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Cambodia Petroleum Master Plan 2022-2040

Prepared by the General Department of Petroleum, Ministry of Mines and Energy of Cambodia

Supported by the Economic Research Institute for ASEAN and East Asia

Cambodia Petroleum Master Plan 2022-2040

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Preface

Until March 2020 before the spread of COVID-19, Cambodia's gross domestic product had achieved an annual average growth rate of about 7.7% over the past 2 decades, thanks in large part to the government's efforts in policy reform that have attracted foreign direct investment into Cambodia. So far, energy has played a critical role in supporting the country's economic activities and growth. The COVID-19 pandemic has caused a global recession, and Cambodia's economy has been hard hit. The Asian Development Bank reported that Cambodia's economy contracted by 3.1% in 2020 and is estimated to have recovered to positive growth of 4% in 2021 and expected to achieve growth of 5.5% in 2022. As a result of the pandemic, Cambodia's energy demand fell by 5%–10%, in which oil and electricity demand declined by about 15%–20% from the 2019 level.

The past success of fast economic growth helped lift the well-being of people through income generation and employment. This strong economic growth was due in part to the fast growth of energy consumption. Energy demand, especially oil with the highest share in total primary energy supply in 2018 (42%), increased with the increased number of vehicles. As a result, oil supply rose at an annual average 6% per year over the 2010–2018 period. Between 2017 and 2018, growth was almost 10%, indicating a rapid increase in oil transport demand, which was gasoline and diesel oil. Currently, all petroleum products are imported, and most are shipped by tankers from Thailand, Singapore, and Viet Nam. However, LPG can be imported by tank- trucks from Thailand and Viet Nam, so the import route is different from gasoline and diesel oil. As petroleum demand is expected to grow to meet end-use demand, the transportation routes, receiving terminals, and distribution terminals of petroleum products must be adequately studied and assessed to ensure efficient logistics costs in Cambodia's petroleum supply chain.

In this regard, the Ministry of Mines and Energy (MME) of Cambodia realises there is a need to conduct a study on the country's Petroleum Master Plan to obtain an overview the entire petroleum supply chain in terms of logistics, storage, and distribution.

On behalf of the ministry, I am very thankful to Prof Hidetoshi Nishimura, President of the Economic Research Institute for ASEAN and East Asia (ERIA), who honoured my request for ERIA's support to the MME in formulating the Petroleum Master Plan. I would like to thank the ERIA experts and the MME staff for their efforts in producing this important policy document. During the project period, ERIA also conducted capacity-building trainings, such as on a basic understanding of the petroleum demand survey and petroleum demand estimation techniques. Lastly, the MME would like to show its great appreciation to ERIA for its technical and financial support in producing this master plan.

Suy Sem

Minister of Mines and Energy, Cambodia

March 2022

Acknowledgements

The Cambodia Petroleum Master Plan is an important document to guide the development of petroleum policy and regulations in downstream activities. This master plan was prepared by experts from the Economic Research Institute for ASEAN and East Asia (ERIA) assisted by the technical staff of the General Department of Petroleum, Ministry of Mines and Energy. This report could not have been produced without the huge support of many people interviewed by ERIA experts and ministry staff. Data and information were gathered from line ministries and agencies, and oil companies. I am very thankful, therefore, to those who supported the experts in carrying out this study. I also would like to thank the experts of ERIA and the staff members of the General Department of Petroleum for their efforts and time in preparing this document.

Special acknowledgement is also given to Shigeru Kimura, Special Adviser on Energy Affairs to the President of ERIA, for his excellent leadership of this project.

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March 2022

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List of Abbreviations and Acronyms

AAGR	average annual growth rate
BAU	business-as-usual scenario
EBT	energy balance table
ERIA	Economic Research Institute for ASEAN and East Asia
GDP	gross domestic product
LPG	liquefied petroleum gas
MME	Ministry of Mines and Energy, Cambodia
NIS	National Institute of Statistics
TFEC	total final energy consumption
TPES	total primary energy supply

Executive Summary

According to the Cambodia National Energy Statistics (2019), oil demand in Cambodia is significant, and its share per total primary energy supply (TPES) was 42% in 2018, followed by biomass (33%). The demand for gasoline and diesel oil, mainly used as road transport fuels, accounted for 81% of total oil demand in 2018. Oil in Cambodia is all imported from Singapore, Thailand, and Viet Nam. There are two main oil import places in Cambodia serving as primary terminals due to their storage capacity: Sihanoukville along the coastline and Phnom Penh along the Mekong River. The share of oil unloaded at Sihanoukville is approximately 70%; that unloaded at Phnom Penh is the remaining 30%. Currently, tank trucks transport gasoline and diesel oil to each province directly from the primary terminals in Sihanoukville and Phnom Penh. In addition, a small amount of oil is transported by rail from Sihanoukville to Phnom Penh and Battambang due to poor railway condition.

According to the Cambodia Energy Outlook 2019, part of the East Asia Summit (EAS) Energy Outlook (2020) that includes 17 EAS countries except for Russia, oil demand, especially gasoline and diesel oil, will increase 1.8 times from 2018 to 2030 and 3.2 times to 2040 due to continuous stable economic growth. Thus, the General Department of Petroleum (GDP), Ministry of Mines and Energy (MME) should seek optimal oil logistics from the primary terminals to each province in 2030 and 2040 to show oil companies – which make economical and rational investments to accomplish resilient petroleum supply chains in Cambodia – a better oil supply chain in the future.

Firstly, gasoline and diesel oil demand of the whole country in 2030 and 2040, based on the Cambodia Energy Outlook 2019, is allocated to all provinces based on existing petroleum supply chains getting from interviews of the oil companies and the estimated provincial population in 2030 and 2040 . Secondly, the following transport options are assumed for moving gasoline and diesel oil in 2030 and 2040: (i) pipeline but only between Sihanoukville and Phnom Penh, (ii) rehabilitation of railway system between Sihanoukville and Phnom Penh and Sihanoukville and Battambang in 2040, (iii) enhancement of terminal capacity in the Mekong River, and (iv) appropriate improvement on national roads.

The cost minimum approach (linear programming method) – representing the economic and rational decisions of oil companies regarding investment in resilient petroleum supply chain between their primary terminals to each province – is applied to extract several policy recommendations to guarantee an optimal solution to the petroleum supply chain in 2030 and 2040. In 2030, a pipeline system between Sihanoukville and Phnom Penh will accelerate the country's economic and rational oil supply chain due to high oil demand (more than 50% of total Cambodia demand) in Phnom Penh. However, the Mekong River terminal and railway transport will remain to reflect oil supply business practices. In 2040, the pipeline system will not be sufficient due to the significant increase in oil demand. Therefore, the Mekong River terminal needs enhancement. In addition, the railway system to Battambang should also be rehabilitated to expand oil transport capacity.

The optimisation approach to the oil supply chain is based on economically rational human behaviour. However, the actual oil supply chain depends on both the economic rationale and historical business practice. Thus, this model is a useful reference when the General Department of Petroleum/Ministry of Mines and Energy (GDP/MME) prepares an oil supply chain plan for Cambodia, including all

transport modes: pipeline, railway, and tank truck. In addition, the GDP/MME should prepare safety guidelines or regulations on all transport modes regarding oil transport.

Chapter 1

Review of Current and Future Petroleum Demand

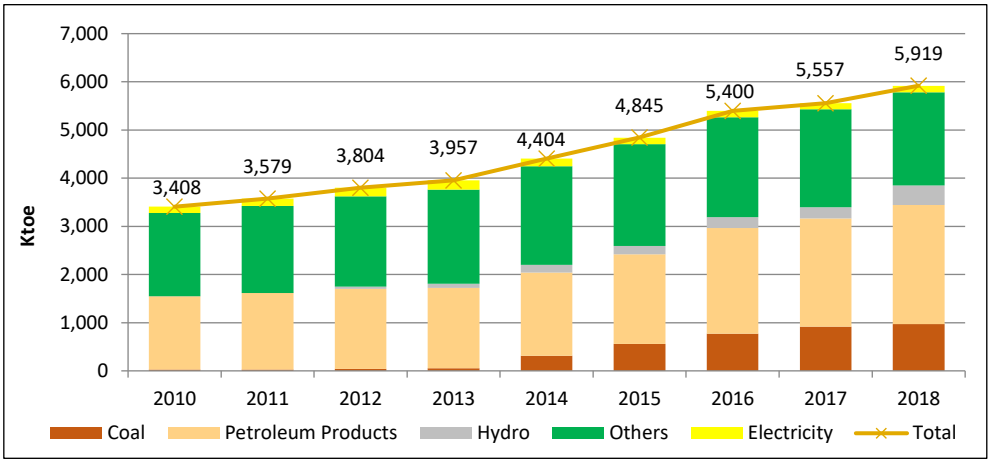
1. Total Primary Energy Supply, by Energy

Cambodia's total primary energy supply (TPES) increased from 3,408 ktoe in 2010 to 5,919 ktoe in 2018, at an annual average rate of 7.1% per year (Figure 1.1). However, most of the TPES (51%) in 2010 came from 'Others', where biomass was dominant. By 2018, the share had decreased to 33%. Cambodia shifted from non-commercial energy to commercial energy (oil and electricity), especially in the residential sector, while biomass grew only 1.4% per year.

Oil had the highest share in the TPES in 2018 (42%) as its demand increased with the number of vehicles. Oil supply grew at an average 6% per year over 2010–2018. Between 2017–2018, the growth was almost 10%, indicating a rapid increase in the road transport demand of gasoline and diesel oil.

Hydro supply share in the TPES was 7% in 2018. Although small, hydro supply increased the fastest at 74.7% in 2017–2018. On the other hand, coal supply increased by 6.2% between 2017 and 2018, while the import of electricity supply increased by 8.9% in the same period.

Figure 1.1. Total Primary Energy Supply, 2010–2018



Ktoe = kiloton of oil equivalent.
Source: MME (2020).

2. Total Final Energy Consumption, by Energy and Sector

Cambodia's total final energy consumption (TFEC) increased steadily by an average 7.2% per year from 2,461 ktoe in 2010 to 4,297 ktoe in 2018 (Figure 1.2). The commercial sector grew at 18.8% per year on average over the 2010–2018 period, as reflected by the opening of new buildings due to a remarkable influx of foreign direct investment for the construction of commercial buildings.

Transport sector consumption also grew faster than the TFEC at an annual 7.4% per year, while the industry and residential sectors grew more slowly at 5.1% and 3.3% per year, respectively. Although

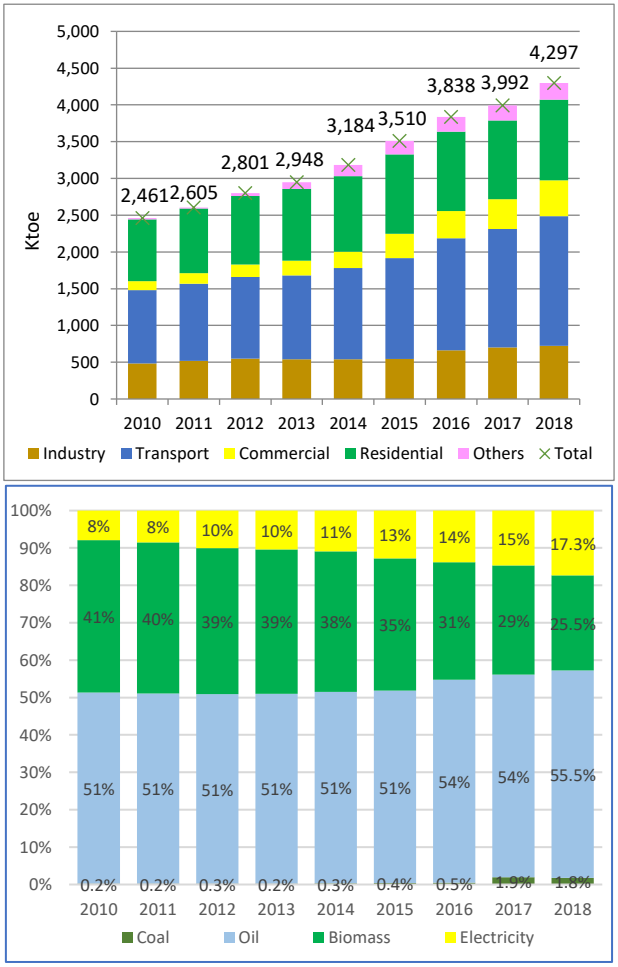
the commercial sector grew fast, its share in the TFEC was only 11% in 2018. The transport sector has always been dominant; its share in the TFEC was 40% in 2010 and 41% in 2018.

Oil is the fuel consumed by the transport sector. Thus, by fuel type, oil consumption has the highest share in the TFEC (51% in 2010 and 55.5% in 2018). Total oil consumption increased at an average annual rate of 8.3%, from 1,258 ktoe in 2010 to 2,383 ktoe in 2018.

Electricity consumption grew faster than oil, at an average annual rate of 18.3% over the 2010–2018 period, in line with the increase in commercial sector consumption, most of which is electricity. Thus, the share of electricity in the TFEC increased from 8% in 2010 to 17% in 2018.

Coal is consumed only in the industry sector. The consumption increased by almost 39% over 2010–2018, especially for cement production. Although it recorded the fastest growth, coal constituted less than 2% of the TFEC in 2018. The residential sector mainly consumed biomass. As household income increased, especially in the urban areas, more efficient fuels, such as liquefied petroleum gas (LPG) and electricity, replaced biomass. Thus, biomass consumption grew slower than the other fuels, at an average rate of 1.1% per year. As a result, the share of biomass in the TFEC fell from 41% in 2010 to 25.5% in 2018.

Figure 1.2. Total Final Energy Consumption, by Sector and by Fuel, 2010–2018



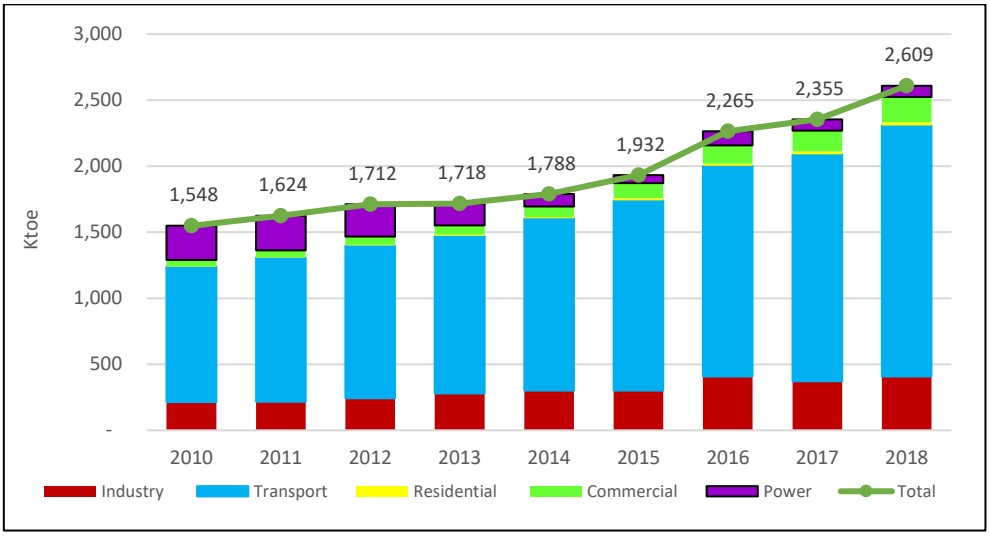
Ktoe = kiloton of oil equivalent.
Source: MME (2020).

3. Oil Consumption in Cambodia

3.1. By sector

The country's total oil consumption by sector increased from 1,548 ktoe in 2010 to 2,609 ktoe in 2018 (Figure 1.3). The average annual growth rate was 6.7% over the 2010–2018 period. Consumption grew faster between 2017 and 2018 at 10.8%, indicating an increasing number of vehicles in the road transport sector. As a result, the transport sector's share in total oil consumption reached 73% in 2018. This includes the oil used for international aviation bunkers. The remaining shares were those of the industry (16%), residential (1%), commercial (7%), and power generation (3%) sectors.

Figure 1.3 Oil Consumption, by Sector, 2010–2018



Ktoe = kiloton of oil equivalent.
Source: MME (2020).

3.2. By product

By product, Cambodia's oil consumption was dominated by diesel oil, with a share of almost 55% in 2018 (Figure 1.4). Diesel oil consumption increased at an annual average of 10%, from 610 ktoe in 2010 to 1,307 ktoe in 2018. Most of the consumption was in the transport sector; its use included boilers and standby generators in the industry and commercial sectors.

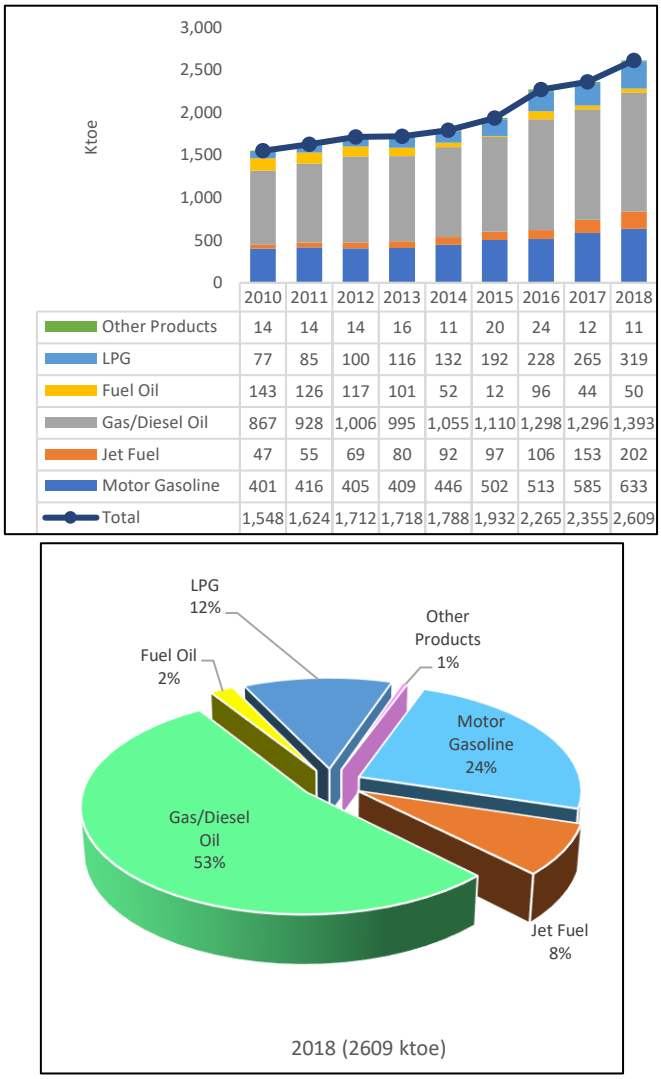
Gasoline was another product mainly used for road transport. The share of gasoline in the total oil consumption was the second highest (27% in 2018). Gasoline consumption increased at an average rate of 6% per year, slower than diesel oil.

Jet fuel experienced the fastest growth (20% per year) in line with the increase in domestic and international flights. Although showing the fastest growth, the share in the total oil consumption was around 8% in 2018.

Liquefied petroleum gas (LPG) is the other product with fast growth over 2010–2018 (19.5% per year). LPG consumption had been increasing rapidly as a substitute for biomass, mainly in the commercial sector. The transport sector (taxis and three-wheelers) and the residential sector also consumed LPG. LPG's share in the commercial sector was around 60% of total LPG consumption in 2018. In total oil consumption, the share of LPG increased from 6% in 2010 to 13% in 2018.

The remaining products were fuel oil and other petroleum products with a combined share of 2.6% in total oil consumption. These products were consumed by the industry, transport, and power sectors.

Figure 1.4. Oil Consumption, by Product Type, 2010–2018



	2010	2011	2012	2013	2014	2015	2016	2017	2018
Other Products	14	14	14	16	11	20	24	12	11
LPG	77	85	100	116	132	192	228	265	319
Fuel Oil	143	126	117	101	52	12	96	44	50
Gas/Diesel Oil	867	928	1,006	995	1,055	1,110	1,298	1,296	1,393
Jet Fuel	47	55	69	80	92	97	106	153	202
Motor Gasoline	401	416	405	409	446	502	513	585	633
Total	1,548	1,624	1,712	1,718	1,788	1,932	2,265	2,355	2,609

Ktoe = kiloton of oil equivalent, LPG = liquefied petroleum gas.
Source: MME (2020).

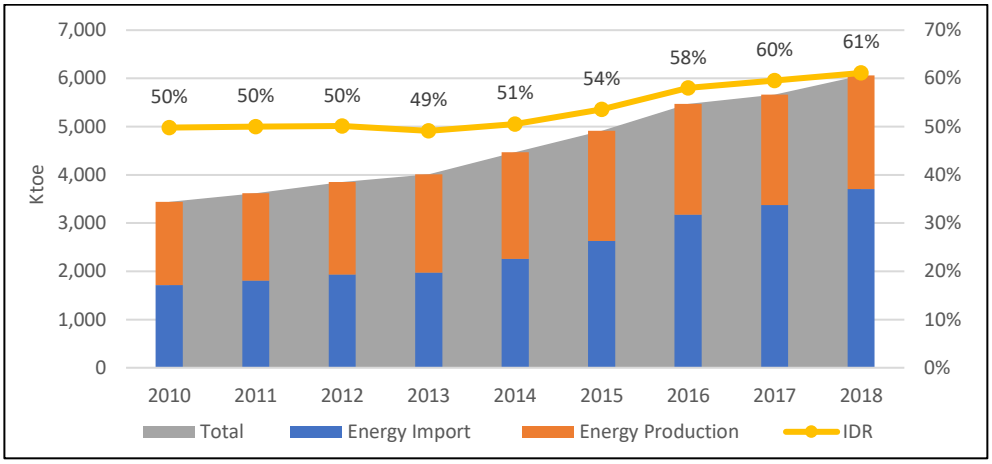
4. Import Dependency

Cambodia imports oil, coal, and electricity. Total energy import increased from 1,712 ktoe to 3,703 ktoe in 2010–2018, at an average rate of 10% per year. Domestic energy production (biomass and hydro), on the other hand, increased by only 4% per year. The resulting import dependency, which is the ratio of import to total (import + production), increased from 50% in 2010 to 61% in 2018 (Figure 1.5).

Cambodia imported 100% of its petroleum products from Singapore, Thailand, and Viet Nam to supply domestic consumption. These imported petroleum products increased at an average rate of 7% in 2010–2018. Between 2017 and 2018, the increase was 11%. The rapid increase of jet fuel and LPG

resulting from increased air traffic, commercial, residential, and road transport largely contributed to the high growth of imported petroleum products in 2017 and 2018.

Figure 1.5 Import Dependency Ratio, 2010–2018

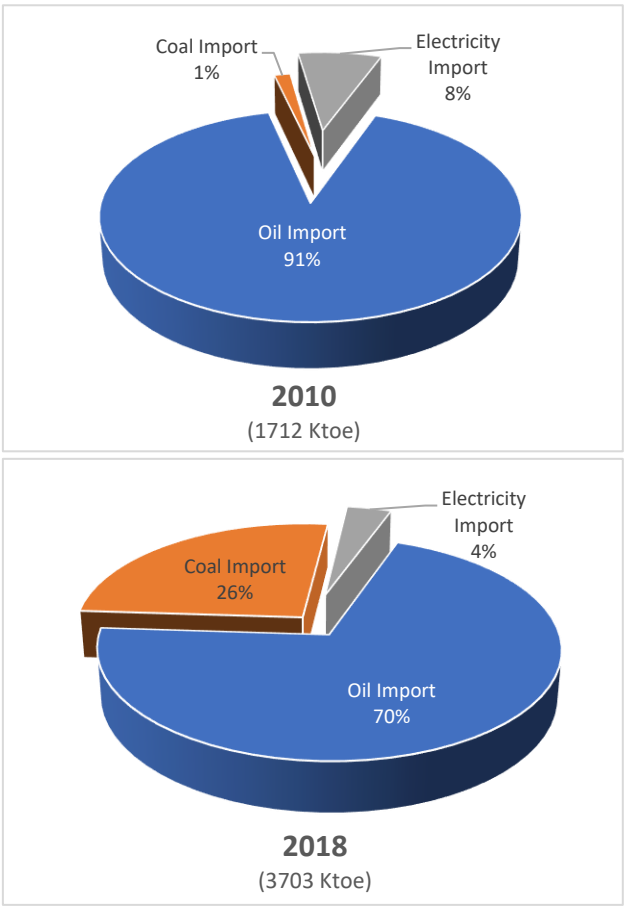


Ktoe = kiloton of oil equivalent, IDR = import dependency ratio.
Source: MME (2020).

Compared to the other fuel imports (coal and electricity), oil imports constituted 91% of total imported fuel in 2010 (Figure 1.6). However, in 2018, the imported share of oil declined to 70% due to the rapid increase of coal imports (58% per year). This rapid growth of coal imports was due to the increasing demand for power generation.

Electricity import was necessary to avoid frequent power shortages in the dry season. Cambodia's reliance on hydropower created a supply vulnerability caused by seasonal changes. The inclusion of coal in the generation mix complements hydropower generation. This will further secure the country's supply mix and address short-term needs during the dry season. Compared to 2010, electricity imports in 2018 increased slightly (1.7 ktoe) at an average rate of 0.2% per year. Consequently, the share of electricity imports in total energy imports decreased to 4% in 2018.

Figure 1.6 Energy Import, by Fuel Type, 2010 and 2018



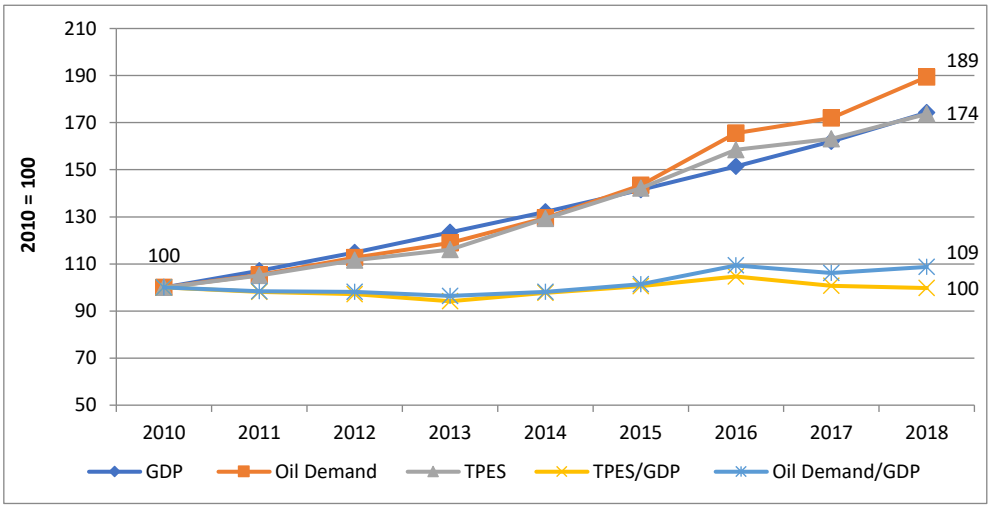
Ktoe = kiloton of oil equivalent.
Source: MME (2020).

5. Energy Intensity (Petroleum Demand/GDP, TPES/GDP)

Oil demand increased faster than the TPES in 2010–2018 (Figure 1.7). By 2018, oil demand had grown 1.9 times that of 2010, while the TPES was only 1.7 times that of 2010. Compared to the gross domestic product (GDP), TPES growth was the same as GDP. As a result, the primary energy intensity, defined as TPES divided by GDP, did not change.

The demand intensity of oil in 2018 increased by 1.1 times from 2010 as transport demand grew faster than GDP.

Figure 1.7. Energy Intensity, 2010–2018



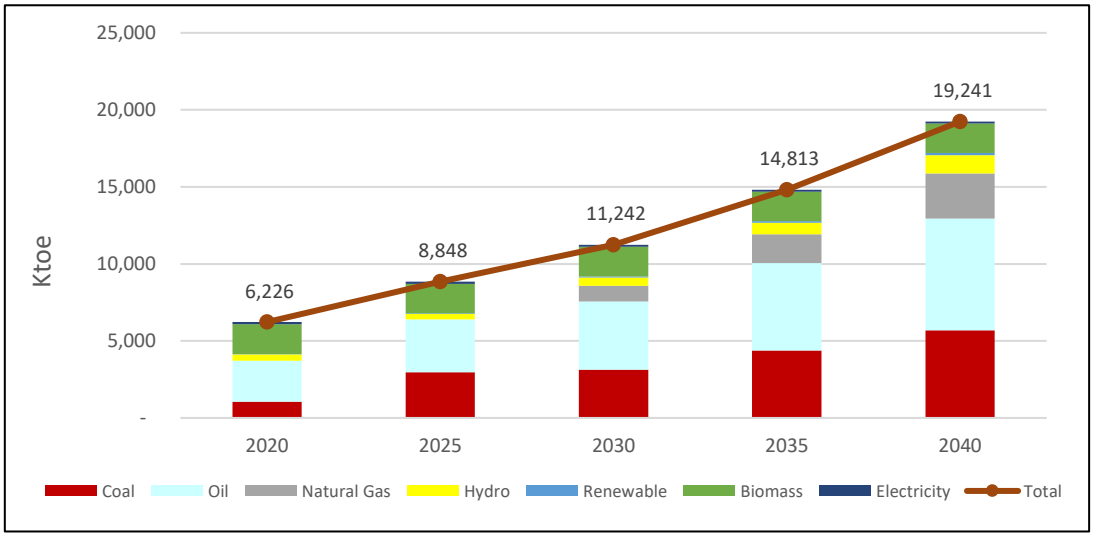
GDP = gross domestic product, TPES = total primary energy supply.
Source: MME (2020).

6. Business-As-Usual Scenario (BAU) up to 2040

The Business-as-Usual Scenario (BAU) was based on the Cambodia country result for the East Asia Summit energy outlook 2020, published by ERIA (Kimura and Han, 2021). This outlook used 2018 as the base year, and demand had been forecasted up to 2050 based on the government's specific socio-economic assumptions and existing energy policies. The BAU scenario result for 2040 is used in this study.

Cambodia's TPES is forecast to reach 19,241 ktoe in 2040, growing at an average annual rate of 5.5% (Figure 1.8). Oil has the highest share in TPES over the projection period. However, the share is expected to decrease from 42% in 2018 to 38% in 2040 since other fuels (coal and renewable) will be growing faster than oil. Oil supply will increase at an average rate of 5% per year over the 2018–2040 period. Coal will grow at an average 8.4% per year while renewables will grow by 24% per year. The rapid increase of coal and renewables is in line with the plan to increase coal and renewable power (solar and wind) capacity to meet the increase in electricity demand.

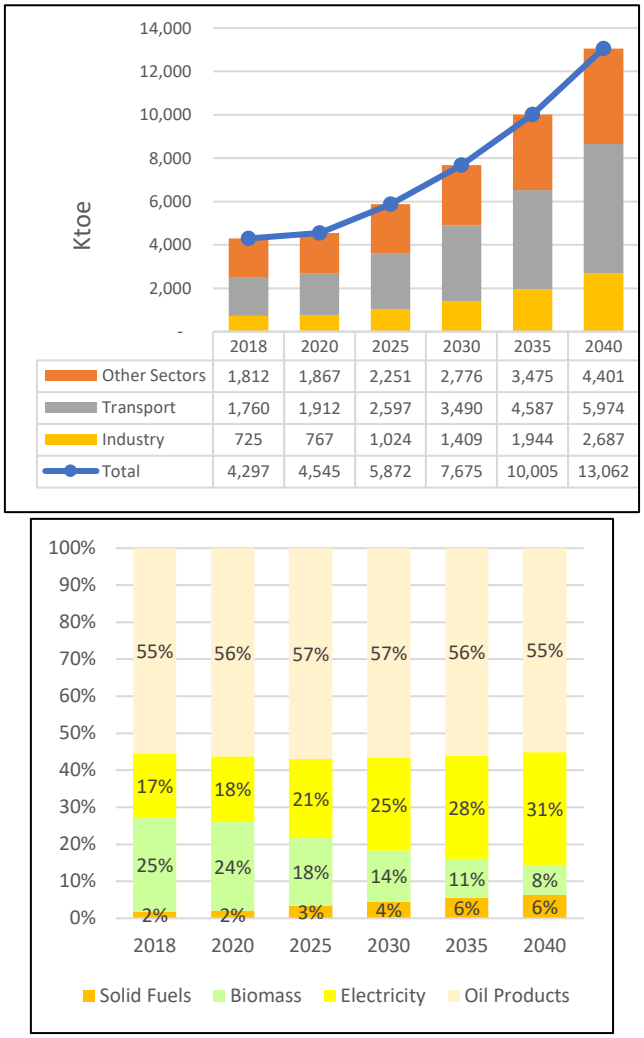
Figure 1.8. Total Primary Energy Supply, 2018–2040



Ktoe = kiloton of oil equivalent, TPES = total primary energy supply.
Source: Kimura and Han (eds.) (2021).

In BAU, driven by assumed strong economic growth and an increasing population, the TFEC is projected to increase to 13,062 ktoe by 2040 at an average annual rate of 5.2% (Figure 1.9). By fuel, oil will dominate the TFEC in 2040 at a share of 55% while biomass share will decline to 8%.

Figure 0.9. Total Final Energy Consumption, BAU



	2018	2020	2025	2030	2035	2040
Other Sectors	1,812	1,867	2,251	2,776	3,475	4,401
Transport	1,760	1,912	2,597	3,490	4,587	5,974
Industry	725	767	1,024	1,409	1,944	2,687
Total	4,297	4,545	5,872	7,675	10,005	13,062

Ktoe = kiloton of oil equivalent.
Source: Kimura and Han (eds.) (2021).

Cambodia's total oil demand will grow at an average rate of 5,4% per year over the projected period and reach 8,301 ktoe in 2040 (Figure 1.10). This will be the demand for the final sector (including international aviation) and the power sector (oil input for generating electricity). Most of the oil demand will still be from the transport sector, with a share reaching 83% of total oil demand in 2040. The oil demand of the transport sector will grow at an average annual rate of 6,1% and will reach 6,926 ktoe by 2040.

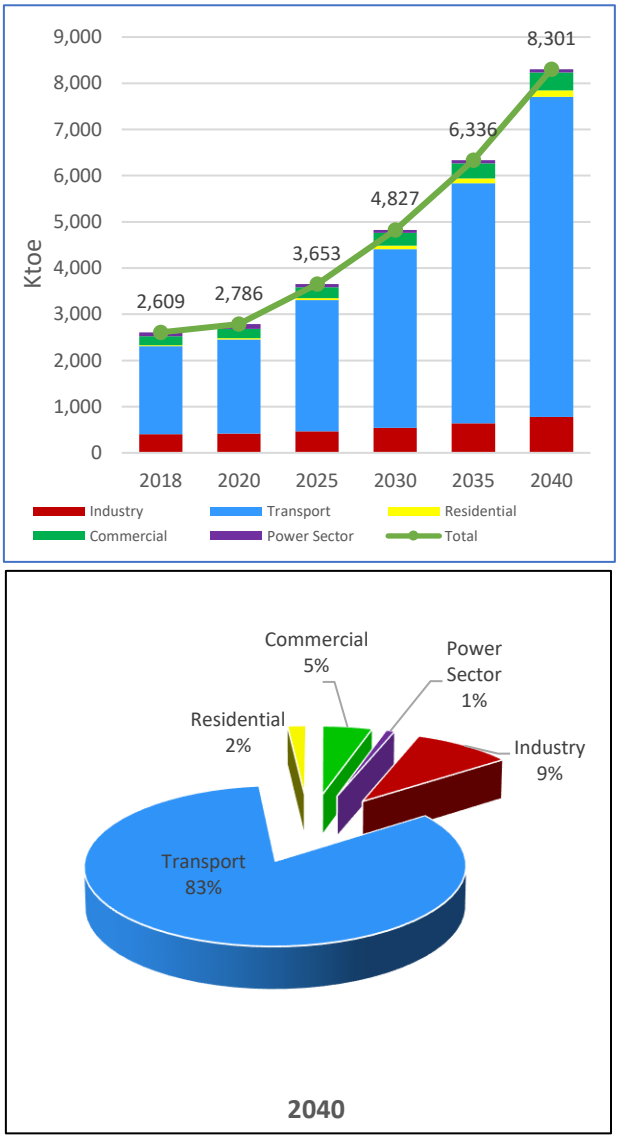
The smallest oil demand will be that of the power sector. The share of power sector demand in total oil demand will be around 1% in 2040; in 2018, the share was around 3.3%. The average growth rate of power sector oil demand will be –1.1% per year over the projection period (2018–2040),

The oil demand of the industry sector is projected to increase to around 781 ktoe by 2040, growing at an average annual rate of 3% over the projection period. The industry sector share in total oil demand is forecast to be around 9% in 2040, while that of the commercial sector is expected to be be 5% in

2040. Commercial sector oil demand is projected to grow at an average rate of 3.2% per year between 2018 and 2040.

The oil demand of the residential sector will only be around 2% of total oil demand, but it is expected to grow fastest at 8.2% per year. This rapid growth is due to the increase of LPG demand as a substitute for biomass

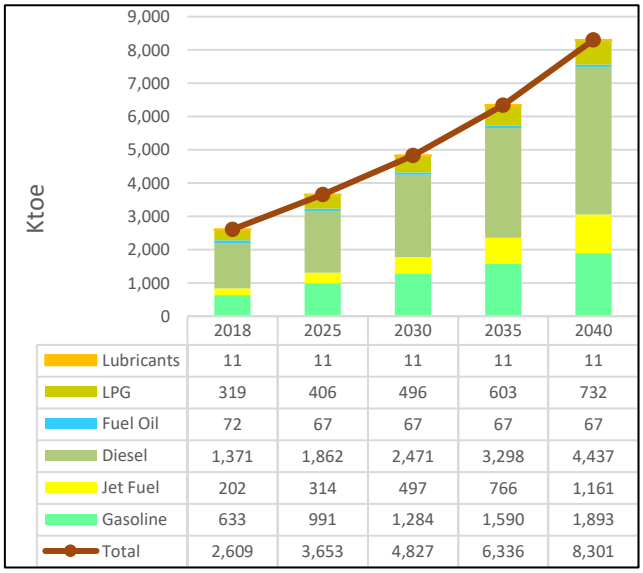
Figure 0.10. Oil Demand Projection, by Final Sector, BAU, 2018–2040



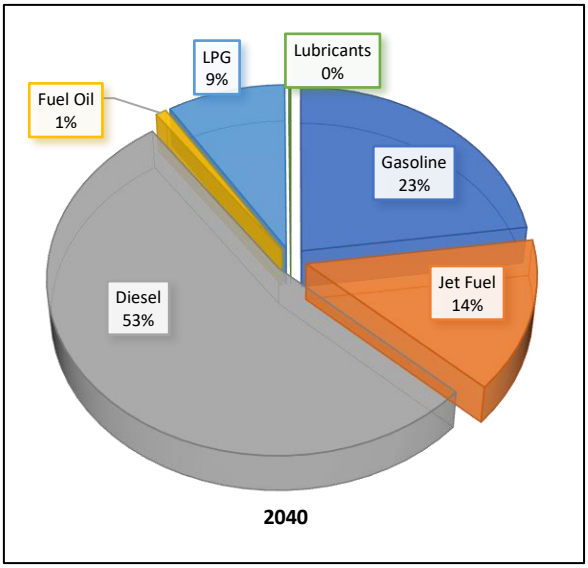
Ktoe = kiloton of oil equivalent.
Source: Kimura, S. and P. Han (eds.) (2021).

Jet fuel demand will grow fastest at 8.3% per year over the projection period by product type. International and domestic flights are expected to increase as economic development continues, increasing business and tourist travel. Jet fuel demand is expected to reach 1,161 ktoe by 2040 (Figure 1.11).

Figure 0.11. Oil Demand, by Product Type, BAU, 2018–2040



	2018	2025	2030	2035	2040
Lubricants	11	11	11	11	11
LPG	319	406	496	603	732
Fuel Oil	72	67	67	67	67
Diesel	1,371	1,862	2,471	3,298	4,437
Jet Fuel	202	314	497	766	1,161
Gasoline	633	991	1,284	1,590	1,893
Total	2,609	3,653	4,827	6,336	8,301



Ktoe = kiloton of oil equivalent, LPG = liquefied petroleum gas.
Source: Kimura and Han (eds.) (2021).

Diesel demand will be growing slower than jet fuel at an average 5.5% per year. However, diesel is forecast to have the highest share in total oil demand (53%) in 2040. Most diesel demand will come from the road transport sector (82%). The remaining share will be from the industry, commercial, and power sectors. Diesel demand is projected to reach 4,437 ktoe by 2040.

The share of gasoline in total oil demand is forecast at around 23% in 2040, consumed only in the road transport sector. Gasoline demand will increase as the economy improves and income increases. As a result, the average growth rate of gasoline demand will be 5.1% per year, reaching 1,893 ktoe by 2040.

LPG demand will be growing at an average rate of 3.8% per year over the projection period. More houses are expected to use LPG for cooking as a substitute for biomass, especially in urban areas. Similarly, the commercial and road transport sectors' use of LPG is also expected to increase. LPG consumption of the transport sector includes car and three-wheel tuk-tuks.

LPG demand is forecast to reach 732 ktoe by 2040. The commercial sector will have the highest share (53%) in the country's total LPG demand of 2040. The remaining share will be from the transport (28%) and the residential sectors (19%).

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Ministry of Mines and Energy Cambodia [MME] (2020), Energy Demand and Supply of Cambodia 2010–2018. Jakarta: ERIA.

Chapter 2

Survey on Macroeconomic Data in Cambodia

Cambodia or Kampuchea (the local name for the country) is in the southeastern part of the Indochina Peninsula in Southeast Asia. The country has a total area of 181,035 km^2 and is bordered by Viet Nam to the east and south, the Lao PDR in the northeast, Thailand in northwest, and the Gulf of Thailand in the west.

Cambodia is divided into 25 provinces (Figure 2.1). However, the capital Phnom Penh is not a province but an 'autonomous municipality.' Governmentally, it is equivalent to a province and also administered at the same level as the other 24 provinces.

Figure 2.1. Provinces of Cambodia

Source: NIS (2019).

Provinces are divided into districts (*srok*). The districts of Phnom Penh are called *khan*, normally written as Khan for addresses in English. The number of districts in each province varies, from 2 in the smallest provinces to 14 in Battambang, Prey Veng, and Siem Reap.

1. Population

The National Institute of Statistics (NIS) of the Ministry of Planning in Cambodia provided the country's provincial population data, population density, and population distribution by rural and urban areas. Based on the 2019 census, the country's total population was 15.3 million people (Table 2.1).

Compared to the last census in 2008, the population grew at an average rate of 1.2% per year over 2008–2019.

Table 2-1. Population and Household Data, by Province, 2019

Provinces	Population	Area (km^2)	Population Density (Person/km^2)	Number of Households	Household Size (person/HH)
Banteay Meanchey	859,545	6,679	129	177,526	4.8
Battambang	987,400	11,702	84	218,584	4.5
Kampong Cham	895,763	4,549	197	215,923	4.1
Kampong Chhnang	525,932	5,521	95	122,925	4.3
Kampong Speu	872,219	7,017	124	187,835	4.6
Kampong Thom	677,260	13,814	49	154,458	4.4
Kampot	592,845	4,873	122	138,374	4.3
Kandal	1,195,547	3,179	376	273,111	4.4
Koh Kong	123,618	10,090	12	26,716	4.6
Kratié	327,825	11,094	34	86,137	4.3
Mondulkiri	88,649	14,288	6	19,609	4.5
Phnom Penh	2,129,371	679	3,136	399,203	5.3
Preah Vihear	251,352	13,788	18	56,331	4.5
Prey Veng	1,057,428	4,883	217	227,008	4.7
Pursat	411,759	12,692	32	102,253	4.0
Ratanak Kiri	204,027	10,782	19	47,417	4.3
Siem Reap	1,006,512	10,299	98	218,659	4.6
Preah Sihanouk	302,887	1,938	156	51,983	5.8
Stung Treng	159,565	11,092	14	34,627	4.6
Svay Rieng	524,554	2,966	177	131,937	4.0
Takéo	899,485	3,563	252	199,362	4.5
Oddar Meanchey	261,252	6,158	42	56,331	4.6
Kep	41,798	336	124	9,347	4.5
Pailin	71,600	803	89	16,833	4.3
Tbong Khmum	775,296	5,250	148	169,281	4.6
Total	15,288,489	178,035	86	3,341,770	4.6

Source: NIS (2019).

Phnom Penh has the highest population at 2,129,371 (13.9%) while Kep has the lowest population share (0.3%). The other provinces, populated by more than 1,000,000 people, are Kandal, Prey Veng, and Siem Reap. Phnom Penh's population density is also the highest.

2. Number of Households

Based on the 2019 population census, the number of households (HH) was 3.3 million, resulting in an average household size of 4.6 people. The largest household size is in Preah Sihanouk province (5.8 persons/HH); Phnom Penh's was slightly below, at 5.3 persons/HH.

Detailed information on households, such as floor space and type of dwelling, is not available on the NIS website, which contains only some key tables of the Statistical Yearbook of Cambodia. The complete tables of the yearbook are available only in hard copy.

The result of the 2019 population census is not yet final on the NIS website. However, a review of the 2008 census results revealed data on the distribution of population and households by rural and urban areas in each province (Table 2.2).

Table 2.2. Population and Households, by Province, Urban and Rural, 2008

	Number of Households			Population		
	2008			2008		
	Total	Urban	Rural	Total	Urban	Rural
Cambodia Total	2,817,637	506,579	2,311,058	13,181,162	2,490,657	10,690,505
Province						
Bantey Meanchey	144,658	37,174	107,484	667,559	175,120	492,439
Battambang	209,702	35,671	174,031	1,011,460	174,930	836,530
Kampong Cham	368,114	25,056	343,058	1,665,361	114,315	1,551,046
Kampong Chhnang	100,801	8,294	92,507	467,518	41,357	426,161
Kampong Speu	149,270	10,564	138,706	710,548	53,467	657,081
Kampong Thom	133,878	6,677	127,201	625,168	31,041	594,127
Kampot	129,646	9,816	119,830	581,992	46,995	534,997
Kandal	255,029	36,329	218,700	1,239,086	182,430	1,056,656
Koh Kong	24,166	7,395	16,771	115,850	35,661	80,189
Kratié	65,323	7,439	57,884	315,692	35,049	280,643
Mondulkiri	12,270	938	11,332	59,748	4,495	55,253
Phnom Penh	250,597	233,218	17,379	1,255,062	1,171,827	83,235

Preah Vihear	33,115	2,061	31,054	169,189	10,067	159,122
Prey Veng	226,312	7,009	219,303	940,696	32,107	908,589
Pursat	83,412	5,389	78,023	393,783	24,944	368,839
Ratanak Kiri	27,485	3,746	23,739	149,315	18,775	130,540
Siem Reap	179,754	34,169	145,585	884,672	169,084	715,588
Preah Sihanouk	44,656	18,353	26,303	215,741	85,785	129,956
Stung Treng	20,922	3,242	17,679	108,738	15,951	92,787
Svay Rieng	114,758	3,562	111,196	478,566	16,261	462,305
Takéo	183,742	2,688	181,054	839,334	13,108	826,226
Oddar Meanchey	38,398	3,608	34,790	182,232	18,071	164,161
Kep	7,193	962	6,231	35,401	4,618	30,783
Pailin	14,436	3,218	11,218	68,451	15,199	53,252

Source: NIS (2009).

The Cambodia Socio-Economic Survey (CSES) 2017 (NIS, 2018) included information on the floor area of occupied dwellings. On average, the dwelling space per household in 2017 was about 50 square metres (m^2). The average floor area of houses in Phnom Penh was almost 53 m^2, while in urban and rural areas outside Phnom Penh, the range was 48 to 59 m^2 (Table 2.3).

Table 2.3. Floor Area by Geographical Domain, 2017 (in % average m^2/HH)

Floor Area	Cambodia	Phnom Penh	Other Urban	Other Rural
00–19	3.2	2.2	3.5	3.3
20–39	34.2	27.7	28.1	35.9
40–59	36.6	37.1	31.8	37.1
60–79	15.3	21.8	16.7	14.3
80–99	6.2	6.7	9.5	5.6
100++	4.6	4.5	10.4	3.8
Total	100	100	100	100
Average square metres per household	49.8	52.7	58.9	48.1

Source: NIS (2018).

The 2008 population census and the 2017 CSES provided data on households' main energy source for lighting and cooking. In the 2008 population census, the data included urban and rural areas and provinces. In the 2017 CSES, the data is by geographical domain. The detailed data by urban and rural

areas and by province for the 2017 CSES are not available. Tables 2.4 and 2.5 show the data on fuel for lighting, while Tables 2.6 and 2.7 show information on fuel for cooking.

Table 2.4. Number of Households, by Main Source of Lighting: Urban and Rural, Province (1998 and 2008)

	1998				2008			
	Total	City Power (inc. 'and generator')	Kerosene	Battery	Total	City Power (inc. 'and generator')	Kerosene	Battery
Cambodia Total	2,162,086	305,212	1,726,670	76,898	2,817,637	695,020	1,088,127	959,643
Urban	364,58	221,491	122,023	20,759	506,579	431,503	37,509	25,490
Rural	1,797,505	83,721	1,604,647	66,139	2,311,058	263,517	1,050,618	934,153
Province								
Bantey Meanchey	110,994	12,150	93,921	3,173	144,658	40,827	73,519	26,482
Battambang	146,661	18,362	122,011	3,952	209,702	48,507	116,053	39,309
Kampong Cham	311,151	33,375	257,312	16,582	368,114	59,857	127,157	173,653
Kampong Chhnang	81,201	4,357	73,021	3,136	100,801	10,920	55,085	33,342
Kampong Speu	114,959	3,714	109,117	1,113	149,270	14,995	60,357	71,890
Kampong Thom	105,583	6,685	94,383	1,524	133,878	14,890	73,449	42,837
Kampot	104,498	6,270	96,637	692	129,646	15,091	70,191	42,353
Kandal	203,357	24,127	158,843	18,013	255,029	86,689	37,730	121,850
Koh Kong	21,401	7,901	12,031	166	24,166	10,492	10,354	1,883
Kratié	48,761	5,732	39,415	2,018	65,323	8,546	31,903	23,524
Mondulkiri	5,615	367	2,691	86	12,270	2,513	6,523	1,637
Phnom Penh	167,758	131,291	29,393	2,523	250,597	232,871	4,359	7,372
Preah Vihear	21,007	512	9,631	76	33,115	3,159	18,314	4,779
Prey Veng	192,735	6,684	173,135	11,905	226,312	15,778	63,867	144,503
Pursat	67,022	5,927	59,055	1,298	83,412	12,817	59,269	10,290
Ratanak Kiri	16,646	2,335	7,006	57	27,485	4,693	15,370	3,536
Siem Reap	125,387	10,943	111,359	2,032	179,754	38,717	104,084	33,013
Preah Sihanouk	30,075	11,101	17,894	154	44,656	24,193	14,723	3,354
Stung Treng	14,126	1,779	8,542	244	20,922	3,873	12,445	1,117
Svay Rieng	97,796	4,143	89,337	3,717	114,758	12,684	37,489	63,053
Takéo	153,863	6,229	142,662	4,162	183,742	20,024	63,430	98,100
Oddar Meanchey	12,208	245	11,744	122	38,398	5,937	22,357	8,517
Kep	5,282	385	4,737	59	7,193	1,197	4,611	1,156
Pailin	4,000	599	2,793	94	14,436	5,750	5,488	2,093

Note: *) Including generator.
Source: NIS (2009).

Table 2.5. Main Sources of Lighting, by Geographical Domain (%), 2017

Sources of lighting	2017			
	Cambodia	Phnom Penh	Other urban	Other rural
Publicly provided electricity/City power	78.0	99.6	95.9	72.4
Generator	0.2	0.1	-	0.2
Battery	11.9	-	2.4	14.8
Kerosene lamp	1.3	-	0.4	1.6
Candle	1.3	0.2	0.3	0.2
None	0.1	-	-	0.1
Solar	7.9	-	0.7	10.0
Other	0.5	0.1	0.3	0.6
Total	100	100	100	100
Number of households	3,438,000	377,000	372,000	2,689,000

Source: NIS (2018).

Table 2.6. Number of Households, by Main Source for Cooking, Rural and Urban, Province (2008 and 2013)

Region	Number of Hoseholds							
	2008				2013			
	Total	Firewood	Charcoal	Liquefied Petroleum Gas (LPG)	Total	Firewood	Charcoal	Liquefied Petroleum Gas (LPG)
Total	2,162,086	1,946,789	113,700	37,627	3,163,226	2,465,016	265,659	384,166
Urban	364,581	229,263	89,819	32,059	657,951	218,819	124,969	292,226
Rural	1,797,505	1,717,526	23,881	5,568	2,505,275	2,246,198	140,690	91,940
Province								
Bantey Meanchey	110,994	100,613	8,484	571	161,423	107,885	40,281	6,720
Battambang	146,661	135,560	6,385	944	230,304	177,611	34,203	13,443
Kampong Cham	311,151	301,024	2,992	1,764	403,628	372,534	12,516	14,080
Kampong Chhnang	81,201	77,819	1,539	332	111,355	94,172	12,008	4,275
Kampong Speu	114,959	111,190	1,257	390	157,982	145,558	4,806	5,597
Kampong Thom	105,583	100,938	1,763	313	149,404	138,573	7,726	2,165
Kampot	104,498	97,724	4,118	360	136,148	111,120	11,554	10,129
Kandal	203,357	196,177	3,540	1,320	238,435	202,965	8,988	24,340

Koh Kong	21,401	14,707	5,783	559	25,658	12,725	8,093	4,366
Kratié	48,761	46,452	1,500	196	73,050	65,061	4,524	2,922
Mondulkiri	5,615	5,482	28	10	15,251	13,191	622	1,265
Phnom Penh	167,758	72,365	57,607	27,406	352,702	71,548	34,467	233,864
Preah Vihear	21,007	20,676	182	49	48,242	42,934	4,208	835
Prey Veng	192,735	177,256	2,381	791	255,960	246,296	2,267	6,795
Pursat	67,022	63,585	1,256	394	96,284	86,564	7,610	1,860
Ratanak Kiri	16,646	16,019	268	48	36,178	30,595	1,654	3,711
Siem Reap	125,387	120,461	1,776	500	189,708	152,472	22,977	12,073
Preah Sihanouk	30,075	21,408	7,532	567	51,955	19,031	19,567	12,178
Stung Treng	14,126	13,367	618	64	25,359	20,710	2,809	1,471
Svay Rieng	97,796	87,382	624	432	130,972	120,416	968	9,358
Takéo	153,863	147,988	1,547	522	200,099	184,091	4,873	8,825
Oddar Meanchey	12,208	11,891	187	28	50,266	34,508	13,681	1,243
Kep	5,282	5,086	75	15	8,378	7,256	266	640
Pailin	4,000	1,619	2,258	52	14,483	7,200	4,992	2,010

Source: NIS (2009).

Table 2.7. Main Sources of Cooking, by Geographical Domain (%) (2017)

Sources of lighting	2017			
	Cambodia	Phnom Penh	Other urban	Other rural
Firewood	66.7	8	35.5	79.1
Charcoal	7.4	3.3	17.2	6.6
Liquefied petroleum gas (LPG)	24.4	84.9	45.6	13.0
Kerosene	0.0	0.0	0.0	0.0
Publicly provided electricity/City power	1.3	3.4	1.7	0.9
Household generator	0.0	0.0	0.0	0.0
None/do not cook	0.0	0.0	0.0	0.0
Other	0.3	0.0	0.0	0.3
Total	100	100	100	100
Number of households	3,438,000	377,000	372,000	2,689,000

Source: NIS (2018).

3. GDP in the National Account

The NIS and the Ministry of Commerce, Cambodia prepare the country's annual National Account. The latest was 2018. The gross domestic product (GDP) table is accessible on the NIS website for both production and expenditure approaches and at current as well as constant 2000 prices. Table 2.8 shows the GDP by Economic activities (production approach) at constant 2000 prices.

Table 2.8. GDP, by Economic Activity, at Constant Prices (billion riels, 2000)

	2010r/	2011/r	2012/r	2013/r	2014/r	2015/r	2016/r	2017/p	2018/p
AGRICULTURE, FISHERIES & FORESTRY	**8,311**	**8,567**	**8,936**	**9,076**	**9,101**	**9,120**	**9,241**	**9,401**	**9,505**
Crops	4,474	4,665	4,894	4,925	4,951	4,967	5,064	5,174	5,241
Livestock & Poultry	1,247	1,249	1,259	1,260	1,263	1,263	1,271	1,287	1,290
Fisheries	2,062	2,127	2,270	2,392	2,395	2,401	2,425	2,467	2,506
Forestry	527.4	526.8	513.5	498.7	492.8	488.6	480.5	474.0	466.8
INDUSTRY	**8,088**	**9,259**	**10,123.8**	**11,209.7**	**12,340.6**	**13,787.8**	**15,285.1**	**16,781.5**	**18,759.1**
Mining	193.4	231.7	293.1	346.5	431.0	517.0	614.9	720.5	836.3
Manufacturing	6,219	7,224	7,720	8,478	9,041	9,875	10,571.2	11,252.6	12,275.6
Food, Beverages	626.5	646.3	694.8	735.8	783.9	843.4	901.4	966.8	1,027
Textile,Wearing Apparels,etc	4,696	5,631	5,997	6,637	7,075	7,772	8,294	8,777	9,621
Wood, Paper and publishing	120.7	124.0	130.6	136.7	144.0	151.0	158.2	166.1	174.4
Rubber Manufacturing	77.1	87.6	95.7	104.0	117.5	123.5	135.5	146.8	158.4
Other Manufacturing	698.6	734.9	801.2	864.0	921.1	986.0	1,082	1,196	1,295
Non-Metallic	210.3	223.2	243.0	260.7	277.5	293.3	319.5	344.9	371.0
Basic Metal	76.5	81.0	87.2	95.3	102.7	113.7	127.0	140.8	152.5
Other manufacturing	411.9	430.8	471.0	508.1	540.9	579.0	635.6	710.2	771.5
Electricity, Gas & Water	190.8	200.5	216.3	231.5	253.9	278.2	302.3	328.4	353.9
Construction	1,485	1,603	1,895	2,154	2,614	3,117	3,797	4,480	5,293
SERVICES	**11,857.2**	**12,449.0**	**13,457.8**	**14,625.9**	**15,903.3**	**17,026.6**	**18,181.6**	**19,457.2**	**20,772.5**
Trade	2,750	2,871	3,048	3,292	3,578	3,855	4,101	4,369	4,642
Hotel & Restaurants	1,485	1,583	1,781	2,027	2,151	2,203	2,260	2,394	2,526
Transport & Communications	1,962	2,076	2,202	2,399	2,584	2,792	3,009	3,249	3,507
Finance	556.6	640.6	730.1	796.0	902.3	976.2	1,054	1,134	1,220
Public Administration	392.6	405.2	411.3	428.7	450.1	470.7	495.7	523.4	554.0
Real Estate & Business	1,772	1,841	2,078	2,243	2,553	2,855	3,137	3,409	3,698
Other services	2,940	3,034	3,207	3,441	3,686	3,874	4,125	4,379	4,625
Taxes on Products les	**2,604**	**2,779**	**2,994**	**3,242**	**3,545**	**3,845**	**4,156**	**4,523**	**4,918**
Less: FISIM	418.8	457.1	530.1	599.0	652.2	709.5	762.6	828.5	901.3
GROSS DOMESTIC PR	**30,403.3**	**32,552.7**	**34,933.4**	**37,503.3**	**40,182.0**	**43,009.3**	**46,033.2**	**49,262.5**	**52,975.7**

Note: FISIM: financial intermediation services indirectly measured; /r – revised estimates; /p – preliminary estimate.
Source: NIS (various years).

Provincial GDP by economic activity is not available on the NIS website. Even the Statistical Yearbook of Cambodia is not available for download. Only national-level data is available under the Statistical Yearbook, and the latest on the website was 2006.

4. Number and Type of Commercial Buildings

The NIS website has no data on the number and type of commercial buildings. However, there is some information on the number of establishments by province due to the NIS economic census of 2011. The data includes the number of establishments by type of business by province (Table 2.9). These are either street business, home, apartment, traditional market, modern shopping mall, exclusive block

or building, etc. Further clarification with the NIS will be necessary to break down by hotel, hospital, office building, school, and other commercial building.

Table 2.9. Number of Establishments, by Kind of Business Place – Provinces (2011)

Provinces	Street Business	Home	Apartment	Traditional Market	Modern Shopping Mall	Exclusive Block or Building	Others	Total
Cambodia	41,771	327,054	13,688	93,139	815	21,254	7,413	505,134
Batneay Meanchey	1,134	13,780	984	4,266	0	1,102	275	21,541
Battambang	2,870	21,340	577	6,934	88	1,720	568	34,097
Kampong Cham	4,029	38,157	1,753	8,974	0	2,516	834	56,263
Kampong Chhnang	1,165	13,920	351	3,130	0	835	289	19,690
Kampong Speu	776	18,295	117	2,422	0	777	154	22,541
Kampong Thom	1,651	14,964	324	3,810	0	1,235	300	22,284
Kampot	1,481	10,402	81	3,577	0	978	523	17,042
Kandal	2,870	29,514	878	5,119	0	1,451	699	40,531
Koh Kong	366	3,115	50	1,198	0	234	88	5,051
Kratie	744	7,550	190	1,806	0	667	89	11,046
Mondul Kiri	27	1,645	119	244	0	184	3	2,222
Phom Penh	11,118	50,029	4,904	26,076	707	2,087	927	95,848
Preah Vihear	289	3,708	201	754	0	320	45	5,317
Prey Veng	2,195	22,553	199	2,997	0	1,461	528	29,933
Pursat	1,285	7,579	142	2,255	0	615	199	12,075
Ratanak Kiri	209	3,735	54	1,061	0	312	109	5,480
Siem Reap	4,197	16,676	1,545	7,476	20	1,566	640	32,120
Preah Sihanouk	858	6,224	395	2,536	0	439	276	10,728
Stung Treng	253	2,866	63	1,081	0	332	70	4,665
Svay Rieng	1,375	11,372	92	1,394	0	779	233	15,245
Takeo	2,184	23,548	597	4,169	0	1,077	422	31,997
Otdar Meanchey	361	3,266	13	920	0	321	31	4,912
Kep	167	948	9	328	0	111	72	1,635
Pailin	167	1,868	50	612	0	135	39	2,871

Source: NIS (2012).

The economic census 2011(NIS, 2012) also has data on the number of establishments by area of business place by province (Table 2.10). However, further clarification is needed to ensure that all these establishments are commercial.

Table 2.10. Number of Establishments, by Area of Business Place – Provinces (2011)

Provinces	Area of Business Place (Establishment)										
	≤ 5m²	5-9m²	10-29m²	30-49m²	30-49m²	50-99m²	100-199m²	200-499m²	500-999m²	≥ 1,000m²	Total
Cambodia	**131,758**	**133,405**	**121,055**	**53,903**	**53,903**	**28,877**	**16,135**	**4,649**	**1,886**	**13,466**	**559,037**
Batneay Meanchey	3,726	4,713	5,673	3,478	3,478	1,837	977	318	100	719	25,019
Battambang	8,837	9,254	8,398	3,414	3,414	1,684	980	403	133	994	37,511
Kampong Cham	12,990	13,567	14,119	7,275	7,275	3,975	2,129	475	214	1,519	63,538
Kampong Chhnang	4,994	6,178	4,984	1,634	1,634	683	449	146	56	566	21,324
Kampong Speu	5,388	7,781	5,344	1,829	1,829	926	579	104	40	550	24,370
Kampong Thom	6,872	6,851	4,706	1,634	1,634	682	461	178	109	791	23,918
Kampot	4,325	3,965	4,056	2,206	2,206	1,021	574	195	82	618	19,248
Kandal	10,098	10,895	10,504	4,316	4,316	2,173	1,176	297	122	950	44,847
Koh Kong	818	1,079	1,254	916	916	511	268	69	16	120	5,967
Kratie	3,210	3,198	2,499	858	858	464	228	105	51	433	11,904
Mondul Kiri	256	599	647	313	313	143	92	29	26	117	2,535
Phom Penh	33,774	20,697	18,829	9,866	9,866	6,480	3,621	1,094	412	1,075	105,714
Preah Vihear	614	1,341	1,641	733	733	496	199	54	17	222	6,050
Prey Veng	7,406	9,336	7,674	2,489	2,489	1,152	544	190	85	1,057	32,422
Pursat	2,578	3,840	3,386	1,035	1,035	458	237	88	39	414	13,110
Ratanak Kiri	793	1,516	1,604	715	715	355	238	53	20	186	6,195
Siem Reap	7,647	8,772	7,836	3,271	3,271	1,808	1,331	327	153	975	35,391
Preah Sihanouk	2,586	1,939	2,986	1,351	1,351	929	504	101	61	271	12,079
Stung Treng	1,210	1,065	1,159	520	520	226	190	57	19	219	5,185
Svay Rieng	3,154	4,495	4,344	1,609	1,609	622	316	120	51	534	16,854
Takeo	9,476	10,162	6,534	2,798	2,798	1,420	630	152	55	770	34,795
Otdar Meanchey	240	907	1,625	1,079	1,079	547	241	52	6	215	5,991
Kep	508	441	319	140	140	91	64	22	8	42	1,775
Pailin	258	814	934	424	424	194	107	20	11	109	3,295

Source: NIS (2012).

The 2011 economic census provides the number of establishments per industrial classification (ISIC Rev. 4.1). The number of establishments per ISIC Rev 4.1 is broken down by province (Table 2.11). The ISIC code on accommodation and food service usually relates to hotels and restaurants, while that on human health and social work covers hospitals. The ISIC code on financial and insurance activities includes banks and commercial office buildings. Further clarification on the detailed breakdown for each ISIC will still be needed from the NIS.

Table 2.11. Number of Establishments, by Main Activity Sector – Provinces (2011)

Province	Total	Mining and Quarrying	Manufacturing	Electricity, Gas, Steam and Air conditioning supply	Water supply, Sewerage, Waste management and Remediation activities	nstruction	Wholesale and Rental trade, repair of motor vehicles and motorcycles	Transportation and Storage	Accomodation and Food Service activities	Information and Communication	Financial and Insurance activities	Real estate activities	Professional, Scientific and Technical activities	Administrative and Support service activities	Education	Human health and Social work activities	Arts, Entertainment and Recreation	Other service activities
Cambodia	**505,134**	**179**	**71,416**	**4,607**	**461**	**188**	**292,350**	**1,557**	**69,662**	**4,711**	**3,584**	**120**	**957**	**6,023**	**9,874**	**4,865**	**1,780**	**32,780**
01 Banteay Meanchey	21,541	14	2,664	216	33	23	13,021	69	2,133	280	466	1	57	175	549	218	102	1,511
02 Battambang	34,097	16	2,913	284	35	12	21,281	47	4,491	375	377	7	79	588	787	353	119	2,333
03 Kampong Cham	56,263	17	7,403	727	83	18	33,506	56	7,638	442	431	0	81	644	1,086	476	87	3,568
04 Kampong Chhnang	19,690	4	5,560	256	12	3	9,701	64	2,092	88	80	0	17	201	417	113	48	1,034
05 Kampong Speu	22,541	8	6,003	281	27	1	12,140	31	1,975	79	83	0	23	285	381	139	23	1,062
06 Kampong Thom	22,284	24	4,120	215	12	6	12,724	14	2,664	190	104	0	18	204	597	170	24	1,198
07 Kampot	17,042	14	1,499	211	6	7	9,823	26	3,104	157	115	3	13	215	431	161	40	1,217
08 Kandal	40,531	10	5,314	417	75	9	22,357	239	6,911	191	293	5	75	561	652	408	103	2,911
09 Koh Kong	5,051	0	241	26	5	0	3,056	12	1,015	36	37	0	5	40	128	58	57	335
10 Kratie	11,046	1	1,029	118	40	7	6,605	23	1,863	137	39	0	8	100	294	117	38	627
11 Mondul Kiri	2,222	20	131	5	1	2	1,407	0	295	58	19	0	1	12	85	38	16	132
12 Phnom Penh	95,848	18	8,705	117	63	68	57,829	539	14,734	1,363	826	84	395	827	909	1,359	434	7,588
13 Preah Vihear	5,317	4	1,432	62	0	1	2,734	9	459	70	14	0	11	47	192	33	17	232
14 Prey Veng	29,933	3	4,475	517	13	13	17,434	48	3,584	167	120	1	28	679	702	223	81	1,845
15 Pursat	12,075	1	1,489	153	13	1	7,258	15	1,607	72	46	1	18	101	326	87	110	767
16 Ratanak Kiri	5,480	4	415	27	0	1	3,552	17	750	80	10	0	6	25	187	57	36	303
17 Siem Reap	32,120	2	3,570	255	12	2	19,892	71	4,278	304	208	5	41	399	668	296	191	1,926
18 Preah Sihanouk	10,728	0	726	44	18	7	5,935	71	2,536	111	60	7	19	72	152	93	80	797
19 Stung Treng	4,665	2	749	22	1	0	2,496	14	768	115	7	2	7	31	180	42	26	202
20 Svay Rieng	15,245	0	2,391	257	8	3	8,579	152	1,553	164	81	3	26	444	354	112	58	1,060
21 Takeo	31,997	1	9,879	311	3	4	15,182	30	3,778	118	101	0	22	282	514	205	44	1,523
22 Otdar Meanchey	4,912	0	367	63	1	0	3,229	2	592	40	22	0	3	35	190	61	24	283
23 Kep	1,635	15	144	8	0	0	746	6	507	20	2	1	2	31	37	13	0	103
24 Pailin	2,871	1	197	15	0	0	1,863	2	335	54	43	0	2	25	56	33	22	223

Source: NIS (2012).

5. Number and Type of Factories

As for the commercial sector, the NIS Economic Census 2011 report provided data on the number of establishments by ISIC rev. 4. The number of establishments of the manufacturing subsector is available only for the whole of Cambodia. Further clarification with the NIS is necessary to break down the manufacturing sector by province.

The Ministry of Industry and Handicraft of Cambodia has a database of factories registered under it. This data was provided during the preparation of the Cambodia National Energy Statistics 2016. The information is not accessible on the website of the ministry. The data lists the number and types of factories from 1994 to 2014 by location in the provinces of Cambodia. Table 2.12 shows only the list of factories in Battambang provinces between 1994 to 2014. An updated version is needed from the ministry.

Table 2.12. List of Factories in Battambang Provinces, 2012–2020

Nº	Name of Company	Product	ISIC Rev.4	Year	Location	Address	Capital Investment (US$)	Employee	Investment Source
1	Aerosoft Summit Footwear Co., Ltd.	Shoes	1520	2012	SampovLun	Vealvong, Tasta	20,000,000	99	Cambodia (Thailand)
2	Battambang Agro Industry Co., Ltd.	Casava Flour Mill	1062	2012	Kamreang	Thmey, Oda	19,677,000	31	Cambodia
3	Battambang Conch Cement Co., Ltd.	Portland Cement	2394	2017	RattanakMundul	PhnomDaunmay, Sdao	174,779,000	455	Cambodia
4	Battambang Rice Investment Co., Ltd.	Rice Mill	1061	2012	ThmorKol	PoiYong, TaPoung	3,708,000	51	Cambodia
5	Capital Food Investment Import Export Co., Ltd.	Rice Mill	1061	2012	ThmorKol	NR5, Otaky, Otaky	5,824,000	119	Cambodia
6	Dongfang Paper Mill Industry Technology (Cambodia) Co., Ltd.	Paper	1702	2019	SangKe	SrahKeo, KamPungPreas	11,111,000		China
7	Hunan Er-Kang (Cambodia) Investment Co., Ltd.	Starch, Medicine Raw Material	1061 2100	2013	RattanakMundul	Takroik, Treng	18,881,000	23	China
8	Kai Gao Paper Industry Co., Ltd.	Paper Pulp	1701	2019	RatanakMundul	Phcheav, Treng	5,000,000	8	China
9	Kai Gao Paper Industry Co., Ltd. No.1	Chemical	2013	2020	RatanakMundul	TaKruok, Treng	5,000,000	8	China
10	Khmer Envelope Co., Ltd.	Envelope	1702	2015	KamReang	DeyKrohom, TaSen	3,178,000	145	Japan
11	Ly Taimeng Co., Ltd.	Casava Flour Mill	1061	2010	Kamreang	Oda, Oda	1,083,000	25	Cambodia
12	Mei Jing Rice (Cambodia) Co., Ltd	Rice Mill	1061	2015	MongRussey	NR5, SteoungChok, PreyToch	24,043,000	86	China
13	Ni Mei (Cambodia) Pharmaceutical Co., Ltd.	Medicine	2100	2017	RattanakMundul	Phcheav, Treong	5,000,000	10	China
14	Phoenix Industrial Co., Ltd.	Starch, Capsule, Ethanol, Biochemical	1062 1061 2011 2100	2016	RattanakMundul	Phcheav, Treng	47,352,000	100	China
15	Thaneakea Srov (Kampuchea) Plc.	Rice	1061	2018	ThmorKol	HaiSan, Chrey	1,540,000	20	Cambodia
16	Wang Kang Biochemical Co., Ltd.	Alcohol, Sodium Nitrat Powder, Flour	2011 2012 1062	2015	RattanakMundul	Takruk, Treng	37,632,000	203	China

Source: Author's revision.

6. Number of Vehicles Registered, by Province

The NIS Statistical Yearbook has data on the estimated number of vehicles in Cambodia, by type of vehicle. The data available on the website is from 1992 to 2005 (Table 2.13).

The Ministry of Public Works and Transport of Cambodia has data on registered and newly registered vehicles by type. The data, also by province, is available on request.

Table 2.13. Estimated Number of Vehicles in Cambodia, 1992–2005

	1992	1998	1999	2000	2001	2002	2003	2004	2005
Phnom Penh									
Cars, minibuses and pickups	112,573	144,830	149,411	151,090	156,320	162,997	17,564	185,420	195,268
Bus	1,873	2,387	2,443	2,483	2,554	2,736	2,843	3,045	3,207
Trucks	8,080	18,781	22,527	25,876	26,525	27,830	28,998	30,448	32,065
Other vehicles	3	317	353	371	396	421	428	440	463
Motorcycles	225,903	361,441	382,027	426,571	470,261	487,217	515,108	537,772	566,334
Total vehicles	**348,432**	**527,756**	**556,761**	**606,391**	**656,056**	**681,201**	**718,941**	**757,125**	**797,337**
% change	-	5.50%	5.50%	8.90%	8.20%	3.80%	5.50%	5.30%	5.30%
Provinces									
Cars	22,515	31,438	35,901	42,761	44,241	46,130	48,038	49,878	51,960
Bus	375	426	432	435	442	460	426	457	476
Trucks	1,616	1,776	1,794	1,943	2,008	2,138	1,450	1,498	1,561
Other vehicles	-	-	-	-	-	-	-	-	-
Motorcycles	45,181	72,327	76,925	86,932	95,670	99,061	104,640	109,172	113,729
Total vehicles	**69,686**	**105,966**	**115,051**	**132,070**	**142,360**	**147,790**	**154,554**	**161,005**	**167,725**
% change	-	5.40%	8.60%	14.80%	7.80%	3.80%	4.60%	4.20%	4.20%
Cambodia									
Cars	135,088	176,268	185,312	193,851	200,561	209,128	219,602	235,298	247,322
Bus	2,248	2,813	2,875	2,918	2,996	3,196	3,269	3,502	3,681
Trucks	9,696	20,557	24,321	27,819	28,533	29,968	30,448	31,946	33,578
Other vehicles	3	317	353	371	396	421	428	440	462
Motorcycles	271,084	433,768	458,952	513,503	565,931	586,278	619,748	646,944	680,002
Total vehicles	**418,118**	**633,722**	**671,812**	**738,461**	**798,416**	**828,991**	**873,495**	**918,130**	**965,046**
% change	-	5.50%	6.00%	9.90%	8.10%	3.80%	5.40%	5.10%	5.10%

Source: NIS (2006).

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Chapter 3

Introduction of Energy Consumption Survey for Selected Provinces

1. Introduction

The Economic Research Institute for ASEAN and East Asia (ERIA), in collaboration with the General Department of Petroleum, Ministry of Mines and Energy of Cambodia, estimated the petroleum product consumption by sector and prepared the Cambodia Petroleum Supply Master Plan. The master plan aimed to draw an appropriate map of Cambodia's petroleum supply chain and system for 2040. From supply sites to final demand sites, the petroleum supply chain was based on the forecast of provincial demand for each petroleum product.

The existing data on petroleum demand was at the national level. The data was annual and covered demand by product and by sector. However, demand data by province and product were not available. It was necessary, therefore, to conduct an energy consumption survey at the provincial level to estimate the consumption of petroleum products in the province.

The survey aimed to collect the necessary petroleum consumption data at the provincial level to estimate consumption by sector and type of petroleum product. A local consultant conducted the survey based on the questionnaires prepared for the industry, road transport, residential, and commercial sectors.

This chapter provides an overview of the petroleum demand survey in provinces and presents the major results of the survey.

2. Methodology

2.1. Selection of provinces to be surveyed

The Kingdom of Cambodia has 25 provinces. Due to the survey limitations, the survey team selected six provinces as samples, using the following approach:

- All provinces were classified into small, medium, and large groups in terms of petroleum demand. Since no data on the petroleum demand of the provinces was available, the classification was based on the provinces' population:
  - Large: total population of more than 900,000
  - Medium: total population from 800,000 to 900,000
  - Small: total population less than 800,000
- Two provinces were chosen to represent the groups: Phnom Penh and Siem Reap (a total of six provinces were chosen)
- The six provinces selected were Kampong Cham, Kampong Speu, Preah Sihanouk, Battambang, Siem Reap, and Phnom Penh City.

2.2 Selection of samples

The energy consumption surveys were conducted in four sectors (residential, commercial, industry, and transport) for each province selected, using questionnaires provided by ERIA.

The proposed sample size in each province was 3,600, broken down by sector as follows:

- Factories : 100 x 6 = 600
- Transport : 200 x 6 = 1,200
- Commercial buildings : 100 x 6 = 600
- Households : 200 x 6 = 1,200

The number of samples for each type of end user was modified slightly to reflect the real condition of the area. The total final samples for the selected provinces numbered 2,015 for the four sectors surveyed. The breakdown was as follows:

1) Phnom Penh (total 440 samples)
    - Industry and/or factory: Total 30 samples (15 factories, 15 handicrafts)
    - Commercial buildings: Total 10 samples (5 hotels, 5 offices and/or supermarkets)
    - Transportation or vehicle: Total 200 samples (10 buses, 10 trucks, 20 pick-ups, 30 SUVs, 30 sedans, 50 motorcycles, 20 motor taxis, 20 tuk-tuks)
    - Residential or households: Total 200 samples (30 thatched/zinc/tile roof wooden houses, 140 flats)
2) Provinces. In each of the five provinces = 315 samples (total 315 X 5=1,575 samples) Some are in provincial towns, some in district centres
    - Industry: Total 15 samples (5 factories, 10 handicrafts).
    - Commercial building: total 10 samples (5 hotels, 5 offices or ~~/~~supermarkets)
    - Transportation or vehicle: total 145 samples (5 buses, 5 trucks, 10 pick-ups, 20 SUVs, 20 sedans, 60 motorcycles, 25 motor taxis)
    - Residential and household: total 145 samples (50 thatched/zinc/tile roof wooden houses, 85 flats, 10 mansions)

2.3 Design of the questionnaire

The questionnaires were prepared in close consultation with the study team members, consisting of the local consultant team, the General Department of Petroleum, and the ERIA expert team. The questionnaire consisted of two parts: general information and consumption data. The content of the questionnaire for each sector was:

- Factories: ISIC, petroleum consumption (name, litre/month), purpose, main product (name, production [/month])
- Transport: vehicle type, engine capacity, petroleum consumption (name, litre or kg/month), driving distance (km/month)
- Buildings: building type, floor area (m^2), petroleum consumption (name, litre/month), purpose
- Households: type, family size, petroleum consumption (name, litre or kg/month), purpose

The questionnaires are shown in section 3.5.

3.2.4 Distribution and collection of survey questionnaires

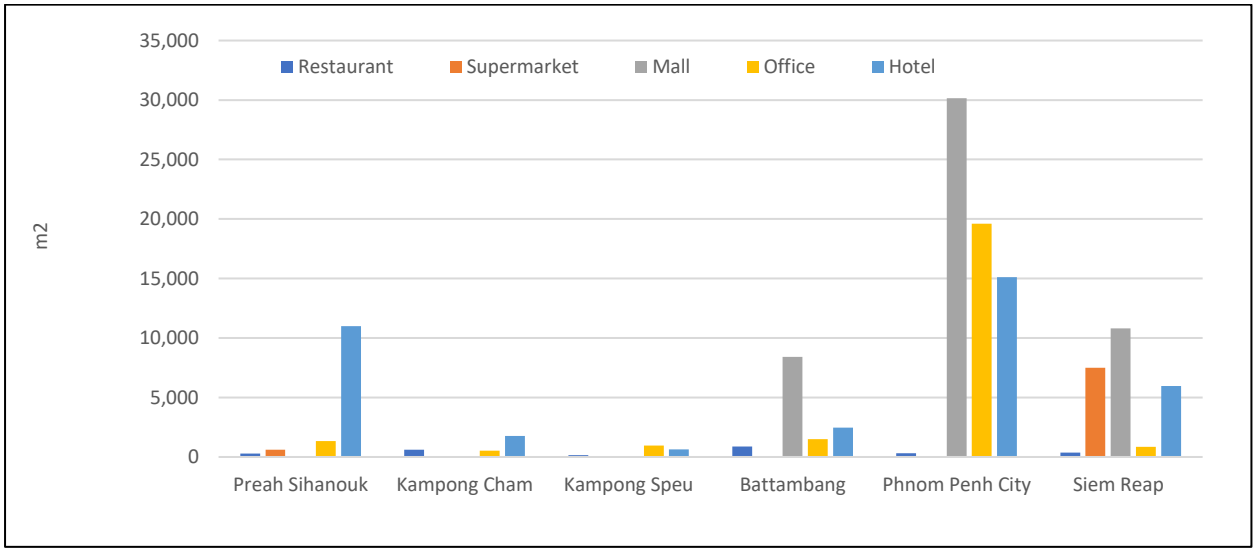
The consultant team conducting the survey comprised of one team leader, one field supervisor, and four surveyors.

3. Major Results from the Survey

3.1 Commercial sector

The samples for the commercial sector in the selected provinces covered hotels, office buildings (banks), restaurants, malls, and supermarkets. Fuel consumed includes liquefied petroleum gas (LPG) for cooking in hotels and restaurants, electricity, diesel backup generators, and in some hotels for heating boilers. The survey collected the floor area of each building category and the monthly consumption of LPG, diesel, and electricity. The average floor area for each category in each province is shown in Figure 3.1.

Figure 3.1. Average Floor Space of Selected Samples of the Commercial Sector

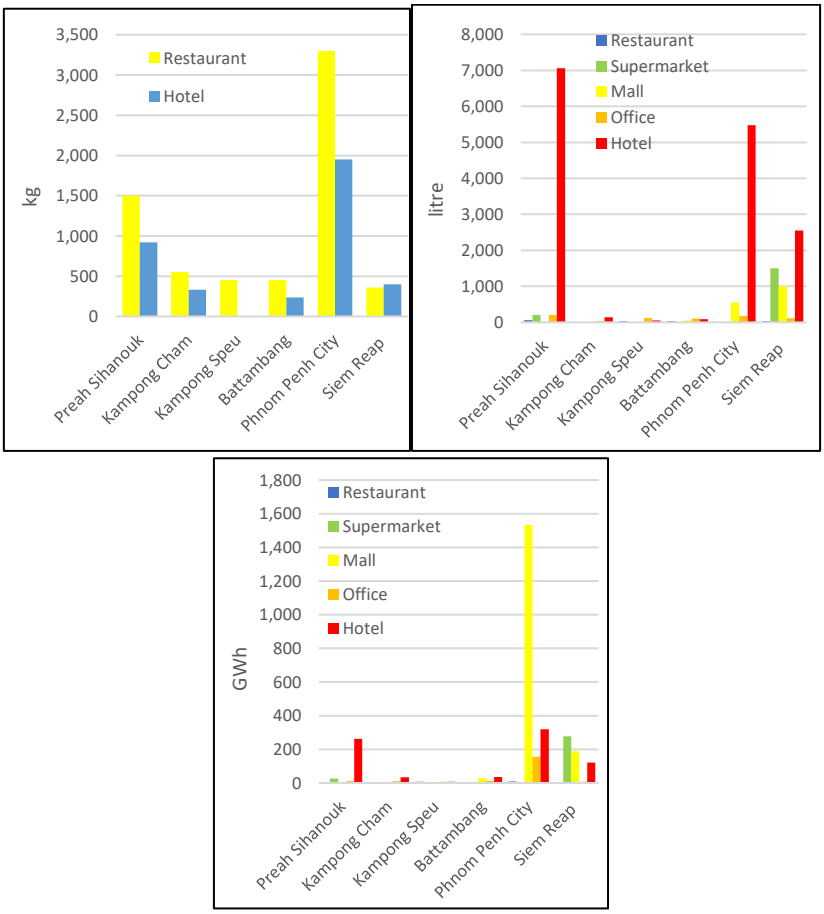


Source: Consultant's report.

LPG is used in hotels and restaurants in all provinces. It is also consumed in malls in Phnom Penh. Usually, LPG is not provided by the mall but by the tenant of the food court or restaurant in the mall. In this regard, LPG was deleted from the estimation. The average monthly consumption of LPG ranges from 322 kg/month in Battambang to 3,300 kg/month in Phnom Penh.

Diesel is mainly used for backup electricity for most buildings. Also, hotels consumed diesel for boilers to provide hot water to guest rooms. Most of the samples in the commercial sector have their generator due to Cambodia's occasional blackouts. These respondents have one or two generators. They have fuel storage tanks of various sizes, depending on the capacity of the generators. The monthly consumption of LPG, diesel, and electricity is shown in Figure 3.2.

Figure 3.2. Monthly Consumption of LPG, Diesel, and Electricity in the Commercial Sector



Source: Consultant's report.

Based on the survey's monthly consumption and floor area, the unit consumption of LPG, diesel, and electricity (energy intensity) for each category was estimated by dividing the fuel consumption by floor area. The monthly intensity of the fuel consumed by the commercial category is shown in Table 3.1.

Table 3.1. Monthly LPG, Diesel, and Electricity Intensity

Province	Type of Building	LPG (kg/m2)	Diesel (litre/m2)	Electricity (MWh/m2)
Preah Sihanouk	Restaurant	0.20	0.20	21
	Supermarket	0.33	0.33	45
	Mall			
	Office	0.16	0.16	10
	Hotel	0.42	0.42	41
Kampong Cham	Restaurant	1.14	0.01	7
	Supermarket			
	Mall			
	Office	0.00	0.12	21
	Hotel	0.10	0.06	17

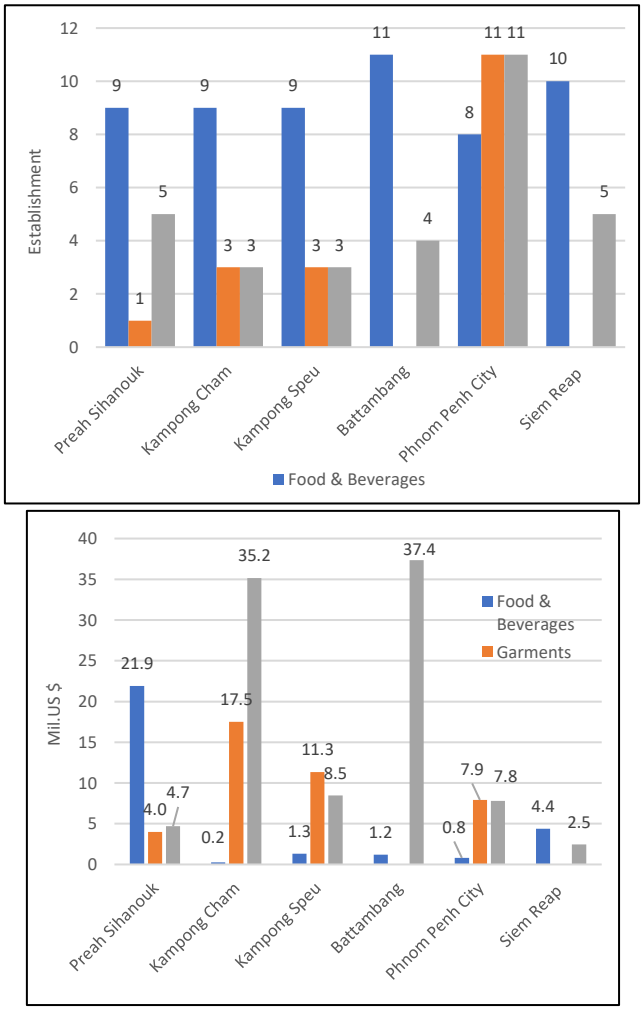
Kampong Speu	Restaurant	2.72	0.19	46
	Supermarket			
	Mall			
	Office	0.00	0.23	14
	Hotel	0.00	0.08	11
Battambang	Restaurant	0.57	0.06	5
	Supermarket			
	Mall	0.00	0.01	3
	Office	0.00	0.16	13
	Hotel	0.10	0.05	16
Phnom Penh City	Restaurant	9.15	0.00	26
	Supermarket			
	Mall	0.19	0.02	50
	Office	0.00	0.04	11
	Hotel	0.55	0.50	29
Siem Reap	Restaurant	1.00	0.08	13
	Supermarket	0.00	0.20	37
	Mall	0.00	0.09	17
	Office	0.00	0.16	10
	Hotel	0.04	0.29	18

Source: Consultant's report.

3.2. Industry sector

The industries surveyed were grouped into three: food and beverages, garments, and others. Figure 3.3 shows the sample size and annual revenue for each group.

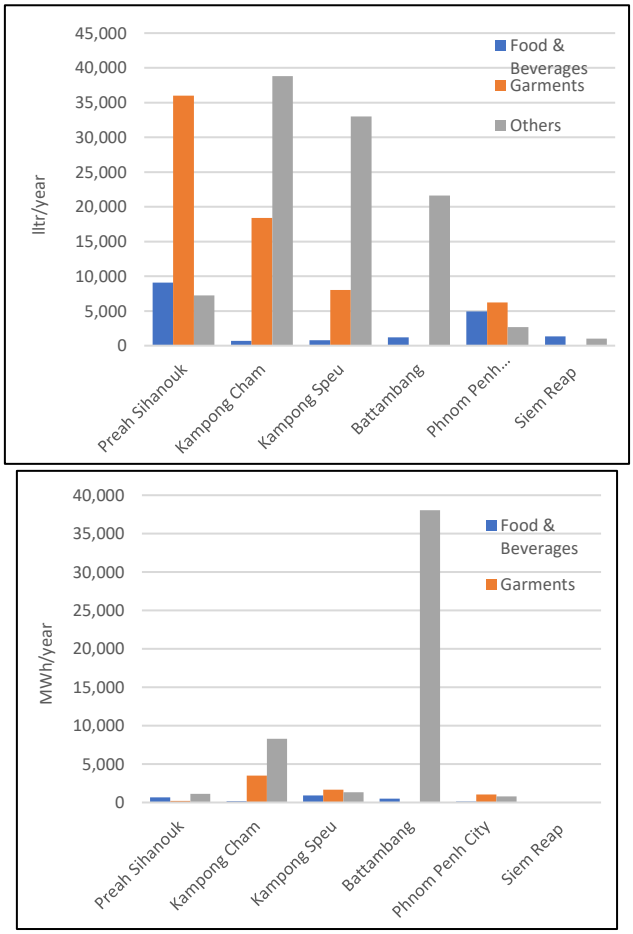
Figure 3.3. Sample Size and Annual Revenue of the Industry Sub-sectors



Source: Consultant's report.

None of the industries surveyed consumed LPG. Usually, industries consumed LPG for the non-manufacturing process, such as heating water for drinking; thus, LPG is usually excluded from the consumption of industry. On the other hand, diesel was mainly consumed for backup generators as the Electricite du Cambodge (EDC) cut off supply during certain hours due to electricity supply shortage. The average annual consumption of diesel was 1,217 litres in Siem Reap to 30,000 litres in Battambang. For electricity, the average yearly consumption was 206 MWh to around 10,220 MWh, the highest in Battambang where one of the samples is the cement factory. Figure 3.4 shows the average annual diesel and electricity consumption by sub-sector.

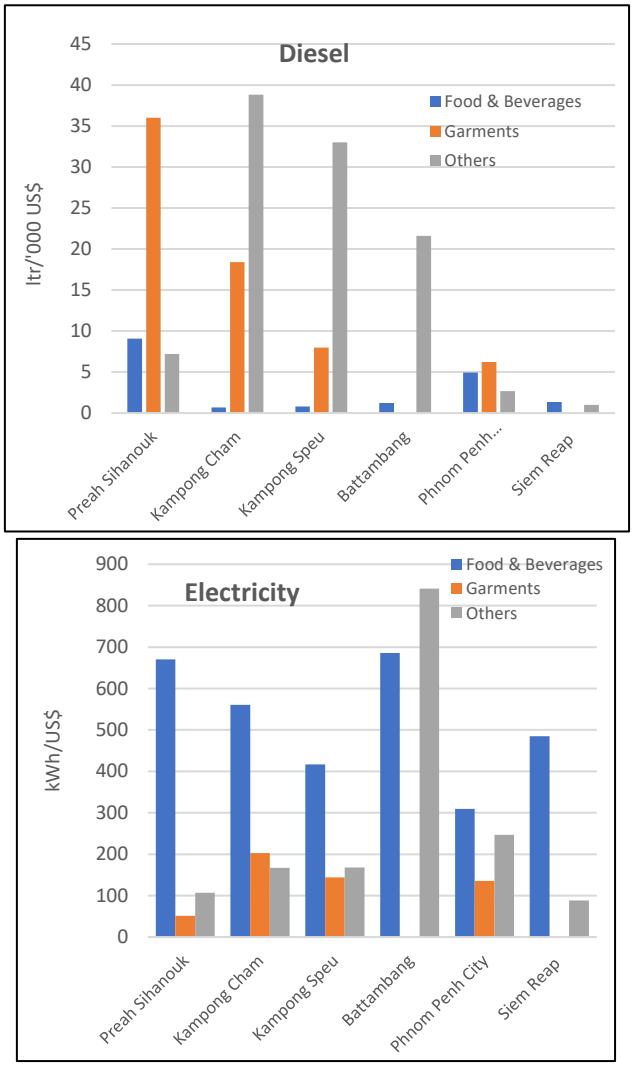
Figure 3.4. Average Annual Diesel and Electricity Consumption



Source: Consultant's report.

The average unit consumption of diesel and electricity (intensity) is the average consumption divided by the revenue (Figure 3.5). The average diesel intensity for the selected provinces ranged from 1.2 litres/'000 US$ in Kampong Speu to 5.2 litres/'000 US$ in Siem Reap. The average electricity intensity ranged from 227 to 727 kWh/'000US$ for Seam Reap and Battambang. One of the respondents in Battambang is the cement factory.

Figure 3.5. Average Fuel Intensity of Surveyed Industries

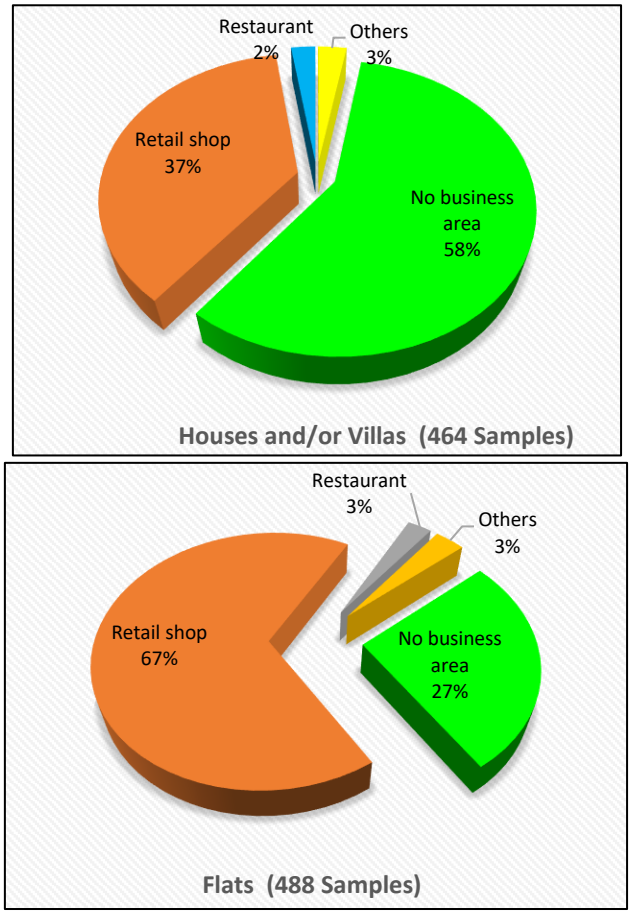


Source: Consultant's report.

3.3 Residential sector

The type of dwellings surveyed were broken down into houses and/or villas and flats. Flats are dwellings that occupy only a part of a building. Houses and/or villas (including wooden houses), are dwellings of relatively affluent households. The total samples for the six provinces were 464 for houses and/or villas and 488 for flats. Some of the sampled houses have business activities. Figure 3.6 shows the breakdown of the sampled houses, by type of business.

Figure 3.6. Household Profile for Houses and/or Villas and Flats



Source: Consultant's report.

The respondents use LPG for cooking, gasoline for their vehicles, and diesel for backup generators or pumped-up water. However, the use of fuel for transportation and backup generator was not considered household fuel consumption. Thus, the result here is only for LPG and electricity.

The average monthly LPG consumption of houses and/or villas is 6–10 kg., while flats, 8–10 kg (Table 3.2). The monthly electricity consumption is between 151–289 kWh for houses and/or villas and 183–367 kWh for flats. The high consumption of flats compared to houses and/or villas is due to the higher sample of flats with retail shops compared to no business.

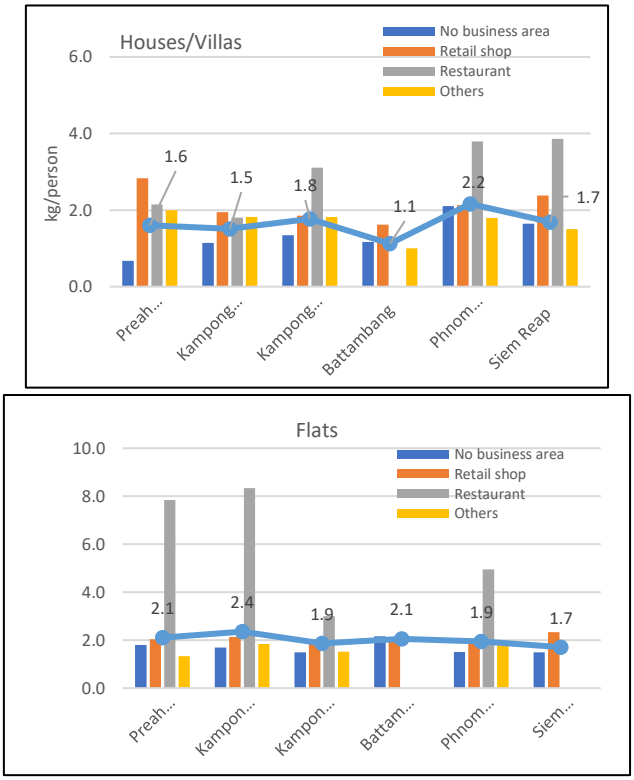
Table 3.2. Average Monthly LPG and Electricity Consumption, by House Type

Province	Type of Building	LPG (kg/m2)		Electricity (MWh/m2)	
		Houses/ Villas	Flats	Houses/ Villas	Flats
Preah Sihanouk	No business area	4	7	79	114
	Retail shop	14	9	461	261
	Restaurant	17	24	140	120
	Others	11	7	300	245
Kampong Cham	No business area	5	7	94	147
	Retail shop	9	9	221	193
	Restaurant	9	28	400	178
	Others	6	7	87	176
Kampong Speu	No business area	5	7	103	181
	Retail shop	8	8	177	252
	Restaurant	21	18	275	230
	Others	12	6	221	320
Battambang	No business area	6	9	140	268
	Retail shop	8	11	196	404
	Restaurant				
	Others	6		80	
Phnom Penh City	No business area	9	7	218	207
	Retail shop	9	9	337	338
	Restaurant	20	21	857	324
	Others	9	9	345	440
Siem Reap	No business area	8	8	231	320
	Retail shop	13	11	315	293
	Restaurant	27		367	
	Others	12		1400	

Source: Consultant's report.

The energy intensity of LPG for the household sector is the LPG consumption divided by the persons in the specific household. Figure 3.7 shows the LPG intensity for the two types of households based on the surveyed data.

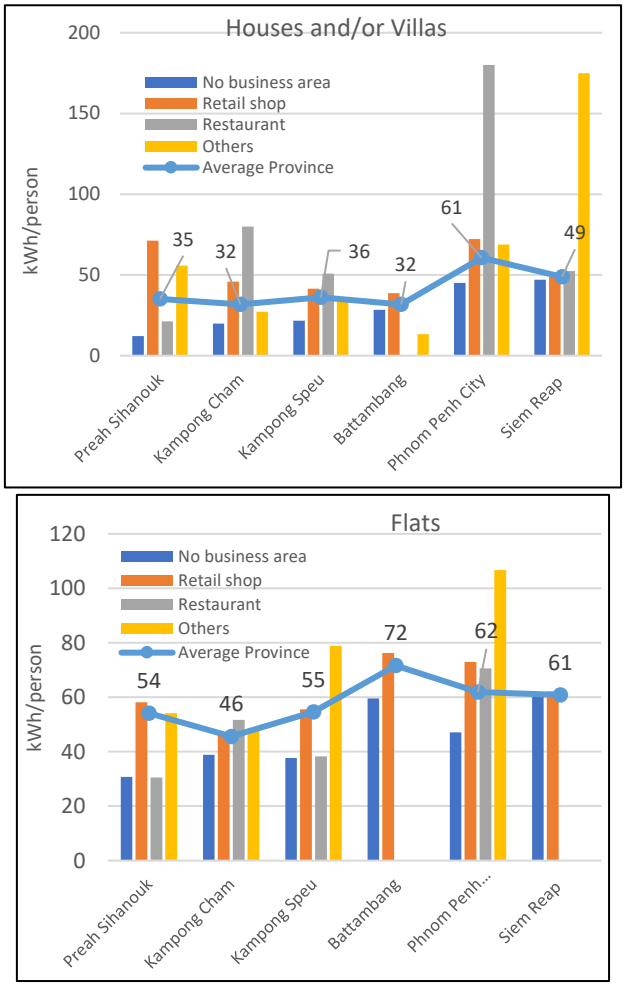
Figure 3.7. Average Monthly LPG Intensity, by House Type



Source: Consultant's report.

Similarly, the average monthly electricity intensity is consumption divided by the persons in the specific household types (Figure 3.8)

Figure 3.8. Average Monthly Electricity Intensity, by House Type

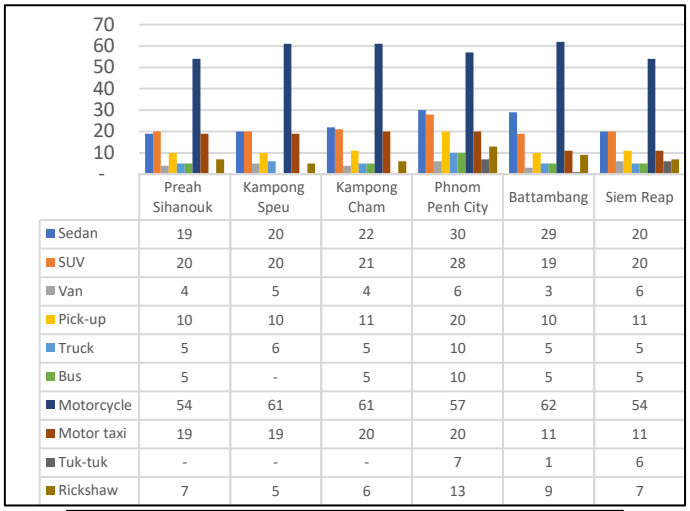


Source: Consultant's report.

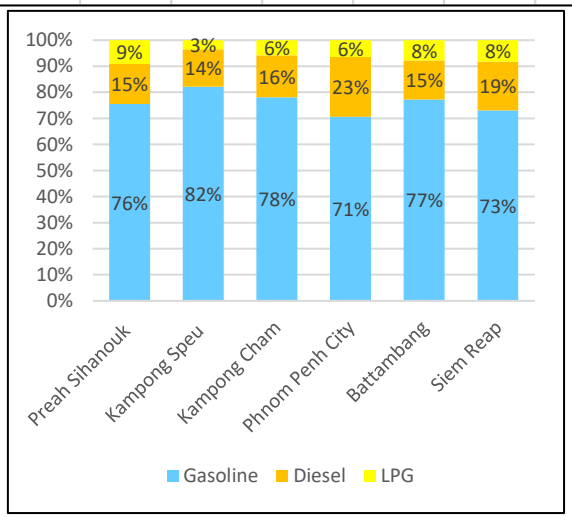
3.4 Transport sector

Sampled were sedans, SUVs and/or minibuses, vans, pick-ups, trucks, buses, motorcycles, motor taxis, and three-wheeled tuk-tuks. The total sample vehicles for the six selected provinces numbered 920. Figure 3.9 shows the breakdown.

Figure 3.9. Sampled Vehicles, by Province and Vehicle Type



	Preah Sihanouk	Kampong Speu	Kampong Cham	Phnom Penh City	Battambang	Siem Reap
Sedan	19	20	22	30	29	20
SUV	20	20	21	28	19	20
Van	4	5	4	6	3	6
Pick-up	10	10	11	20	10	11
Truck	5	6	5	10	5	5
Bus	5	-	5	10	5	5
Motorcycle	54	61	61	57	62	54
Motor taxi	19	19	20	20	11	11
Tuk-tuk	-	-	-	7	1	6
Rickshaw	7	5	6	13	9	7



Source: Consultant's final paper.

Motorcycles and motor taxis combined have the largest share of the vehicles sampled, the highest in Kampong Speu (55%) and the lowest in Phnom Penh (38%). The share of sedans and SUVs on average are 15% and 14%, respectively. Since these vehicles mainly consume gasoline, those surveyed were gasoline vehicles ranging from 71% to 82% of the total vehicles sampled. The parking lot survey result provided the data on the monthly consumption by fuel, and the distance travelled for each type of vehicle sampled. Table 3.3 shows the average fuel economy for every kind of vehicle in the selected province.

Table 3.3. Fuel Economy of Sampled Vehicles, by Province (km/litre)

Province	Fuel Type	Sedan	SUV	Van	Pick-up	Truck	Bus	Motor-cycle	Motor taxi	Tuk-tuk	Rickshaw
Preah Sihanouk	Gasoline	12	8		8			46	44		
	Diesel			10	9	5	4				
	LPG	10	12								11
Kampong Speu	Gasoline	11	8					45	44		
	Diesel			8	10	5					
	LPG										10
Kampong Cham	Gasoline	13	8					44	40		
	Diesel			7	10	8	8				
	LPG		8								14
Phnom Penh City	Gasoline	12	8		8			48	44	42	
	Diesel		13	8	9	4	3				
	LPG										9
Battambang	Gasoline	11	8		9			46	44	35	
	Diesel		11	9	10	3	4				
	LPG		9								9
Siem Reap	Gasoline	14	8					46	44	41	
	Diesel			8	9	3	3				
	LPG		11								11

Source: Consultant's final paper.

Based on fuel economy and the monthly distance travelled, the fuel consumption of each vehicle per year was estimated (Table 3.4).

Table 3.4. Unit Consumption (Fuel Intensity) of Vehicles, by Selected Province (litre/vehicle)

Vehicle Type	Preah Sihanouk			Kampong Speu			Kampong Cham			Phnom Penh City			Battambang			Siem Reap		
	Gasoline	Diesel	LPG	Gasoline	Diesel	LPG	Gasoline	Diesel	LPG	Gasoline	Diesel	LPG	Gasoline	Diesel	LPG	Gasoline	Diesel	LPG
Sedan	811		13,200	964			667			862			937			697		
SUV	1,476		10,776	1,304			1,098		10,080	1,402	1,200		1,256	1,227	15,976	1,345		11,275
Van		6,150			6,447			8,308			9,383			7,260			11,585	
Pick-up	1,312	1,570			1,601			1,378		1,250	1,297		1,249	1,215			1,303	
Truck		31,413			15,273			6,634			6,305			36,000			13,624	
Bus		50,400						22,979			25,506			19,201			64,500	
Motorcycle	120			114			110			107			108			102		
Motor taxi	996			887			745			743			912			827		
Tuk-tuk										841			1,200			859		
Rickshaw			2,589			2,380			1,778			2,455			2,258			2,363

Source: Consultant's final paper.

4 Methodology to Estimate Provincial Oil Consumption

The consumption survey conducted for the industry, road transport, residential, and commercial sectors estimated the unit consumption of the different types of oil consumed by the sectors in the selected provinces. This fuel intensity serves to estimate the oil consumption of the province. Inflating the survey result to the provincial total was done by multiplying the specific energy consumption (intensity) with the respective sector's activity.

The methodology for estimating the provincial total oil consumption of the different sectors and the result is described in the following sections.

4.1 Commercial sector

The fuel intensity (LPG, diesel, and electricity) for each category (shopping mall and restaurant, office, and hotel) was estimated utilising the commercial sampling survey above. The fuel consumption for each category was then calculated by multiplying those intensities by floor area using the following formula.

$$OIL_j = \sum_{i=category}^{n} \left(FOIL_{ij} * FLOOR_{ij}\right)$$

Where,

OIL_j is the total LPG or diesel consumption for province j.

$FOIL_{ij}$ is the LPG or diesel consumption per m^2 for category *I and province j*

$FLOOR_{ij}$ is the total floor area in m^2 for category *I and province j*

The floor areas by category can be obtained from the NIS, Ministry of Planning Cambodia. The data should be by province to estimate the provincial level of the commercial sector's oil and electricity consumption.

4.2 Industry sector

In the industrial survey, the unit consumption (intensity) of oil and electricity was calculated by dividing the fuel consumption into each sub-sector surveyed by its sales revenue and adjusted by the value-added ratio. Multiplying the unit consumption with the sector's GDP resulted in total diesel or LPG for the whole country. Thus, the total oil consumption of the province is:

$$EC_j = \sum_{i=sector}^{n} IEC_{ij} * \left(GDP_{ij}/VAR_i\right)$$

Where,

EC_j is the total energy consumption for province j

IEC_{ij} is the energy consumption per revenue for sector *i* and province *j* (intensity)

GDP_{ij} is the total GDP for sector *I* and province *j*

VAR_i is the value-added ratio for sector *i* (assumed to be 0.5 for all sectors)

The manufacturing sector GDP of the province should be available at the NIS, Ministry of Planning, Cambodia. The data should be by province and at the constant price level.

4.3 Residential sector

The sampling survey in the residential sector was differentiated between houses and/or villas and flats. Each household type was further classified into those with business area and without business area. The business area can be a restaurant, a retail shop, and others. The fuel intensity was calculated above by dividing the consumption by the number of persons in the household. Provincial-level consumption was estimated using the following formula:

$$Fuel_j = \sum_{i=regions}^{n} \left(PFuelij * HSIZEij * N_{ij} * UR_{ij}\right)$$

Where,

$Fuel_j$ is the total fuel consumption (LPG and electricity) for province *i*

$PFuel_{ij}$ is the fuel consumption per person (fuel intensity) for house type *i* and province *j*

$HSIZE_{ij}$ is the household size for house type *i* and province *j*

N_{ij} is the number of households for house type *i* and province *j*

UR_{ij} is the fuel utility rate for house type *i* and province *j*

Regions are defined as Phnom Penh city and other urban and rural areas. The number of households for each region was obtained from the latest Cambodia Socio-economic Census (CSES) by the NIS of Cambodia. The utilisation rate for LPG of each region was then obtained from the main sources of cooking by geographical domain in the CSES housing survey. Similarly, the CSES also included households' primary sources for lighting.

4.4 Transport sector

The parking lot survey estimated the unit fuel consumption (intensity) for the different types of vehicles surveyed in each province. The total oil consumption for the road transport in each selected province was estimated using the following equation:

$$Fuel_j = \sum_{i=vehicle}^{n} \left(FE_{ij} * DIS_{ij} * VEH_{ij}\right)$$

Where,

Fuelj is the total gasoline/diesel/LPG consumption for province *j*

FEij is the fuel economy of vehicle type *i* and province *j*

DISij is the distance travel of vehicle type *i* and province *j*

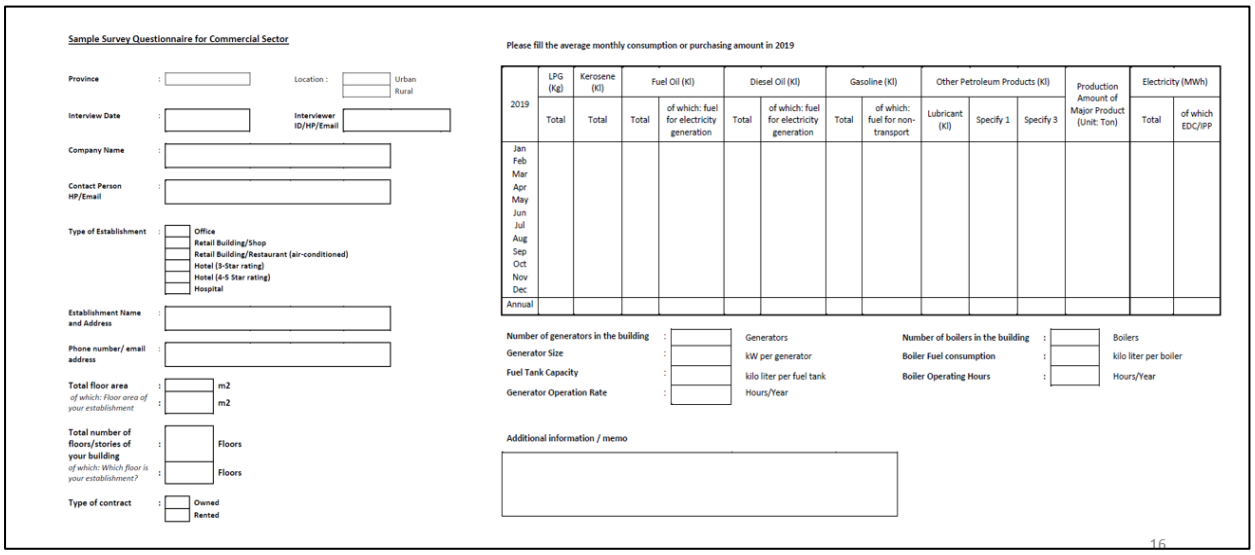
VEHij is the total number of gasoline/diesel/LPG vehicles for type *i* and province *j*

On request by the Ministry of Energy, the Ministry of Transport can provide the number of vehicles by type and fuel consumed. Vehicle registration usually includes the type and fuel consumed.

5. Survey Questionnaires

The survey questionnaire was developed using an excel spreadsheet. The enumerator then transferred the results into a Word format. Table 3.5 shows the questionnaire for the commercial sector, Table 3.6 for the industry sector, Table 3.7 for the residential sector, and Table 3.8 for the transport sector.

Table 3.5. Commercial Sector Questionnaire



Sample Survey Questionnaire for Commercial Sector

Province : Location : Urban / Rural

Interview Date : Interviewer ID/HP/Email :

Company Name :

Contact Person HP/Email :

Type of Establishment : Office; Retail Building/Shop; Retail Building/Restaurant (air-conditioned); Hotel (3-Star rating); Hotel (4-5 Star rating); Hospital

Establishment Name and Address :

Phone number/ email address :

Total floor area : m2

of which: Floor area of your establishment : m2

Total number of floors/stories of your building : Floors

of which: Which floor is your establishment? : Floors

Type of contract : Owned / Rented

Please fill the average monthly consumption or purchasing amount in 2019

2019	LPG (Kg)	Kerosene (Kl)	Fuel Oil (Kl)		Diesel Oil (Kl)		Gasoline (Kl)		Other Petroleum Products (Kl)			Production Amount of Major Product (Unit: Ton)	Electricity (MWh)	
	Total	Total	Total	of which: fuel for electricity generation	Total	of which: fuel for electricity generation	Total	of which: fuel for non-transport	Lubricant (Kl)	Specify 1	Specify 3		Total	of which EDC/IPP
Jan														
Feb														
Mar														
Apr														
May														
Jun														
Jul														
Aug														
Sep														
Oct														
Nov														
Dec														
Annual														

Number of generators in the building : Generators

Generator Size : kW per generator

Fuel Tank Capacity : kilo liter per fuel tank

Generator Operation Rate : Hours/Year

Number of boilers in the building : Boilers

Boiler Fuel consumption : kilo liter per boiler

Boiler Operating Hours : Hours/Year

Additional information / memo

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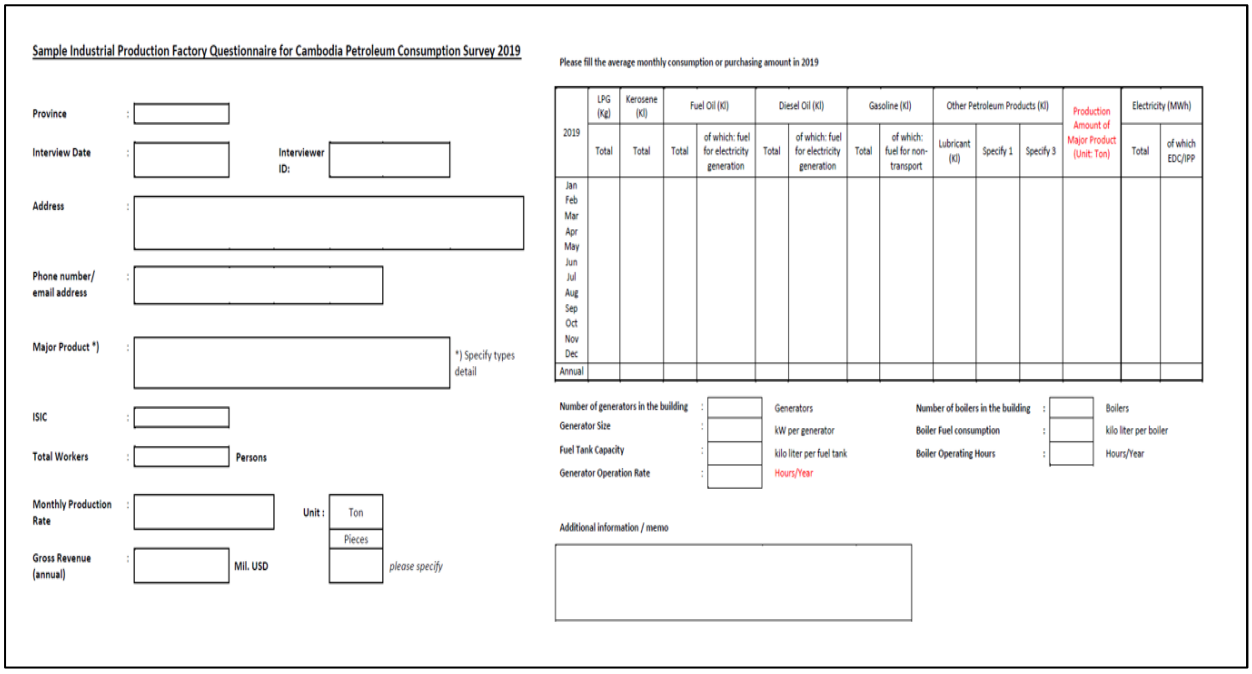
Table 3.6. Industry Sector Questionnaire



Sample Industrial Production Factory Questionnaire for Cambodia Petroleum Consumption Survey 2019

Province :

Interview Date : Interviewer ID:

Address :

Phone number/ email address :

Major Product *) : *) Specify types detail

ISIC :

Total Workers : Persons

Monthly Production Rate : Unit : Ton / Pieces

Gross Revenue (annual) : Mil. USD please specify

Please fill the average monthly consumption or purchasing amount in 2019

2019	LPG (Kg)	Kerosene (Kl)	Fuel Oil (Kl)		Diesel Oil (Kl)		Gasoline (Kl)		Other Petroleum Products (Kl)			Production Amount of Major Product (Unit: Ton)	Electricity (MWh)	
	Total	Total	Total	of which: fuel for electricity generation	Total	of which: fuel for electricity generation	Total	of which: fuel for non-transport	Lubricant (Kl)	Specify 1	Specify 3		Total	of which EDC/IPP
Jan														
Feb														
Mar														
Apr														
May														
Jun														
Jul														
Aug														
Sep														
Oct														
Nov														
Dec														
Annual														

Number of generators in the building : Generators

Generator Size : kW per generator

Fuel Tank Capacity : kilo liter per fuel tank

Generator Operation Rate : Hours/Year

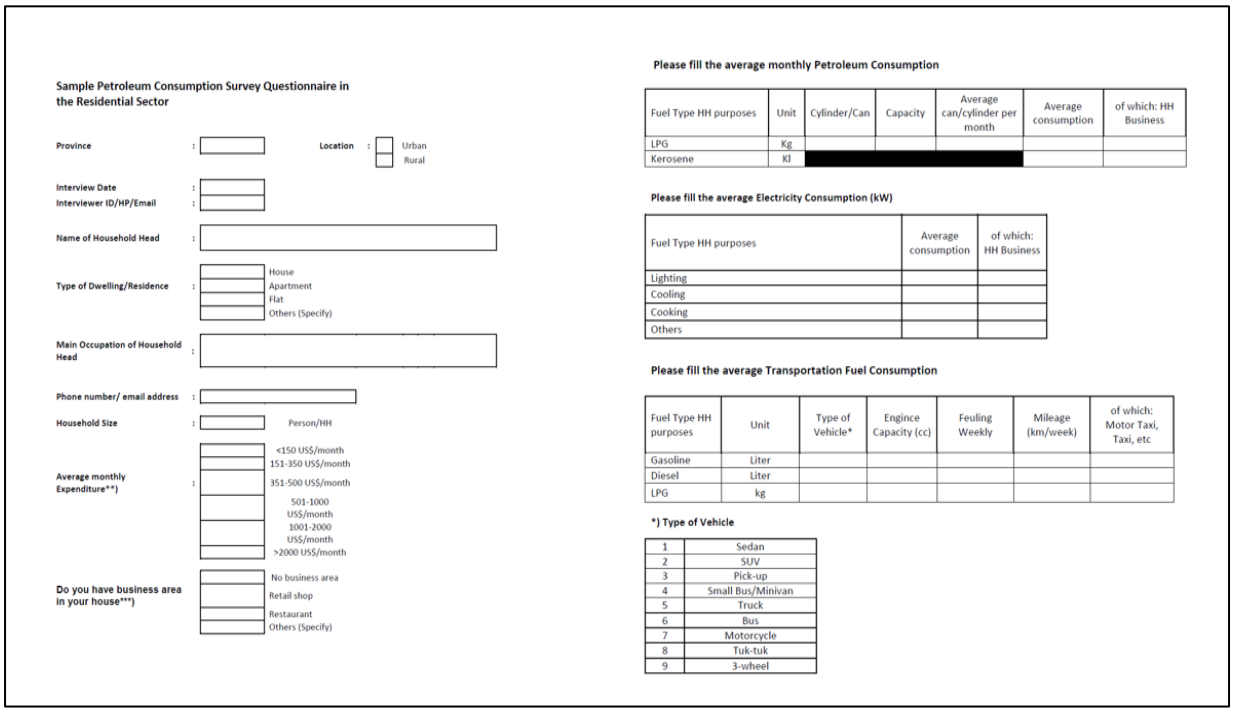
Number of boilers in the building : Boilers

Boiler Fuel consumption : kilo liter per boiler

Boiler Operating Hours : Hours/Year

Additional information / memo

Table 3.7. Residential Sector Questionnaire



Sample Petroleum Consumption Survey Questionnaire in the Residential Sector

Province : Location : Urban / Rural

Interview Date :

Interviewer ID/HP/Email :

Name of Household Head :

Type of Dwelling/Residence : House / Apartment / Flat / Others (Specify)

Main Occupation of Household Head :

Phone number/ email address :

Household Size : Person/HH

Average monthly Expenditure**) : <150 US$/month / 151-350 US$/month / 351-500 US$/month / 501-1000 US$/month / 1001-2000 US$/month / >2000 US$/month

Do you have business area in your house***) : No business area / Retail shop / Restaurant / Others (Specify)

Please fill the average monthly Petroleum Consumption

Fuel Type HH purposes	Unit	Cylinder/Can	Capacity	Average can/cylinder per month	Average consumption	of which: HH Business
LPG	Kg					
Kerosene	Kl					

Please fill the average Electricity Consumption (kW)

Fuel Type HH purposes	Average consumption	of which: HH Business
Lighting		
Cooling		
Cooking		
Others		

Please fill the average Transportation Fuel Consumption

Fuel Type HH purposes	Unit	Type of Vehicle*	Engince Capacity (cc)	Feuling Weekly	Mileage (km/week)	of which: Motor Taxi, Taxi, etc
Gasoline	Liter					
Diesel	Liter					
LPG	kg					

*) Type of Vehicle

1	Sedan
2	SUV
3	Pick-up
4	Small Bus/Minivan
5	Truck
6	Bus
7	Motorcycle
8	Tuk-tuk
9	3-wheel

Table 3.8. Transport Sector Questionnaire

ROAD TRANSPORT QUESTIONNAIRE

Province : Area* :

*) Select Area : Rural / Urban

Site Number : Site Name:

Date : Interviewer Name:

Interviewer ID/HP/EMAIL:

Please fill the average weekly consumption or purchasing amount

Seq.	Plate No.	Type of Vehicle*	Engine Capacity (cc)	Fueling Gasoline in last month (liter/m)	Fueling Diesel Oil in last Month (liter/m)	Fueling LPG in last month (liter/m)	Mileage in last month (km/m)
1							
2							
10							
11							
29							
30							

*) Type of vehicle

1. Sedan
2. SUV
3. Small Bus/Mini Van
4. Pick-up
5 Truck
6. Bus
7. Motor Cycle
8. Motor Taxi
9. Tuktuk
10. Others (specify)

Chapter 4

Current Petroleum Supply Chain in Cambodia

Chapter 4 clarifies the current situation of the petroleum supply chain in Cambodia. All petroleum products are imported, and most are shipped by tankers from Thailand, Singapore, and Viet Nam. However, LPG can be imported by tank-truck, so the import route is different from gasoline and diesel oil. And domestic supply is via cylinder delivery from bottling stations other than LPG service stations. In phase 2, the cost of each transportation means, the total transportation cost of each supply route, and the constraint of transportation volume of each transport means are clarified. (Please refer to Chapter 6).

The biggest import base for gasoline and diesel oil is Sihanoukville terminals by large tankers; the second is Phnom Penh terminals by small tankers via the Mekong River. Sihanoukville accounts for 60% of the total imports; the rest are from Phnom Penh and Kandal, etc. The total storage capacity is about 517,000 kilolitres (kl) nationwide, 70% in Sihanoukville. About 70,000 kl of the new expansion is planned, but about 70% is the second terminal near Phnom Penh. The second terminal receives the transfer volume from the import base.

As mentioned in Chapter 5.2, the demand for petroleum products is concentrated in Phnom Penh, Siem Reap, and Battambang. So, the Phnom Penh and Kandal terminals are the nearest import bases. However, imports to Phnom Penh and Kandal are by small tankers via the Mekong River, and because Phnom Penh and Kandal are near the city centre and expansion is difficult. On the other hand, Sihanoukville, which can import by using large tankers, is expanding as an import base. Oil companies with nationwide sales networks cannot rely only on terminals in Phnom Penh and Kandal. These oil companies have a large terminal in Sihanoukville to import using large tankers and build a second terminal near Phnom Penh for national distribution. The great distance between the demand centre and the import base is a characteristic of Cambodia's oil supply chain. Assuming that demand will more than double or triple in the future, how to prepare the supply route and transportation means will be an important issue.

1. Oil Terminals and Storage Capacity

1.1 Current situation

There are 23 oil terminals nationwide, with a total oil storage capacity of 517,047 kl (excluding jet fuel). Sihanoukville is the largest terminal area with seven oil terminals; the total storage capacity is 366,308 kl, 70.8% of nationwide capacity.

The second-largest oil terminal area is Phnom Penh, with nine oil terminals, with a total storage capacity is 77,459 kl, 15.0% of nationwide capacity. Table 4.1 shows the terminal areas nationwide. Kampot is the third-largest terminal area; it is also a maritime receiving base.

Table 4.1 Storage Capacity of Oil Terminals, by Location (Summary)

Unit:kl

Location	Terminal	Gasoline	Diesel Oil	Fuel Oil	Total Capacity
Sihanoukville	7	145,260	194,288	26,760	366,308
Phnom Penh	9	29,084	43,575	4,800	77,459
Kandal	2	10,000	4,000		14,000
Prey Veng	1	40	40		80
Koh Kong	1	1,000	2,000		3,000
Tbong Khmom	1	500	2,000		2,500
Kampot	1	30,200	14,500		44,700
Battambang	1	7,000	2,000		9,000
Total	**23**	**223,084**	**262,403**	**31,560**	**517,047**

kl = kilolitres.

Source: This project (2020).

Table 4.2 shows the storage tanks and capacity scale by terminal area, Sihanoukville, Phnom Penh, and other areas. Terminals in Sihanoukville have 49 tanks. These include 11 tanks with a capacity of 10,000 kl or more, and 19 tanks of 5,000 kl or more but less than 10,000 kl. These also include 10 tanks with 3,000 kl capacity or more but less than 5,000 kl, and nine tanks of less than 3,000 kl. These indicate many large terminals with large tanks. It also means that large tankers of 5,000–10,000 tonnes can be accepted.

On the other hand, the terminals in Phnom Penh have 40 tanks, including 14 tanks with a capacity of 3,000 kl or more but less than 5,000 kl, and 26 tanks of less than 3,000 kl. The terminal accepts a small tanker of 1,000–2,000 tonnes via the Mekong River, so a large tank is unnecessary. However, there is a reason a larger site is not possible. The other areas include Kandal and Kampot.

Kandal has two tanks with 5,000 kl; Kampot has three tanks of 5,400 kl and two tanks of 5,500 kl. Table 4.2 shows the breakdown of gasoline, diesel oil, and fuel oil.

Table 4.2. Number of Storage Tanks and Capacity Scale (kl), by Terminal Area

(Gasoline + Diesel Oil + Fuel Oil)

	Sihanoukville		**Phnom Penh**		**Other Areas**	
Tank Size	**Number of tanks**	**Total capacity**	**Number of tanks**	**Total capacity**	**Number of tanks**	**Total capacity**
Over 10,000	11	200,000	0	0	0	0
5,000-10,000	19	115,760	0	0	8	44,200
3,000–5,000	10	33,186	17	50,000	6	21,500
under 3,000	9	17,362	23	27,459	9	7,580
Total	**49**	**366,308**	**40**	**77,459**	**23**	**73,280**

Gasoline	**Sihanoukville**		**Phnom Penh**		**Other Areas**	
Tank size	Number of tanks	Total capacity	Number of tanks	Total capacity	Number of tanks	Total capacity
Over 10,000	2	40,000	0	0	0	0
5,000-10,000	11	71,000	0	0	6	33,200
3,000–5,000	6	20,898	6	18,000	4	14,000
under 3,000	7	13,362	7	11,084	4	1,540
Total	**26**	**145,260**	**13**	**29,084**	**14**	**48,740**

Diesel Oil	**Sihanoukville**		**Phnom Penh**		**Other Areas**	
Tank size	**Number of tanks**	**Total capacity**	**Number of tanks**	**Total capacity**	**Number of tanks**	**Total capacity**

Over 10,000	9	160,000	0	0	0	0
5,000–10,000	3	18,000	0	0	2	11,000
3,000–5,000	4	12,288	8	27,200	2	7,500
under 3,000	2	4,000	16	16,375	5	6,040
Total	**18**	**194,288**	**24**	**43,575**	**9**	**24,540**

Fuel Oil	**Sihanoukville**		**Phnom Penh**		**Other Areas**	
Tank size	**Number of tanks**	**Total capacity**	**Number of tanks**	**Total capacity**	**Number of tanks**	**Total capacity**
Over 10,000	0	0	0	0	0	0
5,000–10,000	5	26,760	0	0	0	0
3,000–5,000	0	0	3	4,800	0	0
under 3,000	0	0	0	0	0	0
Total	**5**	**26,760**	**3**	**4,800**	**0**	**0**

kl = kilolitres.

Source: This project.

1.2 Expansion plan

The total capacity of oil terminals planned in the next few years is 70,380 kl, and the total storage capacity of Cambodia will be about 590,000 kl. The two new oil terminals planned in Phnom Penh are inland terminals 20 km–40 km away from central Phnom Penh, not on the Mekong River coast. As for location, delivery can be done to Battambang, Phnom Penh, and Siem Reap without traffic congestion. The two new terminals are the second terminals, and the petroleum products will be transferred from Sihanoukville. Tank trucks seem to be the means of transfer for the time being, but pipeline and railway may be the options in the future.

The quantity that can be delivered from the terminal is calculated by the storage capacity and the combination of the frequency of arrival and the size of the receiving tankers, the number of shipping lanes, and the frequency of shipping per day. In the future, if demand more than doubles, the first response is to increase the shipping lanes and increase the shipping frequency. The second is to increase storage capacity accordingly, but adding large tanks and increasing the size of receiving ships reduce the frequency of arrivals and allow the oil company to enjoy the cheap freight of large tankers.

Table 4.3 Storage Capacity of Expansion Plan, by Location (Summary)

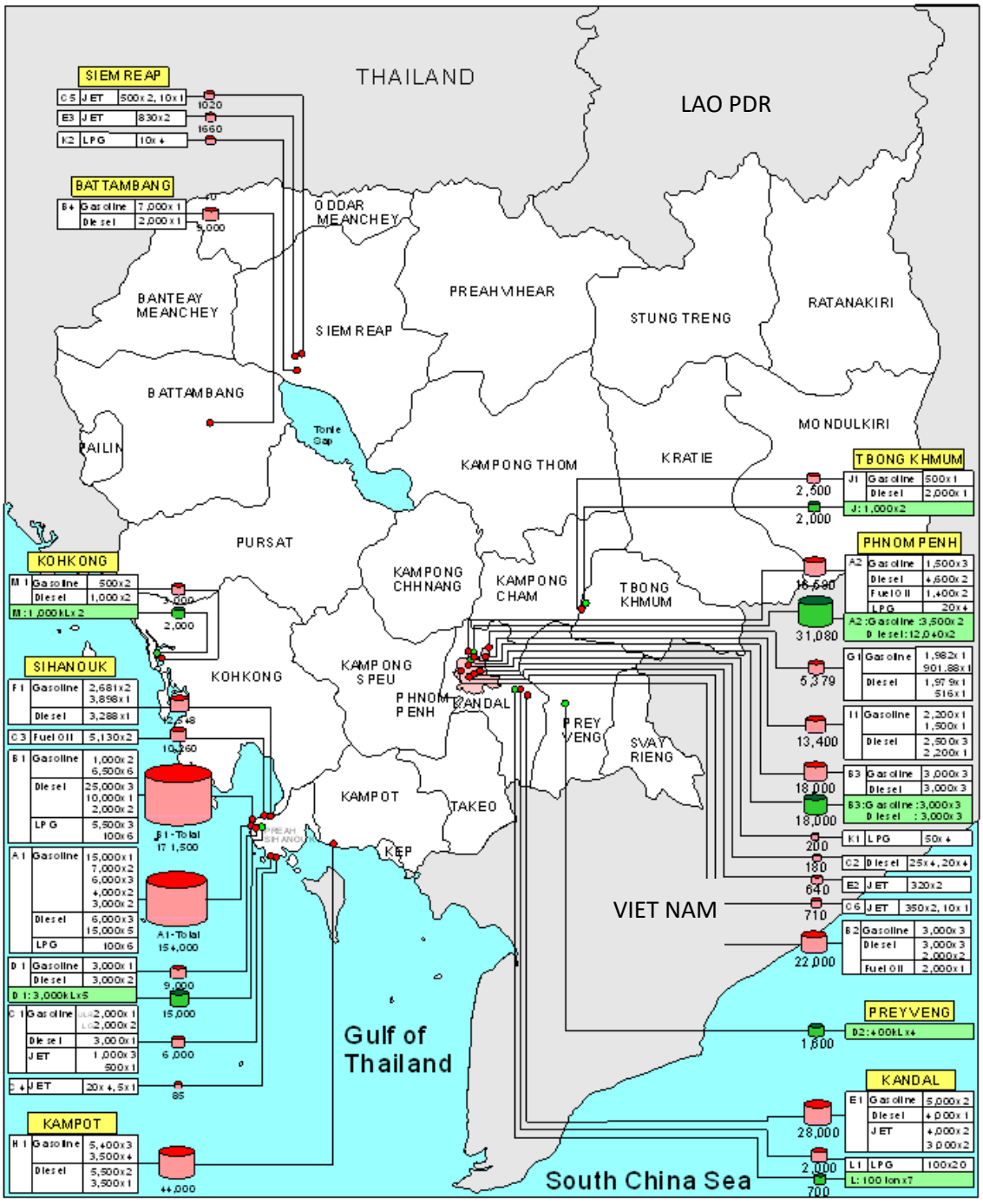
until kl

Location	Terminal	Gasoline	Diesel Oil	Fuel Oil	Total Capacity
Sihanoukville	1				15,000
Phnom Penh	2	16,000	33,080		49,080
Kandal	1				700
Prey Veng	1				1,600
Koh Kong	1				2,000
Tbong Khmom	1				2,000
kl = kilolitres.				**Total**	**70,380**

Source: This project.

Figure 4.1 shows Cambodia's oil storage tanks on a map.

Figure 4.1. Cambodia Oil Terminal Map



Source: This project, 2020.

2. Current Supply Chain of Petroleum Products in Cambodia

2.1 Import route

Currently, all petroleum products are imported, and import terminals are located in Sihanoukville, Kampot, Koh Kong along the Gulf and Phnom Penh, and Kandal along the Mekong River. According to Cambodia's import data (based on customs statistics) released by the ITC (International Trade Centre[1]) statistics of international trade 2020, import volume from Viet Nam in 2018 accounted for about 35%. Imports from Viet Nam are accepted at the terminal in Phnom Penh and Kandal via the Mekong River. Therefore, the remaining 65% is expected to be imported to the coastal terminals of Sihanoukville, Kampot, and Koh Kong.

Almost the same composition ratio is obtained from the results of the delivery volume survey by each terminal of oil companies. The delivery volume from Sihanoukville terminals accounts for 56%. Phnom Penh, the region with the largest demand, is close to the oil terminals along the Mekong River in Phnom Penh and Kandal. However, due to the limited size of oil tankers and terminals, the supply volume from Sihanoukville is high. Freight varies depending on the size of tankers used to import petroleum products. For example, small tankers of 1,000–2,000 tonnes are used for the Phnom Penh and Kandal terminals via the Mekong River.

On the other hand, large tankers of 5,000–10,000 tonnes are used for Sihanoukville. Although the tanker freight fluctuates depending on the supply and demand of ships, the freight difference depending on the tanker size is four to five times. Still, it is actually about two times because Viet Nam is closer than Singapore and Thailand.

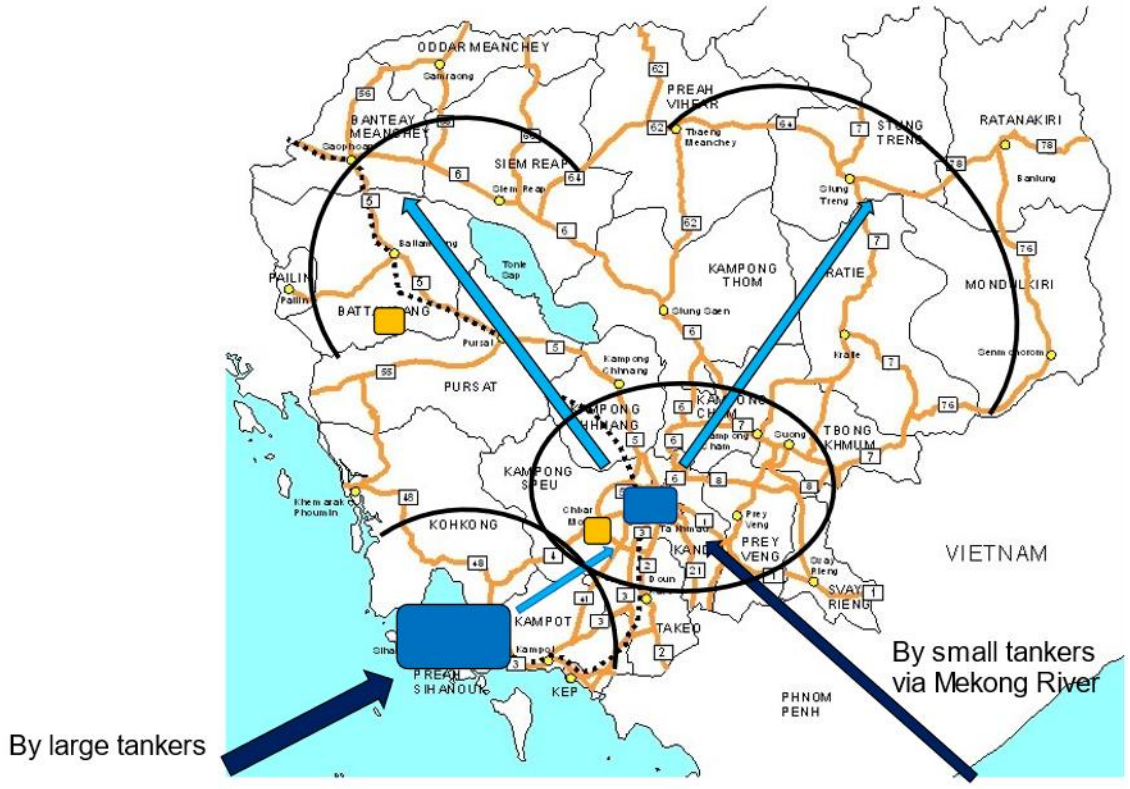
In this project, GDP/MME (General Department of Petroleum, The Ministry of Mines and Energy) and ERIA conducted survey on petroleum companies in 2020 regarding current supply chain nationwide.

[1] The International Trade Centre (ITC), a joint organisation of the United Nations and World Trade Organization, provides international trade statistics.

2.2 Delivery route

Phnom Penh is the centre of Cambodia, and its trunk roads are also concentrated, so delivery from Phnom Penh and Kandal oil terminals is efficient in terms of time and distance. Therefore, the direct delivery area from Sihanoukville is limited to Kampot, Keb, Koh Kong, Kampong Speu, and Takeo, near Sihanoukville. However, some oil companies deliver directly to Battambang and Siem Reap. There are also cases of direct delivery from Sihanoukville and the second delivery from the Phnom Penh terminal. The second delivery means transfer from the Sihanoukville terminal to the Phnom Penh hub terminal. Delivery to the north-eastern provinces is from Phnom Penh and Kandal terminals (Figure 4.2).

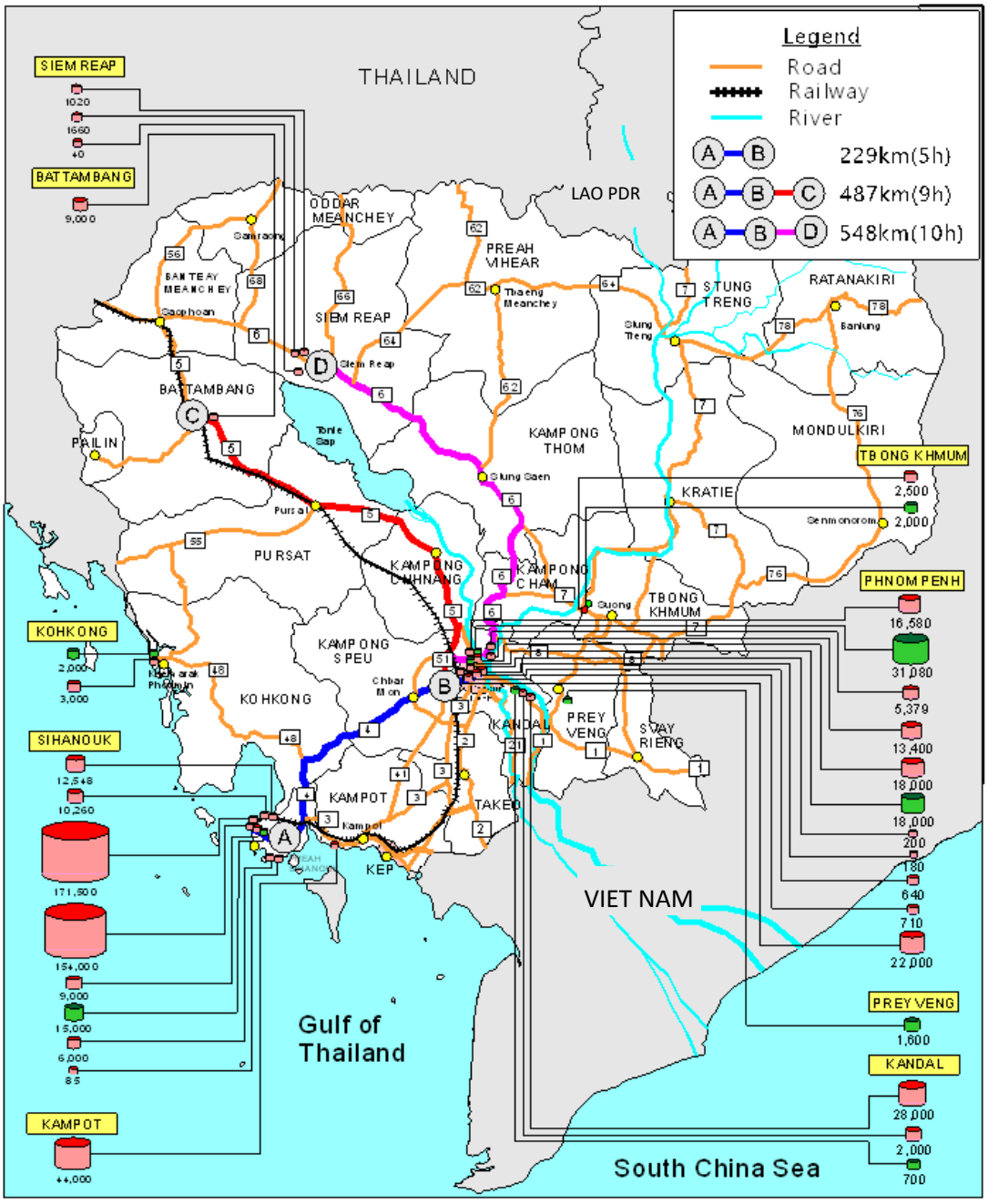
Figure 4.2. Delivery Routes Nationwide



Source: This project, 2020.

For the driver's health, the maximum daily delivery distance of a tank truck is about 250 km. Therefore, it takes 2 days to Battambang and Siem Reap, which are 500 km from Sihanoukville, and 2 days to return. In some cases, drivers change en route, but it takes 4 days to make a round trip. On the other hand, transfer to the terminal in Phnom Penh, 230 km from Sihanoukville, takes 1 day by tank truck, and 1 day from Phnom Penh to Battambang and Siem Reap. In any case, the delivery from Sihanoukville to Battambang and Siem Reap takes 4 days, which is the same. However, oil companies prefer transfer cases to prevent the long working hours of drivers.

Figure 4.3 Delivery by Tank Truck and Railway



Source: This project, 2020.

2.3 Delivery by railway

Two oil companies transport petroleum products from Sihanoukville to Phnom Penh by railway. Railway transportation from Sihanoukville to Phnom Penh takes 2 days (round trip), and the transportation volume is 1,800 kl (60 kl x 30 trains) for one trip.

Transport from Phnom Penh to the Battambang hub terminal also takes 2 days.

Cambodia has two railway lines:

- North Line: Phnom Penh to Battambang, 273 km
- Phnom Penh to Aranyaprathet in Thailand, 390 km
- South Line: Phnom Penh to Sihanoukville, 267 km

The deterioration of rails and rolling stock makes it challenging to increase transportation and speed up. Still, it is expected to improve in the future under a longitudinal railway system for Southeast Asia.[2]

Transportation of petroleum products by railway, including from Sihanoukville to Battambang, is promising.

2.4 Transfer from Sihanoukville terminal to Phnom Penh terminal

Two transfer methods from Sihanoukville to Phnom Penh currently exist: (i) tank-truck transportation which takes 1 day and needs another day for return; and (ii) railway transportation, which also needs 1 day and occurs once a week.

According to the delivery survey, the total transfer volume of gasoline and diesel oil from the Sihanoukville terminal to the Phnom Penh terminal is about 660,000 kl/year. Transfer by tank truck requires more than 100 tank trucks per day. There are other transfers – from Sihanoukville to terminals in Prey Veng and Battambang, and from Koh Kong to Sre Ambil – but not in large quantity.

[2] China–Viet Nam–Lao PDR–Cambodia–Thailand–Malaysia–Singapore

3. Current Supply Chain Issues

All petroleum products comprising Cambodia's oil supply are imported. The distance from Sihanoukville, the largest import base, to the provinces around Phnom Penh, Battambang, and Siem Reap in the west, the main demand areas, is far. Also, the means of transportation mainly depends on the tank trucks.

As explained in Chapter 5.2, demand for petroleum products in 2040 is expected to be more than triple of in 2018. Above all, the demand of Phnom Penh will expand, and the demand composition ratio of gasoline and diesel oil is assumed to be 25.7% (Tables 4.4 and 4.5).

Therefore, the biggest challenge in 2040 is how to supply petroleum products to Phnom Penh and its neighbouring provinces.

The second challenge is to supply petroleum products to Battambang and Siem Reap, which have the next-largest demand. The two provinces are far from Sihanoukville and Phnom Penh.

Table 4.4. Total demand of Gasoline and Diesel Oil, by Province, in 2030 and 2040

Province	Gasoline + Diesel Oil (kl)						
	2018	%	2030	%	2040	%	2018-2040
Banteay Meanchey	129,522	5.3	253,343	5.5	455,261	5.8	5.9
Battambang	215,042	8.8	314,843	6.9	559,018	7.2	4.4
Kampong Cham	127,409	5.2	199,215	4.3	334,100	4.3	4.5
Kampong Chhnang	68,183	2.8	120,381	2.6	208,699	2.7	5.2
Kampong Speu	52,902	2.2	101,502	2.2	174,750	2.2	5.6
Kampong Thom	75,939	3.1	127,445	2.8	225,422	2.9	5.1
Kampot	30,875	1.3	49,723	1.1	84,898	1.1	4.7
Kandal	176,039	7.2	313,542	6.8	520,499	6.7	5.1
Kohkong	9,335	0.4	15,503	0.3	26,971	0.3	4.9
Kratie	79,511	3.2	147,736	3.2	252,724	3.2	5.4
Mondolkiri	48,968	2.0	106,612	2.3	183,546	2.4	6.2
Phnom Penh	566,751	23.1	1,226,439	26.8	2,006,053	25.7	5.9
Preah Vihear	54,709	2.2	119,745	2.6	209,883	2.7	6.3
Prey Veng	89,728	3.7	160,305	3.5	273,086	3.5	5.2
Pursat	94,187	3.8	153,590	3.4	267,816	3.4	4.9

Ratanakiri	49,260	2.0	103,739	2.3	169,798	2.2	5.8
Siem Reap	196,334	8.0	348,007	7.6	608,139	7.8	5.3
Preah Sihanouk	61,264	2.5	128,625	2.8	219,457	2.8	6.0
Stung Treng	34,682	1.4	74,555	1.6	130,909	1.7	6.2
Svay Rieng	68,403	2.8	118,940	2.6	202,952	2.6	5.1
Takeo	55,167	2.2	95,382	2.1	158,936	2.0	4.9
Oddar Meanchey	44,235	1.8	93,814	2.0	167,202	2.1	6.2
Kep	2,105	0.1	3,980	0.1	6,561	0.1	5.3
Pailin	22,548	0.9	35,108	0.8	63,047	0.8	4.8
Tbong Khmum	104,164	4.2	168,380	3.7	289,014	3.7	4.7
Cambodia total	**2,457,262**	**100.0**	**4,580,455**	**100.0**	**7,798,740**	**100.0**	**5.4**

Source: This project (2020).

Total demand for gasoline and diesel oil in Phnom Penh will increase from 566,751 kl in 2018 to 1,226,439 kl in 2030 to 2,006,053 kl in 2040. Also, the total demand of gasoline and diesel oil in the neighbouring provinces of Phnom Penh, the so-called Central Plain – Kampong Cham, Tbong Khmum, Kandal, Phnom Penh, Prey Veng, Svay Rieng, and Takeo – will increase.

Table 4.5 Demand Composition Ratio, by Province in 2030 and 2040

Composition Ratio, %	Gasoline			Diesel Oil		
	2018	2030	2040	2018	2030	2040
Banteay Meanchey	1.5	1.5	1.5	7.2	7.8	7.8
Battambang	3.6	3.0	3.0	11.3	9.1	9.1
Kampong Cham	6.0	5.2	5.2	4.8	3.9	3.9
Kampong Chhnang	2.1	2.0	2.0	3.1	3.0	3.0
Kampong Speu	1.9	1.9	1.9	2.3	2.4	2.4
Kampong Thom	1.5	1.4	1.4	3.9	3.6	3.6
Kampot	1.2	1.0	1.0	1.3	1.1	1.1
Kandal	9.7	9.1	9.1	5.9	5.6	5.6
Kohkong	0.3	0.2	0.2	0.4	0.4	0.4
Kratie	3.1	3.0	3.0	3.3	3.3	3.3
Mondolkiri	1.8	2.0	2.0	2.1	2.5	2.5
Phnom Penh	37.4	40.5	40.5	15.9	18.9	18.9
Preah Vihear	1.5	1.6	1.6	2.6	3.2	3.2
Prey Veng	3.7	3.5	3.5	3.6	3.5	3.5

Pursat	2.5	2.3	2.3	4.5	4.0	4.0
Ratanakiri	3.2	3.4	3.4	1.4	1.6	1.6
Siem Reap	5.2	5.0	5.0	9.4	9.1	9.1
Preah Sihanouk	2.6	2.7	2.7	2.5	2.9	2.9
Stung Treng	0.9	1.0	1.0	1.7	2.0	2.0
Svay Rieng	2.7	2.5	2.5	2.8	2.6	2.6
Takeo	2.9	2.7	2.7	1.9	1.8	1.8
Oddar Meanchey	0.7	0.8	0.8	2.3	2.8	2.8
Kep	0.1	0.1	0.1	0.1	0.1	0.1
Pailin	0.2	0.2	0.2	1.3	1.1	1.1
Tbong Khmum	3.7	3.3	3.3	4.5	3.9	3.9
Cambodia total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: This project (2020).

The following sections discuss the issues to consider in the stable and efficient oil supply in 2030 and 2040.

3.1 Limits of oil terminals along the Mekong River

The delivery from oil terminals along the Mekong River to the Central Plain is efficient in time and distance. However, since the terminal is close to the city, it is difficult to expand the terminal capacity; there is also the problem of traffic jam. Moreover, the water depth is shallow, so it is impossible to import by large oil tankers. Therefore, tripling the delivery volume for 2040 is very difficult. On the other hand, there are plans to establish two second terminals near Phnom Penh, each 20 km to 40 km away from Phnom Penh. In this way, it is effective to establish new second terminals near Phnom Penh and transfer to each province from the Sihanoukville terminals.

3.2 Transfer method from Sihanoukville terminal to Phnom Penh second terminal

Transfer from the Sihanoukville terminal to the Phnom Penh second terminals could be done through tank trucks, railroads, and pipelines.

Which method to choose is determined comprehensively based on economics, safety, and environmental issues. However, it is essential to consider economics first.

In phase 2, the necessary transport volume, transport distance, and unit cost of each means are assumed, and a comparative study is performed.

3.3 Delivery to provinces near the Thai–Viet Nam border

Around the Thai–Viet Nam border provinces are 400 km to 500 km from Sihanoukville and Phnom Penh. Since demand in these provinces will also increase in 2030 and 2040, second terminals along the main road around the Thai–Viet Nam border should be considered. Petroleum products can be transferred from Sihanoukville or Phnom Penh.

In this project, GDP/MME (General Department of Petroleum, The Ministry of Mines and Energy) and ERIA conducted survey on petroleum companies in 2020 regarding current supply chain nationwide.

Chapter 5

Forecast of Petroleum Demand by Province in 2030 and 2040

It is necessary to estimate the demand for petroleum products by province in 2030 and 2040 to consider the petroleum supply plan for those years. Estimating future demand requires analysing the yearly demand for petroleum products from 2007 to 2018. Thus, the demand by province for each petroleum product in 2018 can be projected. Since no data by province is available, the base data for provincial demand in 2018 is estimated based on the survey of the delivery volume of oil companies by province, which was conducted in cooperation with the General Department of Petroleum, Ministry of Mines and Energy, Cambodia.[3] This survey was initially conducted to identify the provinces with a high demand for petroleum products.

Demand for petroleum products increases along with the increase of economic activities. An analysis of the relationship between the province-by-province demand and population shows a significantly high correlation, as an increase of factories, commercial facilities, housing, and movement of people and materials is closely linked to increased economic activity. Therefore, in order to forecast the demand for petroleum products by province in 2030 and 2040, we calculated the total demand outlook for ERIA in 2030 and 2040 by multiplying it by the estimated composition ratio by province.

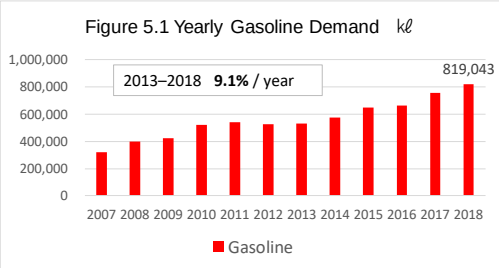
1 Current Petroleum Demand in Cambodia

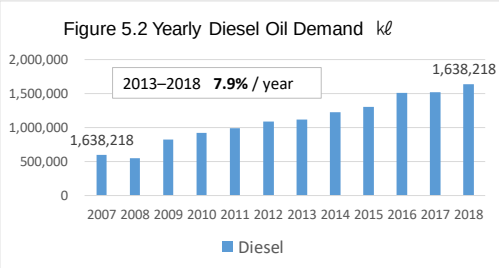
1.1 Yearly demand for petroleum products

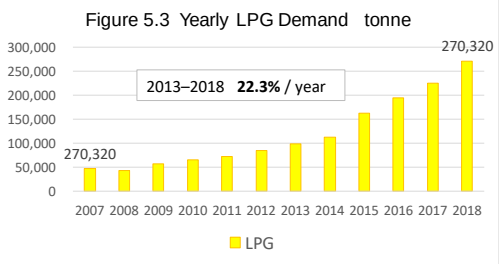
The total demand for petroleum products in Cambodia is increasing further, with economic growth exceeding 7% per year. The average annual growth rates of the major petroleum products over the last 5 years were 9.1% for gasoline, 7.9% for diesel oil, and 22.3% for liquefied petroleum gas (LPG). Fuel oil is decreasing due to electricity fuel conversion. Figures 5.1 to 5.4 show the changes in

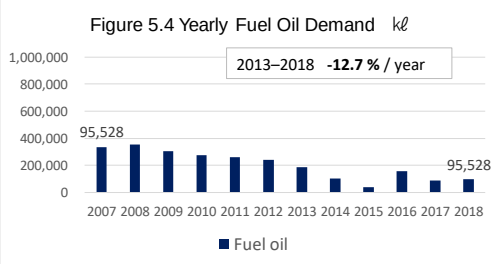
[3] In this project, the General Department of Petroleum/Ministry of Mines and Energy and ERIA conducted a survey on petroleum companies in 2020 regarding the current supply chain nationwide.

petroleum product imports. Cambodia depended on imports for all petroleum products, and the import volume was assumed to equal the demand volume.









kl = kilolitres.

Source: General Department of Petroleum, Ministry of Mines and Energy.

Gasoline demand in 2018 was 819,043 kl, and the growth rate in 2013–2018 was 9.1%. Diesel oil demand in 2018 was 1,638,218 kl, growing at 7.9% per year in 2013–2018. LPG demand was 270,320 tonnes in 2018, and the growth rate was the fastest over 2013–2018 at 22.3% per year. Fuel demand in 2018 was 95,528 kl, with a growth rate of –12.7% in 2013–2018.

1.2 Demand and population analysis, by province

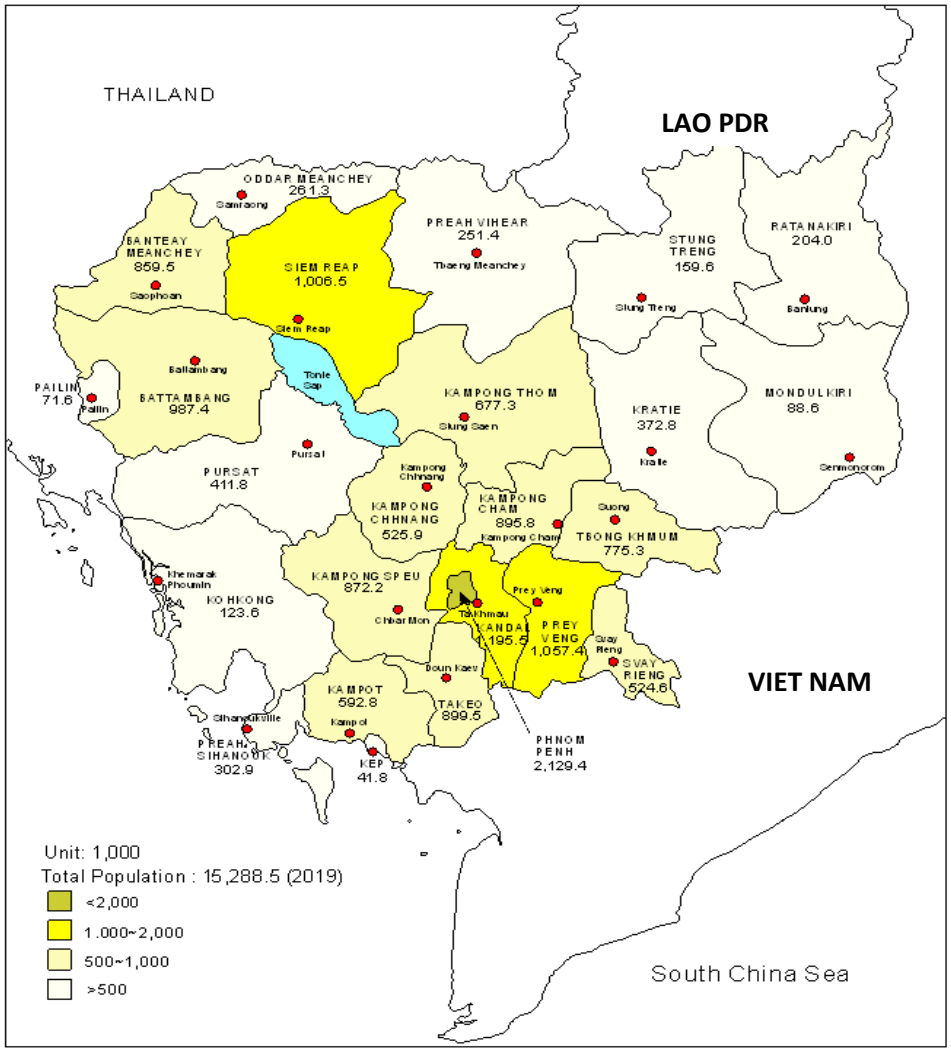
1) Population, by province

Figure 5.5 shows the population by province, based on the 2019 national census conducted by the National Institute of Statistics (NIS), Ministry of Planning. The total population of Cambodia in 2019 was 15,288,489.

As quoted from the General Population Census of the Kingdom of Cambodia 2019, the Central Plain region was the most highly populated of the four regions, with 7,477,444 people constituting 48.9% of the total population. The Central Plain region covers Kampong Cham, Tbong Khmum, Kandal,

Phnom Penh, Prey Veng, Svay Rieng, and Takeo. Tonle Sap is the second most populated region with 4,801,260 people, or 31.4% of the total. This region covers Banteay Meanchey, Battambang, Kampong Chhnang, Kampong Thom, Pursat, Siem Reap, Oddar Meanchey, and Pailin provinces. The plateau and mountain regions covering Kampong Speu, Kratie, Mondul Kiri, Preah Vihear, Ratanak Kiri, and Stung Treng provinces were the third most populous area with 1,948,637 people or 12.7% of the total population. Finally, the coastal and sea region has 1,061,148 people, equal to 6.9%. This region covers Kampot, Koh Kong, Preah Sihanouk, and Kep provinces. Table 5.1 shows the population and composition ratio, by province, in 2018 and 2019.

Figure 5.5. Population by Province, 2019



Source: National Institute of Statistics (2019).

Table 5.1. Population and Composition Ratio, by Province (2018 and 2019)

Province		2018 Population	%	2019 Population	%
1	Banteay Meanchey	841,190	5.6	859,545	5.6
2	Battambang	990,776	6.6	987,400	6.5
3	Kampong Cham	897,847	5.9	895,763	5.9
4	Kampong Chhnang	520,819	3.5	525,932	3.4
5	Kampong Speu	856,812	5.7	872,219	5.7
6	Kampong Thom	672,958	4.5	677,260	4.4
7	Kampot	592,206	3.9	592,845	3.9
8	KandaI	1,185,659	7.9	1,195,547	7.8
9	Kohkong	123,047	0.8	123,618	0.8
10	Kratie	367,600	2.4	372,825	2.4
11	Mondolkiri	85,701	0.6	88,649	0.6
12	Phnom Penh	2,062,833	13.7	2,129,371	13.9
13	Preah Vihear	242,721	1.6	251,352	1.6
14	Prey Veng	1,046,916	6.9	1,057,428	6.9
15	Pursat	410,410	2.7	411,759	2.7
16	Ratanakkiri	198,456	1.3	204,027	1.3
17	Siem Reap	995,971	6.6	1,006,512	6.6
18	Preah Sihanouk	294,379	2.0	302,887	2.0
19	Stung Treng	154,471	1.0	159,565	1.0
20	Svay Rieng	520,612	3.4	524,554	3.4
21	Takeo	894,381	5.9	899,485	5.9
22	Oddar Meanchey	253,284	1.7	261,252	1.7
23	Kep	41,209	0.3	41,798	0.3
24	Pailin	71,498	0.5	71,600	0.5
25	Tbong Khmum	773,989	5.1	775,296	5.1
	Cambodia total	**15,095,745**	**100.0**	**15,288,489**	**100.0**

Source: National Institute of Statistics (2019).

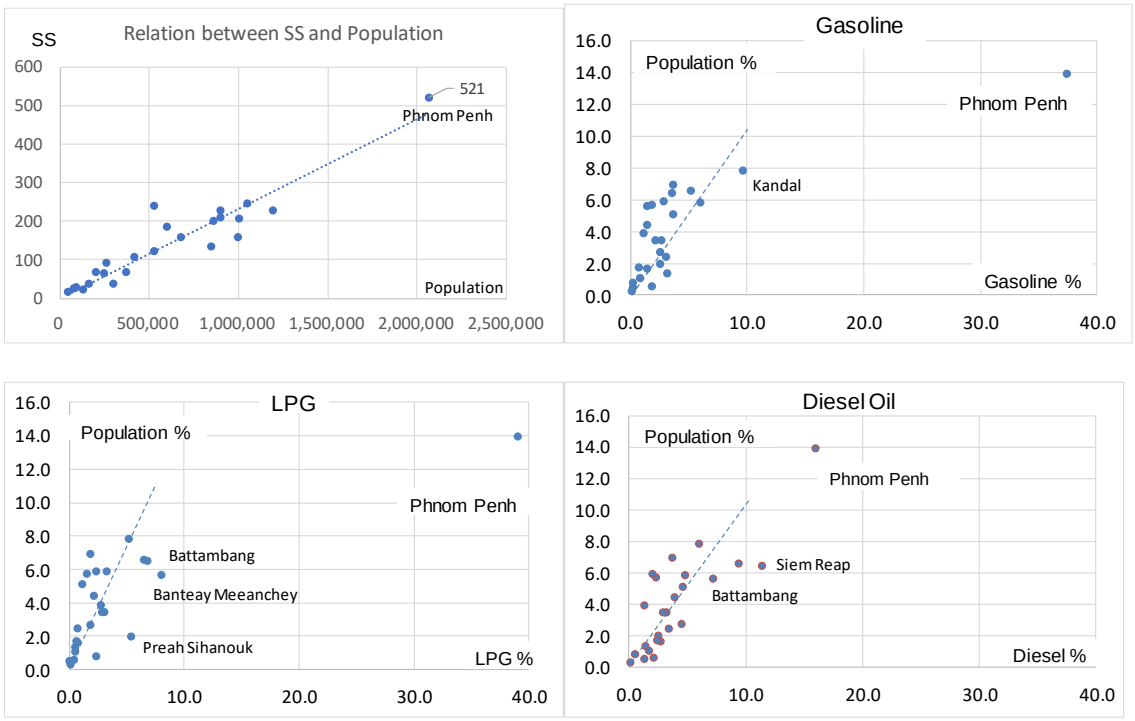
2) Relationship between demand distribution and population distribution

Figure 5.6 shows a strong correlation between the demand composition ratio of petroleum products and the population composition ratio. Regarding gasoline, the demand composition ratio of Phnom Penh is substantial, so it is outside the approximation line. However, Phnom Penh is close to the approximation line of the relationship between the number of petroleum service stations and the population, by province. The reason is due to the remarkably high consumption density of Phnom Penh.

Regarding diesel oil, provinces with a high demand for transportation of agricultural products have a higher demand composition ratio for diesel oil than the population composition ratio.

LPG has the same distribution map as gasoline. This is because LPG demand is high in commercial facilities and restaurants in Phnom Penh.

Figure 5.6. Distribution of Petroleum Products and Population



SS = service stations.

Source: Authors.

2. Application of Oil Company's Information and Data

The composition ratio of petroleum products by province in 2030 and 2040 are estimated using

1) the composition ratio by province in 2018 according to the oil company's data;

2) the estimated composition ratio of population by province in 2030 and 2040;

3) Cambodia's total population in 2030 and 2040, estimated by the ERIA Energy Outlook 2019–2020;

4) the estimated demand per capita for petroleum products by province.

2.1 Demand for petroleum products, by province

There is no data available of petroleum demand statistics by province until now. However, in this study, with the cooperation of oil companies, data of petroleum demand by province in 2018 could be derived from delivery volume to each province. Table 5.2 shows the need for petroleum products by province in 2018, broken down from the national demand using the composition ratio of delivery volume by province. Phnom Penh, where the population is concentrated and economic activity is centred, has the highest demand composition ratio. In addition, the demand of Siem Reap, Kandal, Battambang, and Banteay Meanchey was also large.

Table 5.2. Demand for Petroleum Products, by Province and Composition Ratio, 2018

Unit: kℓ , (LPG ton)

Province	Gasoline (kℓ)		Diesel (kℓ)		LPG (tonne)		Fuel oil (kℓ)	
	%	2018	%	2018	%	2018	%	2018
Banteay Meanchey	1.5	12,197	7.2	117,325	8.0	21,711	0.4	345
Battambang	3.6	29,115	11.3	185,927	6.8	18,318	0.0	0
Kampong Cham	6.0	49,535	4.8	77,874	2.4	6,463	0.6	547
Kampong Chhnang	2.1	17,310	3.1	50,873	2.9	7,715	0.0	0
Kampong Speu	1.9	15,492	2.3	37,410	1.6	4,219	0.2	190

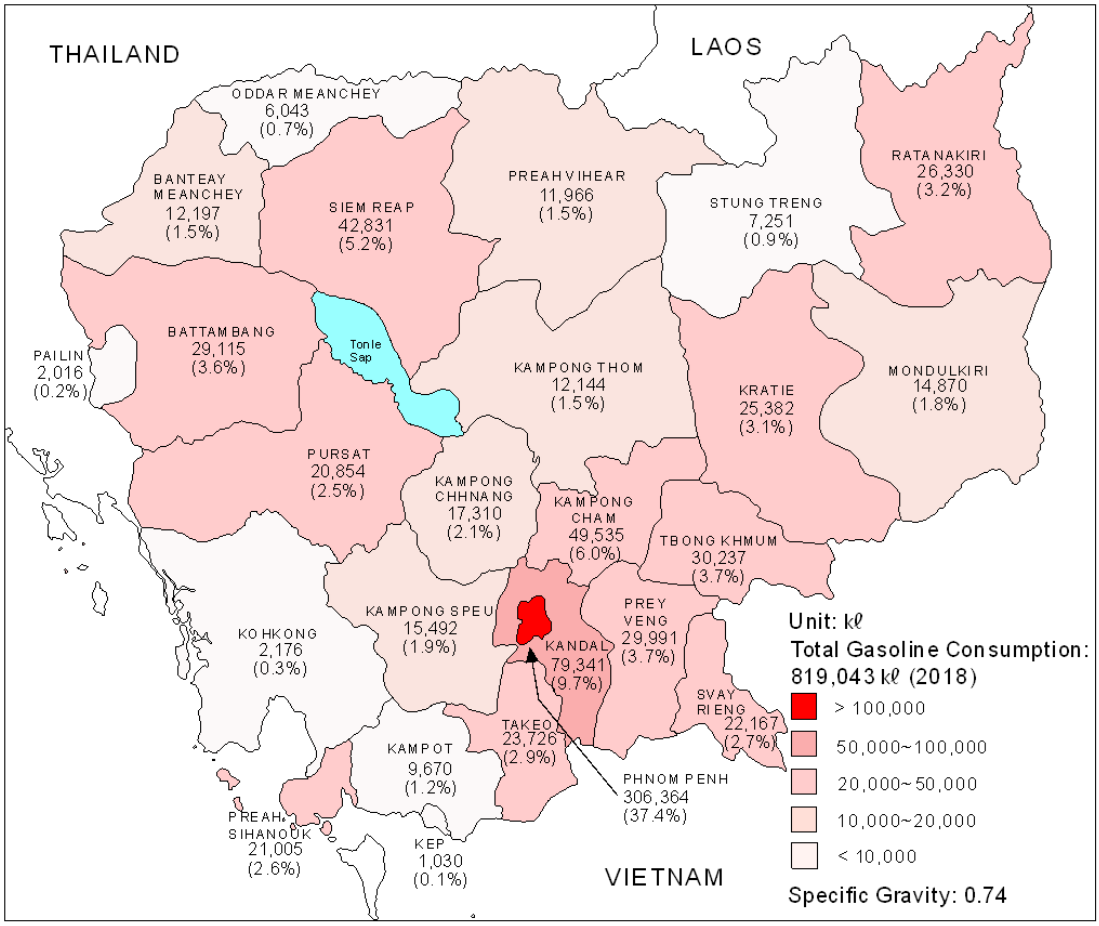
Kampong Thom	1.5	12,144	3.9	63,795	2.2	5,880	0.0	0
Kampot	1.2	9,670	1.3	21,206	2.8	7,488	0.1	142
Kandal	9.7	79,341	5.9	96,698	5.2	14,085	4.9	4,638
Kohkong	0.3	2,176	0.4	7,158	2.4	6,356	0.0	0
Kratie	3.1	25,382	3.3	54,129	0.8	2,086	0.2	230
Mondolkiri	1.8	14,870	2.1	34,098	0.4	1,034	0.0	0
Phnom Penh	37.4	306,364	15.9	260,388	39.1	105,669	84.7	80,947
Preah Vihear	1.5	11,966	2.6	42,742	0.7	1,887	0.0	0
Prey Veng	3.7	29,991	3.6	59,737	1.9	5,112	0.0	0
Pursat	2.5	20,854	4.5	73,333	1.8	4,924	0.0	0
Ratanakkiri	3.2	26,330	1.4	22,930	0.6	1,558	0.0	0
Siem Reap	5.2	42,831	9.4	153,503	6.5	17,511	1.2	1,123
Preah Sihanouk	2.6	21,005	2.5	40,260	5.4	14,500	6.6	6,322
Stung Treng	0.9	7,251	1.7	27,431	0.6	1,517	0.0	0
Svay Rieng	2.7	22,167	2.8	46,236	3.1	8,268	1.0	930
Takeo	2.9	23,726	1.9	31,441	3.2	8,726	0.0	36
Oddar Meanchey	0.7	6,043	2.3	38,192	0.6	1,721	0.0	0
Kep	0.1	1,030	0.1	1,076	0.1	313	0.0	0
Pailin	0.2	2,016	1.3	20,532	0.0	110	0.0	0
Tbong Khmum	3.7	30,237	4.5	73,926	1.2	3,149	0.1	78
Total	**100.0**	**819,043**	**100.0**	**1,638,218**	**100.0**	**270,320**	**100.0**	**95,528**

LPG = liquefied petroleum gas; kl = kilolitres.

Source: General Department of Petroleum, Ministry of Mines of Energy.

The following figures and tables show the demand distribution of major petroleum products by province. Figure 5.7 shows the demand distribution of gasoline.

Figure 5.7. Gasoline Demand, by Province, 2018 (kl)



kl = kilolitres.

Source: Authors.

Phnom Penh had the largest demand for gasoline, with more than 37% share. The total gasoline demand of Kandal and Kampong Cham provinces was 9.7% and 6%, respectively. The shares of the remaining provinces were below 6% (Table 5.3).

Table 5.3. Provinces with Large Demand for Gasoline, 2018

Province	Demand kilolitre (kl)	Composition (%)
Phnom Penh	306,364	37.4
Kandal	79,341	9.7
Kampong Cham	49,535	6.0
Siem Reap	42,831	5.2
Prey Veng	29,991	3.7
Battambang	29,115	3.6

Source: Authors.

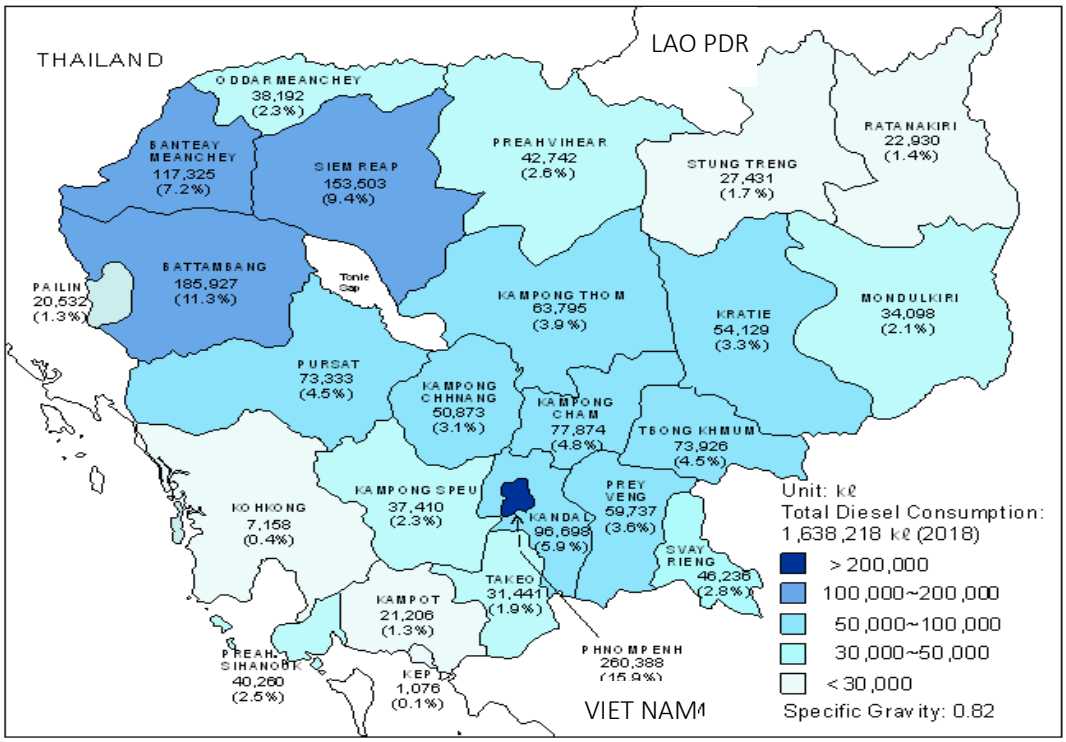
Phnom Penh's demand for diesel oil was around 16%, and Battambang, around 11%. The demand of the remaining provinces for diesel oil will be less than 10% of total Cambodia demand (Table 5.4). Figure 5.8 shows the demand distribution of diesel oil.

Table 5.4. Provinces with Large Demand for Diesel Oil, 2018

Province	Demand kilolitre (kl)	Composition (%)
Phnom Penh	260,388	15.9
Battambang	185,927	11.3
Siem Reap	153,503	9.4
Banteay Meanchey	117,325	7.2
Kandal	96,698	5.9
Kampong Cham	77,874	4.8

Source: Authors.

Figure 5.8. Diesel Oil Demand, by Province, 2018 (kl)



kl = kilolitres.

Source: Authors.

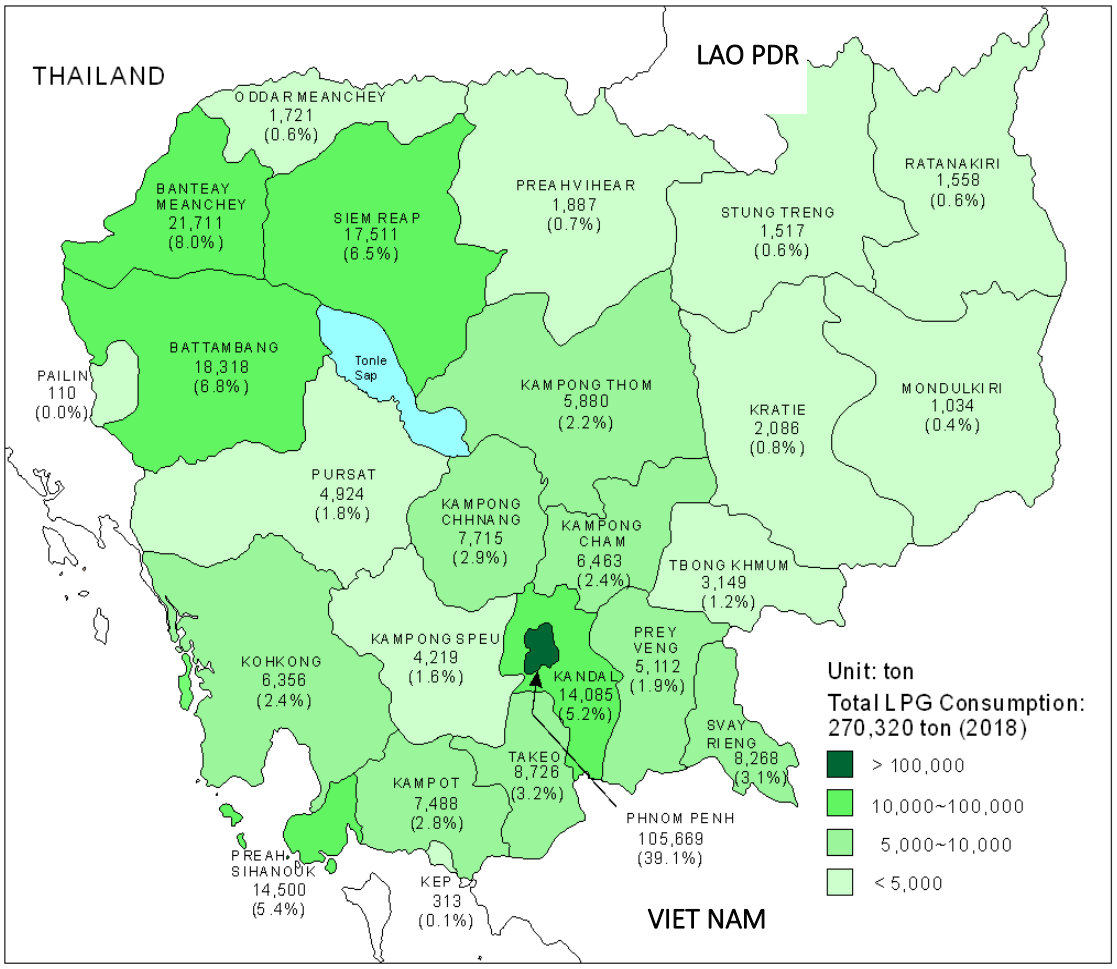
Table 5.5. Provinces with Large Demand for LPG, 2018

Province	Demand, tonne	Composition, %
Phnom Penh	105,669	39.1
Banteay Meanchey	21,711	8.0
Battambang	18,318	6.8
Siem Reap	17,511	6.5
Preah Sihanouk	14,500	5.4
Kandal	14,085	5.2

LPG = liquefied petroleum gas.

Source: Authors.

Figure 5.9. LPG Demand, by Province, 2018 (tonne)



LPG = liquefied petroleum gas.

Source: Authors.

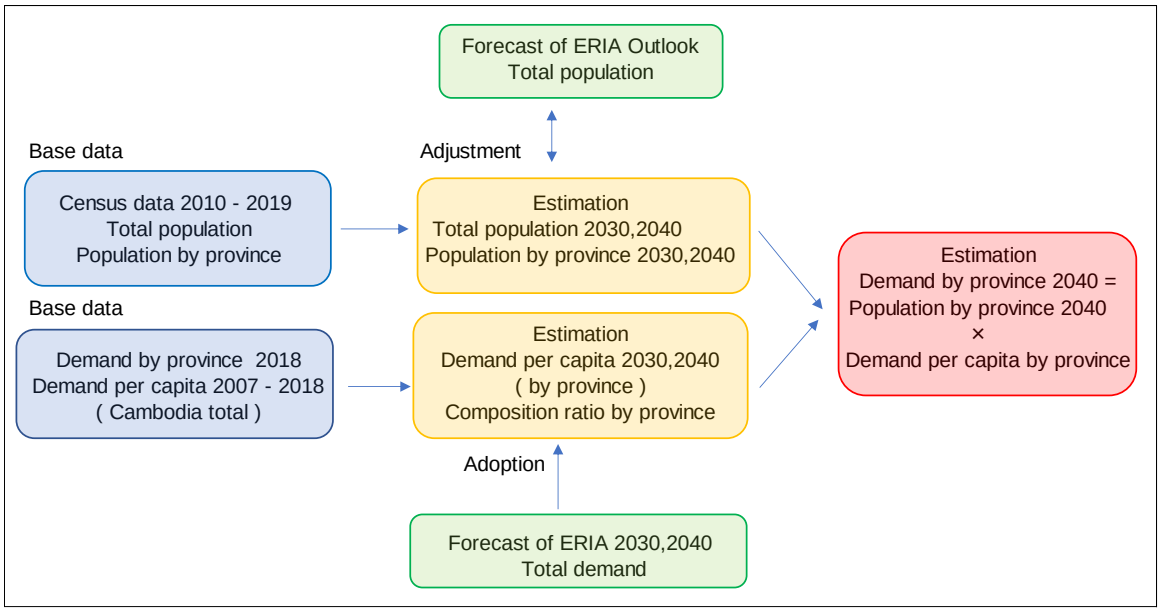
2.2 Petroleum demand, by province, in 2030 and 2040

1) Methodology

Figure 5.10 shows the estimation methodology for forecasting petroleum demand based on the oil companies' survey. As discussed earlier, the base data were the population census data and the demand data. These were used to estimate the 2030 and 2040 population and the provinces' demand per capita using the composition ratio of the population by province.

Since this study aims to create an optimal supply plan for gasoline and diesel oil in 2030 and 2040, the demand forecast by province for 2030 and 2040 will be made for gasoline and diesel oil.

Figure 5.10. Methodology of Estimation



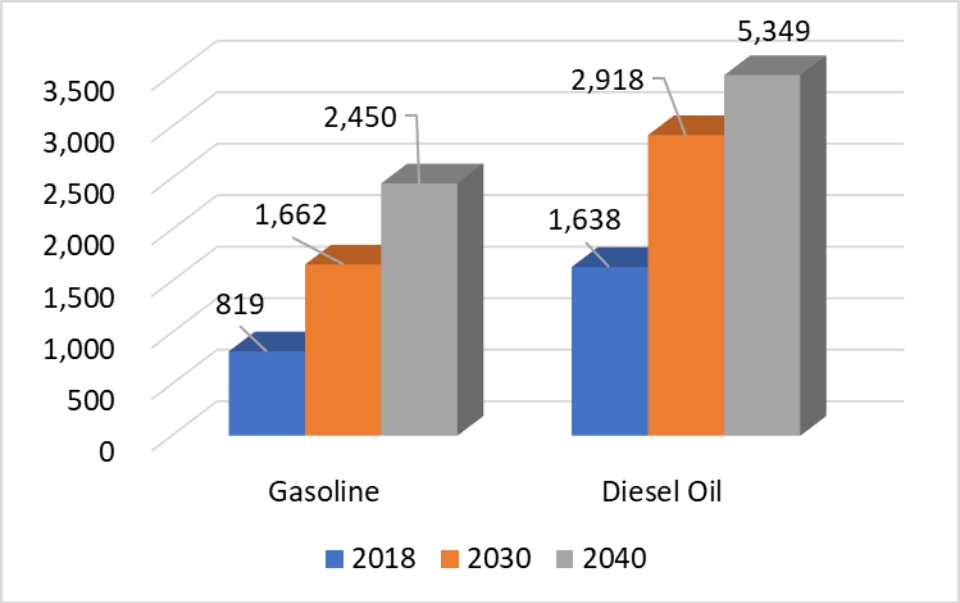
Source: Authors.

2) Forecast of total petroleum demand in 2040

The total demand for petroleum products in 2030 and 2040 was derived based on the ERIA outlook 2019–2020. Gasoline will be 1,662 thousand kl and 2,450 thousand kl in 2030 and 2040, respectively. Diesel oil will reach 2,918 thousand kl in 2030 and 5,349 thousand kl in 2040 (Figure 5.11).

Figure 5.11. Demand for Main Petroleum Products in 2030 and 2040

1,000 kl



kl = kilolitres

Source: ERIA Energy Outlook 2019–2020

3) Breakdown of the demand for petroleum products in 2030, 2040 by province

Since the demand for petroleum products and the population by province are strongly correlated, oil demand by province in 2030 and 2040 is broken down according to the following procedure, focusing on the population factor.

- Estimate the population by province in 2030 and 2040.
- Estimate the demand per capita in 2030 and 2040 of Cambodia's total.
- Estimate the demand per capita by province in 2030 and 2040, using the same growth rate.
- Estimate the demand for petroleum products by province in 2030 and 2040
  - ➢ Demand per capita in 2030, 2040 × population in 2030, 2040 (by province)
  - ➢ Calculate the demand composition ratio in 2030 and 2040 by province.

- ERIA demand forecast 2030 and 2040 × demand composition ratio in 2030 and 2040 by province

The following explains in detail the procedure for estimating the petroleum demand of provinces in 2030 and 2040.

4) Population estimate, by province, in 2030 and 2040

For the total population of Cambodia in 2030 and 2040, this study adopted the ERIA Energy Outlook 2019–2020. The total population in 2030 is 19,460,617, and 22,584,840 in 2040.

Next, the population composition ratio by province 2030 and 2040 is estimated by using the last 10 years' data of the population composition ratio by province. Based on this estimated population composition ratio, the population of the provinces in 2030 and 2040 can be calculated as:

Population composition ratio by province in 2030 × Total population in 2030

Population composition ratio by province in 2040 × Total population in 2040

Although the census population data was from 1998, the last 10 years reflected the impact of recent economic developments. Table 5.6 shows the population by province in 2040.

The population concentration in Phnom Penh will further increase. The composition ratio of Phnom Penh in 2040 increases from 13.9% to 16.8%, and the annual growth rate from 2018 to 2040 is 2.4%, which is higher than the growth rate of Cambodia as a whole of 1.5%.

Table 5.6. Population, by Province

Composition ratio of Population by province					Population by province				
Province	**2008**	**2018**	**2030**	**2040**	**2008**	**2018**	**2030**	**2040**	**2018–40**
Banteay Meanchey	5.1	5.6	6.0	6.2	677,872	915,099	1,162,900	1,401,709	2.0%
Battambang	7.7	6.5	5.7	5.2	1,025,174	1,051,218	1,111,007	1,178,873	0.5%
Kampong Cham	6.9	5.9	5.2	4.8	918,956	953,658	1,017,791	1,088,441	0.6%
Kampong Chhnang	3.5	3.4	3.4	3.3	472,341	559,924	658,344	755,618	1.4%
Kampong Speu	5.4	5.7	5.9	6.1	716,944	928,592	1,152,977	1,370,454	1.8%
Kampong Thom	4.7	4.4	4.2	4.1	631,409	721,033	826,658	932,534	1.2%
Kampot	4.4	3.9	3.6	3.4	585,850	631,162	693,651	758,813	0.8%
Kandal	8.1	7.8	7.6	7.5	1,091,170	1,272,818	1,480,613	1,687,105	1.3%
Kohkong	0.9	0.8	0.8	0.7	117,481	131,608	148,862	166,327	1.1%
Kratie	2.4	2.4	2.5	2.5	319,217	396,921	481,030	563,151	1.6%
Mondolkiri	0.5	0.6	0.7	0.7	61,107	94,379	128,245	160,505	2.4%
Phnom Penh	11.2	13.9	15.7	16.8	1,501,725	2,266,997	3,048,193	3,793,422	2.4%
Preah Vihear	1.3	1.6	1.9	2.0	171,139	267,597	365,648	458,975	2.5%
Prey Veng	7.1	6.9	6.8	6.7	947,372	1,125,772	1,325,764	1,523,277	1.4%
Pursat	3.0	2.7	2.5	2.4	397,161	438,372	490,556	543,878	1.0%
Ratanakiri	1.1	1.3	1.5	1.6	150,466	217,214	285,834	351,519	2.2%
Siem Reap	6.7	6.6	6.5	6.5	896,443	1,071,565	1,266,790	1,459,257	1.4%
Preah Sihanouk	1.7	2.0	2.2	2.3	221,396	322,463	426,201	525,428	2.2%
Stung Treng	0.8	1.0	1.2	1.3	111,671	169,878	229,236	285,832	2.4%
Svay Rieng	3.6	3.4	3.3	3.2	482,788	558,457	645,955	733,183	1.2%
Takeo	6.3	5.9	5.6	5.4	844,906	957,621	1,092,166	1,227,515	1.1%
Oddar Meanchey	1.4	1.7	1.9	2.0	185,819	278,137	372,488	462,548	2.3%
Kep	0.3	0.3	0.3	0.3	35,753	44,499	53,961	63,197	1.6%
Pailin	0.5	0.5	0.4	0.4	70,486	76,228	84,017	92,109	0.9%
Tbong Khmum	5.7	5.1	4.7	4.4	761,036	825,405	911,729	1,001,171	0.9%
Cambodia total	**100.0**	**100.0**	**100.0**	**100.0**	**13,395,682**	**16,276,615**	**19,460,617**	**22,584,840**	**1.5%**

Source: Authors.

5) Estimate of the demand per capita in 2040 of Cambodia total

The demand per capita in 2030 and 2040 of Cambodia total is estimated using historical data of demand per capita from 2007 to 2018, by trend function after conversion to logarithm. Gasoline demand per capita is estimated 44.4 litre/year in 2030 and 51.3 litre/year in 2040. Diesel demand per capita is estimated 105.4 litre/year in 2030 and 129.2 litre/year in 2040.

Table 5.7. Demand per Capita, 2030 and 2040 (Cambodia total)

Products	2018	2030	2040
Gasoline	37.2	44.4	51.3
Diesel Oil	82.5	105.4	129.2

Source: Authors.

6) Estimate of the demand per capita in 2040, by province

The demand per capita by petroleum product by province in 2040 is calculated by the AAGR (Table 5.7). The start of calculation is demand per capita by petroleum product by province in 2018.

7) Demand for petroleum products, by province, in 2030 and 2040

Demand for petroleum products by province in 2030 and 2040 is calculated by multiplying the demand per capita by province with the population by province:

Demand per capita by province in 2030 × Population in 2030 by province

Demand per capita by province in 2040 × Population in 2040 by province

After this calculation, the demand composition ratio in 2030 and 2040 by province can be calculated (Table 5.8). As observed from the table, the composition ratio of Phnom Penh becomes even larger in 2040 compared to 2018.

Table 5.8. Demand Composition Ratio, by Province, 2040

Province	Gasoline			Diesel Oil		
	2018	2030	2040	2018	2030	2040
Banteay Meanchey	1.5	1.5	1.5	7.2	7.6	7.8
Battambang	3.6	3.0	2.7	11.3	10.0	9.1
Kampong Cham	6.0	5.2	4.7	4.8	4.2	3.9
Kampong Chhnang	2.1	2.0	1.9	3.1	3.0	3.0
Kampong Speu	1.9	1.9	1.9	2.3	2.4	2.4
Kampong Thom	1.5	1.4	1.3	3.9	3.7	3.6
Kampot	1.2	1.0	1.0	1.3	1.2	1.1

Kandal	9.7	9.1	8.7	5.9	5.7	5.6
Kohkong	0.3	0.2	0.2	0.4	0.4	0.4
Kratie	3.1	3.0	3.0	3.3	3.3	3.3
Mondolkiri	1.8	2.0	2.1	2.1	2.3	2.5
Phnom Penh	37.4	40.5	42.4	15.9	17.7	18.9
Preah Vihear	1.5	1.6	1.7	2.6	3.0	3.2
Prey Veng	3.7	3.5	3.4	3.6	3.6	3.5
Pursat	2.5	2.3	2.1	4.5	4.2	4.0
Ratanakkiri	3.2	3.4	3.5	1.4	1.5	1.6
Siem Reap	5.2	5.0	4.8	9.4	9.2	9.1
Preah Sihanouk	2.6	2.7	2.8	2.5	2.7	2.9
Stung Treng	0.9	1.0	1.0	1.7	1.9	2.0
Svay Rieng	2.7	2.5	2.4	2.8	2.7	2.6
Takeo	2.9	2.7	2.5	1.9	1.8	1.8
Oddar Meanchey	0.7	0.8	0.8	2.3	2.6	2.8
Kep	0.1	0.1	0.1	0.1	0.1	0.1
Pailin	0.2	0.2	0.2	1.3	1.1	1.1
Tbong Khmum	3.7	3.3	3.0	4.5	4.1	3.9
Cambodia total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: Authors.

Based on this ratio, the demand for petroleum products, by province, in 2030 and 2040 can be calculated (Table 5.9) using the following formula:

ERIA demand forecast 2030 × Demand composition ratio in 2030 by province

ERIA demand forecast 2040 × Demand composition ratio in 2040 by province

Table 5.9. Demand for Petroleum Products, by Province, 2040

Province	Gasoline (kℓ)			Diesel Oil (kℓ)		
	2018	2030	2040	2018	2030	2040
Banteay Meanchey	12,197	25,349	37,359	117,325	227,995	417,902
Battambang	29,115	50,322	74,164	185,927	264,522	484,854
Kampong Cham	49,535	86,456	127,419	77,874	112,759	206,681
Kampong Chhnang	17,310	33,284	49,053	50,873	87,098	159,645
Kampong Speu	15,492	31,458	46,363	37,410	70,044	128,387
Kampong Thom	12,144	22,769	33,557	63,795	104,675	191,864
Kampot	9,670	17,380	25,614	21,206	32,344	59,284
Kandal	79,341	150,935	222,449	96,698	162,607	298,050
Kohkong	2,176	4,026	5,933	7,158	11,477	21,038
Kratie	25,382	50,306	74,141	54,129	97,430	178,584
Mondolkiri	14,870	33,045	48,702	34,098	73,567	134,845
Phnom Penh	306,364	673,668	992,854	260,388	552,771	########
Preah Vihear	11,966	26,740	39,409	42,742	93,005	170,474
Prey Veng	29,991	57,760	85,126	59,737	102,545	187,960
Pursat	20,854	38,164	56,246	73,333	115,426	211,570
Ratanakiri	26,330	56,662	83,508	22,930	47,077	86,289
Siem Reap	42,831	82,806	122,040	153,503	265,201	486,099
Preah Sihanouk	21,005	45,401	66,912	40,260	83,224	152,545
Stung Treng	7,251	16,002	23,583	27,431	58,554	107,326
Svay Rieng	22,167	41,931	61,798	46,236	77,009	141,154
Takeo	23,726	44,252	65,219	31,441	51,129	93,717
Oddar Meanchey	6,043	13,235	19,506	38,192	80,578	147,696
Kep	1,030	2,042	3,009	1,076	1,938	3,552
Pailin	2,016	3,634	5,356	20,532	31,474	57,691
Tbong Khmum	30,237	54,621	80,500	73,926	113,759	208,514
Cambodia total	**819,043**	**1,662,245**	**2,449,820**	**1,638,218**	**2,918,210**	**5,348,920**

kl = kilolitres.

Source: Authors.

Tables 5.10 to 5.12 show the provinces with large demand.

Table 5.10. Provinces with Large Demand for Gasoline, 2040

Province	Demand, kl	Composition, %
Phnom Penh	992,854	42.4
Kandal	222,449	8.7
Siem Reap	122,040	4.8
Kampong Cham	127,419	4.7
Ratanakkiri	83,508	3.5
Prey Veng	85126	3.4

kl = kilolitres.

Source: Authors.

Table 5.11. Provinces with Large Demand for Diesel Oil, 2040

Province	Demand, kl	Composition, %
Phnom Penh	1,013,199	18.9
Siem Reap	486,099	9.1
Battambang	484,854	9.1
Banteay Meanchey	417,902	7.8
Kandal	298,050	5.6
Pursat	211,570	4.0

kl = kilolitres.

Source: Authors.

Table 5.12. Total Demand for Gasoline and Diesel Oil in 2030 and 2040

Province	Gasoline+Diesel Oil (kl)			Gasoline+Diesel Oil (%)	
	2018	2030	2040	%	2018–40
Banteay Meanchey	129,522	253,343	455,261	5.8	5.9
Battambang	215,042	314,843	559,018	7.2	4.4
Kampong Cham	127,409	199,215	334,100	4.3	4.5
Kampong Chhnang	68,183	120,381	208,699	2.7	5.2
Kampong Speu	52,902	101,502	174,750	2.2	5.6
Kampong Thom	75,939	127,445	225,422	2.9	5.1
Kampot	30,875	49,723	84,898	1.1	4.7
Kandal	176,039	313,542	520,499	6.7	5.1
Kohkong	9,335	15,503	26,971	0.3	4.9
Kratie	79,511	147,736	252,724	3.2	5.4
Mondolkiri	48,968	106,612	183,546	2.4	6.2
Phnom Penh	566,751	1,226,439	2,006,053	25.7	5.9
Preah Vihear	54,709	119,745	209,883	2.7	6.3
Prey Veng	89,728	160,305	273,086	3.5	5.2
Pursat	94,187	153,590	267,816	3.4	4.9
Ratanakkiri	49,260	103,739	169,798	2.2	5.8
Siem Reap	196,334	348,007	608,139	7.8	5.3
Preah Sihanouk	61,264	128,625	219,457	2.8	6.0
Stung Treng	34,682	74,555	130,909	1.7	6.2
Svay Rieng	68,403	118,940	202,952	2.6	5.1
Takeo	55,167	95,382	158,936	2.0	4.9
Oddar Meanchey	44,235	93,814	167,202	2.1	6.2
Kep	2,105	3,980	6,561	0.1	5.3
Pailin	22,548	35,108	63,047	0.8	4.8
Tbong Khmum	104,164	168,380	289,014	3.7	4.7
Cambodia total	**2,457,262**	**4,580,455**	**7,798,740**	**100.0**	**5.4**

kl = kilolitres.

Source: Authors.

Table 5.12 shows that the total demand for gasoline and diesel oil in 2040 will increase more than three times from 2018. Therefore, it is necessary to prepare more than thrice the supply capacity. The provinces with the largest increase in demand will be around the Phnom Penh and the west areas. The total demand of these two areas accounts for about 80% of the total national demand.

These areas, however, are far from Sihanoukville, the main supply site. Thus, this condition will become significant in considering the future supply plan.

3. Application of Results from the Energy Consumption Survey

This chapter presents the petroleum demand forecast by province in 2040 based on the result of the energy consumption survey to compare to the forecasted results mentioned in section 5.2. The first step is to estimate the total oil consumption of the final sector in 2018, by province, using the survey result and adjusted to the national level consumption of the Energy Balance Table (EBT) 2018. Next, the demand in 2040 is projected based on the growth of socio-economic activities. Since activities data is limited, the future demand forecast of oil products, by province, was adjusted. The consumption survey covers (i) gasoline consumed by the transport sector; (ii) diesel oil consumed by the industry, transport, and commercial sectors; and (iii) LPG consumed by the transport, commercial, and residential sectors.

3.1. Sectoral petroleum consumption, by province, 2018

1) Transport sector

Gasoline-based vehicles surveyed accounted for around 71% to 82% of the total vehicles sampled (see Chapter 3). The parking lot survey revealed each vehicle's fuel economy and distance travelled in the surveyed provinces. The average fuel consumption (gasoline, diesel, and LPG) per vehicle per year was estimated. Multiplied this with the number of vehicles will result in total fuel consumption of the sector.

The number of vehicles by type in each province is not available. In this case, the number of vehicles by province in 2018 was estimated based on the number of vehicles nationwide and the province's share of the national urban population. The provincial share of the urban population was based on the 2019 population census of Cambodia. This share was assumed to be the same for 2018 (Table 5.13). Because the number of vehicles is concentrated in urban areas, the urban population was selected for this estimation.

Table 5.13. Assumed Urban Population in 2018

	Province	Urban Population (2018)	
		Person	Share (%)
1	Banteay Meanchey	327,653	5.5
2	Battambang	209,921	3.5
3	Kampong Cham	133,371	2.2
4	Kampong Chhnang	125,768	2.1
5	Kampong Speu	538,780	9.0
6	Kampong Thom	73,069	1.2
7	Kampot	61,693	1.0
8	KandaI	797,833	13.4
9	Kohkong	58,871	1.0
10	Kratie	42,221	0.7
11	Mondolkiri	34,075	0.6
12	Phnom Penh	2,129,371	35.6
13	Preah Vihear	25,491	0.4
14	Prey Veng	63,351	1.1
15	Pursat	75,259	1.3
16	Ratanakkiri	31,810	0.5
17	Siem Reap	318,469	5.3
18	Preah Sihanouk	167,584	2.8
19	Stung Treng	46,126	0.8
20	Svay Rieng	161,473	2.7
21	Takeo	296,325	5.0
22	Oddar Meanchey	93,551	1.6
23	Kep	34,438	0.6
24	Pailin	57,140	1.0
25	Tbong Khmum	69,808	1.2
Cambodia total		5,973,451	100.0

Source: Author's calculation.

The number of vehicles nationwide also needed to be estimated because the statistics only covered vehicles by type (sedan, truck, bus, and motorcycle), not by the fuel they consumed. Since the survey provided the average consumption of gasoline, diesel, and LPG per vehicle and the EBT 2018 has data on each fuel consumption for road transport, the number of vehicles for each fuel was estimated.

Table 5.14 shows the estimated number of vehicles by fuel and province and the resulting fuel consumption.

Table 5.14. Number of Vehicles and Consumption of Petroleum, 2018

Province		Number of Vehicles (Units)			Consumption		
		Gasoline	Diesel	LPG	Gasoline (Kl)	Diesel (Kl)	LPG (tonne)
1	Banteay Meanchey	80,980	5,181	1,958	46,037	70,355	6,355
2	Battambang	51,882	3,320	1,255	23,044	45,075	4,072
3	Kampong Cham	32,963	2,109	797	16,308	4,032	514
4	Kampong Chhnang	31,084	1,989	752	17,671	21,273	1,989
5	Kampong Speu	133,160	8,520	3,220	75,702	63,509	4,597
6	Kampong Thom	18,059	1,155	437	10,267	8,613	623
7	Kampot	15,248	976	369	8,668	7,272	526
8	Kandal	197,185	12,616	4,769	94,077	171,315	15,476
9	Kohkong	14,550	931	352	9,027	6,939	502
10	Kratie	10,435	668	252	6,474	4,977	360
11	Mondolkiri	8,422	539	204	5,225	10,588	817
12	Phnom Penh	526,276	33,672	12,727	292,984	300,176	18,657
13	Preah Vihear	6,300	403	152	3,909	7,921	611
14	Prey Veng	15,657	1,002	379	7,470	7,468	541
15	Pursat	18,600	1,190	450	11,540	23,386	1,804
16	Ratanakkiri	7,862	503	190	4,878	9,885	763
17	Siem Reap	78,710	5,036	1,904	37,553	82,593	6,989
18	Preah Sihanouk	41,418	2,650	1,002	25,697	52,074	4,018
19	Stung Treng	11,400	729	276	7,073	14,333	1,106
20	Svay Rieng	39,908	2,553	965	24,760	50,175	3,871
21	Takeo	73,237	4,686	1,771	45,438	92,078	7,104
22	Oddar Meanchey	23,121	1,479	559	14,345	29,069	2,243
23	Kep	8,511	545	206	5,281	10,701	826
24	Pailin	14,122	904	342	8,762	17,755	1,370
25	Tbong Khmum	17,253	1,104	417	10,704	21,692	1,674
Cambodia total		**1,476,344**	**94,459**	**35,704**	**812,896**	**1,133,255**	**87,409**

kl = kilolitres; LPG = liquefied petroleum gas.
Source: Author's calculation.

1) Industry sector

As discussed in Chapter 3, the industry survey was grouped into three types of industries: food and beverages, garments, and others. The petroleum consumed by the industries surveyed was only diesel. LPG consumption recorded during the survey was excluded since it is usually used for non-manufacturing processes, such as heating water for drinking, etc.

The survey result provided the average diesel consumption (litre/'000 US$/year). This was revised to average diesel consumption per factory (litre/factory/year) since the available data was on the number of factories by type by province. The General Department of Petroleum of the MME provided the data from the Ministry of Industry, Science, Technology, and Innovation. Industrial establishments totalled 1,844, and the distribution by type and province is shown in Table 5.15.

Table 5.15. Distribution of Industrial Establishments, by Type and Province, 2018

Province		Garment	Food & Beverages	Others	Total
1	Banteay Meanchey	5	2	13	20
2	Battambang	0	8	8	16
3	Kampong Cham	6	2	15	23
4	Kampong Chhnang	12	4	11	27
5	Kampong Speu	70	14	129	213
6	Kampong Thom	0	4	7	11
7	Kampot	1	5	14	20
8	Kandal	114	13	145	272
9	Kohkong	1	1	5	7
10	Kratie	0	2	9	11
11	Mondolkiri	0	0	2	2
12	Phnom Penh	407	37	333	777
13	Preah Vihear	0	2	3	5
14	Prey Veng	0	2	3	5
15	Pursat	3	3	2	8
16	Ratanakkiri	0	2	4	6
17	Siem Reap	1	4	1	6
18	Preah Sihanouk	15	19	170	204
19	Stung Treng	0	0	1	1
20	Svay Rieng	23	1	101	125
21	Takeo	28	4	39	71
22	Oddar Meanchey	0	1	1	2

Province		Garment	Food & Beverages	Others	Total
23	Kep	0	0	0	0
24	Pailin	0	1	0	1
25	Tbong Khmum	0	1	10	11
Cambodia total		**686**	**132**	**1,026**	**1,844**

Source: Authors calculation.

Table 5.16 shows the diesel consumption of the provinces by type, with total consumption adjusted to be in line with the Cambodia EBT 2018 (around 136 ktoe or 161,887 kl). The garment factories consumed 41,522 kl (26%), while food and beverages and others consumed 9,978 kl (6%) and 110,387 kl (68%), respectively.

The garment factories mainly consumed electricity, and most of them were in Phnom Penh City. Thus, the diesel consumption will mainly be for backup power since these factories are connected to the grid (purchase electricity from Electricite du Cambodge).

For the 'other' industries, Kampot province included four cement plants. The Kampot Cement Company alone consumed almost 2,000 tonnes/year, approximately 2,400 kl/year (Samrith, 2019).

Table 5.16. Diesel Consumption in 2018 and Share by Province

Province		Diesel Consumption (Kl)				Provincial Share (%)			
		Garment	Food & Beverages	Others	Total	Garment	Food & Beverages	Others	Total
1	Banteay Meanchey	372	52	1,278	**1,702**	0.9	0.5	1.2	**1.1**
2	Battambang	-	94	1,280	**1,374**	0	0.9	1.2	**0.8**
3	Kampong Cham	760	12	4,004	**4,776**	1.8	0.1	3.6	**2.9**
4	Kampong Chhnang	893	104	1,081	**2,078**	2.1	1	1	**1.3**
5	Kampong Speu	3,853	92	29,289	**33,234**	9.3	0.9	26.5	**20.5**
6	Kampong Thom	-	104	688	**792**	0	1	0.6	**0.5**
7	Kampot	74	130	10,427	**10,632**	0.2	1.3	9.4	**6.6**
8	Kandal	8,480	338	14,255	**23,073**	20.4	3.4	12.9	**14.3**
9	Koh Kong	74	26	492	**592**	0.2	0.3	0.4	**0.4**
10	Kratie	-	52	885	**937**	0	0.5	0.8	**0.6**
11	Mondul Kiri	-	-	197	**197**	0	0	0.2	**0.1**
12	Phnom Penh	19,209	239	19,818	**39,267**	46.3	2.4	18	**24.3**
13	Preah Vihear	-	52	295	**347**	0	0.5	0.3	**0.2**
14	Prey Veng	-	52	295	**347**	0	0.5	0.3	**0.2**
15	Pursat	223	78	197	**498**	0.5	0.8	0.2	**0.3**
16	Ratanak Kiri	-	52	393	**445**	0	0.5	0.4	**0.3**
17	Siem Reap	74	83	9	**166**	0.2	0.8	0	**0.1**
18	Preah Sihanouk/ Sihanoukville	3,715	8,209	10,562	**22,486**	8.9	82.3	9.6	**13.9**
19	Stung Treng	-	-	98	**98**	0	0	0.1	**0.1**
20	Svay Rieng	1,711	26	9,929	**11,666**	4.1	0.3	9	**7.2**
21	Takeo	2,083	104	3,834	**6,021**	5	1	3.5	**3.7**
22	Oddar Meanchey	-	26	98	**124**	0	0.3	0.1	**0.1**
23	Kep	-	-	-	**-**	0	0	0	**0**
24	Pailin	-	26	-	**26**	0	0.3	0	**0**
25	Tbong Khmum	-	26	983	**1,009**	0	0.3	0.9	**0.6**
Total		**41,522**	**9,978**	**110,387**	**161,887**	**100**	**100**	**100**	**100**
%		**26**	**6**	**68**	**100**				

kl = kilolitres.

Source: Author's calculation.

2) Residential and commercial sectors

LPG is the only petroleum product consumed by the surveyed households in the selected provinces. The survey revealed the average LPG consumption per person (Chapter 3). The total LPG consumption of households in the province was estimated based on the provincial urban population.

This urban population composition of the province was also the basis for calculating the average petroleum consumption (LPG and diesel) of the commercial sector. The average fuel consumption of the commercial sector based on the survey was in kg/m2/year for LPG and lt.km2/year for diesel (Chapter 3). Since no data is available on the number of buildings and floor area by building type per province, the distribution of total consumption is assumed to follow the urban population ratio.

The total petroleum consumption of LPG in the EBT 2018 was almost 25 ktoe (21,201 tonnes) for the residential sector and 191 ktoe (162,209 tonnes) for the commercial sector. The diesel consumption of the commercial sector for 2018 was 220 ktoe (262,117 kl). Table 5.17 shows the 2018 petroleum consumption of the residential and commercial sectors.

Table 5.17. Consumption of Petroleum of the Residential and Commercial Sectors, 2018

Province		LPG Consumption (tonne)		Diesel Consumption (kl)
		Residential	Commercial	Commercial
1	Banteay Meanchey	1,163	8,897	14,378
2	Battambang	416	5,700	9,211
3	Kampong Cham	360	3,622	5,852
4	Kampong Chhnang	446	3,415	5,519
5	Kampong Speu	1,746	14,631	23,642
6	Kampong Thom	259	1,984	3,206
7	Kampot	219	1,675	2,707
8	Kandal	2,832	21,665	35,009
9	Kohkong	209	1,599	2,583
10	Kratie	150	1,147	1,853
11	Mondolkiri	121	925	1,495
12	Phnom Penh	8,434	57,823	93,437
13	Preah Vihear	90	692	1,119
14	Prey Veng	225	1,720	2,780
15	Pursat	267	2,044	3,302
16	Ratanakkiri	113	864	1,396
17	Siem Reap	975	8,648	13,975
18	Preah Sihanouk	483	4,551	7,354
19	Stung Treng	164	1,253	2,024
20	Svay Rieng	573	4,385	7,086
21	Takeo	1,052	8,047	13,003
22	Oddar Meanchey	332	2,540	4,105
23	Kep	122	935	1,511

Province		LPG Consumption (tonne)		Diesel Consumption (kl)
		Residential	Commercial	Commercial
24	Pailin	203	1,552	2,507
25	Tbong Khmum	248	1,896	3,063
Cambodia total		**21,201**	**162,209**	**262,117**

LPG = liquefied petroleum gas; kl = kilolitres.

Source: Author's calculation.

3.2. Petroleum demand 2040

1) Total sectoral demand

Cambodia's sectoral demand for petroleum products in 2040 followed ERIA's energy outlook and energy saving potential 2020 (Kimura and Han, 2021). The unit is in thousand tonnes of oil equivalent (ktoe) and has been converted to the original unit based on the calorific value and fuel density of the fuel. Table 5.18 shows the sectoral petroleum demand of Cambodia in 2040.

Table 5.18. Sectoral Petroleum Demand of Cambodia, 2040

Sector	Gasoline (kl)	Diesel (kl)	LPG (tonne)
Industry		521,147	
Road	2,449,820	4,553,775	173,258
Residential			120,675
Commercial		273,998	327,422
Total	**2,449,820**	**5,348,920**	**621,355**

kl = kilolitres; LPG = liquefied petroleum gas.

Source: Authors calculation.

2) Urban population 2040

Application of the oil companies' information and data (section 5.2) forecasted the total population of Cambodia for 2040 by adopting the United Nations' medium-range forecast (Table 5.6). Based on this, the population composition ratio by province in 2040 was also estimated.

The petroleum consumption survey used the urban population composition ratio as the basis for calculating provincial petroleum demand. In 2018, Cambodia's urban population was 39% of the total population. This study assumes that this share will increase to 45% by 2040 (8,637,318 persons). Using this assumption and the 2040 projected provincial total population from the oil companies survey, the 2040 urban population of the provinces was calculated. This estimate provides the urban population composition ratio to be used in projecting the 2040 petroleum demand (Table 5.19).

Table 5.19. Projected Urban Population in 2018 and 2040 and Composition, by Province

Province		Urban Population 2018		Urban Population 2040	
		Person	Share (%)	Person	Share (%)
1	Banteay Meanchey	327,653	5.5	515,910	6.0
2	Battambang	209,921	3.5	241,992	2.8
3	Kampong Cham	133,371	2.2	156,474	1.8
4	Kampong Chhnang	125,768	2.1	174,467	2.0
5	Kampong Speu	538,780	9.0	817,375	9.5
6	Kampong Thom	73,069	1.2	97,143	1.1
7	Kampot	61,693	1.0	76,243	0.9
8	Kandal	797,833	13.4	1,087,072	12.6
9	Kohkong	58,871	1.0	76,481	0.9
10	Kratie	42,221	0.7	61,578	0.7
11	Mondolkiri	34,075	0.6	59,569	0.7
12	Phnom Penh	2,129,371	35.6	3,208,182	37.1
13	Preah Vihear	25,491	0.4	44,943	0.5
14	Prey Veng	63,351	1.1	88,115	1.0
15	Pursat	75,259	1.3	95,982	1.1
16	Ratanakkiri	31,810	0.5	52,918	0.6
17	Siem Reap	318,469	5.3	445,811	5.2
18	Preah Sihanouk	167,584	2.8	280,695	3.2
19	Stung Treng	46,126	0.8	79,778	0.9

20	Svay Rieng	161,473	2.7	217,918	2.5
21	Takeo	296,325	5.0	390,455	4.5
22	Oddar Meanchey	93,551	1.6	159,925	1.9
23	Kep	34,438	0.6	50,275	0.6
24	Pailin	57,140	1.0	70,975	0.8
25	Tbong Khmum	69,808	1.2	87,040	1.0
	Cambodia total	**5,973,451**	**100.0**	**8,637,318**	**100.0**

Source: Author's calculation.

3) Provincial petroleum demand 2040

The sectoral petroleum demand of Cambodia and the urban population composition ratio were the bases in forecasting the 2040 petroleum demand at the provincial level. For road sector demand, the number of vehicles for the different fuels was calculated by assuming that the average fuel consumption of the different vehicle types is the same as in 2018. Table 5.20 shows the projected petroleum demand for the road sector.

Table 5.20. Petroleum Demand of the Road Transport Sector, 2040

Province		Consumption		
		Gasoline (Kl)	Diesel (Kl)	LPG (tonne)
1	Banteay Meanchey	138,742.34	281,467.97	12,597.53
2	Battambang	69,448.15	180,331.33	8,071.01
3	Kampong Cham	49,146.13	16,129.09	1,019.74
4	Kampong Chhnang	53,255.72	85,105.51	3,942.91
5	Kampong Speu	228,142.90	254,078.71	9,112.16
6	Kampong Thom	30,940.59	34,457.98	1,235.79
7	Kampot	26,123.61	29,093.40	1,043.39
8	Kandal	283,520.26	685,373.58	30,674.95
9	Kohkong	27,205.48	27,762.49	995.66
10	Kratie	19,511.31	19,910.79	714.07
11	Mondolkiri	15,746.67	42,360.01	1,619.26
12	Phnom Penh	882,965.08	1,200,903.80	36,981.92

13	Preah Vihear	11,779.90	31,689.03	1,211.35
14	Prey Veng	22,512.53	29,875.07	1,071.43
15	Pursat	34,778.75	93,558.09	3,576.36
16	Ratanakkiri	14,700.21	39,544.95	1,511.65
17	Siem Reap	113,172.12	330,428.11	13,853.59
18	Preah Sihanouk	77,443.65	208,330.67	7,963.68
19	Stung Treng	21,315.53	57,340.76	2,191.92
20	Svay Rieng	74,620.06	200,734.93	7,673.32
21	Takeo	136,937.47	368,374.59	14,081.54
22	Oddar Meanchey	43,231.65	116,297.19	4,445.59
23	Kep	15,914.47	42,811.41	1,636.51
24	Pailin	26,405.64	71,033.65	2,715.34
25	Tbong Khmum	32,259.81	86,781.90	3,317.34
Cambodia total		**2,449,820**	**4,533,775**	**173,258**

kl = kilolitres; LPG = liquefied petroleum gas.

Source: Author's calculation.

For the residential and commercial sectors, the average LPG consumption per person for 2040 was assumed to be the same as in 2018. As a result, the 2040 LPG consumption of these sectors was calculated and adjusted to the 2040 EBT of Cambodia, as discussed above. Similarly, the 2040 diesel consumption for the commercial sector was also calculated. Table 5.21 shows the projected petroleum demand in 2040 for the residential and commercial sectors.

Table 5.21. Petroleum Demand of the Residential and Commercial Sectors, 2040

Province		LPG Consumption (tonne)		Diesel Consumption
		Residential	Commercial	Commercial (Kl)
1	Banteay Meanchey	7,208	19,557	16,366
2	Battambang	1,871	9,173	7,677
3	Kampong Cham	1,650	5,932	4,964
4	Kampong Chhnang	2,438	6,614	5,535
5	Kampong Speu	10,342	30,985	25,929
6	Kampong Thom	1,357	3,682	3,082
7	Kampot	1,065	2,890	2,419
8	Kandal	15,188	41,209	34,484
9	Kohkong	1,069	2,899	2,426
10	Kratie	860	2,334	1,954
11	Mondolkiri	832	2,258	1,890
12	Phnom Penh	49,613	121,615	101,772
13	Preah Vihear	628	1,704	1,426
14	Prey Veng	1,231	3,340	2,795
15	Pursat	1,341	3,638	3,045
16	Ratanakkiri	739	2,006	1,679
17	Siem Reap	5,327	16,900	14,142
18	Preah Sihanouk	3,157	10,641	8,904
19	Stung Treng	1,115	3,024	2,531
20	Svay Rieng	3,045	8,261	6,913
21	Takeo	5,455	14,801	12,386
22	Oddar Meanchey	2,234	6,062	5,073
23	Kep	702	1,906	1,595
24	Pailin	992	2,690	2,252
25	Tbong Khmum	1,216	3,299	2,761
Cambodia total		**120,675**	**327,422**	**273,998**

LPG = liquefied petroleum gas; kl = kilolitres.

Source: Author's calculation.

The provincial petroleum demand of the industry sector in 2040 was projected using the same decomposition ratio of industrial establishments by type as in 2018 (Table 5.22).

Table 5.22. Industrial Diesel Demand in 2040, by Province

Province		Diesel Consumption (Kl)			
		Garment	Food & Beverages	Others	Total
1	Banteay Meanchey	1,197	168	4,114	5,479
2	Battambang	-	302	4,121	4,423
3	Kampong Cham	2,445	38	12,890	15,374
4	Kampong Chhnang	2,874	335	3,481	6,690
5	Kampong Speu	12,403	298	94,286	106,987
6	Kampong Thom	-	335	2,215	2,551
7	Kampot	239	419	33,567	34,225
8	Kandal	27,299	1,089	45,890	74,278
9	Kohkong	239	84	1,582	1,906
10	Kratie	-	168	2,848	3,016
11	Mondolkiri	-	-	633	633
12	Phnom Penh	61,839	770	63,798	126,407
13	Preah Vihear	-	168	949	1,117
14	Prey Veng	-	168	949	1,117
15	Pursat	718	251	633	1,603
16	Ratanakkiri	-	168	1,266	1,434
17	Siem Reap	239	266	28	533
18	Preah Sihanouk	11,960	26,426	34,000	72,387
19	Stung Treng	-	-	316	316
20	Svay Rieng	5,508	84	31,965	37,556
21	Takeo	6,705	335	12,343	19,383
22	Oddar Meanchey	-	84	316	400
23	Kep	-	-	-	-
24	Pailin	-	84	-	84
25	Tbong Khmum	-	84	3,165	3,249
Cambodia total		133,667	32,122	355,358	521,147

kl = kilolitres.

Source: Author's calculation.

4) Overall petroleum demand, by province, in 2040

The previous sections discussed the sectoral petroleum demand for 2040. This section compiled the sectoral demand by fuel type (gasoline, diesel, and LPG). Overall, Phnom Penh dominates the total demand for all types of fuels. The share will be 36% for gasoline, 27% for diesel, and 33% for LPG (Table 5.23).

The second-largest share is Kandal province at 12% for gasoline, 14% for diesel, and 14% for LPG. Combining these two provinces will make the gasoline share 48%, diesel around 40%, and LPG almost 48%. These provinces are in the central plain areas. Thus, including the other provinces in the area, gasoline share accounts for 60% of the total demand of Cambodia. Diesel accounts for 55%, and LPG is around 60%.

Table 5.23. Petroleum Demand in 2040, by Fuel and by Province

Province		Petroleum Demand 2040		
		Gasoline (kl)	Diesel (kl)	LPG (tonne)
1	Banteay Meanchey	138,742	303,313	39,363
2	Battambang	69,448	192,432	19,115
3	Kampong Cham	49,146	36,467	8,602
4	Kampong Chhnang	53,256	97,331	12,995
5	Kampong Speu	228,143	386,995	50,439
6	Kampong Thom	30,941	40,090	6,275
7	Kampot	26,124	65,737	4,998
8	Kandal	283,520	794,136	87,072
9	Kohkong	27,205	32,094	4,964
10	Kratie	19,511	24,880	3,908
11	Mondolkiri	15,747	44,883	4,709
12	Phnom Penh	882,965	1,429,083	208,210
13	Preah Vihear	11,780	34,232	3,543
14	Prey Veng	22,513	33,787	5,642
15	Pursat	34,779	98,206	8,555
16	Ratanakkiri	14,700	42,657	4,257
17	Siem Reap	113,172	345,103	36,081

18	Preah Sihanouk	77,444	289,621	21,762
19	Stung Treng	21,316	60,188	6,331
20	Svay Rieng	74,620	245,204	18,979
21	Takeo	136,937	400,144	34,338
22	Oddar Meanchey	43,232	121,770	12,742
23	Kep	15,914	44,407	4,245
24	Pailin	26,406	73,369	6,397
25	Tbong Khmum	32,260	92,791	7,832
Cambodia total		**2,449,820**	**5,328,920**	**621,355**

kl = kilolitres; LPG = liquefied petroleum gas.

Source: Author's calculation.

4. Selection of Petroleum Demand, by Province, in 2040

As described earlier, two methods were applied to forecast Cambodia's petroleum demand by province in 2040. One is the application of oil companies' data, and the other is the use of the energy consumption survey results from selected provinces. The first method refers to the oil companies' delivery information of petroleum products to provinces, but the coverage is not 100%. The survey results indicated a useful unit consumption of petroleum products such as fuel economy (kl/km) and kl/floor area. However, the macroeconomic data at the provincial level were not well prepared so far; thus, we depended on the urban population for this forecast. As mentioned, the forecast results of the two methods are different. For gasoline and LPG, Phnom Penh's share using the former method is much higher than the latter (43%–36% of gasoline, and 45%–34% of LPG). For diesel oil, the latter is higher than the former, 26% and 19%, respectively. Thus, the former method results look better than the latter method, so that this time we respected the oil companies' information, even though the petroleum data was limited at the provincial level, and applied the former forecast results of petroleum demand in 2040 to seek optimal petroleum supply chains up to 2040 in Cambodia.

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Chapter 6

Optimal Future Petroleum Supply Chain

Based on the demand for petroleum, which consists of gasoline and diesel oil per province in 2030 and 2040, we examined the optimal future petroleum supply chains from primary terminals to each province's capital by using the logistics optimisation with minimum cost approach model. Chapter 5 clarified that the total demand for gasoline and diesel oil would increase from 2,457,261 kilolitres (kl) in 2018 to 4,580,455 kl in 2030, and 7,798,740 kl in 2040. The Phnom Penh area, which includes nine provinces, is the largest demand area, accounting for 56.5% of the total demand in 2030 and 55.5% in 2040. The West area, which includes five provinces, accounting for 22.8% of the total demand in 2030 and 23.8% in 2040, is the second demand area. The logistics optimisation model aims to find the optimal supply chain in the whole of Cambodia. The model assumes 13 supply routes, with three transportation means (tank-truck, railway, and pipeline).

Two primary terminals are assumed: one for the Sihanoukville terminals, including Kampot and others on the seaside, and the other, for terminals along the Mekong River in Phnom Penh and Kandal. These are the primary terminals used to import petroleum products from Singapore, Thailand, and Viet Nam. The Phnom Penh and Battambang hub terminals are assumed to be secondary terminals. Gasoline and diesel oil will be transferred from primary terminals, mainly Sihanoukville, to these hub terminals. The objective function of the logistics optimisation model minimises total transport costs to move petroleum products from the primary terminals to the province's capitals. However, the model does not represent each oil company, only the nationwide petroleum logistics.

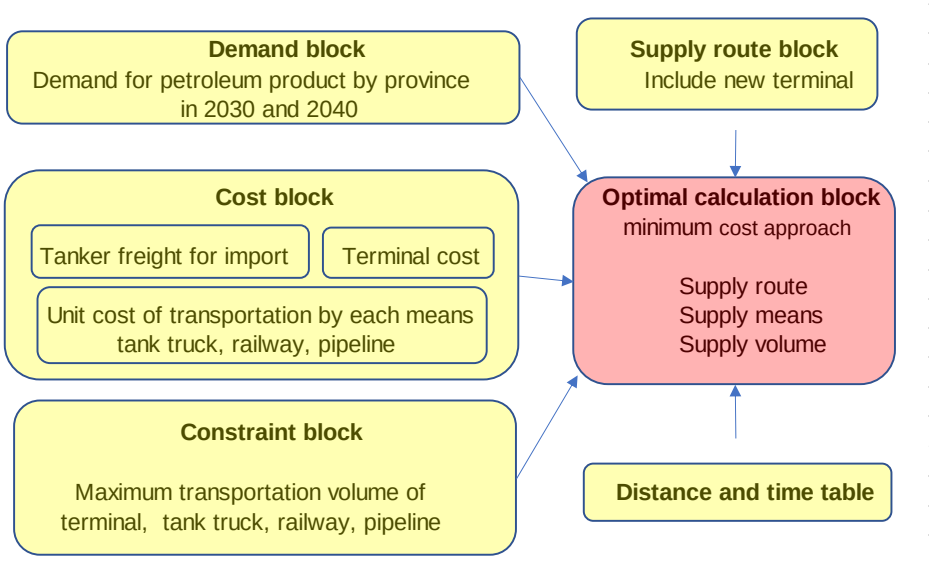
1. Structure of the Logistics Optimisation Model

The logistics optimisation model consists of the following blocks:

- Demand block: demand for gasoline and diesel oil by each province in 2030 and 2040
- Supply route block: 13 supply routes, including new terminals, are assumed.

- Cost block: import freight, terminal cost, transfer cost, final delivery cost, and unit transport cost of tank-trucks, railways, and pipelines
- Constraint block: maximum transportation volume from the primary terminals, by tank-truck, railway, and pipeline
- Optimal calculation block: minimum cost approach

Figure 6.1 Structure of Logistics Optimisation Model for Cambodia



Source: Author.

1.1 Demand block

Table 6.1 is shows gasoline and diesel oil demand by province in 2030 and 2040.

Table 6.1. Demand for Gasoline and Diesel Oil by Province in 2030 and 2040 (kl)

Demand by province	Gasoline + Diesel Oil			2040 Gasoline + Diesel	
	2018	2030	2040	%	2018–2040
Banteay Meanchey	129,522	253,343	455,261	5.8	5.9
Battambang	215,042	314,843	559,018	7.2	4.4
Kampong Cham	127,409	199,215	334,100	4.3	4.5
Kampong Chhnang	68,183	120,381	208,699	2.7	5.2
Kampong Speu	52,902	101,502	174,750	2.2	5.6
Kampong Thom	75,939	127,445	225,422	2.9	5.1
Kampot	30,875	49,723	84,898	1.1	4.7
Kandal	176,039	313,542	520,499	6.7	5.1
Kohkong	9,335	15,503	26,971	0.3	4.9
Kratie	79,511	147,736	252,724	3.2	5.4
Mondolkiri	48,968	106,612	183,546	2.4	6.2
Phnom Penh	566,751	1,226,439	2,006,053	25.7	5.9
Preah Vihear	54,709	119,745	209,883	2.7	6.3
Prey Veng	89,728	160,305	273,086	3.5	5.2
Pursat	94,187	153,590	267,816	3.4	4.9
Ratanakiri	49,260	103,739	169,798	2.2	5.8
Siem Reap	196,334	348,007	608,139	7.8	5.3
Preah Sihanouk	61,264	128,625	219,457	2.8	6.0
Stung Treng	34,682	74,555	130,909	1.7	6.2
Svay Rieng	68,403	118,940	202,952	2.6	5.1
Takeo	55,167	95,382	158,936	2.0	4.9
Oddar Meanchey	44,235	93,814	167,202	2.1	6.2
Kep	2,105	3,980	6,561	0.1	5.3
Pailin	22,548	35,108	63,047	0.8	4.8
Tbong Khmum	104,164	168,380	289,014	3.7	4.7
Cambodia total	**2,457,262**	**4,580,455**	**7,798,740**	**100.0**	**5.4**

kl = kilolitres.

Source: This project.

Table 6.2 shows petroleum demand in four areas in Cambodia.

Table 6.2. Demand for Gasoline and Diesel Oil by Area in 2030 and 2040

	2018		2030		2040		2018–2040
	1,000 kl	%	1,000 kl	%	1,000 kl	%	AGR %
Around PP	1,370,803	55.8	2,588,237	56.5	4,327,640	55.5	5.4
West area	607,681	24.7	1,045,116	22.8	1,852,666	23.8	5.2
Northeast	267,129	10.9	552,387	12.1	946,861	12.1	5.9
SV direct	211,648	8.6	394,714	8.6	671,573	8.6	5.4
Total	**2,457,262**	**100.0**	**4,580,455**	**100.0**	**7,798,740**	**100.0**	**5.4**

kl = kilolitres.

Source: This project.

The Phnom Penh area, which includes nine provinces, is the largest demand area; the Mekong River terminals are the nearest supply base but far from the Sihanoukville terminals, which is the largest base. The West area, which includes five provinces, is the second demand area. It is 200 km–300 km from the Mekong River terminals. On the other hand, it is about 500 km away from the Sihanoukville terminals, and the role of the Battambang hub is great.

The Mekong River terminals are nearest supply base to the Northeast area. Gasoline and diesel oil can be delivered directly to the Sihanoukville area from the Sihanoukville terminals.

1.2 Supply route block

The logistics optimisation model assumes 13 supply routes. A supply route means a supply chain from a primary terminal to each provincial capital using a transportation means via a secondary terminal, if necessary. The following are the 13 supply routes.

1) Direct delivery of petroleum product by tank-truck from the Mekong River terminals
2) Transfer petroleum product from the Mekong River terminals to the Battambang hub terminal by tank-truck, and final delivery by tank-truck
3) Direct delivery by tank-truck from the Sihanoukville terminals
4) Transfer from the Sihanoukville terminals to the Phnom Penh hub terminal by railway, and final delivery by tank-truck

5) Transfer from the Sihanoukville terminals to the Phnom Penh hub terminal by tank-truck, and final delivery by tank-truck.
6) Transfer from the Sihanoukville terminals to the Phnom Penh hub terminal by tank-truck using the highway, and final delivery by tank-truck
7) Transfer from the Sihanoukville terminals to the Phnom Penh hub terminal by pipeline, and final delivery by tank-truck
8) Transfer from the Sihanoukville terminals to the Phnom Penh hub terminal by pipeline, and transfer to the Battambang hub terminal by tank-truck and final delivery by tank-truck
9) Transfer from the Sihanoukville terminals to the Battambang hub terminal directly by railway, and final delivery by tank-truck
10) Import from the Rayon refinery in Thailand to the Battambang hub terminal by pipeline and final delivery by tank-truck
11) Import from Vung Tau in Viet Nam to the Phnom Penh hub terminal by pipeline and final delivery by tank-truck
12) Transfer from the Phnom Penh hub terminal to the Battambang hub terminal by pipeline, and final delivery by tank-truck
13) Transfer from the Phnom Penh hub terminal to the Northeast hub terminal by pipeline, and final delivery by tank-truck.

For each supply route, the total transportation cost is calculated as follows, import freight + primary terminal cost + transfer cost + second terminal cost + final transportation cost represented by US$/kl. These cost elements are shown in the cost block.

1.3 Cost block

1) Import freight

Since the river is shallow, small tankers of 500–2,000 tonnes (deadweight tonne) carry imports at the Mekong River terminals. This is more expensive than the Sihanoukville terminal in terms of unit cost, which tankers of 5,000–10,000 tonnes can carry.

The difference in freight due to tanker size is about five times, but the actual difference is double because many imports are from Viet Nam via the Mekong River, which is nearer than Singapore and Thailand. Based on this information, the import freight to the Mekong River terminals is assumed to be charged U$30/kilolitre (kl), and the import freight to the Sihanoukville terminal is U$17/kl for the logistics optimisation model.

2) Terminal cost

As for the terminal cost, the larger the capacity, the smaller the cost per kilolitre. Table 6.3 shows the costs by capacity category, based on the data of Japanese oil companies.

Table 6.3 Terminal Cost ($/kl)

Category	Size	Terminal cost ($/kl)
Ultra Large	100,000 kl or more	1.5
Large	50,000 kl–100,000 kl	3.0
Medium	10,000 kl–50,000 kl	5.0
Small	10,000 kl or less	8.0

kl = kilolitres.

Source: Author.

3) Unit cost of tank-truck

Oil companies own tank-trucks and transport petroleum products by themselves. So, it is necessary to estimate the daily cost as the unit cost of tank-trucks.

The average cost per year of a tank-truck is estimated from the market price of the tank-truck and the service life of a new and used tank-truck in Asia. The price of a new truck includes import costs. The price of a used truck includes overhaul costs and import costs, and its service life is shorter than a new one. The average cost per year is estimated at $7,630 which is about $8,000 (in case of 20 kl tank-truck).

In addition, tank-truck transport costs include the driver's labour costs, the tank-truck's fuel, maintenance, and overhead costs. The composition ratio of tank-truck costs is about 20% of the total cost. Thus, the yearly expenses of tank-truck transport total about $40,000 ($8,000/0.2).

For example, if the number of working days per year is 200, the tank-truck transport cost per day is $200 (40,000/200). Since the capacity of the tank-truck is 20 kl, the cost/day is about $10/kl per day.

On the logistics optimisation model, the delivery for over 200 km takes 2 days for a round trip, such as Sihanoukville to Phnom Penh and vice versa. So, the cost/kl is calculated at $20 for 230 km. The delivery for 50–200 km takes 1 day. So, the cost/kl is $10 for less than 200 km. The delivery for less than 50 km takes half a day. So, the cost/kl is $5/kl. Based on this idea, tank-truck transport cost was calculated proportionally based on the distance from each primary and secondary terminal to each provincial capital. In principle, we assumed the transportation distance of tank-trucks per day to be 350 km or less.

These are almost the same as the result of the interview with oil companies in Cambodia.

4) Unit cost of railway

Currently, the railway transport of petroleum products has two routes: from Sihanoukville to Phnom Penh and Sihanoukville to Battambang.

The transportation cost of railway is about half that of a tank-truck, so it is effective, but the speed is slow due to the poor condition of the railway, so that the maximum capacity of each route is around 90,000 kl per year (1,800kl/trip, 50 trips). According to informal information, the railway condition will improve in the future, and total transportation capacity will increase to 600,000 kl/y and 1,200,000 kl/y in 2040. The increase of railway fees due to the improvement is assumed to be 3$/kl (in case of all to Battambang). The investment amount for improvement is unclear. However, based on the recent investment of new railway construction in Tanzania, the investment cost is $5.7–$5.8 million/km. If the ratio of oil transportation revenue is assumed to be 10% of total passenger and freight transportation revenue of Cambodia railway company, the total revenue for 30 years will be 2.23 MM$/km. This is about 40% of new railway investment costs in Tanzania, so 3$/kl increase of transport fee seems appropriate.

Tanzania Project 1: Investment amount is $1.2 billion, 207 km, $5.8 million/km

Tanzania Project 2: Investment amount is $1.9 billion, 336 km, $5.7 million/km

Cambodia railway company's revenue for 30 years from petroleum products.

3$ × 1,200,000 kl × 30 years/0.1/ 522 km => $2.23 million/km

Distance from Sihanoukville to Battambang is 522 km.

5) Unit cost of pipeline

According to the World Onshore Pipelines Market Forecast 2019–2023,[4] the total construction cost of a pipeline is 0.6 MM$/km–0.8 MM$/km on average worldwide.

On the other hand, India and Nepal officially opened South Asia's first cross-border oil pipeline. India funded a US$45-million pipeline project with an annual capacity of 2 million metric tonnes and a 69 km length . The unit construction cost of the India and Nepal pipeline was calculated at 0.7 MM$/km.

According to the above information, the construction cost of the Sihanoukville to Phnom Penh pipeline was about 150 MM$. On the other hand, there is also information that the investment amount would be 240 MM$.

If a third-party company constructs the pipeline and sets the fee, adding the project management cost and margin to the calculation is necessary. However, this study based the calculation on the assumption that the oil company constructed and used the pipeline.

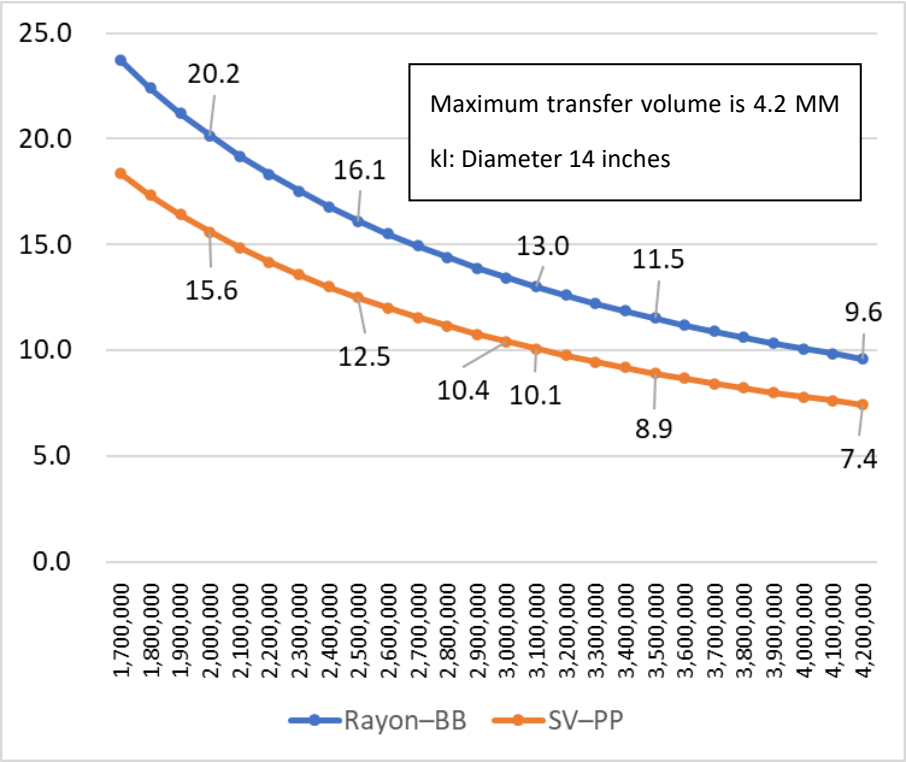
Assumption of calculation for unit cost of pipeline
Construction cost: : 240 MM$
Period of use : 20 years
Operation cost/year : 1% of construction cost
Maintenance cost/year: : 2% of construction cost
Interest cost/year: : 5% of construction cost
Total annual cost : 31.2 MM$

[4] https://www.westwoodenergy.com/reports/world-onshore-pipelines-market-forecast-2019-2023 (accessed 9 May 2020)

The unit cost of a pipeline depends on the transfer volume. Therefore, a larger transfer volume reduces unit cost. Figure 6.2 shows the relationship between transfer volume and unit cost.

Figure 6.2 Unit Cost of Pipeline

$/kl



Source: This project.

Figure 6.2 shows the unit costs of the Sihanoukville–Phnom Penh (SV-PP) and the Rayon–Battambang (Rayon-BB) hub terminals. We calculated the unit cost of the Rayon pipeline assuming that the investment amount of the Rayon pipeline increases with distance. Considering the expected demand scale and relative cost competitiveness, the transportation volume of the pipeline is calculated by iteratively calculating the logistics optimisation model. The unit cost of the pipeline from Viet Nam is same as the Rayon pipeline.

6) Unit cost of highway use

If the highway is used to transfer petroleum products from Sihanoukville to the Phnom Penh hub terminal by tank-truck, transportation that takes 2 days for a round trip will be possible in 1 day; that is, the cost is $10/kl instead of $20/kl. However, highway tolls will be added.

The highway fare is $0.4/km for vehicles over 20 tonnes and $0.32/km for those under 20 tonnes. Since a tank-truck loaded with fuel weighs 20 tonnes or more, the highway toll will be $0.4 × 190 km[5] = $76, and the 20 kl tank-truck will be $3.8/kl. On the other hand, since an empty tank-truck weighs less than 20 tonnes, the highway toll is $0.32 × 190 km = $60.8, and the 20 kl tank-truck is $3.0/kl. So then, transportation via the highway costs $16.8/kl ($10 + $3.8 + $3.0) for a round trip. If the transportation volume of the SV-PP pipeline exceeds 2.0 MM kl/y, the unit price of the pipeline will be less than 15.6$/kl and the use of the highway will be infeasible.

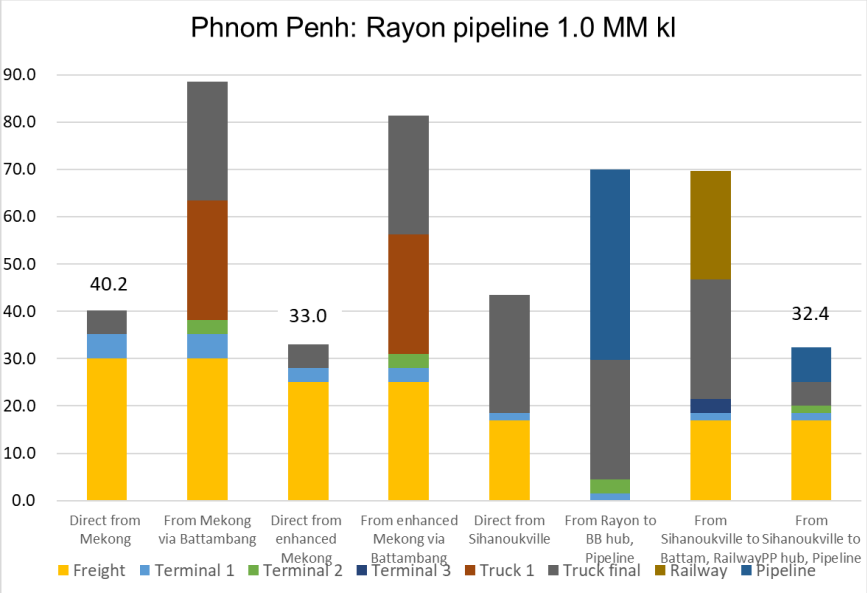
In addition, the maximum amount of tank-trucks that can be received at the hub terminal is 100 units per day due to the unloading work time.

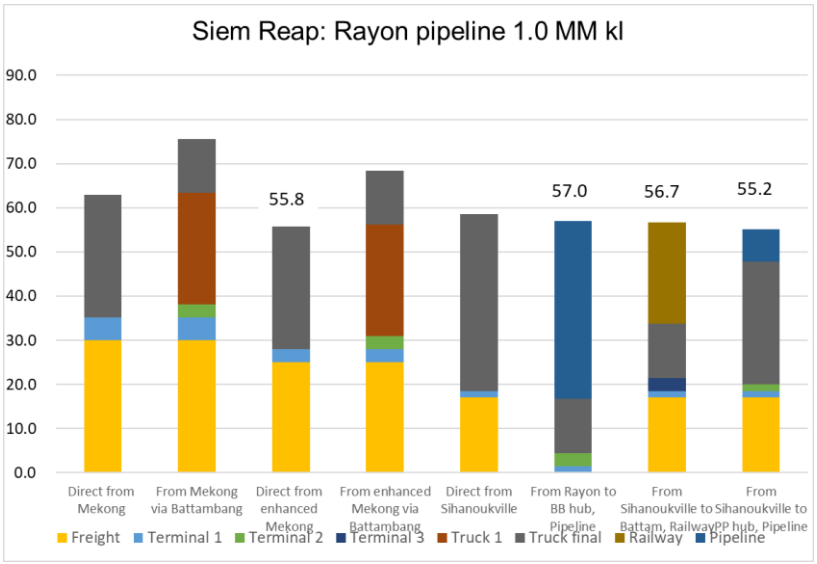
7) Transportation costs to major provincial capitals in 2040

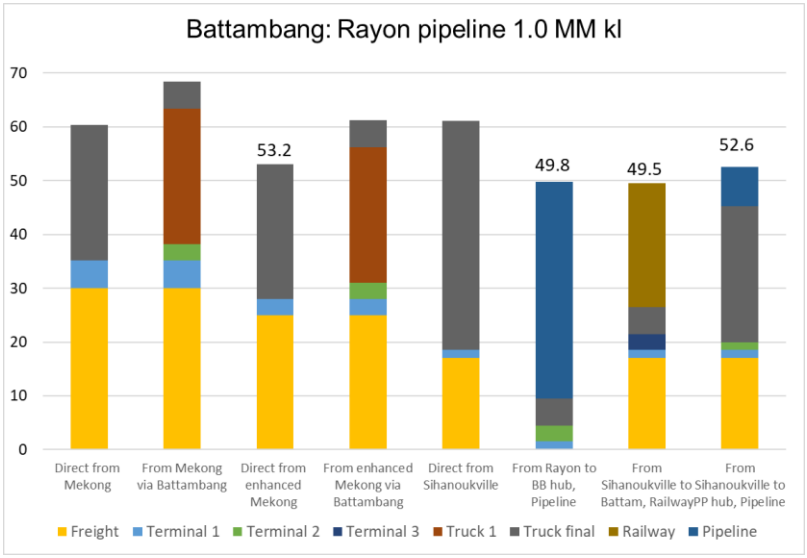
Figure 6.3 shows the total transportation costs – import freight, primary terminal cost, transport cost, second terminal cost, and final delivery cost – to major provincial capitals by supply routes in 2040.

[5] From the entrance to the highway is 190 km.

Figure 6.3. Total Transportation Costs to Major Provincial Capitals, by Supply Route







Source: This project.

The graph above shows when the SV-PP pipeline transport volume is max and Rayon pipeline is 1.0 MM kl case.

1.4 Optimal calculation block

The basic formula for calculating the minimum cost is as follows. And find x^{ij} that minimizes this with the linear programming model (hereinafter LP model). $\sum_{i=1}^{n}, \sum_{j=1}^{n} x^{ij} c^{ij}$

x^{ij} .... Delivery volume to j via supply route i (kl/y)

j is 25 province capitals, i is 11 supply routes

c^{ij} .... Transportation cost to j via supply route i ($/kl)

$\sum_{j=1}^{n} x^{ij}$ =< max supply volume of supply route i

$\sum_{i=1}^{n} x^{ij}$ = demand of province j

1.5 Constraint block

1) The maximum mileage of a tank-truck

The delivery distance of a tank-truck is assumed to be within 350 km. However, for the three provinces over 350 km, petroleum products are transported by tank-trucks from the nearest Mekong River terminal to Ratana Kiri (531 km), Mondolkiri (366 km), and Stung Treng (379 km) because there are no other means of delivery.

2) The maximum delivery volume from the Mekong River

The Mekong River terminals almost have no vacant land and are difficult to expand.

It is also difficult to accept large tankers because the river is shallow at this time.

In addition, the frequency of delivery is limited due to traffic jams. Therefore, the maximum delivery volume from the Mekong River terminals is assumed to be 1.3 million kl/year. However, this will only increase by about 30% from the current delivery volume, estimated at 0.9–1.0 million kl/y. For the LP model, we assumed an enhanced Mekong River terminal with an additional storage tank that can accommodate large tankers in the future, and calculated cases where cost reduction is also attempted.

3) The maximum delivery volume by railway

The maximum delivery volume by railway is limited to 600,000 kl/y in 2030, and 1,200,000 kl/y in 2040 on the LP model. And the railway transportation volume in 2030 was calculated as 480,000 kl/y for Phnom Penh and 120,000 kl/y for Battambang, but the total transportation cost was lower if the total volume is allocated for Battambang. Therefore, in 2040, all transportation volume by railway was allocated for Battambang.

4) Importable volume from Thailand (Rayon refinery)

According to the Energy Balance 2019 of Thailand's Ministry of Energy, the total export volume of gasoline and diesel oil in Thailand is about 5 million kl in 2019 (Table 6.4). There are seven refineries in Thailand with a total capacity of 1,234,500 barrels/day. The Rayon refinery accounts for 17.4% of the total in 215,000 barrels/day. Therefore, the export volume of the Rayon refinery

in 2019 was calculated at 870,000 kl/y. So, on the LP model, we set 1,000,000 kl/y as importable volume.

Table 6.4. Supply and Demand of Gasoline and Diesel Oil in Thailand

Unit: 1,000 kl		Gasoline	Diesel Oil	Total
2019	production	1,747	25,775	27,522
	Import	28	2,374	2,402
	Export	1,223	3,776	4,999
	Consumption	389	24,579	24,968
2018	production	2,278	28,219	30,497
	Import	0	582	582
	Export	1,707	5,533	7,240
	Consumption	437	23,587	24,024
2017	production	2,126	28,258	30,384
	Import	0	813	813
	Export	1,599	5,245	6,844
	Consumption	508	23,223	23,731

kl = kilolitres.

Source: The Ministry of Energy in Thailand

2. Case Study

We conducted several case studies using the logistics optimisation model to find the optimal supply chain in 2030 and 2040. These case studies were based on the premise that one ideal oil company would supply petroleum products nationwide. The case studies were on the following:

- BAU case in 2030 (business-as-usual scenario), where the current supply method continues
- All candidate supply routes are sequentially applied to the LP model to find the optimal solution in 2030.

- BAU case in 2040, where the supply method in the optimal solution in 2030 continues
- All candidate supply routes are sequentially applied to the LP model to find the optimal solution in 2040.

2.1 Case studies in 2030

1) BAU case in 2030

The BAU case in 2030 reflects the existing petroleum supply chain applied by oil companies in Cambodia. It means that there will be no railway improvement, no highway use, no pipeline, no pipeline import from Thailand or Viet Nam. Due to the limited capacity of the Mekong River terminal route, delivery volume from Sihanoukville will increase significantly (2,330,455 kl+1,000,000 kl). As a result, direct delivery from Sihanoukville will be accounted for at 50.9%, followed by from Sihanoukville to the Phnom Penh hub at 21.8%. The storage capacity of the Sihanoukville terminals is enough, but shipping lanes and shipping frequency must be increased. On the other hand, direct delivery from the Mekong River terminals will be at 14.2% (9.2%+5.0%) (Table 6.5). In 2030, the major transport mode for transporting petroleum products to each provincial capital will still be tank-trucks.

Table 6.5. BAU Case in 2030

kl/year	%	Supply Route
422,843	9.2	Direct from Mekong
227,157	5.0	From Mekong via Battambang hub
2,330,455	50.9	Direct from Sihanoukville
480,000	10.5	From Sihanoukville to PP hub, Railway
120,000	2.6	From Sihanoukville to BB hub, Railway
1,000,000	21.8	From Sihanoukville to PP hub, Tank truck
4,580,455	100.0	Cost: US$ 234,329,081 $

Supply Volume to Each Area by Supply Route

Supply Route	Around PP	West Area	Northeast	SV Direct	Total
Direct from Mekong	0	168,495	254,348	0	422,843
From Mekong via Battambang hub	0	227,157	0	0	227,157
Direct from Sihanoukville	1,935,740	0	0	394,714	2,330,455
From Sihanoukville to PP hub, Railway	365,177	114,823	0	0	480,000
From Sihanoukville to BB hub, Railway	0	120,000	0	0	120,000
From Sihanoukville to PP hub, Tank truck	287,320	414,641	298,039	0	1,000,000
Total	2,588,237	1,045,116	552,387	394,714	4,580,455

kl = kilolitres.

Source: Author.

2) SV-PP pipeline case in 2030

This case study reflects a pipeline system between SV and PP. Transfer volume via the SV-PP pipeline is over 3.0 MM kl and unit cost is 10.4$/kl. Since the SV-PP pipeline has strong cost competitiveness if the transporting amount is large such as more than 2 million kl, transfer from SV to PP by tank-trucks will be zero and direct delivery from SV by tank-trucks will decrease. And the total transportation cost as the objective function is –9.7% compared with the BAU case.

Table 6.6. SV-PP Pipeline Case in 2030

kl/year	%	Supply Route	
422,843	9.2	Direct from Mekong	
227,157	5.0	From Mekong via Battambang hub	
293,212	6.4	Direct from Sihanoukville	
480,000	10.5	From Sihanoukville to PP hub, Railway	
120,000	2.6	From Sihanoukville to BB hub, Railway	
3,037,243	66.3	From Sihanoukville to PP hub, Pipeline	
4,580,455	100.0	Cost: US$	211,617,923 $

Supply Volume to Each Area, by Supply Route

Supply Route	Around PP	West Area	Northeast	SV Direct	Total
Direct from Mekong	118,940	229,347	74,555	0	422,843
From Mekong via Battambang hub	0	227,157	0	0	227,157
Direct from Sihanoukville	0	0	0	293,212	293,212
From Sihanoukville to PP hub, Railway	480,000	0	0	0	480,000
From Sihanoukville to BB hub, Railway	0	120,000	0	0	120,000
From Sihanoukville to PP hub, Pipeline	1,989,297	468,612	477,832	101,502	3,037,243
Total	2,588,237	1,045,116	552,387	394,714	4,580,455

kl = kilolitres.

Source: Author.

3) Optimal solution case in 2030

This case study reflects that all of the railway capacity would be allocated to the BB hub terminal. Railway is cost-competitive for transportation to the west area. When 600,000 kl of petroleum products would be transferred from the SV to the BB hub, the transport cost from the Mekong River terminal to the BB hub terminal will decrease to zero, and the decreased volume will be transferred to direct delivery from the Mekong River terminal for a total of 650,000 kl. And the total transportation cost will be –12.5% compared with BAU case. This is optimal case in 2030.

Table 6.7. Optimal Solution Case in 2030

kl/year	%	Supply Route	
650,000	14.2	Direct from Mekong	
0	0.0	From Mekong via Battambang	
293,212	6.4	Direct from Sihanoukville	
0	0.0	From Sihanoukville to PP hub, Railway	
600,000	13.1	From Sihanoukville to BB hub, Railway	
3,037,243	66.3	From Sihanoukville to PP hub, Pipeline	
4,580,455	100.0	Cost: US$	205,456,148 $

Supply Volume to Each Area, by Supply Route

Supply Route	Around PP	West Area	Northeast	SV Direct	Total
Direct from Mekong	438,537	211,463	0	0	650,000
From Mekong via Battambang hub	0	0	0	0	0
Direct from Sihanoukville	0	0	0	293,212	293,212
From Sihanoukville to PP hub, Railway	0	0	0	0	0
From Sihanoukville to BB hub, Railway	0	600,000	0	0	600,000
From Sihanoukville to PP hub, Pipeline	2,149,701	233,652	552,387	101,502	3,037,243
Total	2,588,237	1,045,116	552,387	394,714	4,580,455

kl = kilolitres.

Source: Author.

2.2 Case studies in 2040

1) BAU case in 2040

The demand for gasoline and diesel oil will increase 1.7 times from 2030 to 7.8 MM kl.

BAU case in 2040, when the supply means of optimal solution case in 2030 will continue, the SV-PP pipeline will reach 4.2 MM kl (max capacity) and direct delivery from SV will be over 2.3 MM kl, which will be big volume.

Table 6.8. BAU Case in 2040

kl/year	%	Supply Route
627,537	8.0	Direct from Mekong
22,463	0.3	From Mekong via Battambang
2,348,740	30.1	Direct from Sihanoukville
0	0.0	From Rayon to BB hub, Pipeline
600,000	7.7	From Sihanoukville to BB hub, Railway
4,200,000	53.9	From Sihanoukville to PP hub, Pipeline
7,798,740	100.0	Cost: US$ 350,555,051 $

Supply Volume to Each Area, by Supply Route

Supply Route	Around PP	West Area	Northeast	SV Direct	Total
Direct from Mekong	0	627,537	0	0	627,537
From Mekong via Battambang	0	22,463	0	0	22,463
Direct from Sihanoukville	1,677,167	0	0	671,573	2,348,740
From Rayon to BB hub, Pipeline	0	0	0	0	0
From Sihanoukville to BB hub, Railway	0	600,000	0	0	600,000
From Sihanoukville to PP hub, Pipeline	2,650,473	602,666	946,861	0	4,200,000
Total	4,327,640	1,852,666	946,861	671,573	7,798,740

kl = kilolitres.

Source: Author.

2) Enhanced Mekong River terminal and enhanced railway case in 2040

An enhanced Mekong terminal means expanded storage capacity and receiving large oil tankers with 5,000 tonnes; the maximum supply amount will be 1.3 MM kl. And we assumed US$7 cost down from the existing Mekong River terminal. An enhanced railway can transport 1.2 MM kl/y due to improvement, and contribute to the West area demand by allocating all the capacity to the BB hub. So then, the direct delivery volume will decrease to 1.1 MM kl. As a result, the total transportation cost will be 4.7% compared with the BAU case. This is the optimal case in 2040.

Table 6.9. Enhanced Mekong River Terminal and Railway Case in 2040

kl/year	%	Supply Route	
1,300,000	16.7	Direct from enhanced Mekong	
0	0.0	From enhanced Mekong via Battambang	
1,098,740	14.1	Direct from Sihanoukville	
1,200,000	15.4	From Sihanoukville to BB hub, Railway	
4,200,000	53.9	From Sihanoukville to PP hub, Pipeline	
7,798,740	100.0	Cost: US$	334,078,729

Supply Volume to Each Area, by Supply Route

Supply Route	Around PP	West Area	Northeast	SV Direct	Total
Direct from enhanced Mekong	819,202	44,527	436,271	0	1,300,000
From enhanced Mekong via Battambang	0	0	0	0	0
Direct from Sihanoukville	427,167	0	0	671,573	1,098,740
From Sihanoukville to BB hub, Railway	0	1,200,000	0	0	1,200,000
From Sihanoukville to PP hub, Pipeline	3,081,271	608,139	510,590	0	4,200,000
Total	4,327,640	1,852,666	946,861	671,573	7,798,740

kl = kilolitres.

Source: Author.

3) Possibility of import from Rayong refinery (in Thailand)

The importation by tank-trucks from the Rayong refinery (in Thailand) cannot rule out the possibility of illegal imports, so we excluded it from consideration. On the other hand, the Rayon-BB hub pipeline is cost-competitive because it does not require tanker freight, and it would be effective for the West area. However, we assumed the importable volume from the Rayon refinery would be limited to 1.0 MM kl/y, so the unit cost will increase, and the transport cost will be larger than other means of supply. Therefore, the import from the Rayon refinery by pipeline cannot be feasible.

4) Other result of case studies in 2040

- SV-PP double pipelines

When the enhanced Mekong River terminal and enhanced railway would not be realised, an additional SV-PP pipeline was considered.

The transfer volume of SV-PP double pipelines was 5.1 MM kl; it is a small volume and the total transportation cost was +4.3% compared with the BAU case.

- PP-BB pipeline

Since the demand for the West area is 1.9 MM kl, the transfer volume of PP-BB pipeline is small and the unit cost is high. The LP model cannot select PP–BB pipeline because the cost of direct delivery by tank-truck from the PP hub is lower than pipeline.

The above two may be effective when the demand further increases.

- Viet Nam-PP pipeline

We considered of pipeline imports from the Ho Chi Minh or Vung Tau oil terminals in Viet Nam. But the LP model did not select the Viet Nam pipeline because the distance required for the pipeline is more than 300 km, and the cost is higher than the SV-PP pipeline.

3. Conclusions

- The optimal solution for 2030 is the SV-PP pipeline case (Table 6.7).

By allocating all rail transportation to BB in addition to the SV-PP pipeline, the transportation cost to the west area will be reduced and the total transportation cost will be –12.5% compared with the BAU case.

- The optimal solution for 2040 is the SV-PP pipeline, enhanced Mekong River terminal, and enhanced railway case (Table 6.9). And the total transportation cost will be –4.7% compared with the BAU case.

In addition, in this case, all transportation method is domestic.

Chapter 7

Conclusion

According to the Cambodia energy statistics 2010–2018, the demand for petroleum products was dominant and increased at around 8.3% per year from 2010–2018. The major petroleum products were diesel oil and gasoline, used mainly for vehicle transport. This petroleum demand is projected to increase 1.8 times from 2018 to 2030 and 3.2 times to 2040, according to the Cambodia energy outlook 2019. Consequently, the current petroleum supply chain to support the transportation of petroleum products from primary terminals to tertiary terminals in each province will be resilient, applying the current land transportation mode (tank truck) and the pipeline, railway, and highway systems as well as secondary storages.

Next, this study divided future gasoline and diesel oil demand at the national level into each province. Therefore, this study used sales data from oil companies in Cambodia and estimated the consumption of petroleum products at the provincial level based on the energy consumption survey results. The energy consumption survey was successful but the estimation of petroleum product consumption did not succeed due to the lack of provincial macroeconomic information and data on vehicle ownership . Finally, this study chose the estimation results of provincial petroleum product demand based on the oil company data.

In addition, through interviews of oil companies, the current petroleum supply chain which represents transportation of petroleum products from primary terminals to each province was reviewed.

Finally, this study simulated future petroleum supply chain applying the cost minimum approach (linear programming method) based on several given data:(i) future petroleum demand in each province in 2030 and 2040; (ii) supply constraint on primary terminals (Sihanoukville and Mekong River); (iii) unit transportation cost of tank truck, railway, highway and pipeline, and other parameters such as import freight. Firstly, this study produced the BAU scenario of 2030; it also reflected the current supply chain system, and conducted several case studies to include the new transport system, such as the enhanced Mekong River terminal and the rehabilitated

railway and pipeline, to seek for resilient petroleum supply chain in 2030 and 2040. As a results, the cost minimum approach was suggested: (i) in 2030, a pipeline between Sihanoukville and Phnom Penh could contribute to minimising the national logistic cost of petroleum products, (ii) in 2040, the enhancement of Mekong River storages and the rehabilitated railway system between Sihanoukville and Battambang could contribute to minimising the national oil logistic cost.

If the current land transport system can transport petroleum products from the primary terminals to each province in 2030, direct delivery from Sihanoukville will cover around half of the total petroleum product amount in 2030, and the delivery amount from Sihanoukville to Phnom Penh will be significant. Therefore, this system will not be resilient because of many issues – the need for a remarkable number of tank-trucks and shipping lanes at primary terminals and tank truck drivers to engage in long-distant driving.

If a pipeline system will apply between Sihanoukville and Phnom Penh, direct delivery from Sihanoukville will sharply go down. On the other hand, the pipeline system will take the highest share (66.3%), followed by direct delivery from the Mekong River terminal. Thus, the issues mentioned above will be solved but certain amounts of shipping lanes will still be necessary at the secondary terminal near Phnom Penh. The pipeline system will also accomplish a significant cost down of petroleum logistics in the whole of Cambodia.

On the other hand, the construction of the pipeline system between Sihanoukville and Phnom Penh, which is almost 220 km, will need a certain amount of investment (US$200–US$240 million). Thus, at least more than 2 million kl per year of oil demand, consisting mainly of gasoline and diesel oil, will be indispensable. In addition, safety regulations to cover both construction and operation of the pipeline should be formulated under the leadership of the General Department of Petroleum/MME, Cambodia.

The cost minimum approach was implemented to simulate petroleum transportation from the primary terminals to each province with the view of economic rationale. However, actual petroleum transportation does not follow economic rational behavior 100% and includes historical business practices. Nevertheless, under these conditions, the cost minimum approach can provide us with many meaningful outputs, and these outputs will surely contribute to formulating appropriate petroleum supply chain policies to be responded by the General

Department of Petroleum/MME. These policies will also be a good feedback to oil companies in Cambodia.