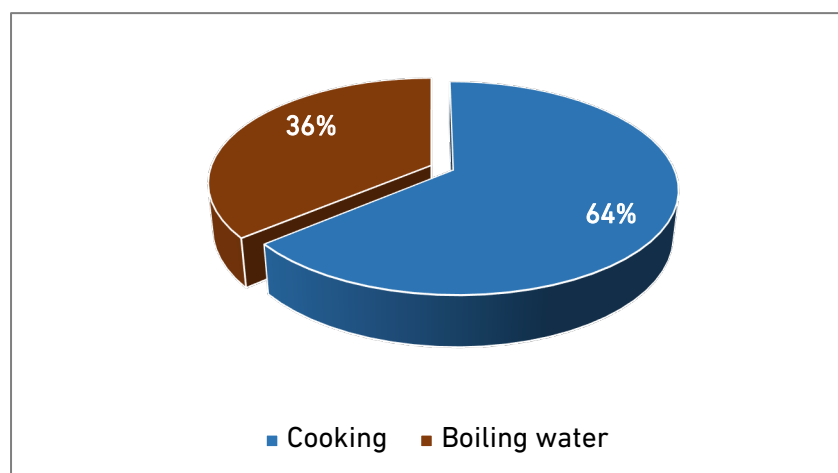
| | LPG Consumption (kg/month) | LPG Intensity (kg/person) |
|-------------------------------------|-------------------------------|------------------------------|
| Urban | 5.5 | 1.8 |
| Stung Mean Chey 1 | 7.5 | 2.2 |
| Tuol Sangke | 5.0 | 1.5 |
| Chroy Chongvar | 10.0 | 2.0 |
| Boeng Keng Kang 3 | 7.5 | 2.0 |
| Rural | 2.5 | 0.6 |
| Chongruk (Kampong Speu) | 2.5 | 0.7 |
| Prey Puoch (Kandal) | 3.0 | 0.7 |
| Kampong Thkov and Snuol (Siem Reap) | 2.0 | 0.5 |
| Total | 3.7 | 1.4 |

kg = kilogram.

Source: Author.

Biomass is another source of energy used by some households for cooking and/or heating water. The results showed that only 35% of the respondents use biomass (12% in urban areas and 24% in rural areas). The types of biomass are firewood and charcoal; households do not use biogas. About 17% of the respondents (mostly rural households) use firewood, while 29% of the respondents use charcoal. The average firewood consumption is 1 m³/month. The average charcoal consumption is around 8.0 kg/month, but rural respondents use more charcoal (10.0 kg/month) than urban respondents (4.5 kg/month). The results also show that two-thirds of biomass-consuming households use it primarily for cooking, while one-third use it for heating water (Figure 3.2). The reasons for using biomass are mainly preference, habit, availability, and cost-effectiveness. Some households also use biomass as a back-up source when the LPG supply is interrupted or insufficient.

Figure 3.2. Main Uses of Biomass in the Household Sector



Source: Author.

Electricity is another alternative energy source used by some households for cooking or heating water as well as to power other home appliances, such as air conditioners, refrigerators, and washing machines. Only 67% of the respondents reported using electricity for cooking, 33% reported using electricity for heating water, while almost all reported using electricity for other reasons. Only 6% of the respondents reported using electricity as their main source for cooking. This indicates that electricity is predominantly not a source that households in this sector use for cooking; they mainly use LPG or biomass. Table 3.8 shows the average electricity consumption for cooking, heating, lighting, and other usage by study site. Electricity consumption varies by area and usage, but urban households generally consume more than rural households. Consumption can also be influenced by the availability, affordability, and convenience for households.

Table 3.8. Monthly Electricity Consumption for Cooking, Heating, Lighting, and Other Uses by Area in the Residential Sector
(kilowatt-hour)

| Commune | Total | Cooking | Heating | Lighting | Other |
|-------------------------|------------|-----------|-----------|-----------|-----------|
| Urban | 110 | 17 | 15 | 33 | 63 |
| Stung Mean Chey 1 | 72 | 15 | 10 | 28 | 37 |
| Tuol Sangke | 110 | 12.8 | 3 | 22 | 77 |
| Chroy Chongvar | 154 | 20 | 19 | 63 | 64 |
| Boeng Keng Kang 3 | 182 | 26 | 24 | 41 | 104 |
| Rural | 81 | 12 | 8 | 20 | 48 |
| Chongruk | 85 | 19 | 8 | 18 | 50 |
| Prey Puoch | 82 | 13 | 9 | 25 | 49 |
| Kampong Thkov and Snuol | 78 | 11 | 7 | 19 | 48 |
| Total | 90 | 14 | 9 | 25 | 51 |

Source: Author.

2.3. Commercial Sector

This sub-section presents the commercial sector findings from 130 establishments that use LPG for cooking and/or heating water. The sample size for malls/supermarkets was 21, which is lower than the initial sample size of 30. This is because there are not many malls/supermarkets in the study area, and some declined to participate in the study. The data collected from this sector included floor area, type and size of LPG container, monthly LPG consumption, monthly biomass consumption, monthly electricity consumption, and usage patterns of different energy sources.

The floor area is the total area of the establishment. The results showed that the average floor area is 5,704 m² for hotels, 386 m² for restaurants, and 4,650 m² for malls/supermarkets. The differences in the floor area amongst the types of establishments can be explained by the fact that hotels and malls/supermarkets have more facilities and services than restaurants, such as guest rooms, conference halls, shops, swimming pools, cinemas, and more. Table 3.9 shows the average floor area and the number of floors for each type of establishment.

Table 3.9. Average Floor Area and Number of Floors for Each Type of Establishment in the Commercial Sector

| Type | | All | Phnom Penh | Siem Reap |
|---------------------------------|------------------------------|-------|------------|-----------|
| Hotels | Floor area (m ²) | 5,640 | 6,000 | 4,750 |
| | Number of floors | 6 | 8 | 3 |
| Restaurants | Floor area (m ²) | 386 | 381 | 410 |
| | Number of floors | 1 | 1 | 1 |
| Shopping Malls/ Supermarkets | Floor area (m ²) | 4,650 | 5,000 | 3,130 |
| | Number of floors | 2 | 3 | 2 |

m² = square metre.

Source: Author.

The average monthly LPG consumption by malls/supermarkets was not calculated, as consumption is managed by individual vendors in the food courts rather than by managerial bodies of malls/supermarkets; however, AEON Mall Phnom Penh is an exception. The only available data from this mall was its monthly LPG consumption of around 300 kg/month for food court cooking. The consumption amount is large, which reflects demand.

Table 3.10 shows the distribution of the types of LPG containers used by hotels and restaurants. Amongst the five types of LPG containers, the 5-kg cylinder is not used. The most popular type of LPG container is the 45-kg cylinder, which is used by 77.5% of hotel

respondents and 82.5% of restaurant respondents. The second most popular is the 250-g can for restaurant respondents and the 15-kg cylinder for hotel respondents. Most establishments' preference for the 45-kg cylinder indicates that they consume more than 45 kg of LPG per month, making the 45-kg cylinder the default choice for high LPG consumption. Some restaurant respondents' preference for the 250-g can indicates that they use LPG for small-scale cooking activities, such as hotpots, frying, or grilling. The average monthly LPG consumption varies by type of container.

Table 3.10. Monthly LPG Consumption by Type of Container in the Commercial Sector

| LPG Container Used | Hotels | | Restaurants | | Malls/Supermarkets | |
|--------------------|--------|----------------------|-------------|----------------------|--------------------|----------------------|
| | % | LPG Consumption (kg) | % | LPG Consumption (kg) | % | LPG Consumption (kg) |
| Can (250 g) | 2.5 | 7.5 | 16.0 | 7.5 | | |
| Cylinder (5 kg) | 0 | | 0 | | | |
| Cylinder (15 kg) | 17.5 | 60.0 | 10.0 | 61.0 | | |
| Cylinder (25 kg) | 10.0 | 62.5 | 14.0 | 87.5 | | |
| Cylinder (45 kg) | 77.5 | 180.0 | 82.5 | 250.0 | | |

kg = kilogram.
Source: Author.

As shown in Table 3.11, the average monthly LPG consumption for 4- and 5-star hotels is 150 kg, while large restaurants consume around 250 kg on average. The consumption varies between Phnom Penh and Siem Reap in both hotels and restaurants. The high variations in monthly LPG consumption reflect the frequency of cooking activities performed by the establishments, as they serve many customers and offer various dishes. The average LPG intensity for 4- and 5-star hotels is 0.021 kg/m², which is very low compared to the large restaurants at 0.71 kg/m². This could be due to the different natures and scales of their activities. Restaurants mainly use LPG for cooking large quantities of food, while hotels use LPG for cooking and heating water for a smaller number of guests.

Table 3.11. Monthly LPG Consumption and LPG Intensity by Study Site in the Commercial Sector

| | Hotels | | Restaurants | | Malls/Supermarkets | |
|------------|----------------------|------------------------------------|----------------------|------------------------------------|----------------------|------------------------------------|
| | LPG Consumption (kg) | LPG Intensity (kg/m ²) | LPG Consumption (kg) | LPG Intensity (kg/m ²) | LPG Consumption (kg) | LPG Intensity (kg/m ²) |
| Phnom Penh | 149 | 0.021 | 241 | 0.75 | | |
| Siem Reap | 100 | 0.023 | 172 | 0.38 | | |
| All | 125 | 0.021 | 236 | 0.71 | | |

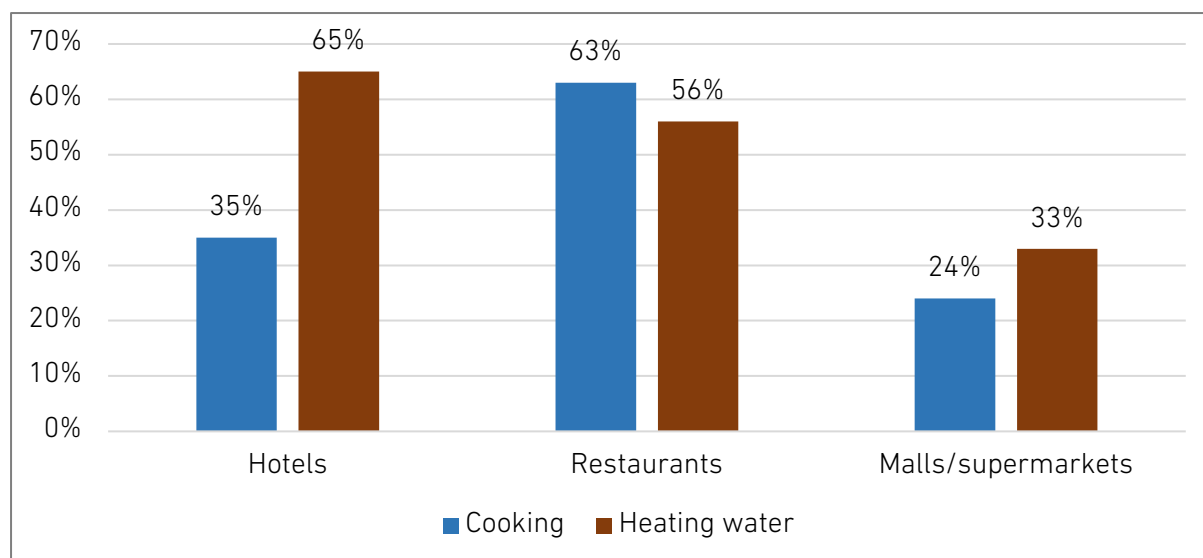
kg = kilogram, m² = square metre.

Source: Author.

Only 17% of the respondents that operate restaurants in Phnom Penh use biomass, mainly charcoal. The average monthly biomass consumption for restaurants is 283 kg. However, hotels and malls/supermarkets do not use any biomass, as they rely on LPG or electricity for their energy needs.

The survey found that only some establishments use electricity for cooking and heating water. About 35% of hotel respondents, 63% of restaurant respondents, and 24% of mall/supermarket respondents use electricity for cooking (Figure 3.3). Yet 65% of hotel respondents, 56% of restaurant respondents, and 33% of mall/supermarket respondents use electricity for heating water.

Figure 3.3. Respondents Using Electricity for Cooking and Heating Water by Type of Establishment (%)



Source: Author.

Electricity consumption for cooking and heating water varies in hotels, restaurants, and malls/supermarkets (Table 3.12). However, it should be noted that the monthly electricity consumption of hotels for heating water is higher than that for cooking, but it is the opposite for restaurants and malls/supermarkets where electricity consumption for cooking is larger than that for heating water. This difference reflects the different natures and activities of these three types of establishments. For instance, a hotel room generally has hot/cold showers and electric kettles for making tea or coffee, so electricity consumption can gradually accumulate due to water heating. Electricity consumption for cooking and heating water is significantly larger in hotels and restaurants. This could be attributed to a dozen or more restaurants or coffee shops in malls.

Table 3.12. Monthly Electricity Consumption for Cooking, Heating, Lighting, and Other Usage by Establishment Type in the Commercial Sector
(kilowatt-hour)

| | Hotels | Restaurants | Malls/Supermarkets |
|--------------------------------------|---------------|--------------|--------------------|
| Cooking | 648 | 616 | 9,500 |
| Boiling water | 818 | 223 | 3,800 |
| Lighting | 3,081 | 810 | 5,490 |
| Other | 7,411 | 1,326 | 19,725 |
| Total electricity consumption | 13,229 | 2,705 | 21,917 |

Source: Author.

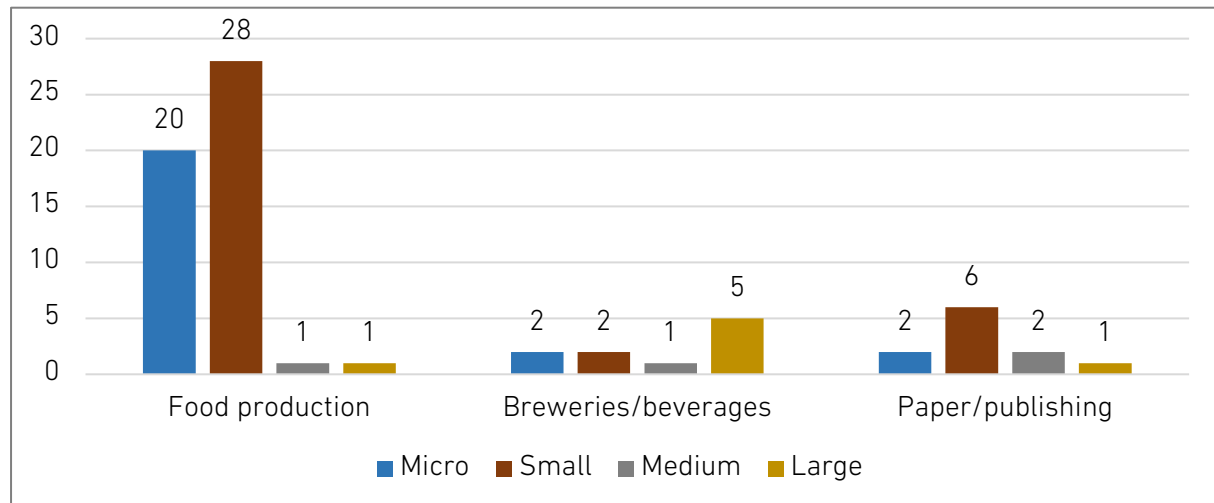
2.4. Industrial Sector

The survey targeted 70 enterprises that used LPG or other fuel sources for heating boilers or furnaces: 40 in food production, 15 in beverage/brewery and 15 in wood/paper production in Phnom Penh, Kandal, and Kampong Speu. However, the sample was reduced to 50 in food production, 10 in beverage/brewery, and 10 in wood/paper production due to the difficulty in accessing the participants. Most of the respondents were located in Phnom Penh, and several were in Kandal. LPG consumption in the industrial sector is not widely seen in factories, so the survey included handicrafts to capture the LPG consumption in this sector. However, it was still difficult to find LPG users in the industrial sector. Therefore, the survey also included some non-LPG users to better understand the potential for LPG in this sector. The data analysis focussed on LPG consumption and the usage and consumption of alternative fuel sources such as biomass or diesel.

Figure 3.4 shows the participants by business size in the industrial sector. Most industries with less than 10 employees were considered micro, and industries with 11–50

employees were considered small. Only a few industries were considered medium (50–100 employees) and large (more than 100 employees).

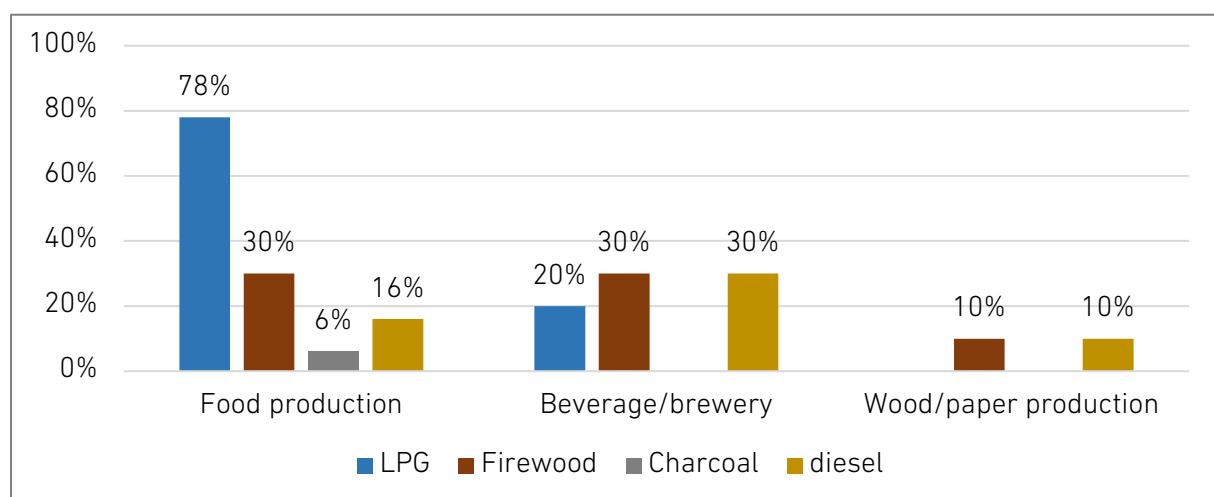
Figure 3.4. Study Participants by Business Size in the Industrial Sector



Source: Author.

The percentage of respondents based on consumption of each type of fuel source is shown in Figure 3.5. The respondents' average monthly LPG consumption and usage are 85 kg for food production and 74 kg for beverage/brewery, while none reported using LPG in wood/paper production. LPG in food production is mainly used for furnaces or other uses (e.g. drying or boiling water with a regular stove). Beverage/brewery respondents only consume LPG for other purposes.

Figure 3.5. Study Respondents Using Each Type of Fuel Source in the Industrial Sector (%)



Source: Author.

The average monthly biomass consumption of the three sub-industry respondents is 15 m³ for food production (using firewood), 300 m³ for food production (using charcoal), 350 m³ for beverage/brewery (using firewood), and 10 m³ for wood/paper production (using firewood). Biomass in food production is used mainly for furnaces or other uses. Beverage/brewery only consumes biomass for boilers and other usage, while the main usage for wood/paper production is other usage.

The respondents' average monthly diesel consumption and usage are 100 litres for food production, 112 litres for beverage/brewery, and 60 litres for wood/paper production. The main purpose of diesel consumption in food production and beverage/brewery is similar to biomass consumption, but the main purpose for wood/paper production is heating boilers. Table 3.13 summarises the industrial plants' monthly biomass consumption and usage by sub-industry.

Table 3.13. Monthly LPG, Biomass, and Diesel Consumption by Sub-Industry in the Industrial Sector

| | Food Production | Beverage/Brewery | Wood/Paper Production |
|----------------------------------|-----------------|------------------|-----------------------|
| LPG consumption (kg/month) | 85 | 74 | |
| Firewood (m ² /month) | 15 | 350 | 10 |
| Charcoal (kg/month) | 300 | | |
| Diesel (litre/month) | 100 | 112 | 60 |

kg = kilogram, m² = square metre.

Source: Author.

3. Summary

The average monthly LPG consumption of 3-wheel vehicles is 200 litres, while the consumption for 4-wheel vehicles is 1,200 litres. The average monthly LPG consumption of urban households is 7.5 kg, while the consumption for rural households is 5.0 kg. The average monthly LPG use of urban households with non-home-based businesses is 5.5 kg compared to 2.5 kg consumed by households with non-home-based businesses in rural areas. The average monthly LPG consumption of hotels is 125 kg, while restaurants consume 236 kg; data for malls/supermarkets were insufficient because they do not manage the LPG consumption of their tenants (i.e. restaurants, coffee shops, or food courts). In the industrial sector, the average monthly LPG consumption is 85 kg for food production and 74 kg for beverage/brewery, while none of the wood/paper production sub-industries use LPG.

This research also identified the potential for LPG consumption growth in each sector. The transport sector may see strong growth as the popularity of 3-wheel vehicles

continues to increase. The residential sector may also witness strong growth as more households switch from firewood to LPG for cooking. The commercial sector has some potential for growth after the pandemic and economic slowdown. Finally, the industrial sector may see some growth as the price of diesel is predicted to increase.

Chapter 4

Estimation of Current LPG Demand by Province in Cambodia

Since Cambodia imports all of its LPG, the study assumed that the total demand volume is equal to the imported volume. The total demand for LPG in 2021 was 325,618 tonnes. This chapter divides total demand by sector (i.e. roads transport, residential, commercial, and industry).

1. Transport Sector Demand

This demand was comprehensively estimated from the following data:

- (i) number of LPG service stations by province, including joint stations;
- (ii) delivery data to LPG service stations from LPG companies by province; and
- (iii) average sales volume of LPG service stations by province.

Currently, there are 740 LPG service stations nationwide, including joint stations, which denotes an LPG annex to a fuel station.

The province with the most LPG service stations is Phnom Penh (containing 17.2% of the total), followed by Battambang (10.7%), Siem Reap (9.3%), Banteay Meanchey (9.1%), and Kampong Speu (6.1%). About 80% of LPG service stations sales in Phnom Penh are for tuk-tuks. Provinces with many tourists have high ratios of tuk-tuks. In Battambang and Banteay Meanchey, the many LPG service stations may be due to the many 4-wheel vehicles. Table 4.1. shows the number of LPG service stations and sales volume by province. Note that the sales volume by province was assumed to be equal to the LPG demand for transport.

Table 4.1. LPG Demand for Transport by Province, 2021

| Province | LPG Service Station | | LPG Demand | |
|-------------------|---------------------|--------------|---------------|--------------|
| | (number) | (%) | (tonne) | (%) |
| Banteay Mean Chey | 67 | 9.1 | 8,040 | 10.0 |
| Battambang | 79 | 10.7 | 9,480 | 11.8 |
| Kampong Cham | 26 | 3.5 | 1,560 | 1.9 |
| Kampong Chhnang | 18 | 2.4 | 1,080 | 1.3 |
| Kampong Speu | 45 | 6.1 | 3,780 | 4.7 |
| Kampong Thom | 33 | 4.5 | 2,772 | 3.4 |
| Kampot | 44 | 5.9 | 3,696 | 4.6 |
| Kandal | 15 | 2.0 | 900 | 1.1 |
| Kohkong | 10 | 1.4 | 600 | 0.7 |
| Kratie | 10 | 1.4 | 600 | 0.7 |
| Mondolkiri | 5 | 0.7 | 300 | 0.4 |
| Phnom Penh | 127 | 17.2 | 25,908 | 32.1 |
| Preah Vihear | 15 | 2.0 | 900 | 1.1 |
| Prey Veng | 24 | 3.2 | 1,440 | 1.8 |
| Pursat | 26 | 3.5 | 1,560 | 1.9 |
| Ratanakiri | 5 | 0.7 | 300 | 0.4 |
| Siem Reap | 69 | 9.3 | 8,280 | 10.3 |
| Preah Sihanouk | 23 | 3.1 | 1,932 | 2.4 |
| Stung Treng | 7 | 0.9 | 420 | 0.5 |
| Svay Rieng | 23 | 3.1 | 1,380 | 1.7 |
| Takeo | 26 | 3.5 | 3,120 | 3.9 |
| Oddar Meanchey | 18 | 2.4 | 1,080 | 1.3 |
| Kep | 2 | 0.3 | 120 | 0.1 |
| Pailin | 6 | 0.8 | 360 | 0.4 |
| Tbong Khmum | 17 | 2.3 | 1,020 | 1.3 |
| Total | 740 | 100.0 | 80,628 | 100.0 |

Sources: General Department of Petroleum and author.

The LPG companies that cooperated in the collection of delivery data to LPG service stations by province could not estimate demand by province nationwide because they deliver mostly to Phnom Penh and its surrounding provinces as well as Sihanoukville and its surrounding provinces. Therefore, per interviews with LPG companies, the average monthly sales volume by province was estimated, and the LPG demand for transport nationwide was estimated. LPG demand in the transport sector in 2021 was thus 80,628 tonnes, accounting for 24.8% of the total demand of 325,618 tonnes.

2. Residential Sector Demand

This was estimated from the following data:

- (i) consumption survey,
- (ii) number of urban and rural households by province, and
- (iii) LPG consumption per household and GDP per capita in neighbouring countries.

2.1. Population Census 2019

According to the 2019 population census, urban households number 1,328,501, which is 37.4% of all households, and rural households account for 2,224,520, or 62.6% of all households (NIS, 2020). The distribution of households by type of fuel used for cooking as well as area is shown in Table 4.2. Also according to the census, 68.7% of households – 86.5% of rural households and 38.9% of urban households – use firewood and charcoal as the main fuel for cooking (NIS, 2020). However, over the past 10 years, the proportion of firewood and charcoal use has decreased, and the proportion of LPG use has increased. In 2019, 27.7% of households used LPG as their main fuel for cooking – 10.7% of rural households and 56.2% of urban households. Rural households mainly used LPG in 'cassette' or 250-g cans.

Thus, the conversion from biomass to LPG is progressing. Urbanisation is also contributing to increased LPG use; a slight increase in the use of electricity for cooking is noted as well.

Table 4.2. Distribution of Households by Type of Fuel Used for Cooking
(%)

| Area | Year | Number of Households | Type of Fuel | | | | | | | |
|-------|------|----------------------|--------------|----------|----------|----------|------|-------------|------|-------|
| | | | Total | Firewood | Charcoal | Kerosene | LPG | Electricity | None | Other |
| Total | 2019 | 3,553,021 | 100.0 | 60.9 | 7.8 | 0.3 | 27.7 | 3.0 | 0.1 | 0.2 |
| | 2008 | 2,817,637 | 100.0 | 83.6 | 7.5 | 0.4 | 7.9 | 0.4 | 0.1 | 0.1 |
| | 1998 | 2,162,086 | 100.0 | 90.0 | 5.3 | 1.8 | 1.7 | | | 1.2 |
| Urban | 2019 | 1,328,501 | 100.0 | 31.0 | 7.9 | 0.4 | 56.2 | 4.2 | 0.2 | 0.1 |
| | 2008 | 506,579 | 100.0 | 34.7 | 25.6 | 0.4 | 37.3 | 1.5 | 0.4 | 0.1 |
| | 1998 | 364,581 | 100.0 | 62.9 | 24.6 | 2.8 | 8.8 | | | 0.9 |
| Rural | 2019 | 2,224,520 | 100.0 | 78.8 | 7.7 | 0.3 | 10.7 | 2.3 | 0.1 | 0.1 |
| | 2008 | 2,311,058 | 100.0 | 94.3 | 3.5 | 0.3 | 1.5 | 0.1 | 0.2 | 0.1 |
| | 1998 | 1,797,505 | 100.0 | 95.6 | 1.3 | 1.6 | 0.3 | | | 1.2 |

Source: NIS (2020).

2.2. Consumption per Household

The study then focussed on the number of urban and rural households by province and estimated the average monthly LPG consumption per household. For the assumptions, the consumption survey and information from LPG companies were cited. Table 4.3 shows the LPG demand from the residential sector in 2021. The number of urban and rural households by province was derived from NIS (2020).

The unit consumption was set to 7.5 kg/month for Phnom Penh, 5.0 kg/month for urban areas other than Phnom Penh, and 0.8 kg/month for rural areas. As a result, the total LPG demand for the residential sector in 2021 is estimated at 116,044 tonnes. By province, Phnom Penh accounts for 44,937 tonnes (38.7% of the total), followed by Kandal, Kampong Speu, and Siem Reap.

According to a microfinance company that lends money to farmers in Battambang, most farmer households use refilled cassette cans of LPG as auxiliary fuel for cooking, thus about 0.5–1.0 kg/month. Few farmers use cylinders; they fill these at LPG service stations.

Table 4.3. LPG Demand for Residential Use by Province, 2021

| Province | Households (number) | | | Ratio (%) | | LPG Demand (tonne) | | |
|-------------------|------------------------|---------|---------|--------------|-------|-----------------------|-------|--------|
| | Total | Urban | Rural | Urban | Rural | Urban | Rural | Total |
| Banteay Mean Chey | 189,588 | 68,660 | 120,928 | 36.2 | 63.8 | 4,120 | 1,161 | 5,281 |
| Battambang | 227,237 | 45,556 | 181,681 | 20.0 | 80.0 | 2,733 | 1,744 | 4,477 |
| Kampong Cham | 217,197 | 30,386 | 186,811 | 14.0 | 86.0 | 1,823 | 1,793 | 3,617 |
| Kampong Chhnang | 126,299 | 28,523 | 97,776 | 22.6 | 77.4 | 1,711 | 939 | 2,650 |
| Kampong Speu | 195,882 | 114,380 | 81,502 | 58.4 | 41.6 | 6,863 | 782 | 7,645 |
| Kampong Thom | 160,766 | 16,118 | 144,648 | 10.0 | 90.0 | 967 | 1,389 | 2,356 |
| Kampot | 143,402 | 13,258 | 130,144 | 9.2 | 90.8 | 795 | 1,249 | 2,045 |
| Kandal | 265,803 | 170,782 | 95,021 | 64.3 | 35.7 | 10,247 | 912 | 11,159 |
| Kohkong | 28,027 | 12,359 | 15,668 | 44.1 | 55.9 | 742 | 150 | 892 |
| Kratie | 86,176 | 9,297 | 76,879 | 10.8 | 89.2 | 558 | 738 | 1,296 |
| Mondolkiri | 20,409 | 7,500 | 12,909 | 36.7 | 63.3 | 450 | 124 | 574 |
| Phnom Penh | 499,299 | 499,299 | 0 | 100.0 | 0.0 | 44,937 | 0 | 44,937 |
| Preah Vihear | 56,713 | 5,650 | 51,063 | 10.0 | 90.0 | 339 | 490 | 829 |
| Prey Veng | 266,934 | 14,168 | 252,766 | 5.3 | 94.7 | 850 | 2,427 | 3,277 |
| Pursat | 103,862 | 17,624 | 86,238 | 17.0 | 83.0 | 1,057 | 828 | 1,885 |

| Province | Households (number) | | | Ratio (%) | | LPG Demand (tonne) | | Total |
|----------------|------------------------|------------------|------------------|--------------|-------------|-----------------------|---------------|----------------|
| | Total | Urban | Rural | Urban | Rural | Urban | Rural | |
| Ratanakiri | 49,741 | 6,877 | 42,864 | 13.8 | 86.2 | 413 | 411 | 824 |
| Siem Reap | 224,672 | 67,845 | 156,827 | 30.2 | 69.8 | 4,071 | 1,506 | 5,576 |
| Preah Sihanouk | 47,381 | 34,060 | 13,321 | 71.9 | 28.1 | 2,044 | 128 | 2,171 |
| Stung Treng | 35,833 | 9,761 | 26,072 | 27.2 | 72.8 | 586 | 250 | 836 |
| Svay Rieng | 132,492 | 37,285 | 95,207 | 28.1 | 71.9 | 2,237 | 914 | 3,151 |
| Takeo | 208,698 | 62,856 | 145,842 | 30.1 | 69.9 | 3,771 | 1,400 | 5,171 |
| Oddar Meanchey | 60,886 | 19,826 | 41,060 | 32.6 | 67.4 | 1,190 | 394 | 1,584 |
| Kep | 9,605 | 7,714 | 1,891 | 80.3 | 19.7 | 463 | 18 | 481 |
| Pailin | 17,177 | 13,050 | 4,127 | 76.0 | 24.0 | 783 | 40 | 823 |
| Tbong Khmum | 178,942 | 15,667 | 163,275 | 8.8 | 91.2 | 940 | 1,567 | 2,507 |
| Total | 3,553,021 | 1,328,501 | 2,224,520 | 37.4 | 62.6 | 94,689 | 21,355 | 116,044 |

Note: Urban is defined as towns identified on the basis of statutory administration or recognised by decrees and laws.

Source: NIS (2020) and author.

2.3. Neighbouring Countries

The LPG demand, number of households, and GDP per capita in the residential sectors of neighbouring countries are shown in Table 4.4. Compared to the Philippines and Viet Nam – which are in similar stages of development as Cambodia – Cambodia's household demand in 2020 is estimated at 113,000 tonnes. Thus, Cambodia's household demand of 116,044 tonnes in 2021 estimated from unit consumption is reliable.

Table 4.4. Residential LPG Demand and Gross Domestic Product per Capita of Neighbouring Countries

| Country | Residential LPG Demand ('000 tonnes) | GDP per Capita (\$) | Households ('000) | GDP (\$ million) | LPG Demand per Household (kg/month) |
|-------------|--------------------------------------|---------------------|-------------------|------------------|-------------------------------------|
| Indonesia | 7,691 | 3,931 | 69,890 | 1,187,319 | 9.17 |
| Philippines | 1,103 | 3,318 | 26,390 | 394,086 | 5.58 |
| Viet Nam | 1,695 | 3,514 | 26,800 | 366,201 | 6.10 |
| Thailand | 1,375 | 7,190 | 21,560 | 505,902 | 3.55 |
| Malaysia | 573 | 10,361 | 6,730 | 373,034 | 1.50 |
| Cambodia | 113 | 1,557 | 3,553 | 26,313 | 2.66 |

GDP = gross domestic product, kg =kilogram.

Sources: IEA (2023), ADB (2022), International Monetary Fund (IMF), Cambodia, <https://www.imf.org/en/Countries/KHM> (accessed 26 December 2023).

3. Commercial Sector Demand

With some exceptions, it was difficult to grasp the number of cases and unit consumption by province of the commercial sector. LPG is also used for cooking and washing in factories, which are also counted as commercial use.

Under these circumstances, LPG demand in Cambodia's commercial sector was estimated from the relationship between the GDP per capita of the services sector and LPG demand in the commercial sectors of the Philippines and Viet Nam. Cambodia's LPG demand by the commercial sector in 2021 is thus estimated at 127,000 tonnes (39.0% of the total demand) (Table 4.5).

Table 4.5. Commercial LPG Demand and Gross Domestic Product per Capita of Neighbouring Countries

| Country | Commercial LPG Demand ('000 tonnes) | GDP per Capita (\$) | Percentage of Services Sector (%) | GDP per Capita Services Sector (\$) |
|-------------|-------------------------------------|---------------------|-----------------------------------|-------------------------------------|
| Indonesia | 206 | 3,931 | 46.1 | 1,812 |
| Philippines | 460 | 3,318 | 61.4 | 2,037 |
| Viet Nam | 280 | 3,514 | 41.6 | 1,462 |
| Thailand | 656 | 7,190 | 60.8 | 4,372 |
| Malaysia | 142 | 10,361 | 55.4 | 5,740 |
| Cambodia | 127 | 1,557 | 39.0 | 607 |

GDP = gross domestic product, kg =kilogram.

Sources: IEA (2023), ADB (2022), International Monetary Fund (IMF), Cambodia, <https://www.imf.org/en/Countries/KHM> (accessed 26 December 2023).

LPG demand of the commercial sector by province in 2021 was estimated by using the composition ratio of electricity consumption of the commercial sector by province in 2021.

Table 4.6. LPG Demand by the Commercial Sector by Province, 2021

| Province | Electricity Consumption | | LPG Demand Commercial | |
|-------------------|-------------------------|-----|-----------------------|-----|
| | (kwh/year) | (%) | (tonne) | (%) |
| Banteay Mean Chey | 204,563,433 | 2.7 | 3,422 | 2.7 |
| Battambang | 220,927,262 | 2.9 | 3,696 | 2.9 |
| Kampong Cham | 205,733,033 | 2.7 | 3,441 | 2.7 |
| Kampong Chhnang | 111,984,350 | 1.5 | 1,873 | 1.5 |
| Kampong Speu | 423,358,873 | 5.6 | 7,082 | 5.6 |
| Kampong Thom | 57,869,516 | 0.8 | 968 | 0.8 |
| Kampot | 120,825,288 | 1.6 | 2,021 | 1.6 |
| Kandal | 393,220,534 | 5.2 | 6,578 | 5.2 |
| Kohkong | 62,317,860 | 0.8 | 1,042 | 0.8 |
| Kratie | 117,600,218 | 1.5 | 1,967 | 1.5 |
| Mondolkiri | 15,282,536 | 0.2 | 256 | 0.2 |

| Province | Electricity Consumption | | LPG Demand Commercial | |
|----------------|-------------------------|--------------|-----------------------|--------------|
| | (kwh/year) | (%) | (tonne) | (%) |
| Phnom Penh | 3,732,008,813 | 49.2 | 62,427 | 49.2 |
| Preah Vihear | 18,248,379 | 0.2 | 305 | 0.2 |
| Prey Veng | 78,197,983 | 1.0 | 1,308 | 1.0 |
| Pursat | 59,239,103 | 0.8 | 991 | 0.8 |
| Ratanakiri | 71,314,107 | 0.9 | 1,193 | 0.9 |
| Siem Reap | 236,986,038 | 3.1 | 3,964 | 3.1 |
| Preah Sihanouk | 759,992,310 | 10.0 | 12,713 | 10.0 |
| Stung Treng | 21,302,059 | 0.3 | 356 | 0.3 |
| Svay Rieng | 311,423,153 | 4.1 | 5,209 | 4.1 |
| Takeo | 205,433,742 | 2.7 | 3,436 | 2.7 |
| Oddar Meanchey | 14,077,218 | 0.2 | 235 | 0.2 |
| Kep | 17,238,302 | 0.2 | 288 | 0.2 |
| Pailin | 34,433,166 | 0.5 | 576 | 0.5 |
| Tbong Khmum | 98,734,131 | 1.3 | 1,652 | 1.3 |
| Total | 7,592,311,407 | 100.0 | 127,000 | 100.0 |

kwh = kilowatt-hour.

Sources: General Department of Energy and author.

4. Industry Sector Demand

Normally, the industrial use of LPG is limited to special uses such as metal processing, glass processing, and pottery making. LPG is also used by beverage manufacturers and food processing manufacturers to clean boilers in their factories. It was difficult to obtain data on the number of factories, their locations, and unit consumption of LPG for these industries; yet it is estimated that the number of factories in these industries is still small. Therefore, LPG demand in the industrial sector was set at approximately 2,000 tonnes, which is the total demand minus the demand in the transport, residential, and commercial sectors (Table 4.7). It was not possible to break down LPG demand in the industrial sector by province.

Table 4.7. LPG Demand by Sector, 2021

| Sector | LPG Demand | |
|--------------|----------------|--------------|
| | (tonne) | (%) |
| Transport | 80,628 | 24.8 |
| Residential | 116,044 | 35.6 |
| Commercial | 127,000 | 39.0 |
| Industry | 1,946 | 0.6 |
| Total | 325,618 | 100.0 |

Source: Author.

The LPG demand by province in 2021 – excluding the industrial sector – is shown in Table 4.8. Phnom Penh has the highest demand at 41.2% of the total.

Table 4.8. LPG Demand by Sector and by Province, 2021
(tonne)

| | Transport | Residential | Commercial | Total (exc. Industry) | % |
|-------------------|-----------|-------------|------------|--------------------------|------|
| Banteay Mean Chey | 8,040 | 5,281 | 3,422 | 16,742 | 5.2 |
| Battambang | 9,480 | 4,477 | 3,696 | 17,653 | 5.5 |
| Kampong Cham | 1,560 | 3,617 | 3,441 | 8,618 | 2.7 |
| Kampong Chhnang | 1,080 | 2,650 | 1,873 | 5,603 | 1.7 |
| Kampong Speu | 3,780 | 7,645 | 7,082 | 18,507 | 5.7 |
| Kampong Thom | 2,772 | 2,356 | 968 | 6,096 | 1.9 |
| Kampot | 3,696 | 2,045 | 2,021 | 7,762 | 2.4 |
| Kandal | 900 | 11,159 | 6,578 | 18,637 | 5.8 |
| Kohkong | 600 | 892 | 1,042 | 2,534 | 0.8 |
| Kratie | 600 | 1,296 | 1,967 | 3,863 | 1.2 |
| Mondolkiri | 300 | 574 | 256 | 1,130 | 0.3 |
| Phnom Penh | 25,908 | 44,937 | 62,427 | 133,272 | 41.2 |
| Preah Vihear | 900 | 829 | 305 | 2,034 | 0.6 |

| | Transport | Residential | Commercial | Total (exc. Industry) | % |
|----------------|---------------|----------------|----------------|--------------------------|--------------|
| Prey Veng | 1,440 | 3,277 | 1,308 | 6,025 | 1.9 |
| Pursat | 1,560 | 1,885 | 991 | 4,436 | 1.4 |
| Ratanakiri | 300 | 824 | 1,193 | 2,317 | 0.7 |
| Siem Reap | 8,280 | 5,576 | 3,964 | 17,820 | 5.5 |
| Preah Sihanouk | 1,932 | 2,171 | 12,713 | 16,816 | 5.2 |
| Stung Treng | 420 | 836 | 356 | 1,612 | 0.5 |
| Svay Rieng | 1,380 | 3,151 | 5,209 | 9,740 | 3.0 |
| Takeo | 3,120 | 5,171 | 3,436 | 11,728 | 3.6 |
| Oddar Meanchey | 1,080 | 1,584 | 235 | 2,899 | 0.9 |
| Kep | 120 | 481 | 288 | 889 | 0.3 |
| Pailin | 360 | 823 | 576 | 1,759 | 0.5 |
| Tbong Khmum | 1,020 | 2,507 | 1,652 | 5,179 | 1.6 |
| Total | 80,628 | 116,044 | 127,000 | 323,672 | 100.0 |

Source: Author.

Chapter 5

Forecast of Future LPG Demand in 2040

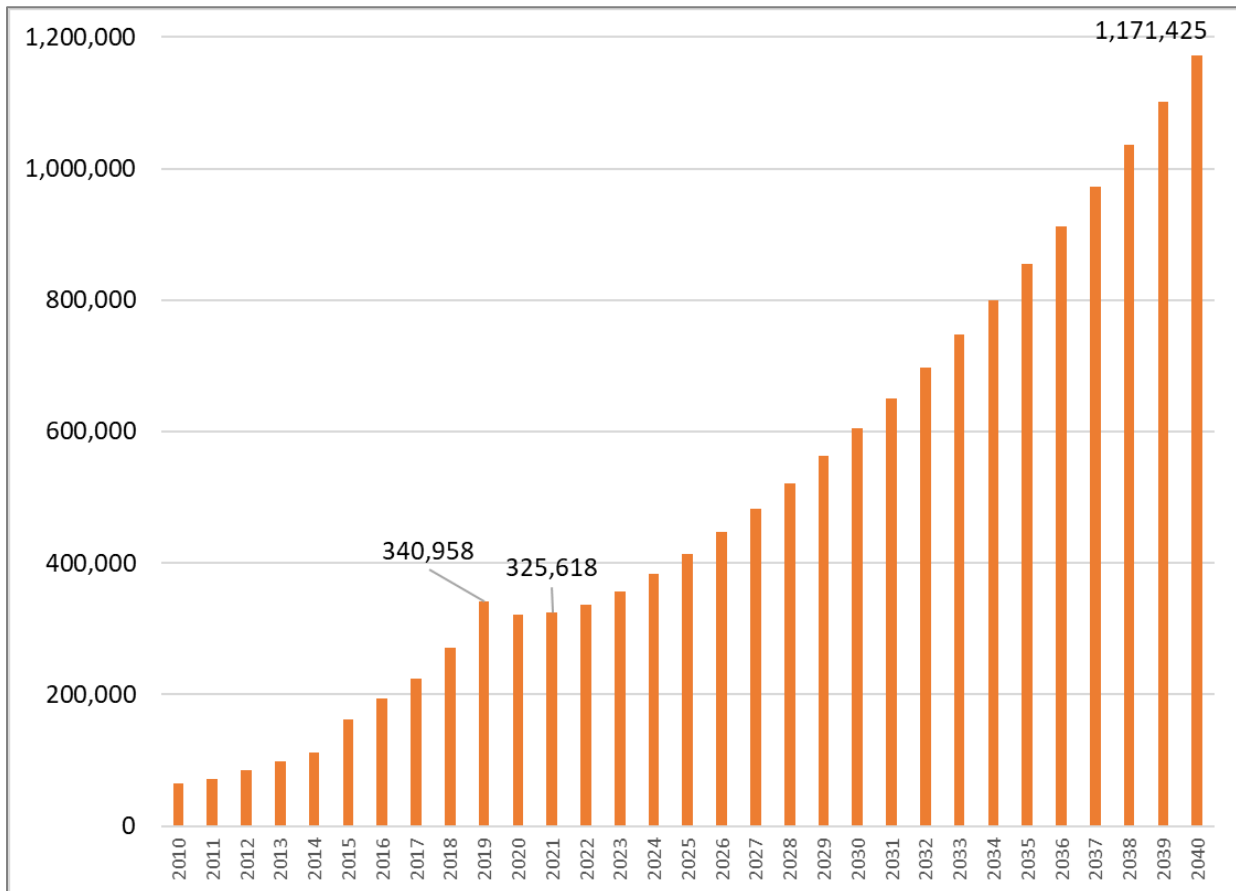
1. Estimation Method

A demand estimation formula, based on historical data from 2010 to 2021, was then created. LPG demand in 2040 was estimated using the following parameters:

- (i) GDP annual growth rate of 6.0% (2023–2040),
- (ii) population annual growth rate of 1.5% (2019–2040), and
- (iii) Consumer Price Index annual growth rate of 3.0% (2022–2040).

As shown in Figure 5.1, in 2020 and 2021, LPG demand decreased compared to 2019 due to the impact of the COVID-19 pandemic, but it began to increase again from 2022. It will increase to 1,171,425 tonnes in 2040, which is 3.6 times the current level.

Figure 5.1. Demand Estimation for LPG in Cambodia, 2040
(tonne)

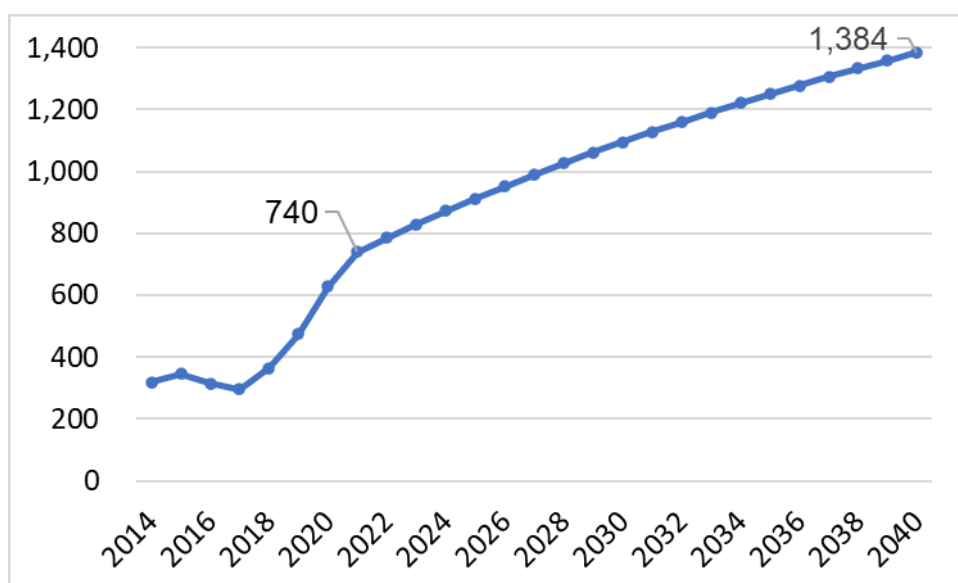


Source: Author.

2. LPG Demand by the Transport Sector, 2040

By using the estimated number of LPG service stations in 2040 and estimated sales volume per year in 2040, the LPG demand for the transport sector was estimated. The number of LPG service stations in 2021 was 740, while the average sales volume per service station was about 109 tonnes per year. By using a non-linear trend function regarding historical data, the number of LPG service stations in 2040 is estimated to be 1,384, with a sales volume per service station – which will increase according to the increase of GDP per capita – of about 246 tonnes (Figure 5.2). As a result, LPG demand of the transport sector in 2040 is estimated at 340,799 tonnes.

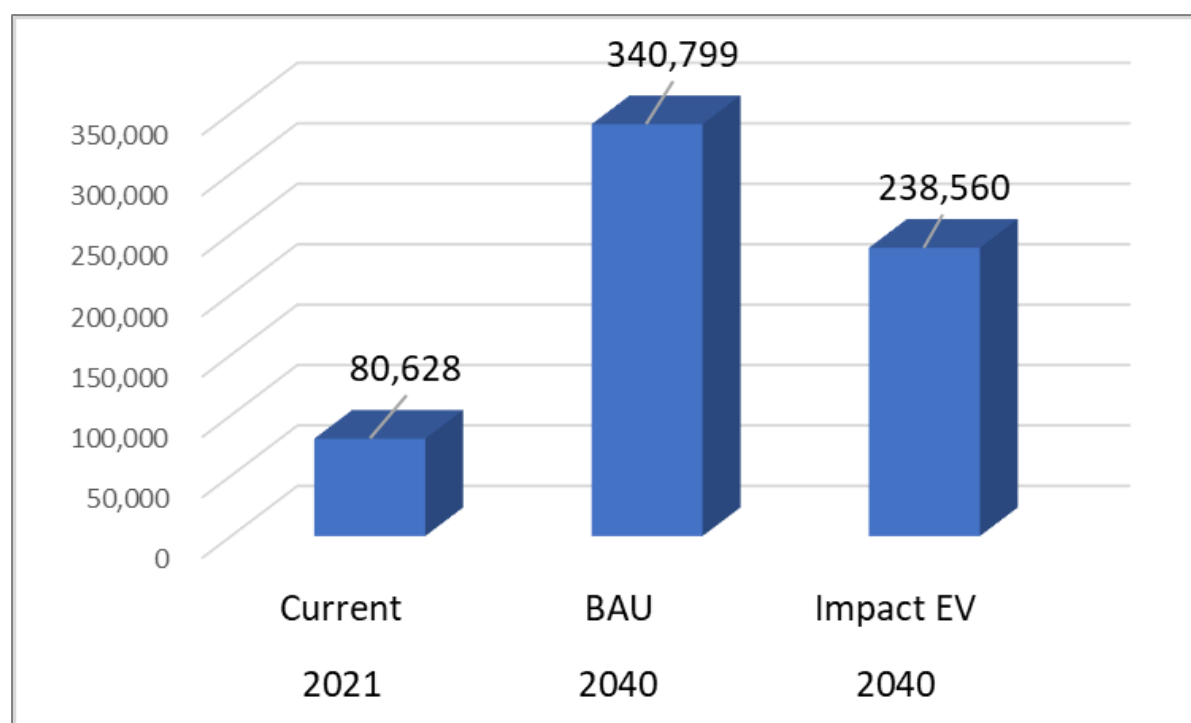
Figure 5.2. LPG Service Stations, 2014–2040
(number)



Source: General Department of Petroleum and author.

However, 3-wheel tuk-tuks, which account for 70%–80% of LPG service station sales volume, will be eventually converted to electric vehicles (EVs) by battery swapping. The Ministry of Public Works and Transport is also aiming for 70% electrification of motorcycles by 2050. Regarding 4-wheel cars, it is aiming for 40% electrification by 2050. Therefore, in this study, 30% of the LPG demand for the transport sector in 2040 is estimated to be converted to electricity. As a result, LPG demand for transport is estimated at 238,560 tonnes (Figure 5.3).

Figure 5.3. LPG Demand by the Transport Sector, 2040
(tonne)



BAU = business as usual, EV = electric vehicle.

Source: Author.

Table 5.1. LPG Demand by the Transport Sector by Province, 2040

| Province | LPG Service Stations | | Sales Volume per Month | LPG Demand | |
|-------------------|----------------------|------|------------------------|------------|------|
| | (tonne) | (%) | | (tonne) | (%) |
| Banteay Mean Chey | 125 | 9.1 | 23 | 23,788 | 10.0 |
| Battambang | 148 | 10.7 | 23 | 28,049 | 11.8 |
| Kampong Cham | 49 | 3.5 | 11 | 4,616 | 1.9 |
| Kampong Chhnang | 34 | 2.4 | 11 | 3,195 | 1.3 |
| Kampong Speu | 84 | 6.1 | 16 | 11,184 | 4.7 |
| Kampong Thom | 62 | 4.5 | 16 | 8,202 | 3.4 |
| Kampot | 82 | 5.9 | 16 | 10,936 | 4.6 |
| Kandal | 28 | 2.0 | 11 | 2,663 | 1.1 |
| Kohkong | 19 | 1.4 | 11 | 1,775 | 0.7 |
| Kratie | 19 | 1.4 | 11 | 1,775 | 0.7 |
| Mondolkiri | 9 | 0.7 | 11 | 888 | 0.4 |
| Phnom Penh | 238 | 17.2 | 38 | 76,656 | 32.1 |
| Preah Vihear | 28 | 2.0 | 11 | 2,663 | 1.1 |

| Province | LPG Service Stations | | Sales Volume per Month | LPG Demand | |
|----------------|----------------------|--------------|---------------------------|----------------|--------------|
| | (tonne) | (%) | | (tonne) | (%) |
| Prey Veng | 45 | 3.2 | 11 | 4,261 | 1.8 |
| Pursat | 49 | 3.5 | 11 | 4,616 | 1.9 |
| Ratanakiri | 9 | 0.7 | 11 | 888 | 0.4 |
| Siem Reap | 129 | 9.3 | 23 | 24,499 | 10.3 |
| Preah Sihanouk | 43 | 3.1 | 16 | 5,716 | 2.4 |
| Stung Treng | 13 | 0.9 | 11 | 1,243 | 0.5 |
| Svay Rieng | 43 | 3.1 | 11 | 4,083 | 1.7 |
| Takeo | 49 | 3.5 | 23 | 9,231 | 3.9 |
| Oddar Meanchey | 34 | 2.4 | 11 | 3,195 | 1.3 |
| Kep | 4 | 0.3 | 11 | 355 | 0.1 |
| Pailin | 11 | 0.8 | 11 | 1,065 | 0.4 |
| Tbong Khmum | 32 | 2.3 | 11 | 3,018 | 1.3 |
| Total | 1,384 | 100.0 | | 238,560 | 100.0 |

Sources: General Department of Petroleum and author.

3. LPG Demand by the Residential Sector, 2040

LPG demand for the residential sector will increase due to:

- (i) more people due to population growth, from 15,552,211 in 2019 to 21,260,772 in 2040;
- (ii) more households, from 3,553,021 in 2019 to 4,687,844 in 2040;
- (iii) more people per household, from 4.7 in 2019 to 4.5 in 2040;
- (iv) greater household income, due to the GDP per capita growth, from \$1,557 GDP per capita in 2020 to \$3,585 GDP per capital in 2040; and
- (v) various lifestyle changes due to urbanisation.

The rural population has been declining at an annual rate of 1.2% over the last 10 years, while the urban population has been increasing at an annual rate of 8.1% (NIS, 2020). It is estimated that this trend of urbanisation will continue in the future. Table 5.2 shows the estimated number of urban and rural households in 2040.

Table 5.2. Population in Cambodia, 2008–2040

| | Population | | | | | Households |
|-----------------|------------|------------|-----------|------------|-----------|------------|
| | 2008 | 2019 | 2008–2019 | 2040 | 2019–2040 | 2040 |
| Urban | 2,614,027 | 6,135,194 | 8.1 | 13,635,551 | 3.9 | 3,004,908 |
| Rural | 10,781,655 | 9,417,017 | (1.2) | 7,625,221 | (1.0) | 1,682,936 |
| Total | 13,395,682 | 15,552,211 | 1.4 | 21,260,772 | 1.5 | 4,687,844 |
| Urban Ratio (%) | 19.5 | 39.4 | | 64.1 | | 64.1 |

() = negative.

Source: NIS (2020) and author.

The LPG unit consumption per household/month – considering the growth of GDP per capita – was set to 14.0 kg/month from 7.5 kg/month for Phnom Penh, 10.0 kg/month from 5.0 kg/month for urban areas other than Phnom Penh, and 3.0 kg/month from 0.8 kg/month for rural areas. As a result, the total LPG demand for the residential sector in 2040 is estimated at 461,309 tonnes. By province, Phnom Penh accounts for 30.5% of the total (140,471 tonnes), followed by Kandal, Kampong Speu, and Siem Reap.

Table 5.3. LPG Demand by the Residential Sector by Province, 2040

| Province | Households | | | Ratio | | LPG Demand | | | % of total |
|-------------------|------------|-------------------|---------|--------------|--------------|------------------|-------|---------|------------|
| | Total | (number) Urban | Rural | (%) Urban | (%) Rural | (tonne) Urban | Rural | Total | |
| Banteay Mean Chey | 222,493 | 131,006 | 91,487 | 58.9 | 41.1 | 15,721 | 3,294 | 19,014 | 4.1 |
| Battambang | 221,891 | 84,442 | 137,449 | 38.1 | 61.9 | 10,133 | 4,948 | 15,081 | 3.3 |
| Kampong Cham | 189,946 | 48,616 | 141,330 | 25.6 | 74.4 | 5,834 | 5,088 | 10,922 | 2.4 |
| Kampong Chhnang | 152,404 | 78,432 | 73,971 | 51.5 | 48.5 | 9,412 | 2,663 | 12,075 | 2.6 |
| Kampong Speu | 258,100 | 196,441 | 61,659 | 76.1 | 23.9 | 23,573 | 2,220 | 25,793 | 5.6 |
| Kampong Thom | 182,812 | 73,380 | 109,432 | 40.1 | 59.9 | 8,806 | 3,940 | 12,745 | 2.8 |
| Kampot | 148,165 | 49,706 | 98,459 | 33.5 | 66.5 | 5,965 | 3,545 | 9,509 | 2.1 |
| Kandal | 303,430 | 231,543 | 71,887 | 76.3 | 23.7 | 27,785 | 2,588 | 30,373 | 6.6 |
| Kohkong | 26,602 | 14,749 | 11,853 | 55.4 | 44.6 | 1,770 | 427 | 2,197 | 0.5 |
| Kratie | 124,528 | 66,366 | 58,162 | 53.3 | 46.7 | 7,964 | 2,094 | 10,058 | 2.2 |
| Mondolkiri | 78,710 | 68,944 | 9,766 | 87.6 | 12.4 | 8,273 | 352 | 8,625 | 1.9 |
| Phnom Penh | 836,136 | 836,136 | 0 | 100.0 | 0.0 | 140,471 | 0 | 140,471 | 30.5 |
| Preah Vihear | 197,590 | 158,959 | 38,631 | 80.4 | 19.6 | 19,075 | 1,391 | 20,466 | 4.4 |
| Prey Veng | 225,242 | 34,014 | 191,227 | 15.1 | 84.9 | 4,082 | 6,884 | 10,966 | 2.4 |
| Pursat | 124,247 | 59,004 | 65,242 | 47.5 | 52.5 | 7,081 | 2,349 | 9,429 | 2.0 |
| Ratanakiri | 194,922 | 162,494 | 32,428 | 83.4 | 16.6 | 19,499 | 1,167 | 20,667 | 4.5 |

| Province | Households | | | Ratio | | LPG Demand | | | % of total |
|----------------|------------------|------------------|------------------|-------------|-------------|----------------|---------------|----------------|--------------|
| | Total | (number) | | (%) | (%) | (tonne) | | | |
| | | Urban | Rural | Urban | Rural | Urban | Rural | Total | |
| Siem Reap | 327,805 | 209,159 | 118,646 | 63.8 | 36.2 | 25,099 | 4,271 | 29,370 | 6.4 |
| Preah Sihanouk | 69,494 | 59,416 | 10,078 | 85.5 | 14.5 | 7,130 | 363 | 7,493 | 1.6 |
| Stung Treng | 96,464 | 76,740 | 19,724 | 79.6 | 20.4 | 9,209 | 710 | 9,919 | 2.2 |
| Svay Rieng | 150,852 | 78,824 | 72,028 | 52.3 | 47.7 | 9,459 | 2,593 | 12,052 | 2.6 |
| Takeo | 210,004 | 99,669 | 110,335 | 47.5 | 52.5 | 11,960 | 3,972 | 15,932 | 3.5 |
| Oddar Meanchey | 104,616 | 73,553 | 31,063 | 70.3 | 29.7 | 8,826 | 1,118 | 9,945 | 2.2 |
| Kep | 11,438 | 10,007 | 1,431 | 87.5 | 12.5 | 1,201 | 52 | 1,252 | 0.3 |
| Pailin | 27,363 | 24,241 | 3,122 | 88.6 | 11.4 | 2,909 | 112 | 3,021 | 0.7 |
| Tbong Khmum | 202,590 | 79,066 | 123,524 | 39.0 | 61.0 | 9,488 | 4,447 | 13,935 | 3.0 |
| Total | 4,687,844 | 3,004,908 | 1,682,936 | 64.1 | 35.9 | 400,723 | 60,586 | 461,309 | 100.0 |

Source: Author.

4. LPG Demand by the Commercial Sector, 2040

The pillars of Cambodia's economic growth are the development of agriculture, progress of industrialisation, and growth of tourism. Cambodia's per capita GDP in 2040 is estimated to be \$3,585 – 2.26 times higher than that of today. Based on the relationship between LPG demand for the commercial sector and GDP per capita of neighbouring countries, Cambodia's LPG demand for its commercial sector is estimated to grow to 437,000 tonnes, outpacing GDP growth.

Table 5.4. LPG Demand by the Commercial Sectors of Neighbouring Countries, 2040

| Country | Commercial LPG Demand ('000 tonnes) | GDP per Capita (\$) | Percentage of Services Sector (%) | GDP per Capita Services Sector (\$) |
|-------------|-------------------------------------|---------------------|-----------------------------------|-------------------------------------|
| Indonesia | 206 | 3,931 | 46.1 | 1,812 |
| Philippines | 460 | 3,318 | 61.4 | 2,037 |
| Viet Nam | 280 | 3,398 | 41.6 | 1,414 |
| Thailand | 656 | 7,190 | 60.8 | 4,372 |
| Malaysia | 142 | 10,361 | 55.4 | 5,740 |
| Cambodia | 277 | 3,585 | 39.0 | 1,398 |

GDP = gross domestic product.

Sources: IEA (2023), ADB (2022), International Monetary Fund (IMF), Cambodia, <https://www.imf.org/en/Countries/KHM> (accessed 26 December 2023).

LPG demand by province in 2040 was calculated by using the composition ratio of electricity consumption for the commercial sector in 2021 (Table 5.5).

Table 5.5. LPG Demand by the Commercial Sector by Province, 2040

| Province | Electricity Consumption | | LPG Demand Commercial | |
|-------------------|-------------------------|-----|-----------------------|-----|
| | (kwh/year) | (%) | (tonne) | (%) |
| Banteay Mean Chey | 204,563,433 | 2.7 | 11,774 | 2.7 |
| Battambang | 220,927,262 | 2.9 | 12,716 | 2.9 |
| Kampong Cham | 205,733,033 | 2.7 | 11,842 | 2.7 |
| Kampong Chhnang | 111,984,350 | 1.5 | 6,446 | 1.5 |
| Kampong Speu | 423,358,873 | 5.6 | 24,368 | 5.6 |
| Kampong Thom | 57,869,516 | 0.8 | 3,331 | 0.8 |

| Province | Electricity Consumption | | LPG Demand Commercial | |
|----------------|-------------------------|--------------|-----------------------|--------------|
| | (kwh/year) | (%) | (tonne) | (%) |
| Kampot | 120,825,288 | 1.6 | 6,954 | 1.6 |
| Kandal | 393,220,534 | 5.2 | 22,633 | 5.2 |
| Kohkong | 62,317,860 | 0.8 | 3,587 | 0.8 |
| Kratie | 117,600,218 | 1.5 | 6,769 | 1.5 |
| Mondolkiri | 15,282,536 | 0.2 | 880 | 0.2 |
| Phnom Penh | 3,732,008,813 | 49.2 | 214,808 | 49.2 |
| Preah Vihear | 18,248,379 | 0.2 | 1,050 | 0.2 |
| Prey Veng | 78,197,983 | 1.0 | 4,501 | 1.0 |
| Pursat | 59,239,103 | 0.8 | 3,410 | 0.8 |
| Ratanakiri | 71,314,107 | 0.9 | 4,105 | 0.9 |
| Siem Reap | 236,986,038 | 3.1 | 13,640 | 3.1 |
| Preah Sihanouk | 759,992,310 | 10.0 | 43,744 | 10.0 |
| Stung Treng | 21,302,059 | 0.3 | 1,226 | 0.3 |
| Svay Rieng | 311,423,153 | 4.1 | 17,925 | 4.1 |
| Takeo | 205,433,742 | 2.7 | 11,824 | 2.7 |
| Oddar Meanchey | 14,077,218 | 0.2 | 810 | 0.2 |
| Kep | 17,238,302 | 0.2 | 992 | 0.2 |
| Pailin | 34,433,166 | 0.5 | 1,982 | 0.5 |
| Tbong Khmum | 98,734,131 | 1.3 | 5,683 | 1.3 |
| Total | 7,592,311,407 | 100.0 | 437,000 | 100.0 |

kwh = kilowatt-hour.

Sources: General Department of Energy and author.

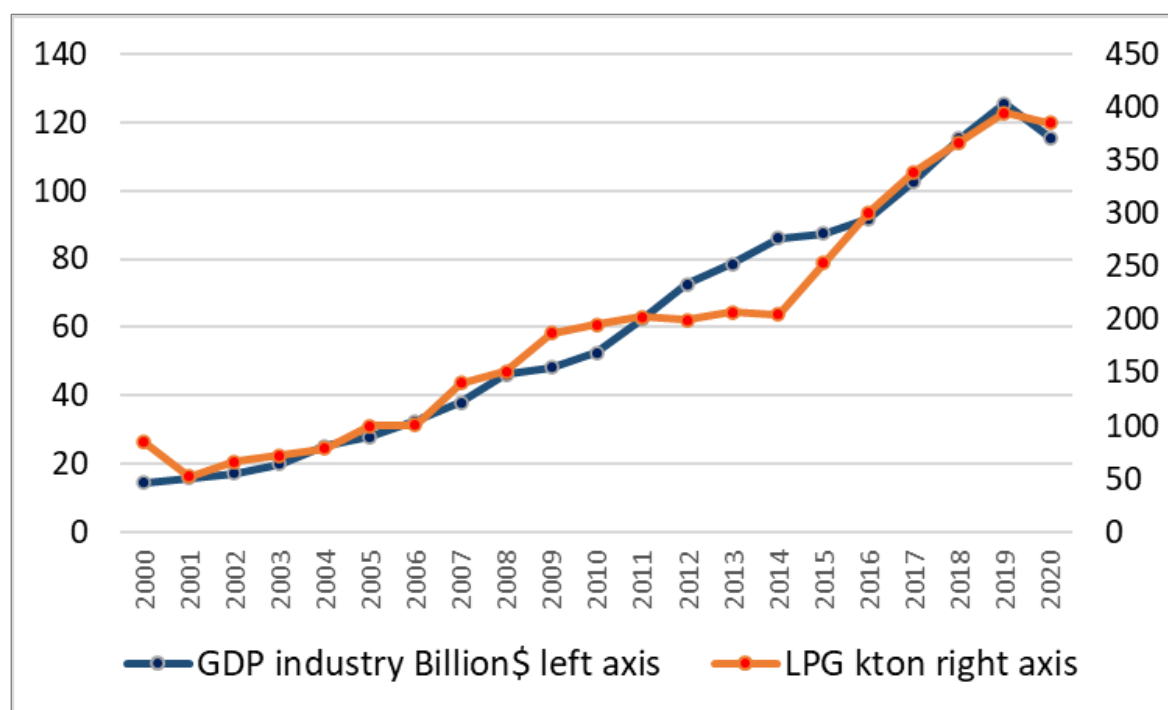
5. LPG Demand by the Industry Sector, 2040

As previously mentioned, the industrial use of LPG is limited to special uses such as metal processing, glass processing, and pottery making. It was difficult to obtain data on the number of factories, locations, and unit consumption of LPG for these industries. It is also estimated that the number of factories in these industries is still small.

By 2040, it is estimated that the above industries will increase due to industrialisation. Figure 5.4 shows a strong relationship between the GDP of the industry sector and its LPG demand in Viet Nam. Based on the GDP estimation of the industry sector and

adjustment with total LPG demand in Cambodia, Cambodia's industrial LPG demand in 2040 is estimated to be 34,556 tonnes.

Figure 5.4. Gross Domestic Product and LPG Demand by the Industrial Sector in Viet Nam



GDP = gross domestic product, kton = kilotonne.

Sources: IEA (2023), ADB (2022), International Monetary Fund (IMF), Cambodia, <https://www.imf.org/en/Countries/KHM> (accessed 26 December 2023).

Based on the above, Cambodia's LPG demand by sector in 2040 is estimated in Table 5.6.

Table 5.6. LPG Demand by Sector in 2021 and 2040

| Sector | 2021 | | 2040 | | Average Annual Growth Rate (%) |
|--------------|----------------|--------------|------------------|--------------|--------------------------------|
| | (tonne) | (%) | (tonne) | (%) | |
| Transport | 80,628 | 24.8 | 238,560 | 20.4 | 5.9 |
| Residential | 116,044 | 35.6 | 461,309 | 39.4 | 7.5 |
| Commercial | 127,000 | 39.0 | 437,000 | 37.3 | 6.7 |
| Industry | 1,946 | 0.6 | 34,556 | 2.9 | 16.3 |
| Total | 325,618 | 100.0 | 1,171,425 | 100.0 | 7.0 |

Source: Author.

The total demand for LPG will increase at an annual rate of 7.0% from 2021 to 2040, reaching 1,171,425 tonnes. The composition ratio of the residential sector will increase to 39.4% due to urbanisation and the growth of LPG consumption of households. The LPG demand of the commercial sector will also increase, and the composition ratio will be 37.3%. The LPG demand of the industry sector will increase due to industrialisation, but the composition ratio will still be small. The LPG demand for the transport sector will also increase, but the growth rate will be below the average due to EV penetration.

LPG demand by sector and by province in 2040 is shown in Table 5.7. Phnom Penh has the highest demand, at 38% of the total. The composition ratios of Banteay Mean Chey, Battambang, Kandal, Preah Sihanouk, and Siem Reap are all around 5%.

Table 5.7. LPG Demand by Sector and by Province, 2040
(tonne)

| | Transport | Residential | Commercial | Industry | Total | % |
|-------------------|-----------|-------------|------------|----------|---------|------|
| Banteay Mean Chey | 23,788 | 19,014 | 11,774 | 1,659 | 56,236 | 4.8 |
| Battambang | 28,049 | 15,081 | 12,716 | 1,697 | 57,544 | 4.9 |
| Kampong Cham | 4,616 | 10,922 | 11,842 | 832 | 28,211 | 2.4 |
| Kampong Chhnang | 3,195 | 12,075 | 6,446 | 660 | 22,376 | 1.9 |
| Kampong Speu | 11,184 | 25,793 | 24,368 | 1,865 | 63,209 | 5.4 |
| Kampong Thom | 8,202 | 12,745 | 3,331 | 738 | 25,016 | 2.1 |
| Kampot | 10,936 | 9,509 | 6,954 | 833 | 28,232 | 2.4 |
| Kandal | 2,663 | 30,373 | 22,633 | 1,692 | 57,361 | 4.9 |
| Kohkong | 1,775 | 2,197 | 3,587 | 230 | 7,789 | 0.7 |
| Kratie | 1,775 | 10,058 | 6,769 | 565 | 19,167 | 1.6 |
| Mondolkiri | 888 | 8,625 | 880 | 316 | 10,708 | 0.9 |
| Phnom Penh | 76,656 | 140,471 | 214,808 | 13,129 | 445,063 | 38.0 |
| Preah Vihear | 2,663 | 20,466 | 1,050 | 735 | 24,914 | 2.1 |
| Prey Veng | 4,261 | 10,966 | 4,501 | 600 | 20,327 | 1.7 |
| Pursat | 4,616 | 9,429 | 3,410 | 531 | 17,985 | 1.5 |
| Ratanakiri | 888 | 20,667 | 4,105 | 780 | 26,439 | 2.3 |
| Siem Reap | 24,499 | 29,370 | 13,640 | 2,052 | 69,561 | 5.9 |
| Preah Sihanouk | 5,716 | 7,493 | 43,744 | 1,731 | 58,684 | 5.0 |
| Stung Treng | 1,243 | 9,919 | 1,226 | 377 | 12,764 | 1.1 |

| | Transport | Residential | Commercial | Industry | Total | % |
|----------------|----------------|----------------|----------------|---------------|------------------|--------------|
| Svay Rieng | 4,083 | 12,052 | 17,925 | 1,035 | 35,095 | 3.0 |
| Takeo | 9,231 | 15,932 | 11,824 | 1,124 | 38,112 | 3.3 |
| Oddar Meanchey | 3,195 | 9,945 | 810 | 424 | 14,374 | 1.2 |
| Kep | 355 | 1,252 | 992 | 79 | 2,679 | 0.2 |
| Pailin | 1,065 | 3,021 | 1,982 | 184 | 6,253 | 0.5 |
| Tbong Khmum | 3,018 | 13,935 | 5,683 | 688 | 23,324 | 2.0 |
| Total | 238,560 | 461,309 | 437,000 | 34,556 | 1,171,425 | 100.0 |

Chapter 6

Optimal Cambodia LPG Supply Chain in 2040

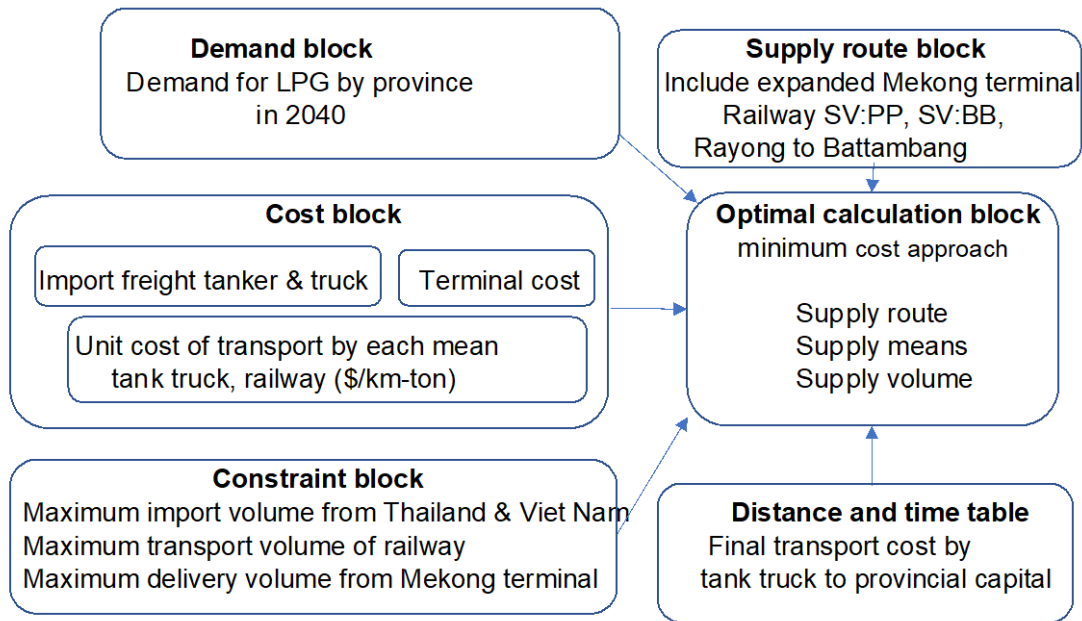
This chapter examines the optimal supply chain for LPG demand in Cambodia, which will increase 3.6 times to 2040, using a cost minimum approach. The study method was to set the total transport cost from importation to each provincial capital by supply chain. It used an LP model to create a cost-minimum supply chain based on demand estimation by province in 2040 and supply constraints for each supply chain.

In addition to examining the current four supply chains, several case studies were conducted.

1. Structure of Logistics Optimisation

Figure 6.1 consists of demand block, supply route block, cost block, constraint block, distance and timetable, and optimal calculation block.

Figure 6.1. Structure of Logistics Optimisation LP Model



Source: Author.

Assumptions are the following. For the existing supply chain, there is direct delivery from the Mekong terminal, direct delivery from the Sihanoukville terminal, land importation for Viet Nam via the Bavet checkpoint, and land importation from Thailand via the Poipet

checkpoint. For additional supply chains, there is direct delivery from an expanded Mekong terminal, utilisation of domestic rail transport, utilisation of Thai rail transport, utilisation of large tankers at the Sihanoukville terminal, and utilisation of the new canal terminal.

Regarding the transport cost from importation origin to the final destination of a provincial capital, it is assumed that this includes the import freight, truck import cost, primary terminal cost, second terminal cost, and transfer cost to the second terminal; and the final delivery cost to 25 provincial capitals by tank trucks according to distance. The transport cost is calculated based on the distance and tonnage for each transport mode based on Table 6.1.

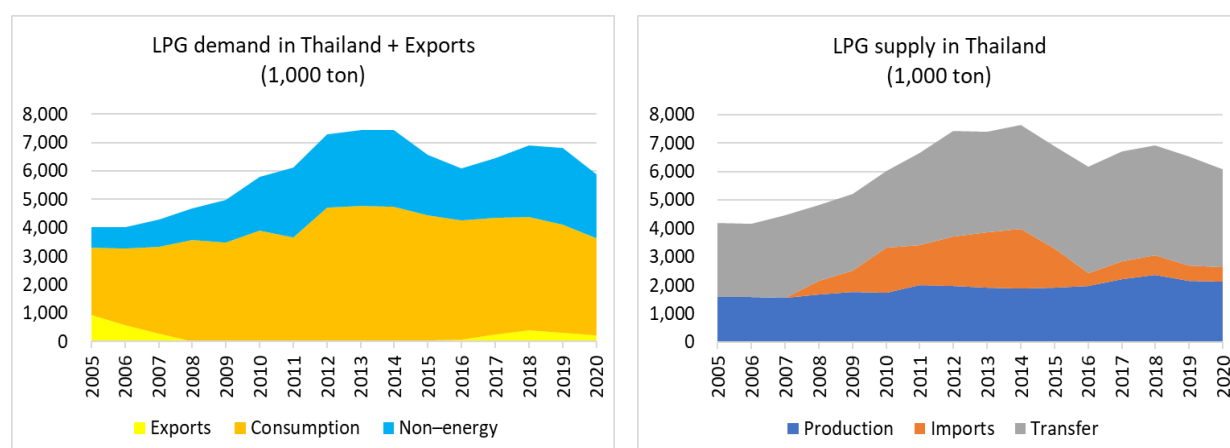
Table 6.1. Unit Cost by Each Transport Mode
(\$/tonne-km)

| Ship | | Railway | Tank Truck | |
|----------------|----------------|---------|--------------------------------|-------------------------------|
| (2,000 tonnes) | (1,000 tonnes) | | (less than 350 km, one driver) | (350 km or more, two drivers) |
| 0.02649 | 0.04967 | 0.06087 | 0.08696 | 0.10435 |

km = kilometre.
Source: Author.

Regarding constraints, it is assumed that the supply volume from the Mekong terminal consists of a 1,000-tonne tanker every 2 days; from Viet Nam, 200,000 tonnes per year; and from Thailand, 20,000 tonnes per year.

Figure 6.2. Supply and Demand for LPG in Thailand, 2005–2020

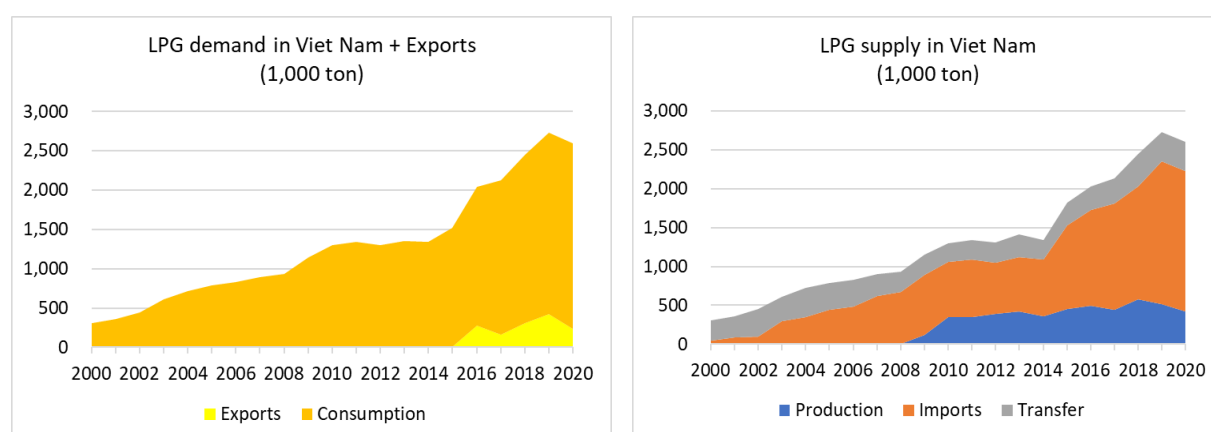


Source: IEA (2023).

In Thailand, final consumption and non-energy demand (i.e. petrochemical raw materials) increased from 2005 to 2014 but appear to have peaked (Figure 6.2). Supply during periods of increased demand was met by increasing product imports. There were no major changes in production at refineries or transfer volume from natural gas fields. The export volume to Cambodia will thus be estimated to stay at the current level.

A carbon-neutral strategy is likely to slow growth in oil demand, making plans for new refineries unlikely. The refinery upgrade plan announced by PTT will reduce the yield of heavy oil and increase the production of petrochemical raw materials. Therefore, a large increase in LPG export volume is unlikely.

Figure 6.3. Supply and Demand for LPG in Viet Nam, 2000–2020



Source: IEA (2023).

LPG consumption in Viet Nam increased an average of 10.8% per year between 2000 and 2020, and it is presumed that demand will continue to grow (Figure 6.3). Currently, Viet Nam has two refineries, but their total capacity is only 60% of the domestic demand of petroleum products. Two more refineries are planned to be built by 2040. However, the increase in production may be absorbed by the increase in domestic demand. Therefore, it is unlikely that the LPG export volume will change significantly from the current situation. The export volume to Cambodia was thus estimated to stay at the current level.

2. Case Studies Using the Optimisation Model

2.1. Business-as-Usual Case

This is the optimal solution if only using the current four supply chains. The Mekong terminal is suitable for around Phnom Penh, the West, and North-East due to short distances, but the supply volume is the constraint. Direct import from Viet Nam is competitive for around Phnom Penh and the North-East, but the supply volume is the constraint. Direct import from Thailand is competitive for the West, but the supply volume

is the constraint. Therefore, the share of the Sihanoukville terminal would reach 65.9% of the total.

Table 6.2. Business-as-Usual Case

| Constraint | tonne/year | % | Supply Route |
|------------|------------------|--------------|---|
| 180,000 | 180,000 | 15.4 | Direct from Mekong terminal |
| 1,200,000 | 771,425 | 65.9 | Direct from Sihanoukville terminal |
| 200,000 | 200,000 | 17.1 | Direct import and delivery from Viet Nam by tank truck |
| 20,000 | 20,000 | 1.7 | Direct import and delivery from Thailand by tank truck |
| | 1,171,425 | 100.0 | Cost = \$56,228,932 Compared with BAU: 0.0% |

BAU = business as usual.

Source: Author.

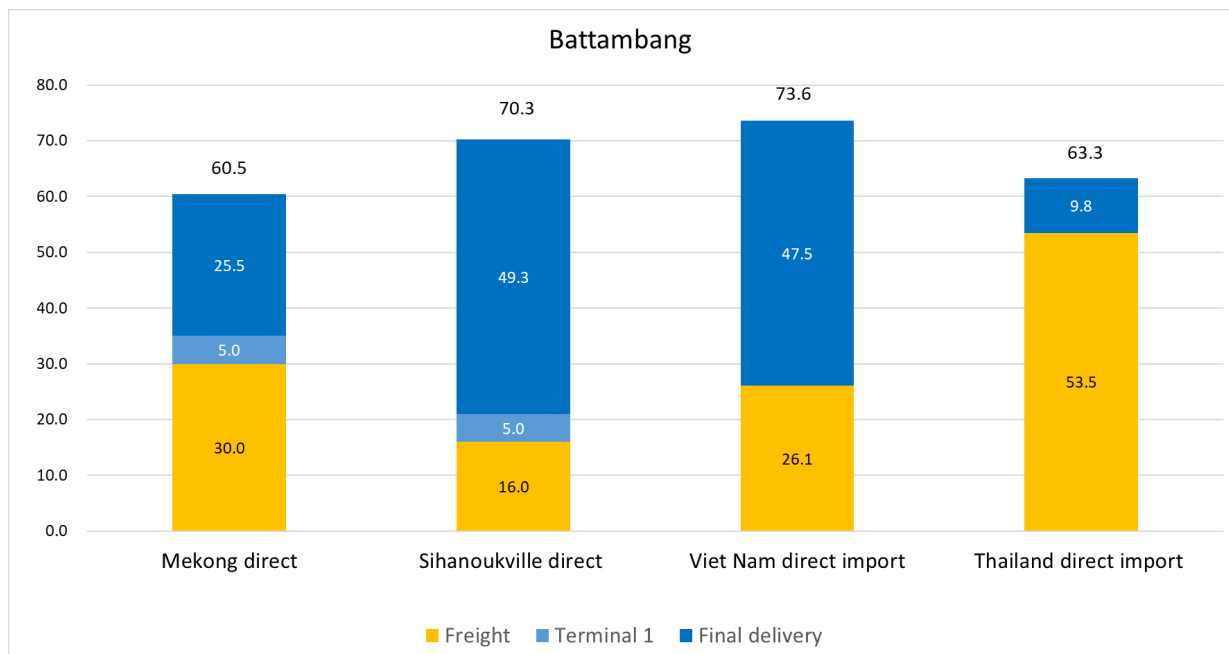
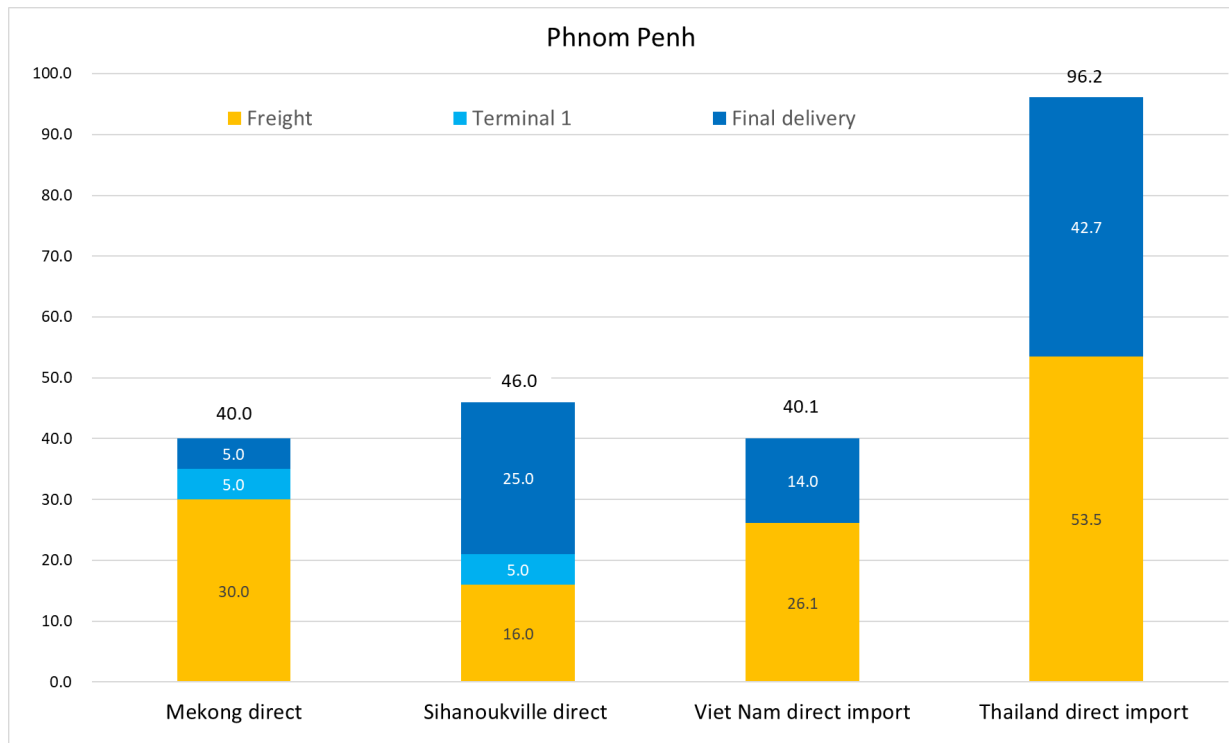
Table 6.3. Breakdown of LPG Supply Areas

| Area | Provinces |
|-------------------|---|
| Around Phnom Penh | Kampong Cham, Kampong Chhnang, Kampong Thom, Kandal, Phnom Penh, Prey Veng, Pursat, Svay Rieng, Tbong Khmom |
| West Area | Banteay Meanchey, Battambang, Siem Reap, Oddar Meanchey, Pailin |
| North-East | Kratie, Ratanakiri, Stung Treng, Mondolkiri, Preah Vihear |
| Sihanoukville | Kampong Speu, Kampot, Kohkong, Preah Sihanouk, Takeo, Kep |

Source: Author.

Figure 6.4 shows the total LPG transport cost of Phnom Penh and Battambang by existing supply routes.

Figure 6.4. LPG Transport Costs to Provincial Capitals by the Current Four LPG Supply Routes (\$/tonne)



Source: Author.

2.2. Case 1: Expanded Mekong Terminal

Since the Mekong terminal is suitable for transporting LPG around Phnom Penh, the West, and the North-East due to short distances, Case 1 examines the Mekong terminal's capacity expansion to 360,000 tonnes from 180,000 tonnes.

The supply volume from the Mekong terminal would increase, and the supply volume from the Sihanoukville terminal would decrease. The transport cost would decrease 1.9% compared to business as usual (BAU).

Table 6.4. Case 1 – Expanded Mekong Terminal

| Constraint | tonne/year | % | Supply Route | |
|------------|------------------|--------------|--|---------------------------------|
| 360,000 | 360,000 | 30.7 | Direct from Mekong terminal | |
| 1,200,000 | 591,425 | 50.5 | Direct from Sihanoukville terminal | |
| 200,000 | 200,000 | 17.1 | Direct import and delivery from Viet Nam by tank truck | |
| 20,000 | 20,000 | 1.7 | Direct import and delivery from Thailand by tank truck | |
| | 1,171,425 | 100.0 | Cost = \$55,148,503 | Compared with BAU: –1.9% |

| Supply Route | Around Phnom Penh | West | North-East | Sihanoukville | Total |
|--|-------------------|----------------|---------------|----------------|------------------|
| Direct from Mekong terminal | 335,086 | 0 | 24,914 | 0 | 360,000 |
| Direct from Sihanoukville terminal | 97,722 | 0 | 0 | 198,705 | 296,427 |
| Transfer from Sihanoukville to Phnom Penh by rail | 111,029 | 0 | 0 | 0 | 111,029 |
| Transfer from Sihanoukville to Battambang by rail | 0 | 183,969 | 0 | 0 | 183,969 |
| Direct import and delivery from Viet Nam by tank truck | 130,922 | 0 | 69,078 | 0 | 200,000 |
| Direct import and delivery from Thailand by tank truck | 0 | 20,000 | 0 | 0 | 20,000 |
| Total | 674,759 | 203,969 | 93,992 | 198,705 | 1,171,425 |

BAU = business as usual.

Source: Author.

2.3. Case 2: Utilisation of Domestic Railway

As shown previously, utilisation of domestic rail from Sihanoukville to Battambang through Phnom Penh is effective for some LPG delivery. In Case 2, the maximum volume is set to 259,200 tonnes per year from Sihanoukville to Phnom Penh and from Sihanoukville to Battambang (i.e. with 24-tonne vehicles, 30 cars, over 360 days).

The transfer volume from Sihanoukville to Phnom Penh by rail would reach 9.5%, all covering around Phnom Penh (Table 6.5). The transfer volume from Sihanoukville to Battambang would reach 15.7%, all covering the West. The supply volume from Sihanoukville terminal would decrease, and the total transport cost would decrease 5.0% compared with BAU.

Table 6.5. Case 2 – Utilisation of Domestic Rail

| Constraint | tonne/year | % | Supply Route | |
|------------|------------------|--------------|--|---------------------------------|
| 360,000 | 360,000 | 30.7 | Direct from Mekong terminal | |
| 1,200,000 | 296,427 | 25.3 | Direct from Sihanoukville terminal | |
| 259,200 | 111,029 | 9.5 | Transfer from Sihanoukville to Phnom Penh by rail | |
| 259,200 | 183,969 | 15.7 | Transfer from Sihanoukville to Battambang by rail | |
| 200,000 | 200,000 | 17.1 | Direct import and delivery from Viet Nam by tank truck | |
| 20,000 | 20,000 | 1.7 | Direct import and delivery from Thailand by tank truck | |
| | 1,171,425 | 100.0 | Cost = \$53,419,324 | Compared with BAU: -5.0% |

| Supply Route | Around Phnom Penh | West Area | North-East | Sihanoukville | Total |
|--|-------------------|----------------|---------------|----------------|------------------|
| Direct from Mekong terminal | 335,086 | 0 | 24,914 | 0 | 360,000 |
| Direct from Sihanoukville terminal | 97,722 | 0 | 0 | 198,705 | 296,427 |
| Transfer from Sihanoukville to Phnom Penh by rail | 111,029 | 0 | 0 | 0 | 111,029 |
| Transfer from Sihanoukville to Battambang by rail | 0 | 183,969 | 0 | 0 | 183,969 |
| Direct import and delivery from Viet Nam by tank truck | 130,922 | 0 | 69,078 | 0 | 200,000 |
| Direct import and delivery from Thailand by tank truck | 0 | 20,000 | 0 | 0 | 20,000 |
| Total | 674,759 | 203,969 | 93,992 | 198,705 | 1,171,425 |

BAU = business as usual.

Source: Author.

2.4. Case 3: Utilisation of Large Tankers at the Sihanoukville Terminal

Regarding imports at Sihanoukville, import freight can be reduced by increasing the size of the tankers. In Case 3, import freight at Sihanoukville is set to -\$5 in the LP model.

As a result, supply volume by using domestic rail would increase. The transfer volume from Sihanoukville to Phnom Penh by rail would reach 11.5%, all covering around Phnom Penh. The transfer volume from Sihanoukville to Battambang would reach 16.2%, all around the West. The supply volume from Viet Nam and Thailand would decrease, and the total transport cost would decrease 10.3% compared with BAU.

Table 6.6. Case 3 – Utilisation of Large Tankers at Sihanoukville Terminal

| Constraint | tonne/year | % | Supply Route | |
|------------|------------------|--------------|--|-----------------------------------|
| 360,000 | 360,000 | 30.7 | Direct from Mekong terminal | |
| 1,200,000 | 296,427 | 25.3 | Direct from Sihanoukville terminal | |
| 259,200 | 134,993 | 11.5 | Transfer from Sihanoukville to Phnom Penh by rail | |
| 259,200 | 189,594 | 16.2 | Transfer from Sihanoukville to Battambang by rail | |
| 200,000 | 176,036 | 15.0 | Direct import and delivery from Viet Nam by tank truck | |
| 20,000 | 14,374 | 1.2 | Direct import and delivery from Thailand by tank truck | |
| | 1,171,425 | 100.0 | Cost = \$50,456,013 | Compared with BAU: – 10.3% |

| Supply Route | Around Phnom Penh | West Area | North-East | Sihanoukville | Total |
|--|-------------------|----------------|---------------|----------------|------------------|
| Direct from Mekong terminal | 335,086 | 0 | 24,914 | 0 | 360,000 |
| Direct from Sihanoukville terminal | 97,722 | 0 | 0 | 198,705 | 296,427 |
| Transfer from Sihanoukville to Phnom Penh by rail | 134,993 | 0 | 0 | 0 | 134,993 |
| Transfer from Sihanoukville to Battambang by rail | 0 | 189,594 | 0 | 0 | 189,594 |
| Direct import and delivery from Viet Nam by tank truck | 106,957 | 0 | 69,078 | 0 | 176,036 |
| Direct import and delivery from Thailand by tank truck | 0 | 14,374 | 0 | 0 | 14,374 |
| Total | 674,759 | 203,969 | 93,992 | 198,705 | 1,171,425 |

BAU = business as usual.

Source: Author.

2.5. Case 4: Utilisation of a New Canal Terminal

A new canal is planned from the Bassac River to Kampot. Details such as water depth and river width are unknown. If a terminal is built near Phnom Penh along the new canal and tankers can transport imports using the new canal, it would become a supply chain equivalent to the Mekong terminal. Case 4 is below for reference.

The new canal would have a total length of 180 km, so the transport distance would be correspondingly longer. Therefore, import freight would be larger than that from the Sihanoukville terminal. As a result of the study, it is found that using 2,000-tonne tankers in the new canal supply route would be valid (Table 6.7). For comparison with Case 1, the supply constraints were both set to 180,000 tonnes.

Table 6.7. Case 4 – Utilisation of New Canal Terminal

| Constraint | tonne/year | % | Supply Route | |
|------------|------------------|--------------|--|---------------------------------|
| 180,000 | 180,000 | 15.4 | Direct from Mekong terminal | |
| 1,200,000 | 296,427 | 25.3 | Direct from Sihanoukville terminal | |
| 259,200 | 111,029 | 9.5 | Transfer from Sihanoukville to Phnom Penh by rail | |
| 259,200 | 183,969 | 15.7 | Transfer from Sihanoukville to Battambang by rail | |
| 180,000 | 180,000 | 15.4 | Direct from New Canal terminal | |
| 200,000 | 200,000 | 17.1 | Direct import and delivery from Viet Nam by tank truck | |
| 20,000 | 20,000 | 1.7 | Direct import and delivery from Thailand by tank truck | |
| | 1,171,425 | 100.0 | Cost = \$51,763,324 | Compared with BAU: -7.9% |

| Supply Route | Around Phnom Penh | West Area | North-East | Sihanoukville | Total |
|--|-------------------|----------------|---------------|----------------|------------------|
| Direct from Mekong terminal | 180,000 | 0 | 0 | 0 | 180,000 |
| Direct from Sihanoukville terminal | 97,722 | 0 | 0 | 198,705 | 296,427 |
| Transfer from Sihanoukville to Phnom Penh by rail | 111,029 | 0 | 0 | 0 | 111,029 |
| Transfer from Sihanoukville to Battambang by rail | 0 | 183,969 | 0 | 0 | 183,969 |
| Direct from New canal terminal | 155,086 | 0 | 24,914 | 0 | 180,000 |
| Direct import and delivery from Viet Nam by tank truck | 130,922 | 0 | 69,078 | 0 | 200,000 |
| Direct import and delivery from Thailand by tank truck | 0 | 20,000 | 0 | 0 | 20,000 |
| | 674,759 | 203,969 | 93,992 | 198,705 | 1,171,425 |

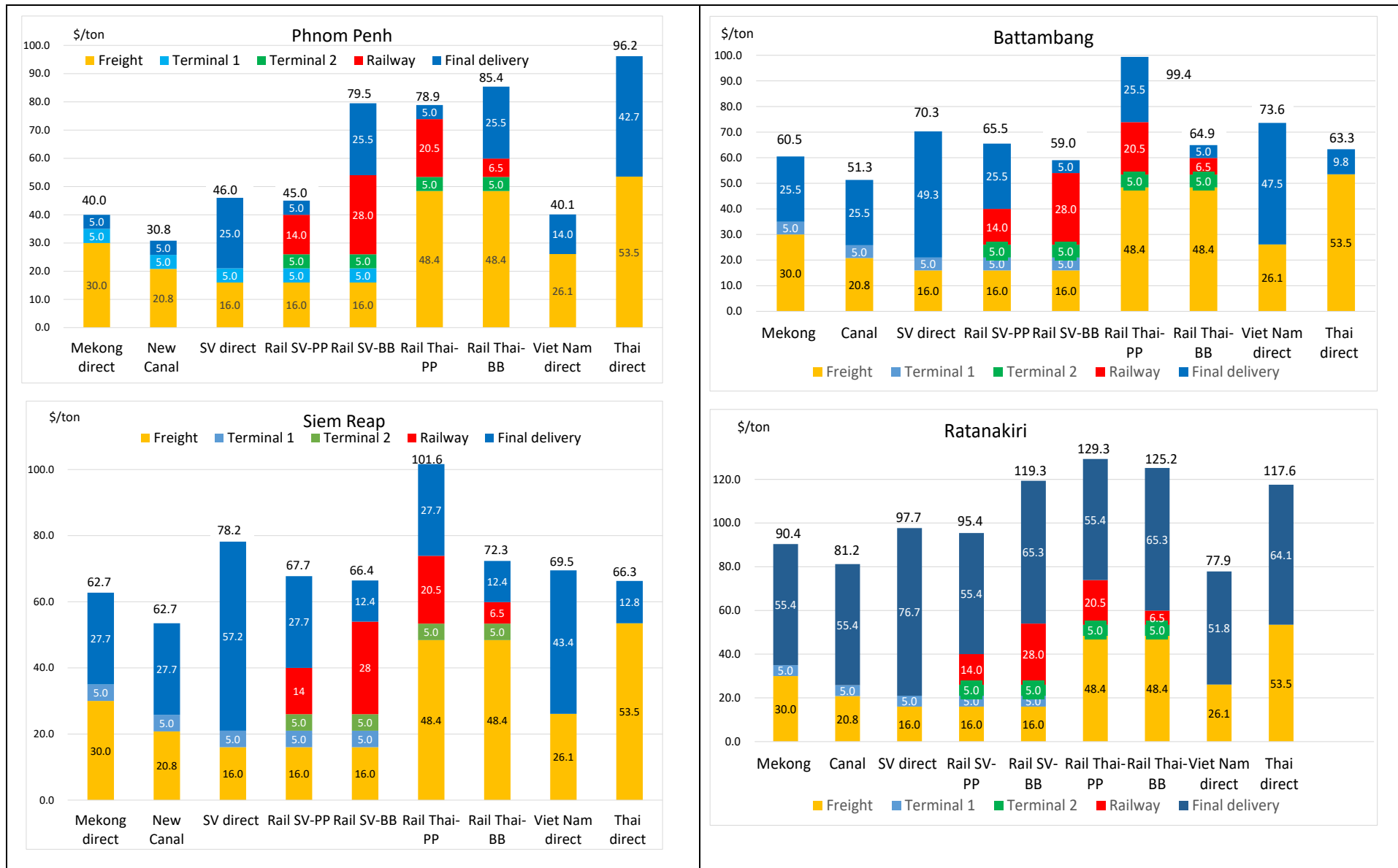
BAU = business as usual.

Source: Author.

2.6. Consideration of Rail Imports from Rayong, Thailand

The distance from Rayong to Poipet, Thailand is 320 km by rail, and the distance from Poipet, Thailand to Battambang, Cambodia by rail is 113 km. A second terminal at Battambang is needed. Yet direct import from Rayong by tank truck would not need a second terminal, as the land route from Rayong to Poipet is only 270 km. Thus, this Thailand rail supply route was not selected in the LP model.

Figure 6.5. LPG Transport Costs to Provincial Capitals by All LPG Supply Routes



BB = Battambang, PP = Phnom Penh, SV = Sihanoukville.

Source: Author.

Chapter 7

Key Findings and Recommendations

1. Key Findings

Chapter 2 reviewed the existing LPG supply chain in Cambodia. Cambodia's LPG supply is entirely covered by product imports. LPG imports in 2019 reached a record high of 340,958 tonnes but decreased to 322,136 tonnes in 2020 due to the COVID-19 pandemic. In 2021, there was a slight recovery to 325,618 tonnes. According to an LPG company's delivery volume survey for 2021, there are four import routes in Cambodia:

- (i) **Import by tankers at the Sihanoukville terminal (21.3% of total imports).** Imported LPG at the Sihanoukville terminal is transported to LPG service stations, bottling stations, and second terminals nationwide by tank trucks. Cylinders filled at bottling stations are delivered to homes and restaurants, with retailers responsible for delivery.
- (ii) **Import by tankers at the Mekong terminal (7.5% of total imports).** The supply chain is the same as that in Sihanoukville, but no company owns a second terminal. Thus, imported LPG along Mekong River is transported to LPG service stations and bottling stations.
- (iii) **Direct import by tank truck from Viet Nam (65.4% of total imports).** Direct land import companies do not have any import terminals or second terminals because the tank trucks are changed at the Viet Nam–Cambodia border. The LPG is then directly transported to other companies' LPG service stations and bottling stations, making this option competitive due to low costs.
- (iv) **Direct import by tank trucks from Thailand (5.8% of total imports).** Due to the long distance to the border, the import area is limited to a part of the northern provinces in Cambodia.

Currently, the Viet Nam route is dominant in terms of delivering LPG, followed by the Sihanoukville route, Mekong route, and Thailand route. Delivering distances are a major factor in this result.

Chapter 3 summarised the LPG consumption survey in Cambodia conducted by CDRI, which covered LPG consumption in the industry, transport, residential, and commercial sectors. Major outcomes of the survey are as follows.

- (i) **Industry sector.** The survey targeted 70 enterprises that use LPG or other fuel sources for heating boilers or furnaces – 40 in food production, 15 in beverage/brewery, and 15 in wood/paper production in Phnom Penh, Kandal, and Kampong Speu. Most of the respondents were in Phnom Penh, and several were in

Kandal. LPG consumption in the industrial sector is not widely seen in factories due to the relatively higher price of LPG compared to other fuels. Factories in Cambodia are still dependent on biomass and diesel oil for their heating demands.

- (ii) **Transport sector (road).** There are two types of vehicles that consume LPG as their transport fuel – 3-wheel tuk-tuks and 4-wheel vehicles. The 3-wheel tuk-tuks run mainly in cities and have a monthly fuel economy of 13.8 km/litre, with a monthly average driving distance of 2,653 km. Four-wheel vehicles run longer distances, such as for interprovincial transport. Their monthly average fuel economy is 6.25 km/litre, and their monthly average driving distance is 7,800 km. The following formula was used to estimate total LPG consumption in the road transport sector:

$$\text{LPG consumption for 3 – wheel} = \frac{\text{driving distance (2,653)}}{\text{fuel economy (13.8) x months (12)}} \times \text{number of 3 – wheel stock}$$

However, vehicle stock data in Cambodia have not yet been prepared, so the total LPG consumption for road vehicle activities cannot be estimated.

- (iii) **Residential sector.** The residential sector in Cambodia consumes LPG for cooking, but cooking with biomass is still dominant in rural areas. According to the LPG consumption survey, urban areas consume 5.5 kg of LPG per month, while rural areas consume 2.5 kg. LPG cassettes are still the dominant LPG containers both in urban and rural areas. However, these results may be overestimated, especially in rural areas. Thus, when total LPG consumption in the residential sector using the survey results is estimated as LPG unit consumption, overestimation may have occurred.
- (iv) **Commercial sector.** This sector covers three types of buildings: hotels, restaurants, and malls/supermarkets. Hotels consume 125 kg of LPG (0.021 kg/m²); restaurants, 236 kg (0.710 kg/m²); and malls/supermarkets, 300 kg (0.060 kg/m²). If the floor area of 4- and 5-star hotels were available, total LPG consumption of hotels could be estimated. Yet there are no official data of this kind in Cambodia.

Chapter 4 estimated current provincial LPG demand in 2021. For the road transport sector, based on the number of LPG service stations per province and delivery amount of LPG, provincial LPG demand for road transport use was estimated. For the residential sector, based on the number of households per province and LPG demand for residential areas, provincial LPG demand for the residential use was estimated. For the commercial sector, referring to correlation between GDP per capita and LPG consumption in the commercial sectors of neighbouring countries and provincial electricity consumption, provincial LPG demands for commercial use were estimated. For the industry sector, no LPG consumption was assumed.

Based on the provincial LPG consumption by sectors in 2021, Chapter 5 forecasted future provincial LPG demand by sector. For the road transport sector, first, the number of LPG service stations and LPG demand per service station were forecasted until 2040 applying

a non-linear function based on historical data and increase of GDP per capita, respectively. After that, EV penetration was included, reducing LPG demand in the road transport sector. For the residential sector, referring to the future population growth rate and increase of GDP per capita as well as a population shift from rural to urban areas, provincial LPG demands for residential use were forecasted. For the commercial sector, the same approach for estimation in 2021 was applied to forecast provincial LPG demand for commercial use until 2040 based on GDP per capita in 2040.

Chapter 6 sought optimal (i.e. cost minimum) LPG supply routes from LPG importation places – Sihanoukville, Mekong River, and borders of Thailand and Viet Nam – to provincial capitals using provincial LPG demand in 2040. Case 2 emerged as the ideal and included rail transport of LPG from Sihanoukville to Phnom Penh and Sihanoukville to Battambang. The objective function would decrease 5% from BAU, and LPG tank truck transport from Sihanoukville would decrease from 50% of Case 1 to 25%. The LPG import amount at Sihanoukville of Cases 1 and 2 would be 591,000 tonnes, so large LPG tankers must be available. The objective function of Case 2 would decrease to 10% from BAU.

2. Policy Recommendations

Based on the key findings mentioned above, the following policy recommendations are extracted:

- (i) LPG demand in the residential sector will increase significantly to 2040 due to urbanisation. However, more than 7 million people will still live in rural areas. Those in rural areas should still be encouraged to shift from biomass to LPG for cooking to maintain healthy conditions (i.e. no smoke in houses) and to reduce time in cooking. Government support will be necessary, such as by providing LPG cooking stoves to villages or subsidising LPG cassettes.
- (ii) A recycling system for LPG cassettes is also important. When those in rural areas purchase new LPG cassettes, they could return old cassettes to LPG retailers. LPG supply companies could then collect the old cassettes from the LPG retailers to refill them at their bottling stations, subsequently resupplying full cassettes to the LPG retailers.
- (iii) Currently, LPG delivery is fully dependent on small LPG tank trucks. To 2040, however, LPG demand will increase 3.6 times from 2019. Consequently, large LPG transport systems such as by rail with secondary terminals are suggested. Due to the mid-size of LPG demand to 2040, an LPG pipeline system for Cambodia is not recommended.

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Appendix

Data Histograms and Associated Tables

A. Transport Sector

Figure A.1. Average Driving Distance, LPG Consumption, and Fuel Economy of 3- and 4-Wheel Vehicles Histogram

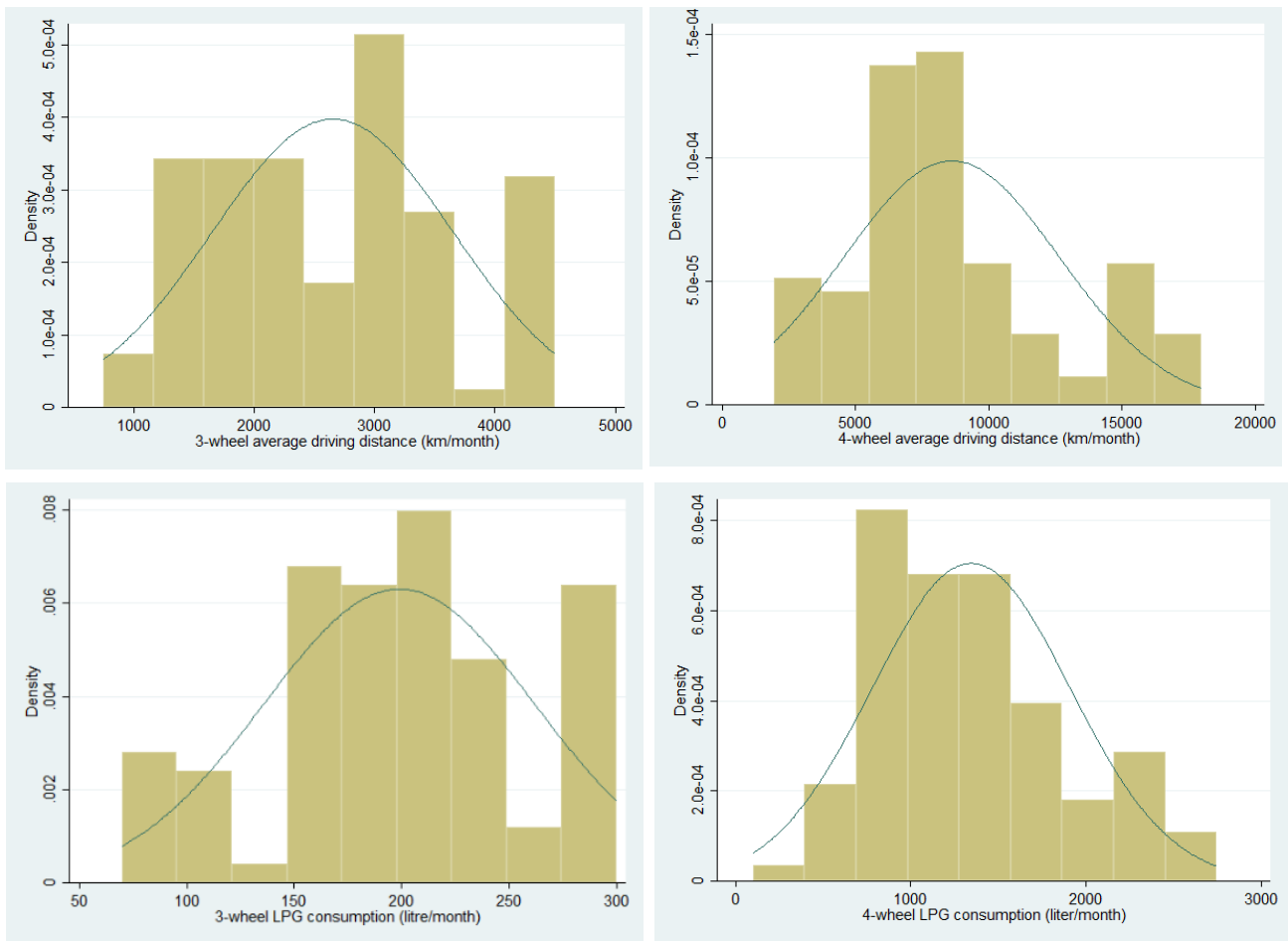
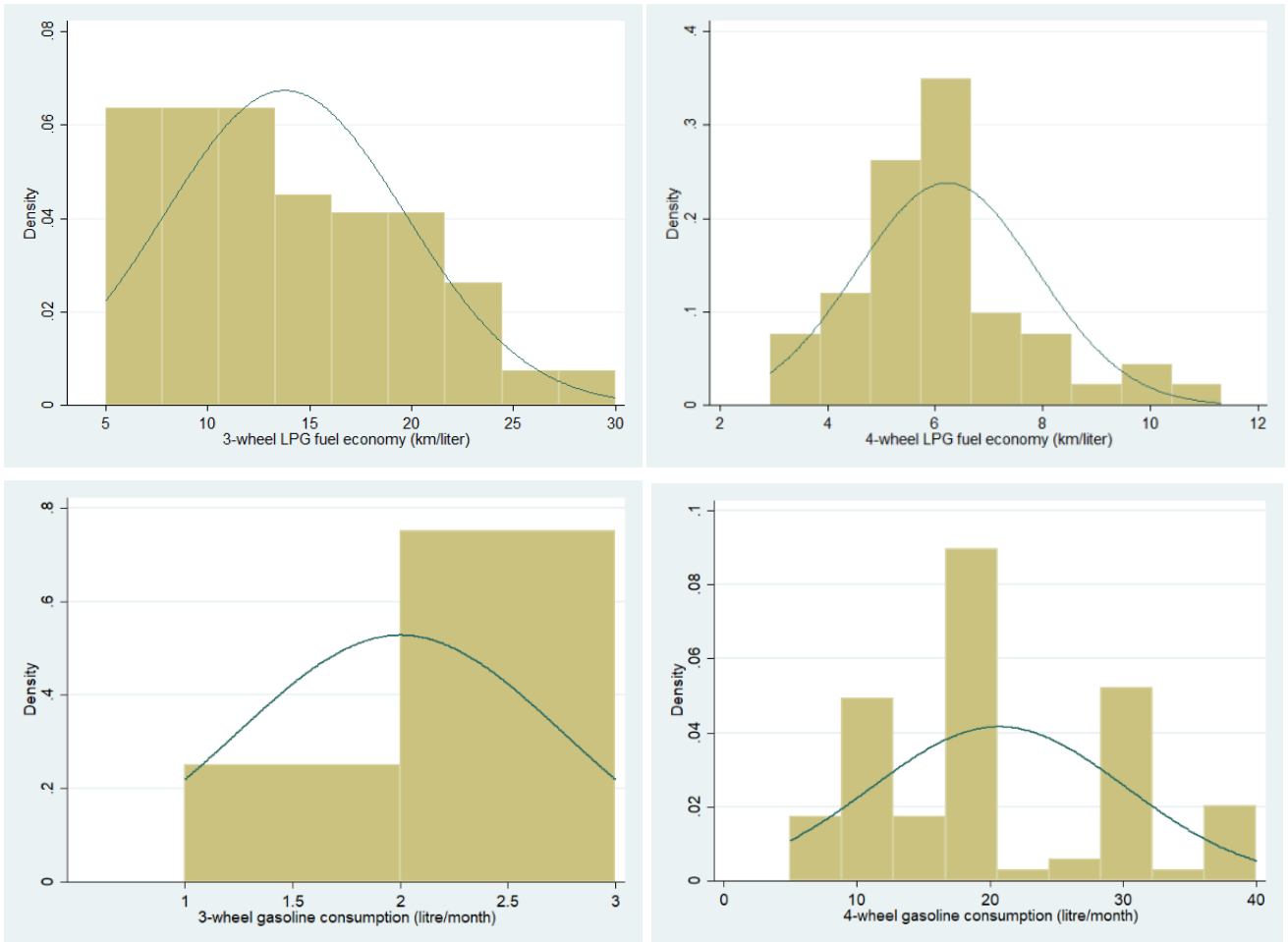


Figure A.1. *Continued*



km = kilometre.

Source: Author.

Table A.1. Observations, Skewness, Mean, and Median of Average Driving Distance, LPG Consumption, Gasoline Consumption, and Fuel Economy of 3- and 4-Wheel Vehicles

| | 3-Wheel | | | | 4-Wheel | | | |
|--------------|-----------------------|---------------------|---------------------|--------------------------|-----------------------|---------------------|---------------------|--------------------------|
| | Driving Distance (km) | LPG Consumption (l) | Fuel Economy (km/l) | Gasoline Consumption (l) | Driving Distance (km) | LPG Consumption (l) | Fuel Economy (km/l) | Gasoline Consumption (l) |
| Observations | 98 | 98 | 96 | 8 | 98 | 95 | 98 | 89 |
| Skewness | 0.292 | (0.005) | 0.4945 | 0 | 0.667 | 0.52 | 0.68 | 0.318 |
| Mean | 2,653 | 199 | 13.8 | 2 | 8,610 | 1,345 | 6.22 | 21 |
| Median | 2,700 | 210 | 12.5 | 2 | 7,800 | 1,200 | 6.25 | 20 |

km = kilometre, l = litre.

Source: Author.

B. Residential Sector

Figure A.2. Histogram of Monthly Can Consumption, Average LPG, LPG Intensity, and Electricity Consumption in Urban Areas, Rural Areas, and Overall

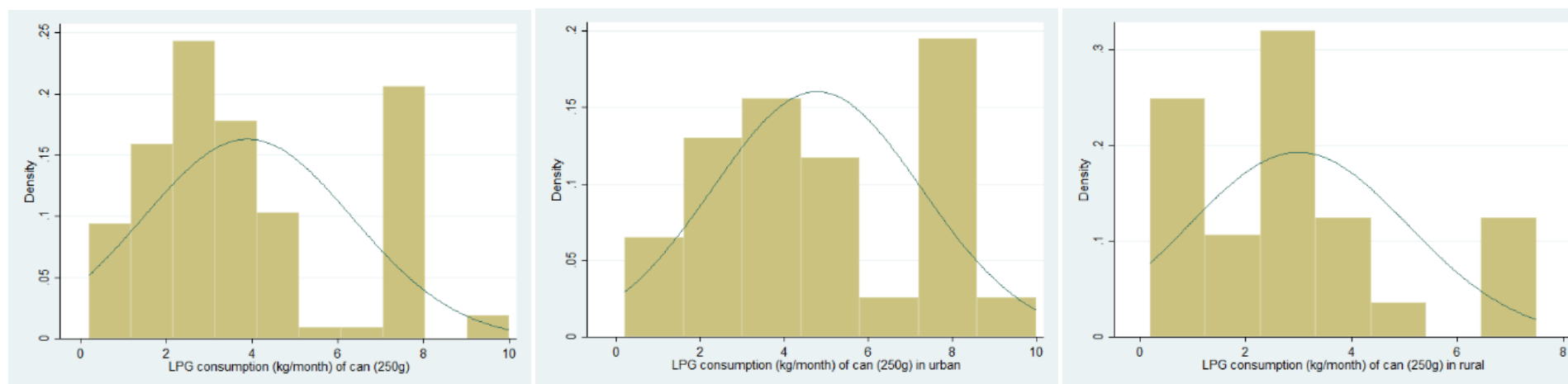


Figure A.2. *Continued*

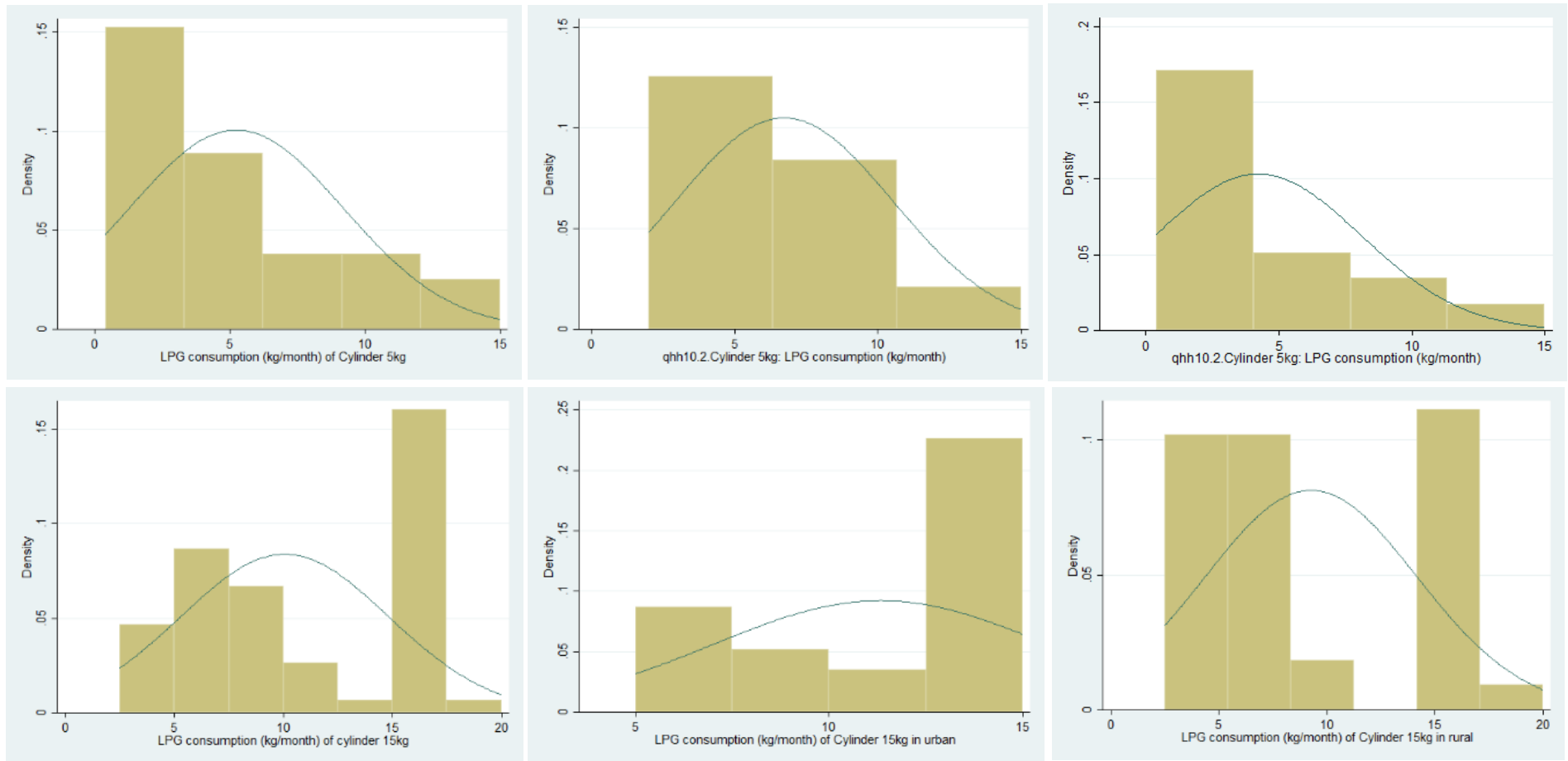


Figure A.2. *Continued*

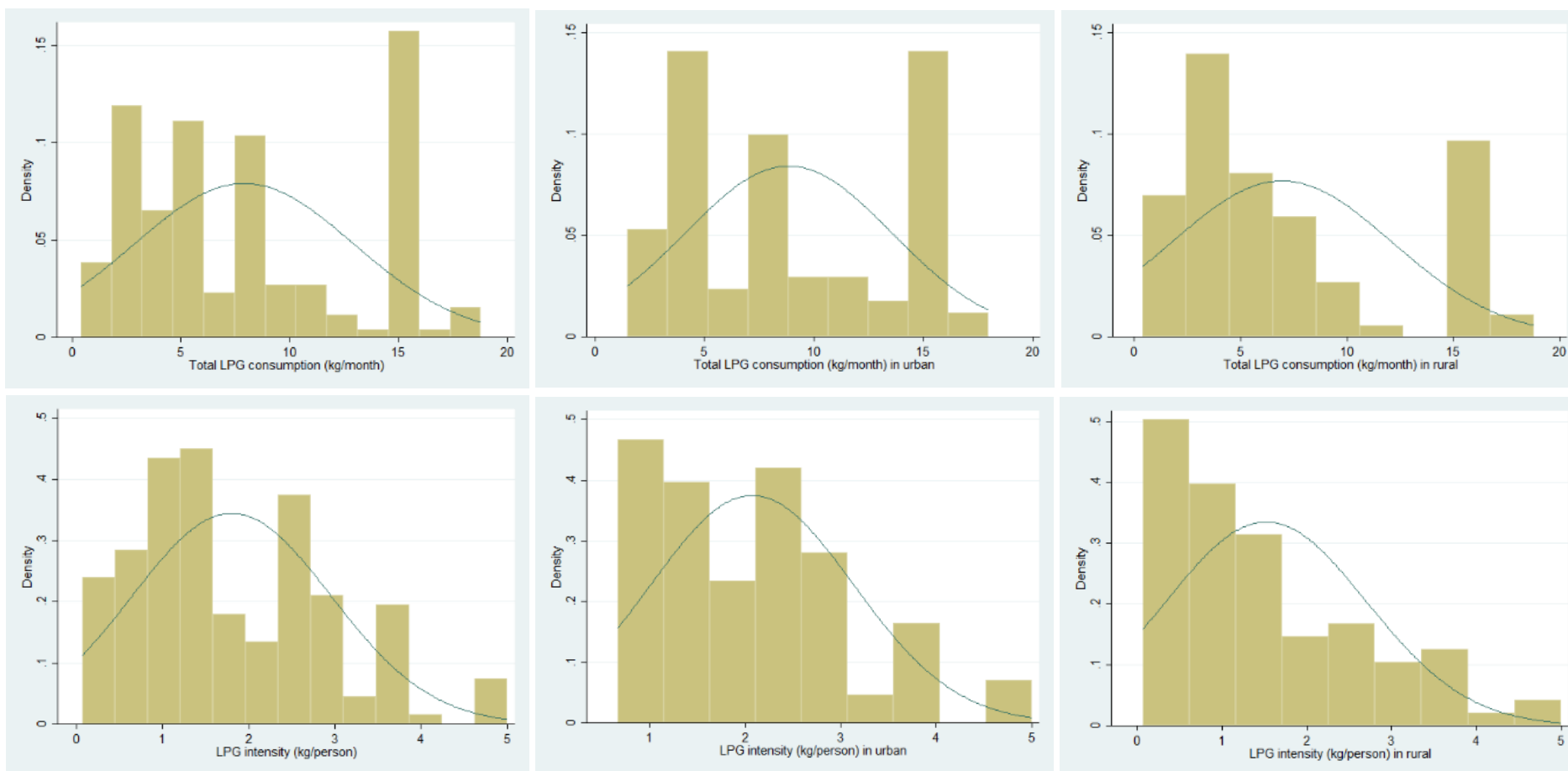
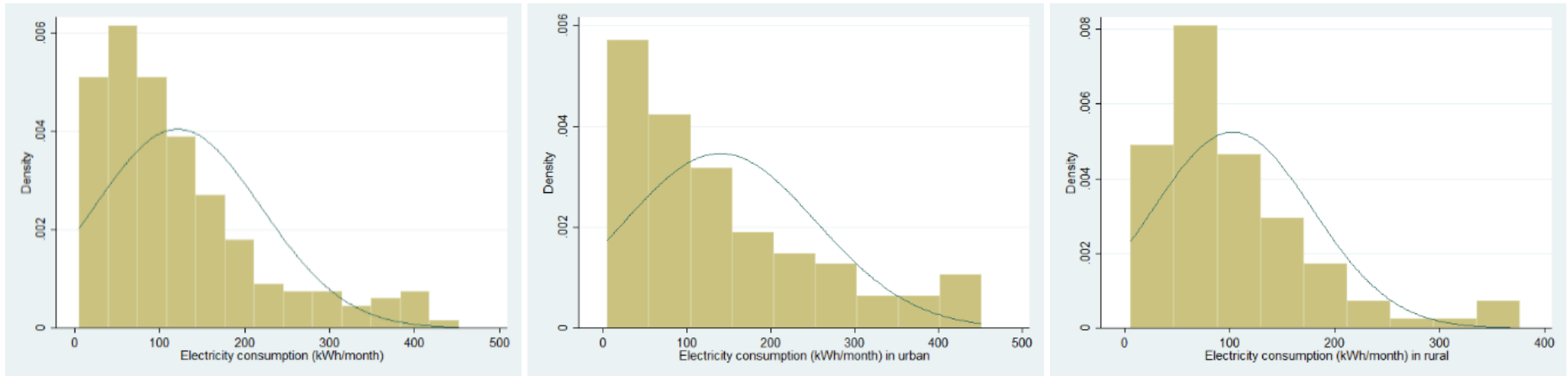


Figure A.2. *Continued*



g = gram, kg = kilogram, kWh = kilowatt-hour.
Source: Author.

Table A.2. Observations, Skewness, Mean, and Median of Monthly Can, Average LPG, LPG Intensity, Biomass, and Electricity Consumption in Urban and Rural Areas

| | | Obs | Skewness | Mean | Median |
|--|---------|-----|----------|------|--------|
| Monthly consumption of 250-g can (kg) | Overall | 109 | 0.54 | 3.89 | 3.70 |
| | Urban | 57 | 0.28 | 5.0 | 4.50 |
| | Rural | 54 | 1.11 | 3.0 | 2.50 |
| Monthly LPG consumption (kg) | Overall | 184 | 0.44 | 7.9 | 7.20 |
| | Urban | 93 | 0.27 | 8.8 | 7.50 |
| | Rural | 91 | 0.71 | 6.9 | 5.00 |
| Monthly LPG intensity (kg) | Overall | 176 | 0.75 | 1.8 | 1.50 |
| | Urban | 89 | 0.70 | 2.07 | 1.91 |
| | Rural | 87 | 1.04 | 1.52 | 1.24 |
| Monthly firewood consumption (m ³) | Overall | 32 | 0.82 | 1.04 | 1.00 |
| | Urban | 2 | 0 | 1.25 | 1.25 |
| | Rural | 30 | 0.86 | 1.02 | 1.00 |
| Monthly charcoal consumption (kg) | Overall | 55 | 1.24 | 10.7 | 8.00 |
| | Urban | 22 | 1.51 | 5.4 | 4.50 |
| | Rural | 35 | 1.19 | 16.5 | 10.00 |
| Monthly electricity consumption (kWh) | Overall | 194 | 1.35 | 121 | 90.00 |
| | Urban | 95 | 1.02 | 140 | 110.00 |
| | Rural | 99 | 1.51 | 103 | 81.00 |

g = gram, kg = kilogram, kWh = kilowatt-hour, m³ = cubic metre.

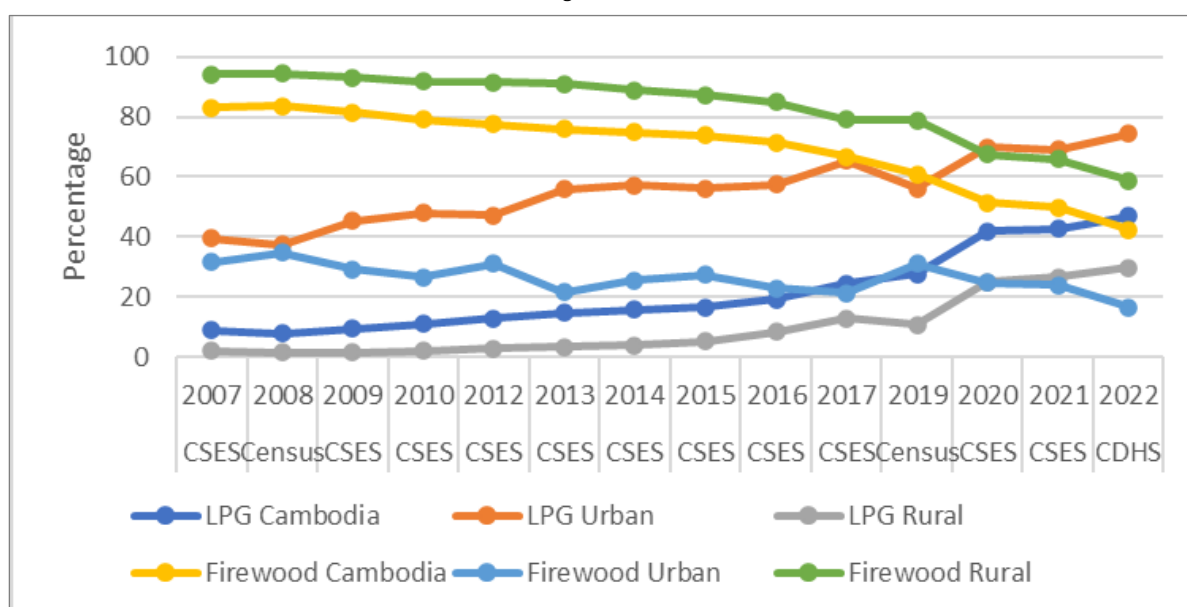
Source: Author.

Table A.3. Monthly Electricity Consumption by Area for Cooking, Boiling, Lighting, and Other Usage
(kilocalorie)

| Commune/Sangkat | Total | Cooking | Boiling | Lighting | Other |
|-------------------------|---------|---------|-----------|-----------|-----------|
| Urban | 94,646 | 14,627 | 12,906 | 28,393 | 54,206 |
| Stung Mean Chey 1 | 61,950 | 12,906 | 8,604 | 24,091 | 31,835 |
| Tuol Sangke | 94,646 | 11,013 | 2,581 | 18,929 | 66,252 |
| Chroy Chongvar | 132,504 | 17,208 | 16,347 | 54,206 | 55,066 |
| Boeng Keng Kang 3 | 156,596 | 22,370 | 20,650 | 35,277 | 89,483 |
| Rural | 69,694 | 10,325 | 6,883 | 17,208 | 41,300 |
| Chongruk | 7,335 | 16,347 | 6,883 | 15,487 | 43,021 |
| Prey Puoch | 70,554 | 11,185 | 7,743 | 21,510 | 42,160 |
| Kampong Thkov and Snuol | 67,112 | 9,464 | 6,022 | 16,347 | 41,300 |
| Total | 77,437 | 12,045 | 7,743.786 | 21,510.52 | 43,881.45 |

Source: Author.

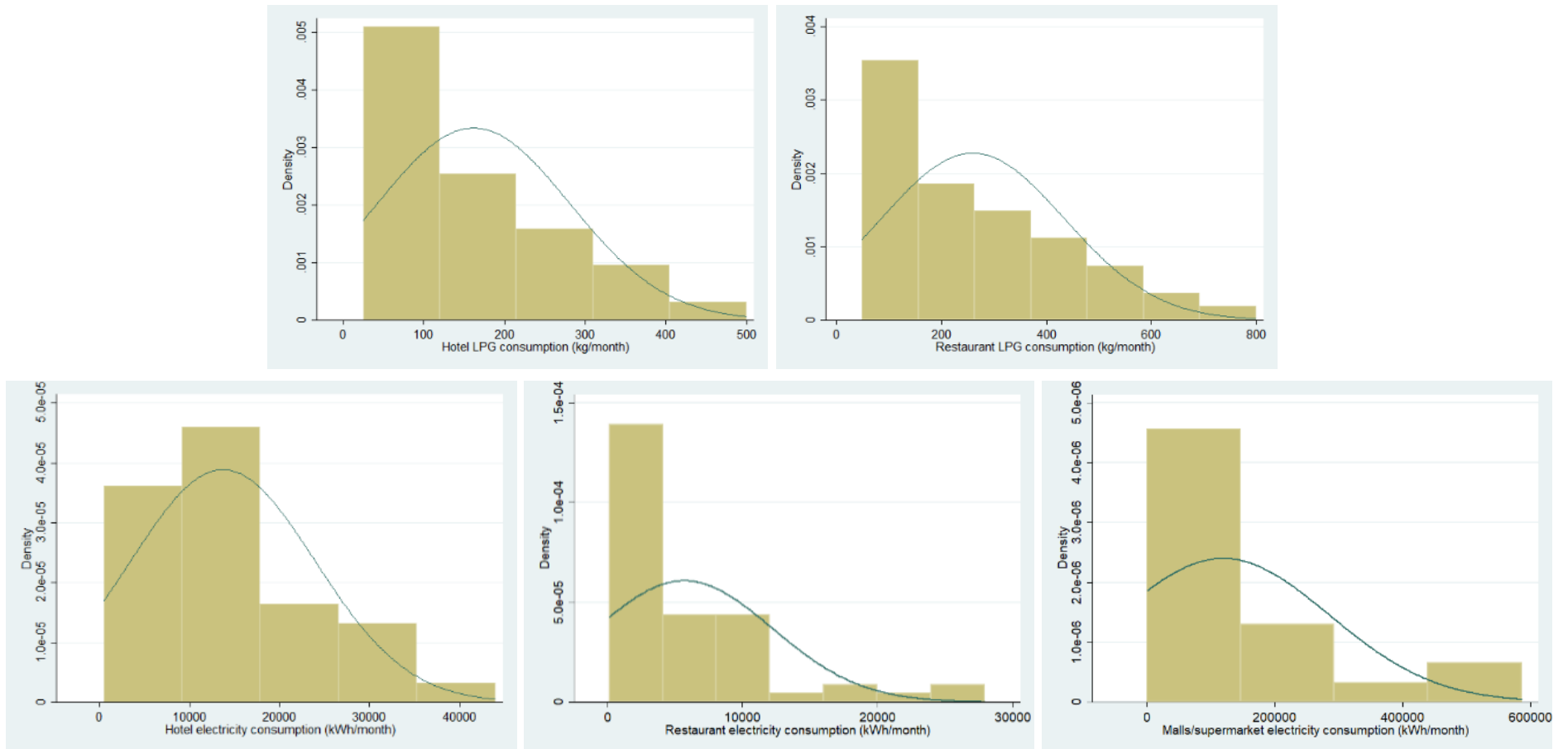
Figure A.3. Share of Firewood and LPG Consumption as the Main Source of Fuel for Cooking, 2007–2022



Source: NIS (2020).

C. Commercial Sector

Figure A.4. Histogram of LPG and Electricity Consumption of the Commercial Sector by Type



kg = kilogram, kWh = kilowatt-hour.

Source: Author.

Table A.4. Observations, Skewness, Mean, and Median of Monthly 45-Kilogram Cylinder, Average LPG, LPG Intensity, Biomass, and Electricity Consumption in the Commercial Sector by Type

| | | Obs | Skewness | Mean | Median |
|--|--------------------|-----|----------|---------|--------|
| Monthly consumption of 45 kg (kg) | Hotels | 29 | 1.38 | 307 | 180 |
| | Restaurants | 43 | 1.25 | 301 | 250 |
| | Malls/supermarkets | | | | |
| Monthly LPG consumption (kg) | Hotels | 33 | 1.04 | 161 | 125 |
| | Restaurants | 50 | 0.84 | 259 | 236 |
| | Malls/supermarkets | 1 | | | 300 |
| Monthly LPG intensity (kg) | Hotels | 29 | 1.84 | 0.03 | 0.02 |
| | Restaurants | 45 | 1.38 | 0.98 | 0.54 |
| | Malls/supermarkets | | | | |
| Monthly firewood consumption (m ³) | Hotels | | | | |
| | Restaurants | 1 | | | 2 |
| | Malls/supermarkets | | | | |
| Monthly charcoal consumption (kg) | Hotels | | | | |
| | Restaurants | 18 | 0.37 | 283 | 220 |
| | Malls/supermarkets | | | | |
| Monthly electricity consumption (kWh) | Hotels | 35 | 0.92 | 13,724 | 13,229 |
| | Restaurants | 58 | 1.74 | 5,680 | 2,704 |
| | Malls/supermarkets | 21 | 1.54 | 119,169 | 21,917 |

kg = kilogram, kWh = kilowatt-hour, m³ = cubic metre.

Source: Author.

D. Industrial Sector

Table A.5. Observations, Skewness, Mean, and Median of Monthly LPG, Biomass, and Diesel Consumption in the Industrial Sector by Type

| | | Obs | Skewness | Mean | Median |
|--|-----------------------|-----|----------|------|--------|
| Monthly LPG consumption (kg) | Food production | 33 | 1.01 | 108 | 85 |
| | Beverage/brewery | 2 | 0 | 74 | 74 |
| | Wood/paper production | | | | |
| Monthly firewood consumption (m ³) | Food production | 9 | 0.92 | 26 | 15 |
| | Beverage/brewery | 1 | | | 350 |
| | Wood/paper production | 1 | | | 10 |
| Monthly charcoal consumption (kg) | Food production | 3 | 0.68 | 583 | 300 |
| | Beverage/brewery | | | | |
| | Wood/paper production | | | | |
| Monthly diesel consumption (litre) | Food production | 7 | 1.63 | 232 | 100 |
| | Beverage/brewery | 2 | 0 | 112 | 112 |
| | Wood/paper production | 1 | | | 60 |

kg = kilogram, m³ = cubic metre.

Source: Author.