ERIA Research Project Report 2025, No.7

# Analysis of the Impact of the Penetration of Electric Vehicles in Cambodia

Economic Research Institute for ASEAN and East Asia

Analysis of the Impact of the Penetration of Electric Vehicles in Cambodia

Economic Research Institute for ASEAN and East Asia (ERIA)
Sentral Senayan II 6th Floor
Jalan Asia Afrika No. 8, Gelora Bung Karno
Senayan, Jakarta Pusat 12710
Indonesia


ERIA Research Project Report FY2025 No.7
Published in June 2025



In this publication, $ refers to United States dollars.

# Preface

As countries around the world accelerate their shift from internal combustion engine (ICE) vehicles to battery electric vehicles (BEVs) in pursuit of decarbonisation, the resulting increase in electricity demand underscores the need for clean power generation systems. For Cambodia, which already relies heavily on hydropower and is planning to incorporate liquefied natural gas (LNG) into its energy mix, the transition to BEVs aligns well with its environmental goals.

However, the broader implications of electric vehicle (EV) adoption must be carefully considered. Key areas of concern include:
i) potential economic losses for Cambodia's domestic oil industry;
ii) the substantial investment needed in the power sector, particularly for new generation capacity and transmission infrastructure;
iii) the development of EV-supporting infrastructure, such as charging stations;
iv) macroeconomic impacts; and
v) implications for energy consumption and carbon dioxide ($CO_2$) emissions.

Given the current limitations in data availability, the Economic Research Institute for ASEAN and East Asia (ERIA) has undertaken a preliminary analysis of the potential positive and negative impacts of EV penetration in Cambodia. The findings indicate that EV adoption will influence several key areas of national planning, including the Power Development Plan, infrastructure development, and energy policy – particularly those related to the oil sector.

This report presents a multi-dimensional analysis of the potential impact of BEV adoption in Cambodia, covering the power and oil sectors, economic growth, infrastructure readiness, and environmental sustainability. It is intended to support evidence-based policymaking and guide the formulation of strategic plans for EV deployment. I hope the insights offered in this report will contribute to shaping a clear and effective direction for Cambodia's transition to electric mobility.

Shigeru Kimura, Mr

Former Senior Policy Fellow for Energy Affairs

Economic Research Institute for ASEAN and East Asia (ERIA)

# Acknowledgements


This report was prepared by the Economic Research Institute for ASEAN and East Asia (ERIA). The ERIA team comprised:

Mr Shigeru Kimura, Former Senior Policy Fellow on Energy Affairs, who supervised the project;

Dr Han Phoumin, Senior Energy Economist, who provided an overview of the current electric vehicle (EV) programme in Cambodia;

Dr Alloysius Joko Purwanto, Energy Economist, who projected the number of EVs and charging stations in Cambodia;

Mr Kei Sudo, Former Programme Manager on Energy, who analysed the impact of EVs on the power sector;

Ms Laksmita Dwi Hersaputri, Research Associate, who provided general support to the project; and

Mr Takahisa Hiruma, Vice President of the ASIAM Research Institute and external expert, who analysed the impact of EVs on Cambodia's oil industry.

I would like to express my sincere gratitude to all ERIA team members for their outstanding contributions to the success of this research study.

Shigeru Kimura, Mr

Former Senior Policy Fellow for Energy Affairs

Economic Research Institute for ASEAN and East Asia (ERIA)

# List of Project Members


Economic Research Institute for ASEAN and East Asia Study Team

Ms Laksmita Dwi Hersaputri, Research Associate, Energy Unit, ERIA

Mr Takahisa Hiruma, Vice President, ASIAM

Mr Shigeru Kimura, Former Senior Policy Fellow for Energy Affairs

Dr Han Phoumin, Senior Energy Economist, Energy Unit, ERIA

Dr Alloysius Joko Purwanto, Energy Economist, Energy Unit, ERIA

Mr Kei Sudo, Former Programme Manager on Energy, Energy Unit, ERIA

# Table of Contents

# List of Figures and Tables

## Figures

## Tables

# Abbreviations

| | |
|---|---|
| AC | alternating current |
| ADB | Asian Development Bank |
| ASEAN | Association of Southeast Asian Nations |
| BAU | business-as-usual |
| BEV | battery electric vehicle |
| CCS | combined charging system |
| $CO_2$ | carbon dioxide |
| DC | direct current |
| EAFO | European Alternative Fuels Observatory |
| EBT | energy balance table |
| EDC | Electricité du Cambodge |
| ERIA | Economic Research Institute for ASEAN and East Asia |
| EU | European Union |
| EV | electric vehicle |
| GDP | gross domestic product |
| GHG | greenhouse gas |
| GWh | gigawatt-hour |
| HEV | hybrid electric vehicle |
| ICE | internal combustion engine |
| Ktoe | kilotonne of oil equivalent |
| kW | kilowatt |
| kV | kilovolt |
| Lao PDR | Lao People's Democratic Republic |
| Mtoe | million tonnes of oil equivalent |
| MME | Ministry of Mines and Energy of Cambodia |
| MW | megawatt |
| PHEV | plug-in hybrid electric vehicle |
| POI | points of interest |
| TFEC | total final energy consumption |
| TOU | time-of-use |
| TPES | total primary energy supply |
| US | United States |

# Executive Summary

The Government of Cambodia is actively promoting the adoption of electric vehicles (EVs), particularly battery electric vehicles (BEVs), as part of its national policy to transition toward a cleaner and more sustainable energy future. This study evaluates the potential impact of EV penetration on Cambodia's energy sector, focusing on changes in fuel consumption, electricity demand, economic implications, and investment needs.

The growing adoption of EVs will affect the energy sector in two major ways: a reduction in gasoline and diesel consumption, and a rise in electricity demand. Benefits of EV adoption include improved air quality, lower $CO_2$ emissions, and the emergence of new industries, such as EV manufacturing and battery recycling. However, challenges remain: high battery costs, long charging times, infrastructure investment needs, and potential economic losses for the oil sector.

To quantify these impacts, the study explores three scenarios based on EV market share – 20%, 40%, and 60% of total vehicle stock by 2050. Under the 60% scenario (EV60%), gasoline consumption is projected to peak around 2035 and decline slightly thereafter, though 2050 levels will still exceed those of 2020. While this transition may harm the oil sector, it will not drastically reduce overall fuel volumes. On a macroeconomic level, however, the EV60% scenario is projected to boost Cambodia's GDP by 2.9% in 2050 compared to the business-as-usual case, primarily due to reduced fuel imports.

Rising EV adoption will significantly increase electricity demand. In the EV60% scenario, electricity demand for EVs is expected to reach 6,277 GWh by 2050. If met through hydropower, Cambodia will need to expand its generation capacity by 2,155 MW, requiring an estimated investment of $5.4 billion. Additional infrastructure costs include $211 million for transmission lines and $664 million for distribution systems.

Energy savings are anticipated due to the higher efficiency of electricity versus fossil fuels. Assuming equal driving conditions, EVs consume less energy (on a thermal basis) than internal combustion engine (ICE) vehicles. Furthermore, $CO_2$ emissions will decline from reduced fuel use. The degree of emissions reduction from electricity generation will depend on the energy mix. Hydropower results in no added $CO_2$ emissions, while gas-fired power plants emit significantly less $CO_2$ than coal-fired ones. Thus, prioritising renewable or low-emission power sources is crucial.

Supporting EV infrastructure is another priority. Cambodia will need to invest in widespread charging networks across urban and commercial areas. Key considerations include selecting internationally compatible plug types and addressing long charging times, particularly for low-voltage chargers. Innovative technologies – such as battery-swapping systems and wireless charging – could help address these challenges.

### Conclusion:

EVs present Cambodia with a compelling opportunity to reduce transport fuel imports, cut emissions, and capitalise on its hydropower potential. However, these benefits will require substantial investments in electricity generation, grid infrastructure, and EV support systems. Strategic planning and smart policy design will be essential to maximise gains and manage the transition's economic and technical challenges.

# Chapter 1

# Current Policies on Electric Vehicles in Cambodia

## 1. Introduction

The Government of Cambodia has shown increasing interest in the adoption of electric vehicles (EVs) to reduce air pollution, enhance energy efficiency, and transition towards cleaner sources of energy (Ned, 2022). Cambodia's EV policy is part of the country's broader efforts to promote sustainable transportation and reduce its carbon footprint. The Government of Cambodia has actively promoted EVs through initiatives such as the development of EV infrastructure; raising public awareness; and implementing supportive policies to encourage EV adoption, including the implementation of incentives for EV manufacturers, importers, and consumers. In 2020, Cambodia introduced import duty exemptions for EVs to reduce costs for consumers and to attract manufacturers. This included offering tax breaks or exemptions on EV imports and reducing registration fees for EVs to make them more affordable for consumers (MPWT, 2023).

As part of its green transport policy, the Government of Cambodia offers a 0% import duty for fully EVs. This is one of the most significant incentives, designed to make EVs more affordable and attractive for both consumers and manufacturers (MPWT, 2023). Whilst fully EVs enjoy duty exemptions, hybrid vehicles are subject to a reduced import duty of approximately 10% to 15%, which is still a reduction from the standard duty on conventional vehicles. In addition to import duty exemptions, EVs also benefit from tax exemptions on road taxes and reduced registration fees. These tax breaks further lower the total cost of ownership of EVs.

The Government of Cambodia is working on improving the charging infrastructure for EVs. This includes expanding the network of EV charging stations across the country, particularly in urban areas (MPWT, 2024). As of 2023, the capital city, Phnom Penh, had around 50 charging stations for EVs. However, there are still challenges in expanding this infrastructure to rural areas. In major cities, there are a relatively small number of public charging stations, but numbers are growing. Chinese automakers, including BYD and Great Wall Motors, have entered the Cambodian market, with the BYD e6 being a common model for commercial EVs. International companies such as Tesla have also shown interest in the market, but EV sales in the car sector remain limited due to high costs and limited charging infrastructure. Government policy encourages public awareness campaigns to highlight the benefits of EVs, including their lower operating costs and reduced environmental impact compared to conventional gasoline or diesel vehicles.

As part of its green growth strategy, Cambodia is integrating electric mobility into its broader environmental and energy goals. This is in line with its commitments to the Paris Agreement and the Sustainable Development Goals. Cambodia has been open to foreign investments in the EV sector. Several international companies have shown interest in setting up EV production and assembly plants in the country, which could help foster local manufacturing capabilities and create jobs. The government has also demonstrated strong political will through the establishment of policies that support sustainable transportation. This includes promoting electric buses for public transportation and encouraging EV usage amongst businesses and governmental fleets (MPWT, 2024).

The penetration of electric cars (four-wheel vehicles) in Cambodia is still quite low. In 2023, electric cars made up less than 1% of the total vehicle market. According to Cambodia's Ministry of Public Works and Transport, approximately 400 to 500 electric cars were registered by the end of 2023, a small number compared to the overall vehicle fleet, which numbers in the hundreds of thousands. In December 2023, the EV stock was just 1,489 vehicles (MPWT, 2024).

The hybrid EVs (HEVs), that combine an internal combustion engine (ICE) with an electric motor, have seen more significant adoption in Cambodia compared to fully electric cars. Hybrid vehicles account for about 2%–3% of total new vehicle sales in Cambodia. This is largely because hybrid vehicles do not require extensive charging infrastructure and are more suited to the local market conditions. The most popular hybrids in Cambodia include Toyota Prius, Honda Insight, and Toyota Corolla Hybrid. These models have been relatively successful in urban markets due to their fuel efficiency and lower emissions compared to conventional gasoline-powered vehicles.

The Government of Cambodia continues to promote hybrid vehicles as part of its broader strategy for sustainable transportation. However, tax incentives for hybrids are not as generous as those for fully EVs. The electric motorcycle and scooter market is one of the fastest-growing segments of Cambodia's EV market. As of 2023, it is estimated that electric motorcycles and scooters make up around 5%–10% of total new motorcycle sales in Cambodia. The trend is largely driven by the affordability of electric motorcycles compared to electric cars. Around 10,000 to 12,000 electric motorcycles are sold annually, which is a significant number considering the popularity of motorcycles in Cambodia. The motorcycle market in Cambodia is dominated by gasoline-powered bikes, but the electric motorcycle segment is quickly gaining ground due to rising fuel prices and government incentives.

Local brands such as Karma and Yadea, as well as international brands such as NIU and Super Soco, are popular in Cambodia. Prices for electric motorcycles typically range from $1,000 to $3,000, which makes them more accessible to the general population. Since 2023, there are several charging stations for electric motorcycles and scooters located in Phnom Penh and other urban areas. These charging points are expanding as part of Cambodia's push to support electric two-wheelers.

Overall, Cambodia's EV policy is still in its early stages, but with the support of both the government and the private sector, the country is positioning itself to play a significant role in the region's transition to a more sustainable and environmentally friendly transportation system.

## 2. The Electric Vehicle Scenarios of Cambodia's Ministry of Public Works and Transport

Cambodia is poised for significant growth in EVs from 2025 to 2045. According to the EV Roadmap for Charging Stations, recently released by the Ministry of Public Works and Transport, the country expects to have over one million electric two- and three-wheelers between 2030 and 2040, and approximately 100,000 electric cars between 2035 and 2042 (MPWT, 2024). This projected growth represents a dramatic increase from the current EV stock of just 1,489 vehicles in December 2023 (MPWT, 2024). This upward trend underscores the urgent need for a robust support system, particularly a widespread network of charging stations, to accommodate the growing number of EVs.

The Ministry of Public Works and Transport's roadmap outlines three scenarios for the future of EVs in Cambodia until 2050. Scenario one is the most conservative estimate, scenario two is the most likely, and scenario three is the aspirational target.

Under all three scenarios, it is projected that Cambodia will have more than one million electric two- and three-wheelers by 2040. By 2050, this number could range from 2.1 million to as high as 7.3 million units (MPWT, 2024). Additionally, the number of electric cars in the country is expected to reach over 100,000 by 2042, with estimates ranging from 300,000 to more than one million by 2050 (MPWT, 2024)

As Cambodia's car stock continues to expand, there is a significant opportunity to electrify its vehicle fleet. The roadmap projects that electricity consumption by EVs will account for between 0.7% and 2.8% of the country's total national electricity consumption by 2040, with electric cars making up half of this demand (MPWT, 2024).

From an economic perspective, EV adoption will result in substantial savings for consumers. The use of electric motorcycles, for example, will save users an average of $133 per year, whilst electric cars will save $1,069 annually (MPWT, 2024). In aggregate, these savings could amount to between $14 million and $78 million per year by 2030. By 2050, total savings could reach between $509 million and $1.8 billion annually (MPWT, 2024).

In terms of environmental benefits, EVs are expected to reduce greenhouse gas (GHG) emissions by 55% compared to ICE vehicles over their lifetime. For electric cars, this reduction is estimated at 22% (MPWT, 2024).

To support this expected growth, Cambodia will need a substantial investment in charging infrastructure. Depending on the scenario, between 9,900 and 33,800 charging points will be required by 2050. This will necessitate an investment of between $168 million and $576 million in infrastructure development (MPWT, 2024).

In addition to charging stations, the country will also require battery disposal facilities. By 2040, hundreds of megawatt-hours of batteries will need to be decommissioned and repurposed for secondary applications. By 2050, between 0.7 gigawatt-hours (GWh) and 2.5 GWh of batteries will need to be decommissioned each year, with between 0.3 GWh and 1.4 GWh recycled to meet between 6% and 9% of the demand for new batteries (MPWT, 2024).

The roadmap stresses that private sector investment will be critical to funding the necessary infrastructure. It also recommends the introduction of early incentive programmes to stimulate the development of a network of fast charging stations across the country (MPWT, 2024).

Cambodia's EV roadmap shows that the transition to EVs in Cambodia presents a tremendous opportunity for both economic savings and environmental benefits. However, to fully realise this potential, substantial investments in infrastructure – including charging stations and battery disposal facilities – will be essential. With the right policies and investments, Cambodia can lead the way in sustainable transportation in Southeast Asia.

## 3. Cambodia's Electric Vehicle Scenarios by the Economic Research Institute for ASEAN and East Asia

The Economic Research Institute for ASEAN and East Asia (ERIA) has projected the penetration of EVs in Cambodia's market under a business-as-usual (BAU) scenario. This scenario assumes that the country's road transport vehicle fleet will evolve until 2050 in line with current market trends, with no additional policy interventions by the Government of Cambodia to accelerate EV adoption (details of the prediction can be found in Chapter 2).

In addition to the BAU scenario, we have developed three alternative scenarios, each representing a different level of EV penetration. These scenarios are defined by exogenously determined percentages of battery EVs (BEVs) within the total road vehicle fleet in Cambodia by 2050:

- EV20: A scenario where BEVs account for 20% of the total road vehicle fleet by 2050.
- EV40: A scenario where BEVs make up 40% of the total road vehicle fleet by 2050.
- EV60: A scenario where BEVs represent 60% of the total road vehicle fleet by 2050.

The expected growth of EVs in Cambodia, based on the above assumptions, are set out in Table 1.1.

Table 1.1 Estimated Number of Electric Light Vehicle Stock by Vehicle Types and Scenario (Thousand Units of Vehicles)

| BAU | | | |
|---|---|---|---|
| | Cars | Minibuses | Pickup trucks |
| 2020 | 0.01 | 0.00 | 0.00 |
| 2025 | 3.85 | 0.26 | 1.61 |
| 2030 | 16.13 | 1.28 | 7.86 |
| 2035 | 33.04 | 2.69 | 16.54 |
| 2040 | 51.51 | 4.24 | 26.09 |
| 2045 | 69.60 | 5.76 | 35.48 |
| 2050 | 87.08 | 7.24 | 44.57 |
| EV20 | | | |
| | Cars | Minibuses | Pickup trucks |
| 2020 | 0.01 | 0.00 | 0.00 |
| 2025 | 9.69 | 0.75 | 4.60 |
| 2030 | 44.64 | 3.65 | 22.45 |
| 2035 | 93.06 | 7.68 | 47.26 |
| 2040 | 146.19 | 12.11 | 74.55 |
| 2045 | 198.33 | 16.47 | 101.37 |
| 2050 | 248.80 | 20.69 | 127.34 |
| EV40 | | | |
| | Cars | Minibuses | Pickup trucks |
| 2020 | 0.01 | 0.00 | 0.00 |
| 2025 | 18.68 | 1.49 | 9.20 |
| 2030 | 88.50 | 7.29 | 44.89 |

| | | | |
|---|---|---|---|
| 2035 | 185.41 | 15.36 | 94.53 |
| 2040 | 291.84 | 24.22 | 149.09 |
| 2045 | 396.38 | 32.94 | 202.73 |
| 2050 | 497.60 | 41.38 | 254.69 |
| EV60 | | | |
| | Cars | Minibuses | Pickup trucks |
| 2020 | 0.01 | 0.00 | 0.00 |
| 2025 | 27.67 | 2.24 | 13.80 |
| 2030 | 132.35 | 10.94 | 67.34 |
| 2035 | 277.75 | 23.04 | 141.79 |
| 2040 | 437.49 | 36.34 | 223.64 |
| 2045 | 594.43 | 49.41 | 304.10 |
| 2050 | 746.40 | 62.07 | 382.03 |

BAU = business-as-usual, EV20 = electric vehicle 20% scenario, EV40 = electric vehicle 40% scenario, EV60 = electric vehicle 60% scenario.
Source: Author's calculations from Chapter 2.

Apart from 2020, the share of electric cars amongst the total number of electric light vehicles is around 63%, followed by electric pickup trucks (around 32%), and electric minibuses (5%). By 2050 the total number of heavy vehicles in Cambodia should reach more than 1 million units. The proportion of electric heavy vehicles by that time should range from between 71,000 units in the BAU scenario to around 607,000 units in the EV60 scenario. Of those, around 90% are predicted to be electric trucks and only 10% will be electric buses.

## 4. Key Challenges and Opportunities

The adoption of EVs, particularly four-wheel vehicles, remains limited in Cambodia due to their high cost, making them unaffordable for the average consumer. Whilst hybrids are more affordable than fully electric cars, they are still priced higher than conventional vehicles. Additionally, whilst progress has been made, the EV charging infrastructure remains largely concentrated in urban areas, leaving rural regions with limited access to charging stations. This disparity in infrastructure poses a significant barrier to the widespread adoption of EVs, especially four-wheel EVs.

Despite these challenges, electric motorcycles are gaining popularity, as they are more accessible to consumers. However, knowledge of EVs remains limited, especially in rural areas, which hinders broader adoption. Recognising these constraints, the Government of Cambodia continues to offer incentives for EV adoption, including tax exemptions and rebates, aimed at reducing costs over time.

As Cambodia's EV charging network expands and more international brands enter the market, the adoption of EVs is expected to increase. Cambodia's young population and growing demand for eco-friendly transportation make it an attractive market for electric motorcycles. Furthermore, rising awareness of air pollution and environmental degradation is likely to further drive demand for EVs. Both the government and citizens are increasingly seeking cleaner energy alternatives, which could accelerate the shift towards electric mobility.

# Chapter 2

# The Current Situation and the Forecast for Electric Vehicle Penetration in Cambodia

## 1. Introduction

This study of EV penetration in Cambodia focuses on the use of more efficient vehicle technology, propulsion, and energy. Nowadays, we are witnessing electromobility as a fast-growing technological and social trend, which has become one of the main opportunities and challenges for smart cities. The opportunities are that the penetration of EVs would help shift oil consumption to electricity, reducing on-street GHG emissions and air pollution and reaching a higher energy efficiency in mobility. On the other hand, smart cities need to build smart infrastructure for EV electric charging (Xu et al. 2016; Wagner, Götzinger, and Neumman, 2013).

HEVs, plug-in HEVs (PHEVs), full BEVs, and fuel cell hydrogen EVs are often considered within the category of EVs. Electricity is produced by these four EV types in different ways. In HEVs, electricity is produced by the braking mechanism; in PHEVs and BEVs, it is produced through the grid system and fed into the vehicle's battery unit during charging. In fuel cell hydrogen EVs, electricity is produced by electrochemical oxidation of hydrogen in the vehicle's fuel cell unit that is equipped with hydrogen storage.

In this chapter we analyse the possibilities for the use of BEVs in Cambodia in the period up to 2050, looking at their impact on energy use at the national level.

## 2. Trends, Policies, and Possibilities

Electromobility is developing rapidly. The International Energy Agency (IEA, 2021), has estimated that by 2020, the number of cars in the global passenger electric car fleet was nearly 10.2 million, which is 3.0 million more than in the previous.

## 3. Methodology and Scenarios

In this study on Cambodia, we define BAU, as the scenario where the country's road transport vehicle fleet develops until 2050 following current market development. We assume that the Government of Cambodia will not introduce any further policy interventions to accelerate EV penetration.

Table 2.1 shows that sales of EVs in Cambodia started in 2020 with only five vehicles sold. That increased to a total of 663 EVs sold in 2022, comprising electric passenger cars as well as two- and three-wheelers. From January to September

2023 alone, around 430 EVs were sold.

Table 2.1 Electric Vehicle Registration in Cambodia from January 2020 to September 2023

| Year | Two-wheeler | Three-wheeler | Passenger car | Total |
|---|---|---|---|---|
| 2020 | 0 | 0 | 5 | 5 |
| 2021 | 7 | 4 | 52 | 63 |
| 2022 | 16 | 335 | 312 | 663 |
| 2023 (September) | 179 | 48 | 203 | 430 |

Source: General Department of Transport (2024).

The data on market development in Cambodia from the last few years shows that, in the BAU scenario, there will be a certain percentage of EVs in the total road vehicle stock during the studied period from 2020 to 2050.

In addition to BAU, we proposed three EV scenarios representing penetration levels of full BEVs in the country's road passenger car fleet during 2020–2050. The reference scenario energy balance table (EBT) analysis conducted by the Working Group of East Asia, the Energy Outlook and the Saving Potential study conducted by ERIA (ERIA, 2023) estimated that by 2050 the use of energy from the transport sector will be 0.198 million tonnes of oil equivalent (Mtoe) for electricity, 3.732 Mtoe for gasoline, and 5.834 Mtoe for diesel fuel (ERIA, 2023). A range of studies provide evidence for the superiority of BEVs over ICEs in terms of average energy efficiency. For example, Martins et al. (2013) estimate that EVs are two times (100%) more efficient than gasoline and diesel fuel road vehicles, whilst the average figure of Zhang, Gong, and Shi (2019) is 2.6 and the average figure from the Department of Energy of the Government of the United States (US) is that EVs are 4.4 times more efficient than ICEs. (Alternative Fuel Data Center, 2021). Considering the traffic and the condition of the road infrastructure in Cambodia, this research assumes that the EVs efficiency is 1.7 times or 70% better than that of the average ICE. Based on this assumption, the percentage share of road EVs in the total vehicle stock (comprising electric, gasoline, and diesel fuel vehicles) will be 7% by 2050.

For the other three scenarios (EV20, EV40, and EV60, as defined in Section 1.3), the level of penetration is represented by the exogenously defined percentages of shares of BEVs in the total number of road transport vehicles in Cambodia in 2050.

In other words, we assume that the total number of EVs in Cambodia will grow linearly from five electric cars in 2020 to reach 7% (BAU scenario), 20% (EV20 scenario), 40% (EV40 scenario), and 60% (EV60 scenario) of the total road vehicle fleet in 2050. The assumptions, methods, and equations used to calculate the exact number of EVs differentiated by categories and types are given in Section 2.4.

## 4. Forecasting Road Transport Vehicle Fleet Numbers

Calculating the total number of road transport vehicles in the future is key to determining energy consumption and the transport sector's profile.

The General Department of Transport – Land Transport Department of Cambodia possesses a set of historical data on the yearly new vehicle registrations of the country from 1990 to September 2017 and from 2018 to September 2022. Assuming only a negligible percentage of vehicles are scrapped each year, Table 2. provides an estimate of road vehicle stock in Cambodia from 1990 to 2022 differentiated into motor cycles (powered two- and three- wheelers), light vehicles (cars, minibuses, and pickup trucks), and heavy vehicles (buses and trucks).

Table 2.2 Estimate of Road Vehicle Stock in Cambodia

| Year | Motorcycles (P2W and P3W) | Light vehicles (cars, minibuses, and pickup trucks) | Heavy vehicles | Total |
|---|---|---|---|---|
| 1990 | 43,733 | 3,427 | 2,290 | **49,450** |
| 1991 | 71,165 | 7,746 | 4,366 | **83,277** |
| 1992 | 107,608 | 12,294 | 6,091 | **125,993** |
| 1993 | 120,152 | 15,870 | 9,094 | **145,116** |
| 1994 | 132,970 | 20,504 | 11,276 | **164,750** |
| 1995 | 152,050 | 25,402 | 14,030 | **191,482** |
| 1996 | 170,472 | 30,295 | 18,123 | **218,890** |
| 1997 | 181,266 | 35,598 | 22,907 | **239,771** |
| 1998 | 203,022 | 38,975 | 25,481 | **267,478** |
| 1999 | 223,169 | 44,196 | 30,264 | **297,629** |
| 2000 | 247,965 | 49,559 | 34,334 | **331,858** |
| 2001 | 291,655 | 54,052 | 37,271 | **382,978** |
| 2002 | 308,611 | 59,470 | 42,007 | **410,088** |
| 2003 | 336,502 | 64,805 | 46,121 | **447,428** |
| 2004 | 359,166 | 75,080 | 51,366 | **485,612** |
| 2005 | 429,689 | 87,887 | 57,253 | **574,829** |
| 2006 | 541,146 | 106,581 | 66,736 | **714,463** |
| 2007 | 671,252 | 121,034 | 76,761 | **869,047** |
| 2008 | 860,167 | 136,936 | 87,426 | **1,084,529** |
| 2009 | 1,135,638 | 157,371 | 98,570 | **1,391,579** |
| 2010 | 1,372,252 | 172,934 | 107,362 | **1,652,548** |
| 2011 | 1,590,469 | 194,747 | 119,061 | **1,904,277** |
| 2012 | 1,823,966 | 216,956 | 134,510 | **2,175,432** |
| 2013 | 2,068,937 | 238,109 | 150,523 | **2,457,569** |

| Year | Motorcycles (P2W and P3W) | Light vehicles (cars, minibuses, and pickup trucks) | Heavy vehicles | Total |
|---|---|---|---|---|
| 2014 | 2,372,117 | 261,902 | 167,799 | 2,801,818 |
| 2015 | 2,714,193 | 296,788 | 189,339 | 3,200,320 |
| 2016 | 3,179,163 | 334,268 | 212,653 | 3,726,084 |
| 2017 | 3,687,696 | 405,780 | 221,674 | 4,315,151 |
| 2018 | 4,190,397 | 473,203 | 231,446 | 4,895,046 |
| 2019 | 4,731,018 | 562,379 | 247,721 | 5,541,119 |
| 2020 | 5,101,619 | 633,010 | 263,063 | 5,997,693 |
| 2021 | 5,533,874 | 690,213 | 276,070 | 6,500,158 |
| 2022 | 6,156,658 | 778,072 | 292,958 | 7,227,689 |

P2W = powered two-wheeler, P3W = powered three-wheeler.
Source: Authors' calculations based on data from General Department of Transport (2024).

Table 2. shows that by 1990, motorcycles made up around 88% of the total road vehicle stock whilst light vehicles made up around 7% and heavy vehicles around 5%. By 2022, motorcycles were still the biggest segment of the total road vehicle stock (around 85%), whilst light vehicles made up 11% and heavy vehicles, 4%. Therefore, in term of percentage share, light vehicles made the biggest increase from 1990 to 2022, whilst the numbers of motorcycles and heavy vehicles dropped.

In terms of compound annual growth rate, the total road vehicle stock in Cambodia grew at an average annual rate of 17%, with light vehicles experiencing the fastest growth (18%) followed by motorcycles (17%) and heavy vehicles (16%).

Based on the historical data relating to road vehicle stock, it is possible to forecast the number of future road transport vehicles using Cambodia's future vehicle ownership rate, measured as the number of vehicles per 1,000 inhabitants.

The usual method to estimate the vehicle ownership rate uses the vehicle ownership model developed by, for example, Dargay, Gately, and Sommer (2007). This model employs an S-shaped function, i.e. the Gompertz function, to estimate the relationship between vehicle or car in the case of Dargay, Gately, and Sommer (2007), ownership, and per capita gross domestic product (GDP).

Equation 1. $\boldsymbol{V_{year} = \gamma . e^{\alpha . e^{\beta . GDPCAP_{year}}}}$

Where

$V_{year}$ = long-run equilibrium of car ownership rate (cars per 1,000 inhabitants at purchasing power parity)

$\gamma$ = saturation level (cars per 1,000 inhabitants)

$GDPCAP_{year}$ = GDP per capita (expressed in constant local current unit of 2018)

$\alpha, \beta$ = parameters defining the shape, or curvature, of the function

Data from the World Bank (2024) estimates that Cambodia's population increased from 8,910,808 inhabitants in 1990 to 16,767,842 inhabitants in 2022, i.e. a growth rate of 2% per year. Observations over 5-year time intervals reveal that population growth rates decreased from 4.15% between 1990 and 1995 to 1.20% between 2015 and 2020.

Between 1990 and 2022, Cambodia's total constant GDP ($ 2015) grew by 7.3% per year, i.e. faster than the total population, from around $2.6 billion in 1990 to around $25 billion in 2022. Observations at 5-year time intervals reveal fluctuations of GDP in Cambodia. Between 1990 and 1995, the annual GDP growth rate was 9.6%. This annual growth rate went down to 7.4% between 1995 and 2000 and went up again to 9.3% between 2000 and 2005. Between 2005 and 2010 the annual GDP growth rate dropped to 6.7% and then went up to 7.2% between 2010 and 2015 before dropping 5.0% between 2015 and 2020, reflecting the effect of the coronavirus disease (COVID-19) pandemic.

Using the historical road vehicle stock data, GDP, and population data from 1999 to 2022, we calculated the vehicle ownership rate and estimated the parameters of Equation 1 for the three vehicle categories: motorcycles, light vehicles, and heavy vehicles, with the estimated parameters detailed in Table 2.3.

Table 2.3 Estimated Parameters of Equation 1

| Parameters | Motorbikes | Light vehicles | Trucks |
|---|---|---|---|
| $\gamma$ | 722 | 98 | 50 |
| $\alpha$ | -6 | -7.4 | -6.6 |
| $\beta$ | $-1.4.10^{-3}$ | $-1.5.10^{-3}$ | $-1.3.10^{-3}$ |

- = negative number, $\alpha, \beta$ = parameters defining the shape, or curvature, of the function, $\gamma$ = saturation level (cars per 1,000 inhabitants).
Source: Authors' calculations.

To forecast future vehicle ownership rates, assumptions on GDP and population growth rates need to be made.

This study assumes that Cambodia's population growth rate will decrease with time following the decline observed in the 5-year interval study that has already been discussed. The annual growth rate between 2022 and 2030 will be 0.95%. After 2030, the annual growth rates are assumed to continue to drop from 0.77% between 2030 and 2035 to 0.37% between 2045 and 2050.

Looking at the relatively strong fluctuation of Cambodia's GDP between 1990 and 2022, a rather pessimistic growth rate of 6% is assumed for the period from 2022 to 2050.

Feeding the projected GDP and population into the Gompertz functions allows us to estimate the future number of motorbikes (powered two- and three-wheelers) (Figure 2.1), light vehicles (cars, minibuses, and pickup trucks) (Figure 2.2), and heavy vehicles (trucks and buses) (Figure 2.3).

The breakdown of the three vehicle categories into more detailed types can be obtained by calculating the average new registered vehicle shares based on the fuel and vehicle type of new registered vehicle data in Cambodia as given in Table 2.4.

**Table 2.4 Vehicle Registration Data by Fuel and Vehicle Type in Cambodia, 2018–2022**

| Year | Motorbikes | | Light vehicles | | | | | Heavy vehicles | |
|---|---|---|---|---|---|---|---|---|---|
| | P2W | P3W | Cars | | Minibus | | Pickup trucks | Buses | Trucks |
| | Gasoline | Gasoline | Gasoline | Diesel | Gasoline | Diesel | Diesel | Diesel | Diesel |
| 2018 | 483,074 | 19,627 | 35,100 | 5,942 | 225 | 4,955 | 21,201 | 901 | 8,871 |
| 2019 | 507,707 | 32,914 | 48,515 | 6,030 | 373 | 5,687 | 28,572 | 814 | 4,131 |
| 2020 | 358,284 | 12,317 | 40,647 | 4,147 | 119 | 2,455 | 23,263 | 262 | 3,351 |
| 2021 | 426,672 | 5,583 | 35,922 | 1,448 | 162 | 1,401 | 18,270 | 109 | 2,978 |
| 2022 | 456,236 | 10,852 | 43,027 | 2,230 | 86 | 2,443 | 18,108 | 246 | 3,017 |

P2W = powered two-wheeler, P3W = powered three-wheeler.
Source: General Department of Transport (2024).

**Table 2.5 Number of Electric Vehicles in Cambodia from January 2020 to September 2023**

| Year | P2W | P3W | Passenger car | Total |
|---|---|---|---|---|
| 2020 | 0 | 0 | 5 | 5 |
| 2021 | 7 | 4 | 57 | 68 |
| 2022 | 23 | 339 | 369 | 731 |
| 2023 (until September) | 262 | 403 | 640 | 1,305 |

P2W = powered two-wheeler, P3W = powered three-wheeler.
Source: Author's calculations based on the sales data from General Department of Transport (2024).

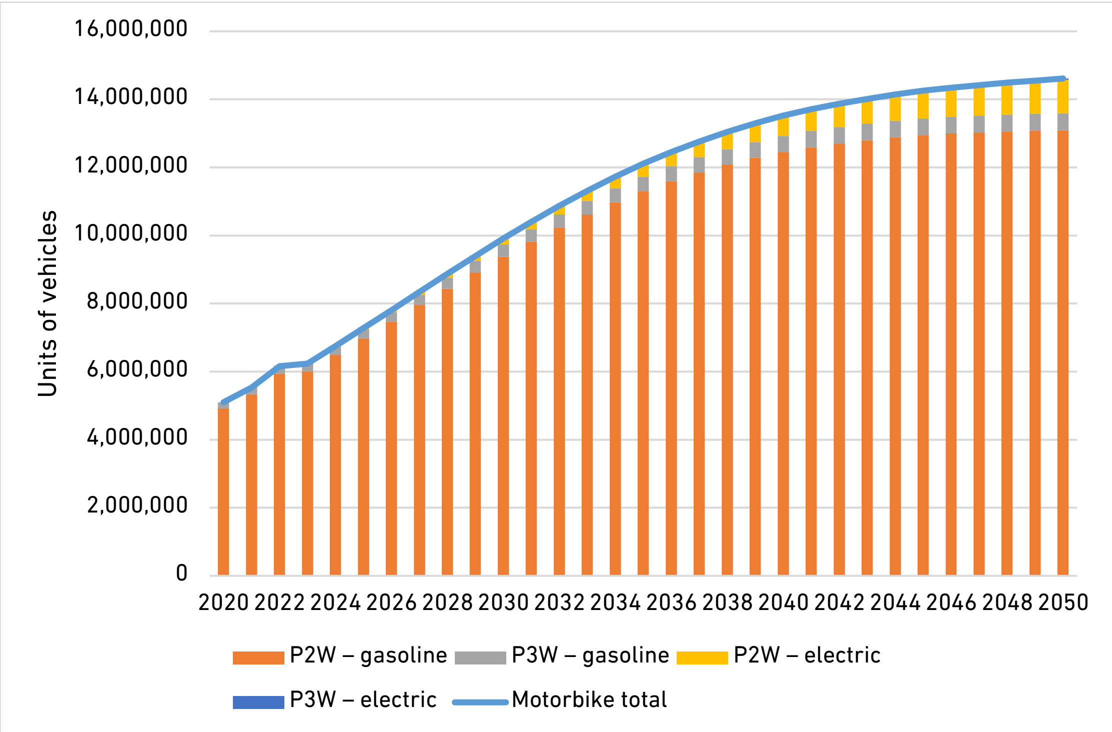
Table 2.5 shows that sales of vehicles in Cambodia have included a certain number of EVs since 2020. Given this, the detailed projection of vehicle stock in Cambodia must include some EVs even in the BAU scenario where no policy measure is put in place to boost EVs sale.

Cambodia's EBT as calculated in ERIA (2023) also shows that in the BAU scenario, electricity will be around 2% of the total energy consumption of the road transport sector by 2050. Assuming energy consumption by EVs is 1.7 times better than energy consumption of the ICE (Section 2.3), it can be assumed that the EV's share of the total road vehicle stock by 2050 will be around 7% in all vehicle categories and types.

Looking at the aggregate total number, it can be expected that the number of motorbikes (Figure 2.1) would grow at an annual rate of 7.4% per annum from 2020 to 2025 and then at 2.8% per annum until from 2020 to 2050. This decrease of growth rates between 2025 to 2050 happens gradually as the ownership rates approach saturation towards 2050. For example, between 2025 and 2030, the average annual growth rate is around 6.4% whilst between 2045 and 2050 it will only be around 0.5%.

It can be expected that the total number of motorbikes will grow from around 7.3 million units in 2025 to 14.6 million units in 2050. The share of gasoline-fuelled powered two-wheelers will decrease from nearly 96% in 2025 to around 90% in 2050.

Figure 2.1 Estimated Numbers of Motorbikes – Business-as-Usual Scenario



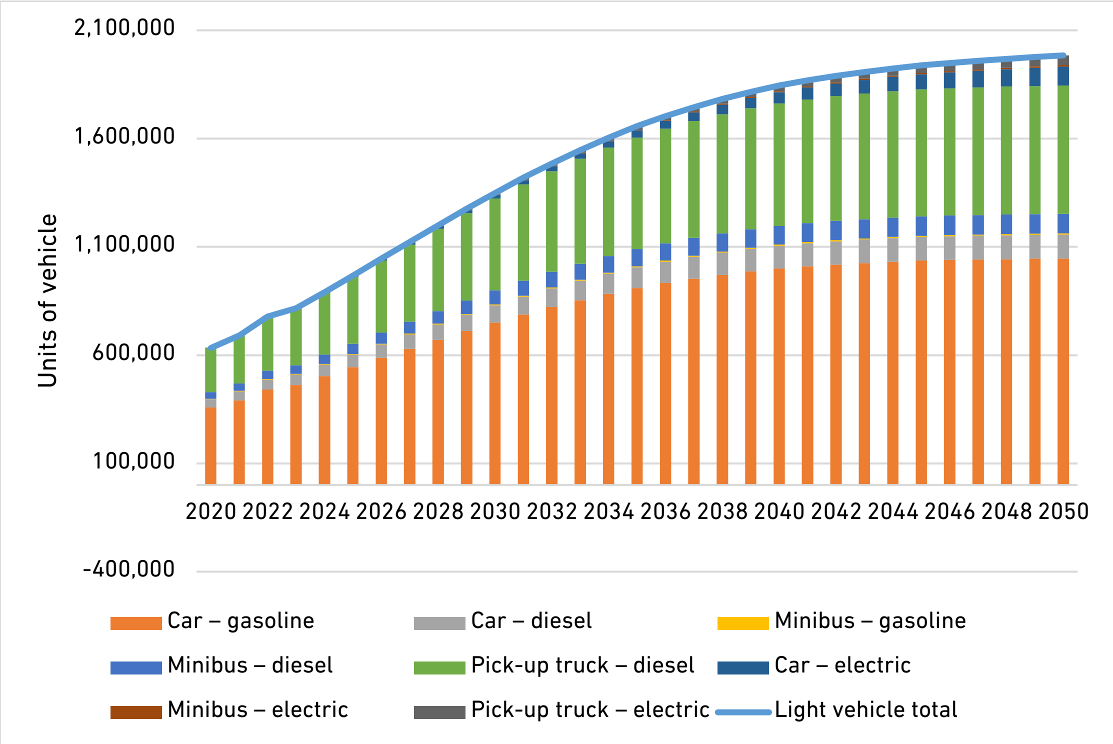

P2W = powered two-wheeler, P3W = powered three-wheeler.
Source: Authors' calculations.

The number of light vehicles (Figure 2.2) is expected to grow at an annual rate of 8.9% from 2020 to 2025 and then decrease to reach an annual growth rate of only around 0.5% between 2045 and 2050.

The total number of light vehicles will grow from around 970,000 units in 2025 to almost 2 million units in 2050. Gasoline-fuelled cars are the dominant type of vehicle, and their share will decrease from around 56.3% in 2025 to 52.7% in 2050.

The share of the next most popular vehicle – diesel-fuelled pickup trucks – will decrease from 31.9% in 2025 to 29.8% by 2050.

Figure 2.2 Estimated Numbers of Light Vehicles – Business-as-Usual Scenario

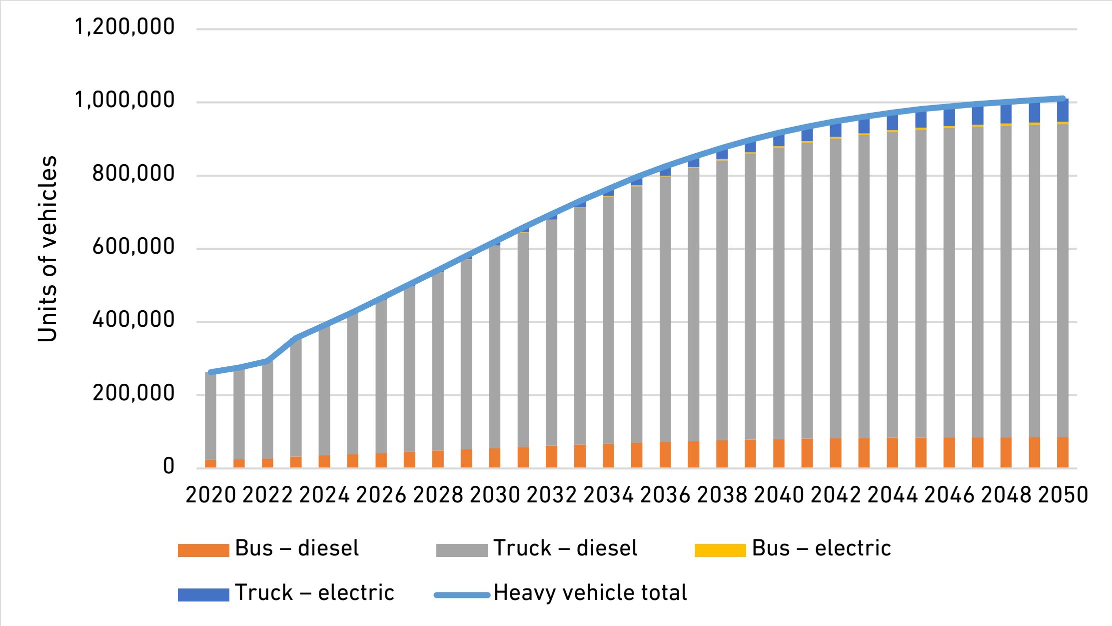



Source: Authors' calculations.

Finally, the total number of heavy-duty vehicles (Figure 2.3) can be expected to grow at 10.6% per year in the 2020–2025 period and then decrease to around 0.6% per year between 2045 and 2050.

In term of absolute numbers, heavy-duty vehicle stock should grow from around 430,000 units in 2025 to slightly more than 1 million units by 2050 with diesel truck's share dominating from 90.4% in 2025 to around 84.5% in 2050.

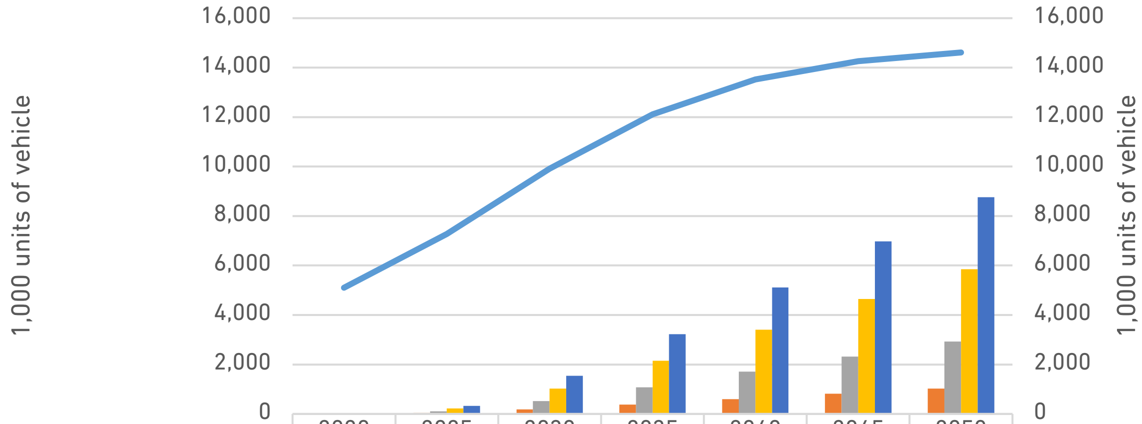
Figure 2.3 Estimated Numbers of Heavy Vehicles – Business-as-Usual Scenario




Source: Authors' calculations.

Figure 2.4 shows that the total motorcycle stock will increase from around 7.2 million in 2025 to reach more than 14.6 million vehicles by 2050. At that point, it is estimated that the number of electric motorcycles in Cambodia will reach more than 1 million units in the BAU scenario and around 8.7 million units in the most ambitious scenario (EV60). Electric powered two-wheelers should comprise around 97.8% of all electric motorcycles during the simulated period with the remaining 2.2% comprising electric powered three-wheelers.

Figure 2.4 Estimated Numbers of Electric Motorcycle Stock by Scenario (Left Axis) versus the Estimated Total Motorcycle Stock (Right Axis)

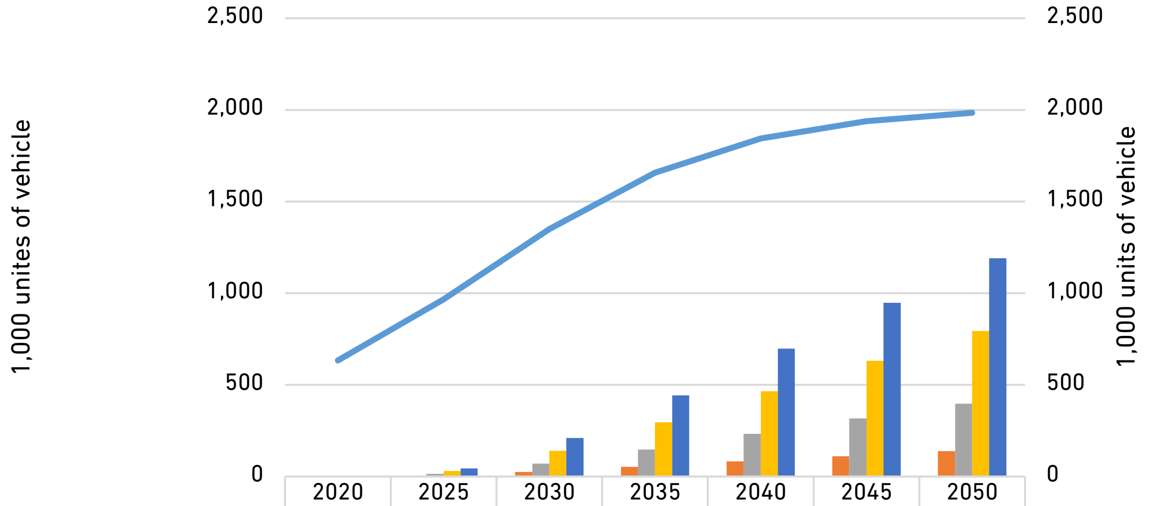



| | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| BAU | 0 | 38 | 181 | 377 | 597 | 813 | 1,023 |
| EV20 | 0 | 109 | 515 | 1,077 | 1,703 | 2,324 | 2,923 |
| EV40 | 0 | 216 | 1,029 | 2,153 | 3,406 | 4,647 | 5,845 |
| EV60 | 0 | 324 | 1,542 | 3,230 | 5,109 | 6,970 | 8,768 |
| Total P2W and P3W | 5,102 | 7,277 | 9,911 | 12,109 | 13,522 | 14,256 | 14,614 |

BAU = business-as-usual, EV20 = electric vehicle 20% penetration scenario, EV40 = electric vehicle 40% penetration scenario, EV60 = electric vehicle 60% penetration scenario, P2W =.powered two-wheeler, P3W = powered three-wheeler.
Source: Authors' calculations.

Figure 2.5 shows that the total light vehicle stock should reach almost 2 million units by 2050, increasing from around 633,000 units in the 2020's. By 2050, the number of electric light vehicles should range from around 139,000 units in the BAU scenario to almost 1.2 million units in the EV60 scenario.

Figure 2.5 Estimated Numbers of Electric Light Vehicle Stock By Scenario (Left Axis) versus the Estimated Total Light Vehicle Stock (Right Axis)




| | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| BAU | 0 | 6 | 25 | 52 | 82 | 111 | 139 |
| EV20 | 0 | 15 | 71 | 148 | 233 | 316 | 397 |
| EV40 | 0 | 29 | 141 | 295 | 465 | 632 | 794 |
| EV60 | 0 | 44 | 211 | 443 | 697 | 948 | 1,191 |
| Total light vehicles | 633 | 968 | 1,349 | 1,657 | 1,845 | 1,938 | 1,984 |

BAU = business-as-usual, EV20 = electric vehicle 20% penetration scenario, EV40 = electric vehicle 40% penetration scenario, EV60 = electric vehicle 60% penetration scenario,
Source: Authors' calculations.

Table 2.6 provides the estimated number of electric light vehicles by types and scenarios. Apart from 2020, the share of electric car amongst the total electric light vehicles is around 63%, followed by electric pickup trucks (around 32%) and electric minibuses (5%).

Table 2.6 Estimated Numbers of Electric Light Vehicle Stock by Scenario and Vehicle Types ('000 of units of vehicles)

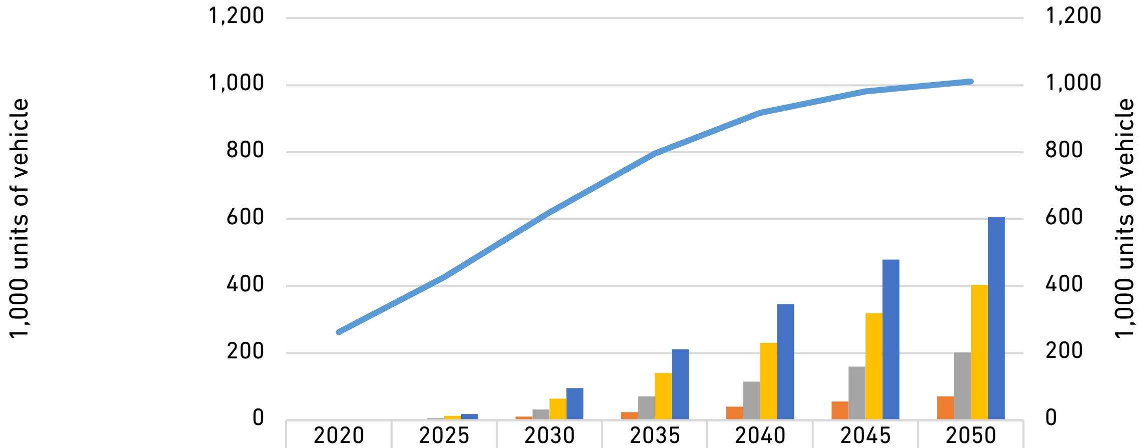
| BAU | | | |
|---|---|---|---|
| | Cars | Minibuses | Pickup trucks |
| 2020 | 0.01 | 0.00 | 0.00 |
| 2025 | 3.85 | 0.26 | 1.61 |
| 2030 | 16.13 | 1.28 | 7.86 |
| 2035 | 33.04 | 2.69 | 16.54 |
| 2040 | 51.51 | 4.24 | 26.09 |
| 2045 | 69.60 | 5.76 | 35.48 |
| 2050 | 87.08 | 7.24 | 44.57 |
| EV20 | | | |
| | Cars | Minibuses | Pickup trucks |
| 2020 | 0.01 | 0.00 | 0.00 |

| | | | |
|---|---|---|---|
| 2025 | 9.69 | 0.75 | 4.60 |
| 2030 | 44.64 | 3.65 | 22.45 |
| 2035 | 93.06 | 7.68 | 47.26 |
| 2040 | 146.19 | 12.11 | 74.55 |
| 2045 | 198.33 | 16.47 | 101.37 |
| 2050 | 248.80 | 20.69 | 127.34 |
| EV40 | | | |
| | Cars | Minibuses | Pickup trucks |
| 2020 | 0.01 | 0.00 | 0.00 |
| 2025 | 18.68 | 1.49 | 9.20 |
| 2030 | 88.50 | 7.29 | 44.89 |
| 2035 | 185.41 | 15.36 | 94.53 |
| 2040 | 291.84 | 24.22 | 149.09 |
| 2045 | 396.38 | 32.94 | 202.73 |
| 2050 | 497.60 | 41.38 | 254.69 |
| EV60 | | | |
| | Cars | Minibuses | Pickup trucks |
| 2020 | 0.01 | 0.00 | 0.00 |
| 2025 | 27.67 | 2.24 | 13.80 |
| 2030 | 132.35 | 10.94 | 67.34 |
| 2035 | 277.75 | 23.04 | 141.79 |
| 2040 | 437.49 | 36.34 | 223.64 |
| 2045 | 594.43 | 49.41 | 304.10 |
| 2050 | 746.40 | 62.07 | 382.03 |

BAU = business-as-usual, EV20 = electric vehicle 20% penetration scenario, EV40 = electric vehicle 40% penetration scenario, EV60 = electric vehicle 60% penetration scenario.
Source: Authors' calculations.

Finally, Figure 2.6 shows that by 2050 the total number of heavy vehicle units in Cambodia should reach more than 1 million. Numbers of electric heavy vehicles in this period should range from 71,000 units in the BAU scenario to around 607,000 units in the EV60 scenario. Of those heavy vehicles, around 90% are electric trucks and only 10% are electric buses.

Figure 2.6 Estimated Numbers of Electric Heavy Vehicle Stock by Scenario (Left Axis) versus the Estimated Total Heavy Vehicle Stock (Right Axis)




| | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| BAU | 0 | 2 | 11 | 25 | 40 | 56 | 71 |
| EV20 | 0 | 6 | 32 | 71 | 116 | 160 | 202 |
| EV40 | 0 | 13 | 64 | 141 | 231 | 320 | 404 |
| EV60 | 0 | 19 | 96 | 212 | 347 | 480 | 607 |
| Total heavy vehicle | 263 | 427 | 620 | 796 | 917 | 982 | 1,011 |

BAU = business-as-usual, EV20 = electric vehicle 20% penetration scenario, EV40 = electric vehicle 40% penetration scenario, EV60 = electric vehicle 60% penetration scenario.
Source: Authors' calculations.

## 2.5 Estimation of Future Energy Use

Table 2.7 and Table 2.8 set out the assumptions of the EV scenarios based on the fuel economy of ICE vehicles, the battery efficiency of EVs, and the average yearly kilometres travelled.

EVs in this report consist of BEVs where the plug-in battery is the only source of energy used in the vehicle. PHEVs and (non-plug-in) HEVs are not considered.

Table 2.7 Assumptions about Internal Combustion Engine Vehicles

| Variable | Unit | P2W | P3W | Cars | Cars | Minibuses and pickup trucks | Trucks | Buses |
|---|---|---|---|---|---|---|---|---|
| | | Gasoline | Gasoline | Gasoline | Diesel | Diesel and gasoline | Diesel | Diesel |
| ICE vehicle fuel economy | km/litre | 35 | 35 | 12 | 15 | 8.5 | 7 | 4.5 |
| kms travelled | km/year | 4,380 | 3,650 | 6,570 | 1,4000 | 15,000 | 3,7500 | 4,4800 |

ICE= internal combustion engine, km = kilometre, P2W = powered two-wheeler, P3W = powered three-wheeler.
Source: Authors' calculations from Ministry of Public Work and Transport Lao PDR (2019).

Table 2.8 Assumptions about the Efficiency of Electric Vehicle Batteries

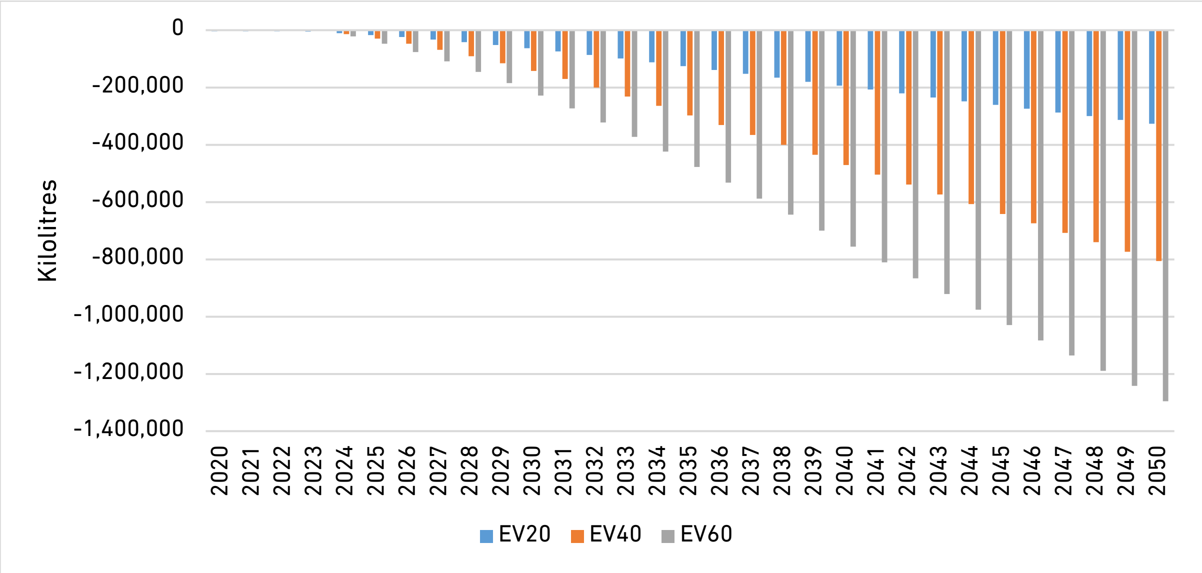
| Variable | Unit | P2W | P3W | Car | Minibuses and pickup trucks | Trucks | Buses |
|---|---|---|---|---|---|---|---|
| EV battery efficiency | km/kWh | 12 | 12 | 5 | 5 | 0.9 | 0.6 |

EV = electric vehicle, km = kilometre, kWh = kilowatt hours.
Sources: Authors' calculations based on IEA (2019) for buses and trucks and Ministry of Public Work and Transport Lao PDR (2019) for other modes of transport.

BEV penetration in each vehicle type was assumed to increase from their stock in 2022 to reach x% in 2050 where x is 20% (EV20), 40% (EV40), and 60% (EV60), whilst BAU scenario's EV percentage by 2050 is 7%. The number of non-EV vehicle units in each vehicle category and type is the number of the corresponding vehicle category or type deduced by the assumed number of EVs of that category or type.

Figure 2.7 shows the difference in gasoline consumption in the three scenarios relative to the BAU scenario. The scenario where EV penetration will be strongest, i.e. the EV60 scenario, is of course expected to bring most of the reduction of gasoline consumption. By 2050 we can expect that gasoline fuel use reduction relative to the consumption in the BAU scenario would range from 330,000 kilolitres, in the EV20 scenario, to 1.3 million kilolitres, in the EV60 scenario.

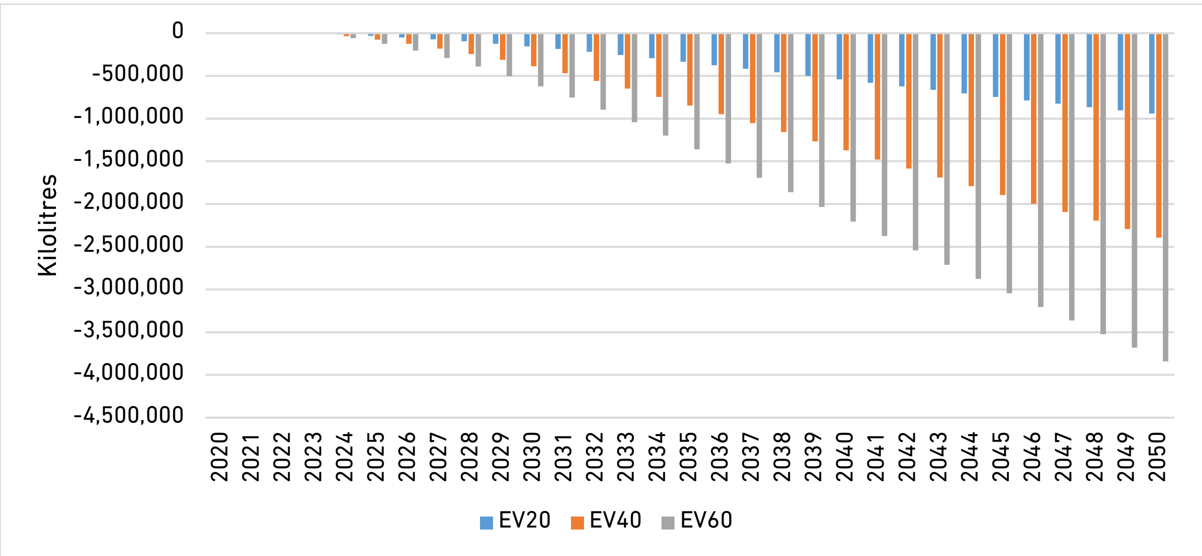
Figure 2.7 Difference in Gasoline Consumption Relative to the Business-as-Usual Scenario




- = negative number, EV20 = electric vehicle 20% penetration scenario, EV40 = electric vehicle 40% penetration scenario, EV60 = electric vehicle 60% penetration scenario.
Source: Author's calculations.

Figure 2.8 shows the difference in the diesel fuel consumption in the three scenarios relative to the BAU scenario. By 2050, diesel fuel use reduction relative to the BAU scenario should range from 950,000 kilolitres, in the EV20 scenario, to 4 million kilolitres in the EV60 scenario.

Figure 2.8 Difference in Diesel Consumption Relative to the Business-as-Usual Scenario

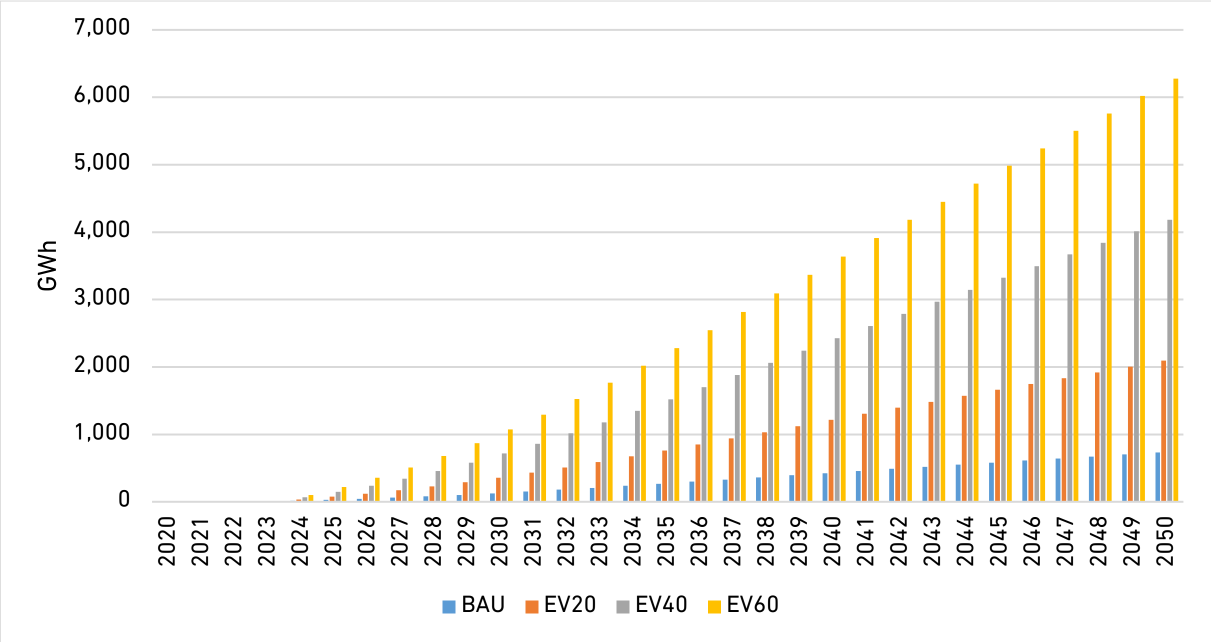



- = negative number, EV20 = electric vehicle 20% penetration scenario, EV40 = electric vehicle 40%

penetration scenario, EV60 = electric vehicle 60% penetration scenario.
Source: Author's calculations.

Finally, Figure 2.9 shows that the need for electricity from road transport modes by 2050 will reach between 732 GWh in the BAU scenario to 6,277 GWh in EV60 scenario. The annual growth rates of the needed power from 2022 to 2050 range from 28.9% in the BAU scenario to 39.2% in the EV60 scenario.

Figure 2.9 Electricity Needed for Electric Vehicles by Scenario




BAU = business-as-usual, EV20 = electric vehicle 20% penetration scenario, EV40 = electric vehicle 40%. penetration scenario, EV60 = electric vehicle 60% penetration scenario, GWh = gigawatt-hour.
Source: Author's calculations.

# Chapter 3

# Impact Analysis of Electric Vehicle Penetration on the Cambodian Oil Industry

## 1. Positive Impact to the National Economy

Chapter 3 analyses the impact that EV20, EV40, and EV60 will have on the oil industry based on the findings from Chapters 1 and 2. EV penetration will decrease demand for gasoline and diesel oil and decrease the revenue generated by oil companies. Decreased gasoline and diesel oil demand will also reduce government tax revenues. However, a decrease in gasoline and diesel imports will reduce the amount of Cambodia's total imports, which will boost GDP. This section analyses the positive impact on GDP from a decrease in gasoline and diesel oil imports.

### 1.1 Components of Cambodia's Gross Domestic Product

According to the Asian Development Bank (ADB), the components of Cambodia's GDP in 2022 is as follows. Since total imports account for 65.8% of GDP, calculating the reduction in the import value of gasoline and diesel oil can reveal the impact on GDP (Table 3.1).

Table 3.1 Components of Cambodia's Gross Domestic Product (%)

(%)

| GDP | Private consumption | Capital formation | Gvernment expenses | Exports | Imports | Statistical difference |
|---|---|---|---|---|---|---|
| 100.0 | 64.0 | 23.4 | 10.3 | 63.9 | -65.8 | 4.2 |

% = percent, GDP = gross domestic product.
Source: ADB (2023)

According to the General Department of Customs and Excise (2024), the total value of Cambodia's imports in 2022 was $29,942 million. And according to the International Trade Centre of the World Trade Organization, gasoline imports amounted to 835,021 tonnes in 2022, with an import value of $852 million. Diesel oil imports in 2022 amounted to 1,482,352 tonnes, with an import value of $1,506 million (ITC, 2024).

Therefore, the total import value of gasoline and diesel oil in 2022 was $2,358 million, or 7.8% of Cambodia's total import value. Clearly, a decrease in oil imports contributed to Cambodia's GDP (Table 3.2).

Table 3.2 Import Data for Gasoline and Diesel, 2022

| Gasoline | | Diesel Oil | | Total | |
|---|---|---|---|---|---|
| Quantity (ton) | Value (US$1,000) | Quantity (ton) | Value (US$1,000) | Quantity (ton) | Value (US$1,000) |
| **835,021** | **852,062** | **1,482,352** | **1,505,787** | **2,317,373** | **2,357,849** |

ITC = International Trade Centre of the World Trade Organization.

Source: ITC (2024)

Note: The ITC is a joint institution between the World Trade Organization (WTO) and the United Nations. The ITC compiles data from United Nations member countries.

## 1.2 The Contribution of Electric Vehicle Penetration to Gross Domestic Product

It is assumed that the proportions of GDP components will remain the same when GDP increases towards 2050. The calculation of the effects of EV20, EV40, and EV60 on the reduction in the import value of gasoline and diesel oil are shown in Table 3.3.

Demand for gasoline and diesel in the BAU scenario is estimated to be 2,273,077 kilolitres for gasoline and 6,739,617 kilolitres for diesel in 2050. But demand for gasoline and diesel oil will decrease in the EV20, EV40, and EV60 scenarios. Gasoline demand is estimated to be 85.7% (EV20), 64.5% (EV40), and 43.0% (EV60) of BAU levels. Diesel oil demand is estimated to be 86.0% (EV20), 64.5% (EV40), and 43.0% (EV60) of BAU levels (Table 3.3).

Table 3.3 Demand for Gasoline and Diesel Oil, 2050

| Gasoline | 2020 kilolitres | 2050 kilolitres | 2020–2050 % | Percentage to BAU in 2050 | Diesel oil | 2020 kilolitres | 2050 kilolitres | 2020–2050 % | Percentage to BAU in 2050 |
|---|---|---|---|---|---|---|---|---|---|
| BAU | 834,419 | 2,273,077 | 3.4 | – | BAU | 1,968,303 | 6,739,617 | 4.2 | – |
| EV20 | 834,419 | 1,946,906 | 2.9 | 85.7 | EV20 | 1,968,303 | 5,797,520 | 3.7 | 86.0 |
| EV40 | 834,419 | 1,466,501 | 1.9 | 64.5 | EV40 | 1,968,303 | 4,348,140 | 2.7 | 64.5 |
| EV60 | 834,419 | 977,668 | 0.5 | 43.0 | EV60 | 1,968,303 | 2,898,760 | 1.3 | 43.0 |

% = percent, BAU = business-as-usual, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario.

Source: Author's calculations.

Table 3.4 Percentage of Oil Imports to Total Imports (%)

| | Percentage of oil import value (Gasoline and Diesel oil) | | | Difference with BAU in 2050 | Boosting effect to GDP |
|---|---|---|---|---|---|
| | 2030 | 2040 | 2050 | | |
| BAU | 7.80 | 7.80 | 7.80 | – | – |
| EV20 | 7.52 | 7.12 | 6.70 | ▲ 1.10 | 0.7 |
| EV40 | 7.12 | 6.10 | 5.03 | ▲ 2.77 | 1.8 |
| EV60 | 6.71 | 5.08 | 3.35 | ▲ 4.45 | 2.9 |

% = percent, BAU = business-as-usual, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario, GDP = gross domestic product.
Source: Author's calculations.

In the BAU scenario, oil imports make up 7.8% of total imports in 2050, but this decreases to 6.7% in the EV20 scenario, 5.0% in the EV40 scenario, and 3.4% in the EV60 scenario. Since a decrease in oil imports will reduce the total amount of imports, the boost effect on GDP in 2050 will be 0.7% in the EV20 scenario, 1.8% in the EV40 scenario, and 2.9% in the EV60 scenario. The figures have been calculated as the percentage of oil import value multiplied by the percentage of total imports to GDP (Table 3.4).

## 2 Impact on Government Tax Revenue. (Decrease in Taxes)

Gasoline and diesel are subject to additional tax, special tax, and value-added tax. Under the latest tax system, gasoline is taxed at $0.2727/litre, and diesel oil is taxed at $0.1597/litre (Table 3.5).

Table 3.5 Ceiling Price Breakdown

| **No** | **Description** | **Gasoline 92** | **Gasoil 50ppm(DO 50ppm)** |
|---|---|---|---|
| | Average MOPS | 0.5786$ | 0.6617$ |
| | Tax | 0.1771 | 0.0641 |
| | *Customs duty* | *0.0000$* | *0.0000$* |
| ① | ***Additional Tax*** | ***0.0200$*** | ***0.0400$*** |
| ② | ***Special Tax*** | ***0.1571$*** | ***0.0241$*** |
| | Premium | 0.20$ | 0.23$ |
| ③ | **VAT (10% of 1+2+3)** | **0.09557** | **0.09558** |
| | Retail price/litre ($) | 1.05127 | 1.05138 |
| | Retail price/litre (KHR) | 4,326KHR | 4,326KHR |
| | Discounted by Gasoline company | 0.0100$ | 0.0100$ |
| | Selling retail price/litre ($) | 1.04$ | 1.04$ |
| | **Selling retail price/litre (KHR)** | **4,300KHR** | **4,300KHR** |
| | **Tax total（①+②+③)** | **$0.2727** | **$0.1597** |

Source: Ministry Of Commerce of Cambodia (December 2023)
Note: 1. $= US dollars, DO= Diesel Oil, KHR= Cambodian riel, MOPS= Mean price Of Platts Singapore
2. ppm= parts per million, VAT=value added tax
3. Exchange rate on 1 December 2023: $1 = 4115KHR.

EV penetration will reduce demand for gasoline and diesel oil, which will result in a decrease in government tax revenue. The amount of tax revenue reduction for EV20, EV40, and EV60 is shown in Table 3.6.

### Table 3.6 Level of Gasoline and Diesel Oil Tax

($000s)

| Gasoline | 2030 | 2040 | 2050 |
|---|---|---|---|
| BAU | 443,989 | 590,197 | 619,868 |
| EV20 | 426,892 | 537,318 | 530,921 |
| EV40 | 405,290 | 461,894 | 399,915 |
| EV60 | 381,836 | 384,134 | 266,610 |

| Diesel oil | 2030 | 2040 | 2050 |
|---|---|---|---|
| BAU | 711,216 | 1,008,570 | 1,076,317 |
| EV20 | 686,801 | 922,210 | 925,864 |
| EV40 | 649,241 | 789,348 | 694,398 |
| EV60 | 611,681 | 656,486 | 462,932 |

Source: Author's calculations

$ = US dollar, BAU = business-as-usual, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario.

Table 3.7 shows the total government tax revenue of gasoline and diesel oil by each EV penetration scenario.

### Table 3.7 Total Gasoline and Diesel Oil Tax

($000s)

| | 2030 | 2040 | 2050 | Decrease from BAU in 2050 | Percentage 2050/2030 |
|---|---|---|---|---|---|
| BAU | 1,155,205 | 1,598,767 | 1,696,185 | – | – |
| EV20 | 1,113,693 | 1,459,528 | 1,456,785 | ▲ 239,400 | 85.9 |
| EV40 | 1,054,531 | 1,251,242 | 1,094,313 | ▲ 601,872 | 64.5 |
| EV60 | 993,517 | 1,040,621 | 729,542 | ▲ 966,643 | 43.0 |

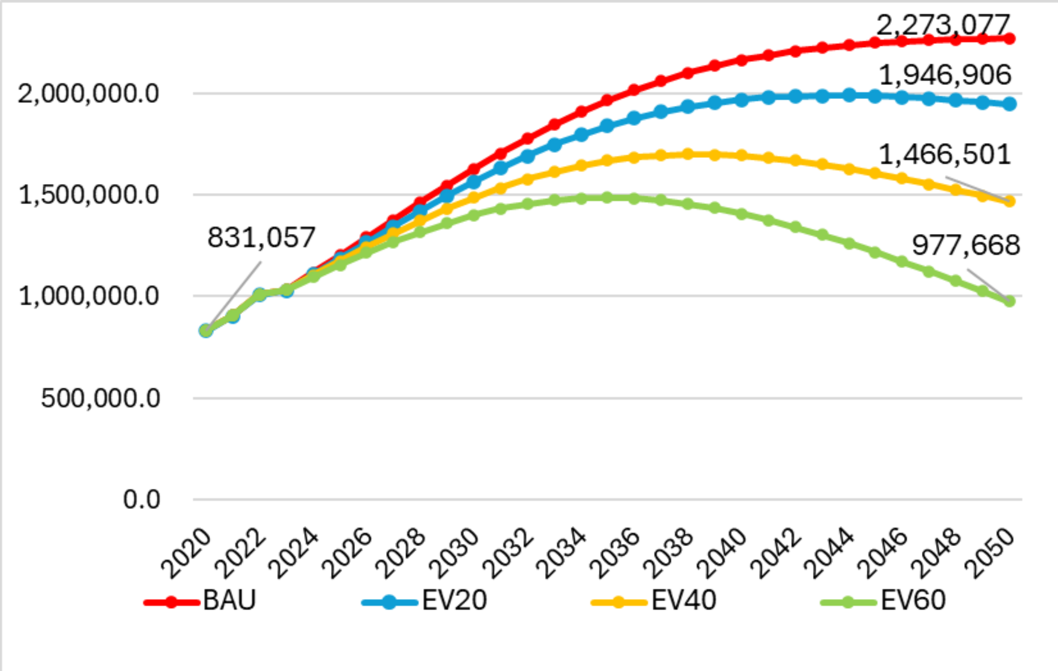
% = percent, ▲= minus, BAU = business-as-usual, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario.
Source: Authors' calculations.

## 3. Negative Impact for the Oil Industry

### 3.1 Demand for Gasoline and Diesel Oil in EV20, EV40, and EV60

#### *3.1.1 Demand for Gasoline*

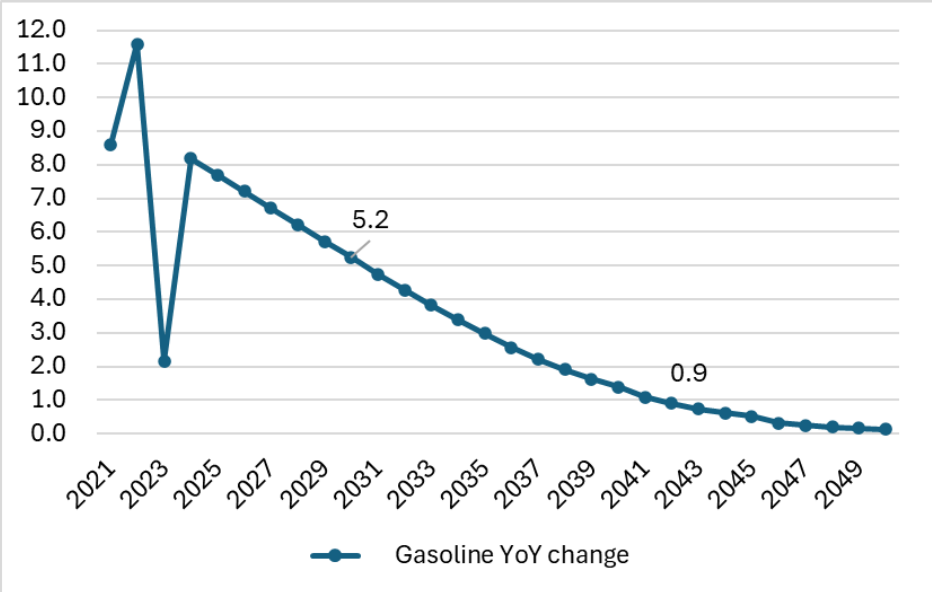
Figure 3.1 Demand for Gasoline by Electric Vehicle Penetration




BAU = business-as-usual, EV20 = electric vehicle 20% penetration scenario, EV40 = electric vehicle 40% penetration scenario, EV60 = electric vehicle 60% penetration scenario
Source: Author's calculations.

Figure 3.1 shows the trends in gasoline demand by EV penetration scenario. In the BAU scenario, the demand growth rate will slow down but will not fall below the previous year's level, but in the EV20 and EV40 scenarios, demand growth will fall below the previous year's level from the 2040s. In the EV60 scenario, demand growth will fall below the previous year's level from the late 2030s. For reference, Figure 3.2 shows the year-on-year growth rate of gasoline demand in the BAU scenario. The growth rate for gasoline is expected to exceed 5% year-on-year until 2030, but is expected to gradually decrease thereafter, falling below 1% from 2042, and remaining almost flat until 2050 (Figure 3.2).

Figure 3.2 Year-on-Year Change in Gasoline Demand in the Business-As-Usual Scenario




% = percent, YoY = year-on-year.
Source: Authors' calculations.

The growth rate of the Consumer Price Index is estimated at 3%/year based on historical data. There is no problem when the growth rate of sales exceeds 3%, but if it falls below 3%, oil companies will need to improve their management by, for example, cutting expenses. In addition, the construction of new import terminals and new petroleum service stations may stagnate after 2040. However, in the BAU scenario, the scale of demand will not shrink, so this is unlikely to have a major impact on the oil industry.

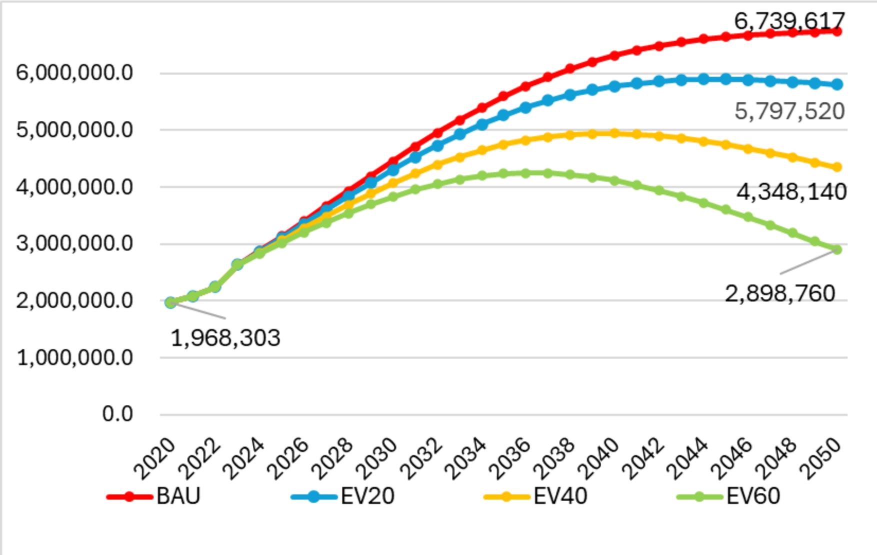
### *3.1.2 Demand for Diesel Oil*

The demand for diesel oil in the BAU scenario will be the same as that for gasoline, although there will be some differences. The year-on-year rate of demand for diesel oil is expected to be over 5% until 2032, but the growth rate is expected to gradually decline thereafter, falling below 1% from 2044, and remaining almost flat until 2050 (Figures 3.3 and 3.4).

In the BAU scenario, estimates suggest that the scale of demand for gasoline and diesel will not shrink, so this is unlikely to have a major impact on the oil industry.

Figure 3.3 Demand for Diesel Oil by Electric Vehicle Penetration

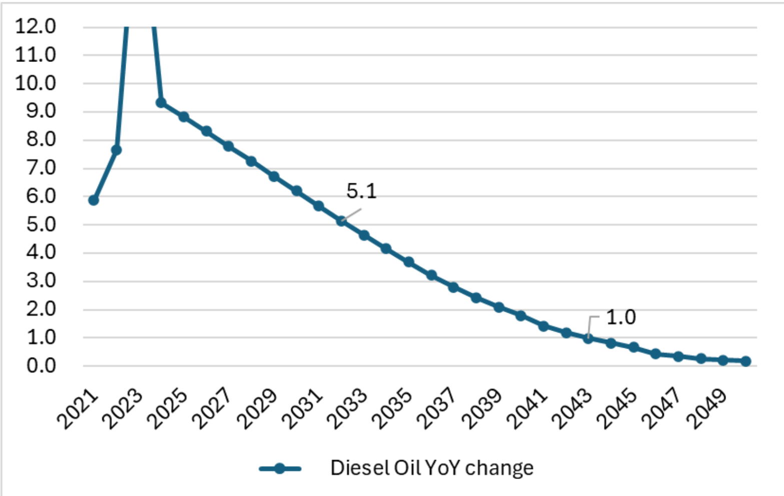
(kilolitres)




BAU = business-as-usual, EV20 = electric vehicle 20% penetration scenario, EV40 = electric vehicle 40% penetration scenario, EV60 = electric vehicle 60% penetration scenario

Source: Authors' calculations.

Figure 3.4 Year-on-Year Change in Diesel Oil Demand in the Business-As-Usual Scenario (%)




% = percent, YoY = year-on-year.

Source: Authors' calculations.

### 3.2 Impact of Electric Vehicle Penetration on Gasoline and Diesel Oil Sales

Sales amounts are calculated at $1.04/litre for both gasoline and diesel oil. Table 3.8 shows the sales amount of gasoline and diesel oil by EV penetration scenario.

#### Table 3.8 Impact of Electrical Vehicle Penetration on Amount of Gasoline and Diesel Oil Sold

($000s)

| | 2030 | 2040 | 2050 |
|---|---|---|---|
| BAU | 1,693,248 | 2,250,842 | 2,364,000 |
| EV20 | 1,628,043 | 2,049,178 | 2,024,782 |
| EV40 | 1,545,660 | 1,761,531 | 1,525,161 |
| EV60 | 1,456,213 | 1,464,979 | 1,016,774 |

| | 2030 | 2040 | 2050 |
|---|---|---|---|
| BAU | 4,631,585 | 6,568,022 | 7,009,202 |
| EV20 | 4,472,596 | 6,005,626 | 6,029,421 |
| EV40 | 4,227,997 | 5,140,401 | 4,522,066 |
| EV60 | 3,983,398 | 4,275,177 | 3,014,711 |

BAU = business-as-usual, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario
Source: Author's calculations

#### Table 3.9 Combined Sales Amounts of Gasoline and Diesel

($000)

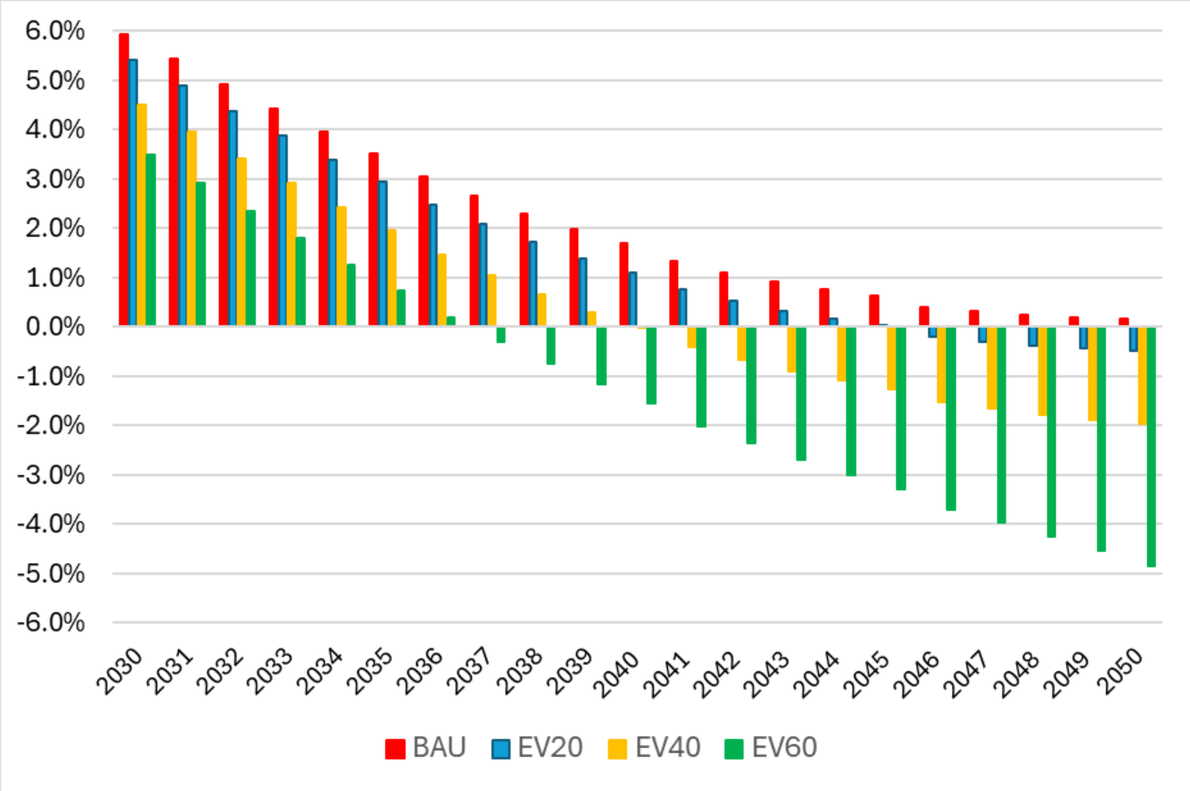
| | 2030 | 2040 | 2050 | Decrease from BAU | | | Percentage to BAU | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 2030 | 2040 | 2050 | 2030 | 2040 | 2050 |
| BAU | 6,324,833 | 8,818,864 | 9,373,202 | – | – | – | – | – | – |
| EV20 | 6,100,639 | 8,054,804 | 8,054,203 | ▲ 224,194 | ▲ 764,060 | ▲ 1,318,999 | 96.5 | 91.3 | 85.9 |
| EV40 | 5,773,657 | 6,901,932 | 6,047,227 | ▲ 551,176 | ▲ 1,916,932 | ▲ 3,325,975 | 91.3 | 78.3 | 64.5 |
| EV60 | 5,439,611 | 5,740,156 | 4,031,485 | ▲ 885,222 | ▲ 3,078,708 | ▲ 5,341,717 | 86.0 | 65.1 | 43.0 |

% = percent, ▲ = minus, BAU = business-as-usual, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario.
Source: Authors' calculations.

The combined sales amount for gasoline and diesel shows a decrease from BAU in 2050 of $1,319 million at the EV20 scenario, $3,326 million at the EV40 scenario and $5,342 million at the EV60 scenario. The percentage to BAU in 2050 is 85.9% for the EV20 scenario, 64.5% for the EV40 scenario, and 43.0% for the EV60 scenario.

The EV60 scenario is particularly low. Figure 3.5 shows that this is because the negative year-on-year growth rate of gasoline and diesel demand will become larger each year after 2040.

Figure 3.5 Year-on-Year Increase Rate of Total Demand of Gasoline and Diesel




Oil

- = negative number, BAU = business-as-usual, EV20 = electric vehicle 20% penetration scenario, EV40 = electric vehicle 40% penetration scenario, EV60 = electric vehicle 60% penetration scenario

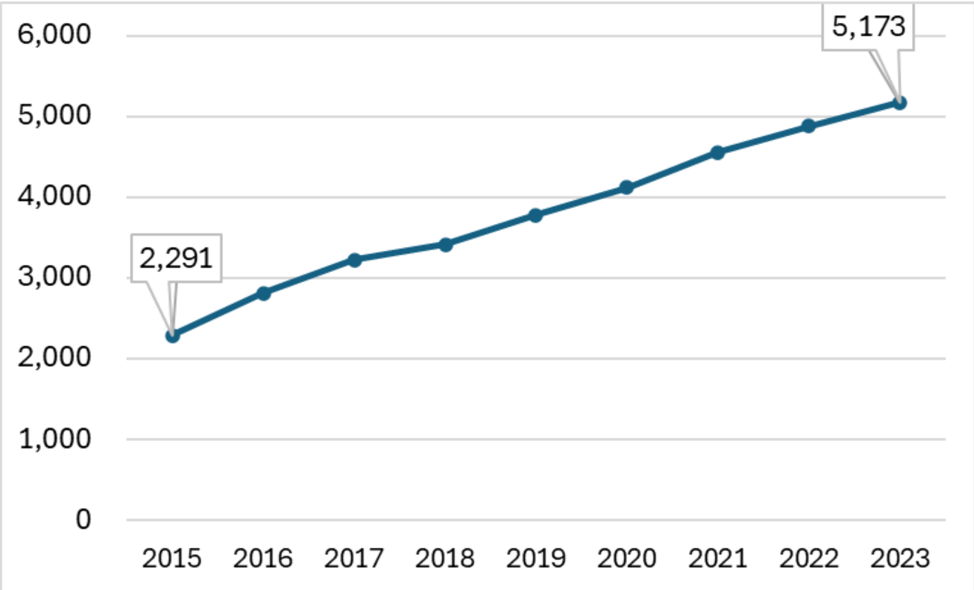
Source: Authors' calculations.

## 3.3 Number of Petroleum Service Stations

### *3.3.1 Current Situation*

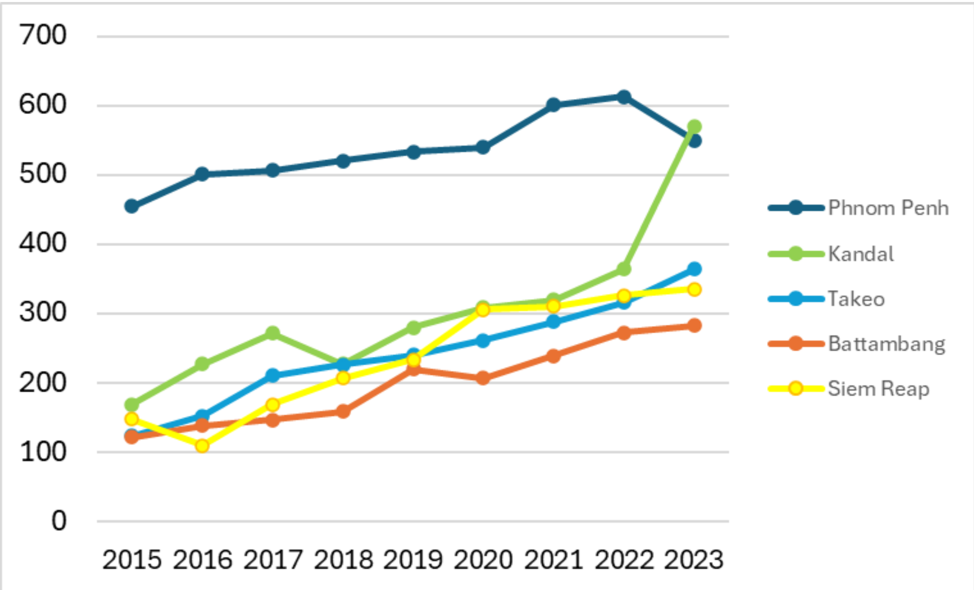
The number of service stations nationwide has increased at an annual rate of 10.7% from 2015 and reached 5,173 in 2023 (Figure 3.6). The province with the most service stations is Phnom Penh, followed by Kandal, Takeo, Battambang, and Siem Reap (Figure 3.7).

Figure 3.6 Number of Service Stations, 2015–2023




Source: Author's estimation

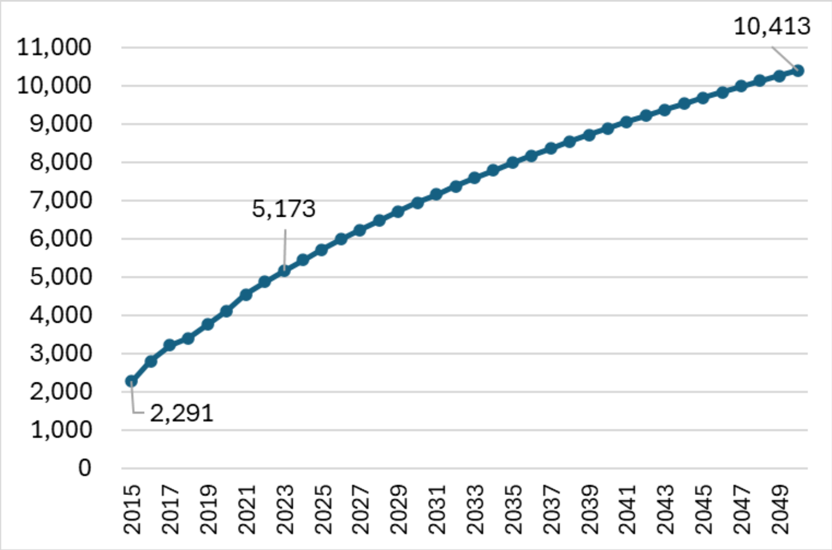
Figure 3.7 Number of Service Stations in Major Provinces




Source: Author's estimation

*3.3.2 Estimation of the Number of Service Stations in the Business-as-Usual Scenario*

Figure 3.8 Estimation of the Number of Service Stations in the Business-as-Usual Scenario



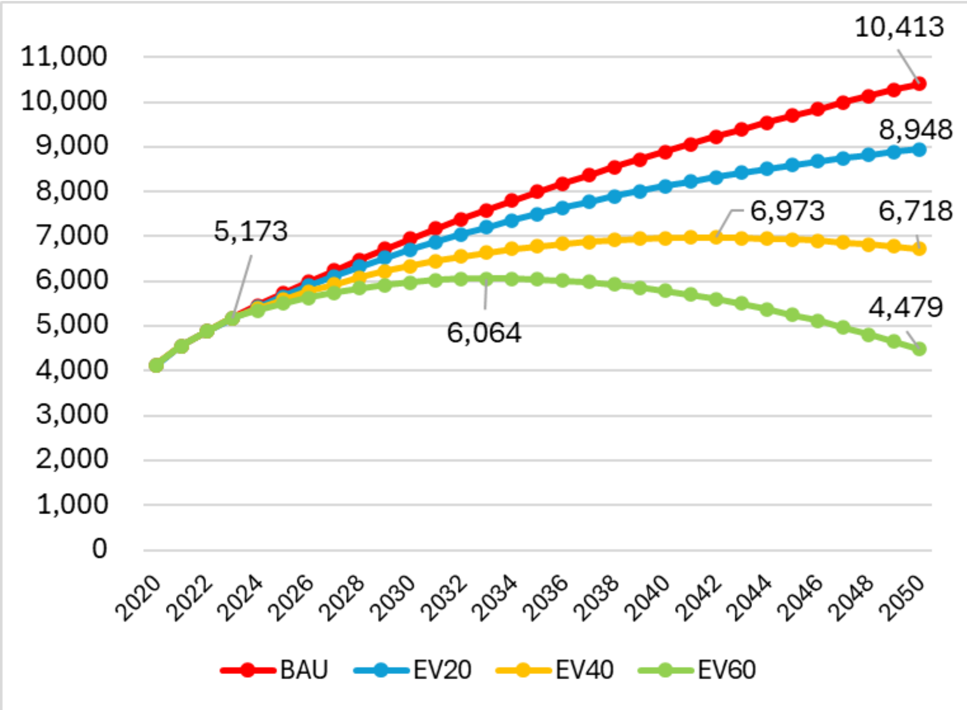

Source: Authors' estimation.

Based on trends from 2015 to 2023, the number of service stations in 2050 is estimated to be 10,413 (Figure 3.8). Based on the sales volume per service station in the BAU scenario, the number of service stations in the EV20, EV40, and EV60 scenarios have also been estimated.

### 3.4 Number of Service Station in 2050 by Level of Electric Vehicle Penetration

The number of service stations for EV20, EV40, and EV60 are estimated in Figure 3.9.

Figure 3.9 Number of Service Stations in 2050 by Electric Vehicle Penetration




BAU = business-as-usual, EV20 = electric vehicle 20% penetration scenario, EV40 = electric vehicle 40% penetration scenario, EV60 = electric vehicle 60% penetration scenario.
Source: Authors' calculations.

Details of the number of service stations and their impact are shown in Table 3.10. In the EV20 scenario, the number of service stations will stagnate, but the number will not decrease, so it is unlikely to have a large impact. In the EV40 scenario, the number of service stations will peak at 6,973 in 2042, then decrease at an average rate of 32 service stations per year to 6,718 service stations in 2050. However, this is still more than the current number of 5,173 service stations, so it cannot be said to have a serious impact. In the EV60 scenario, the number of service stations will peak at 6,064 in 2033 and then decline at an average rate of 93 service stations per year to reach 4,479 in 2050. This is a 26% decrease from the peak and will be lower than the current level of 5,173 service stations, so it will have a major impact.

Table 3.10 The Impact of Electric Vehicle Penetration on the Number of Service Stations

| | EV20 | EV40 | EV60 |
|---|---|---|---|
| Number of service stations | Stagnation but not decline.<br>In 2050, 8,948 SS. | Peak at 6,973 SS in 2042.<br>In 2050, 6,718 SS:(▲32 SS/y). | Peak at 6,064 SS in 2033.<br>In 2050, 4,479 SS:(▲93 SS/y). |
| Impact | Not such a large impact. | SS will decrease from 2040 but numbers will still exceed the current situation (2023). | SS will decrease by 26% from a peak in 2033. Large impact. |

% = percent, ▲ = minus, BAU = business-as-usual, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario, SS = service stations, y = year.
Source: Author calculation

## 4. Challenges and Solutions for the Oil Industry

As mentioned above, the spread of EV is expected to result in either stagnation or a decline in the year-on-year demand for oil depending on the rate of EV adoption. With declining revenue, the oil industry will need to improve management by, for example, reducing costs through greater efficiency. It will also be necessary to prepare for a decline in service stations, storage tanks, and tank trucks.

On the other hand, the oil industry plays an important role in providing a stable and cheap supply of energy, and it is expected to continue to develop as a strong and flexible industry. The challenges facing the oil industry and the measures that it will need to take are outlined below.

### 4.1. New Business in the Energy Field and Other Sectors

Currently (2025), the oil industry has imported, transported, and sold oil to the industrial, transportation, and business sectors. The industry needs to utilise that knowledge and experience to venture into new fields such as supplying new energy sources, including renewable energy, and promoting energy conservation, to make up for declining sales in the oil sector.

### 4.2 Service Stations to Change to New Business Models

Service stations are suitable for roadside businesses. They can be converted into cafes, restaurants, shops, EV sales points, or EV charging stations. However, when constructing a high-rise building, or other such operations that require strengthening the ground through pile driving, the underground tank must be removed beforehand.

### 4.3 Entering the Transportation Business

The oil industry owns its own tank trucks and employs many drivers to transport gasoline and diesel oil throughout Cambodia. It has a wealth of knowledge and experience in transporting goods. As the demand for oil is likely to decrease in the future due to the progress of EV penetration, it is conceivable that the industry could utilise its knowledge, experience, and human resources to transport goods other than oil. With the introduction of EV trucks, the EV truck charging business also offers promising new opportunities.

### 4.4 Utilising Surplus Storage Tanks for National Stockpiles

In the scenario where oil demand peaks, storage tanks at oil import bases may become surplus to requirements. This surplus could be used as a national stockpile, contributing to improving energy security. In this scenario, the government should purchase or borrow the surplus storage tanks

# Chapter 4

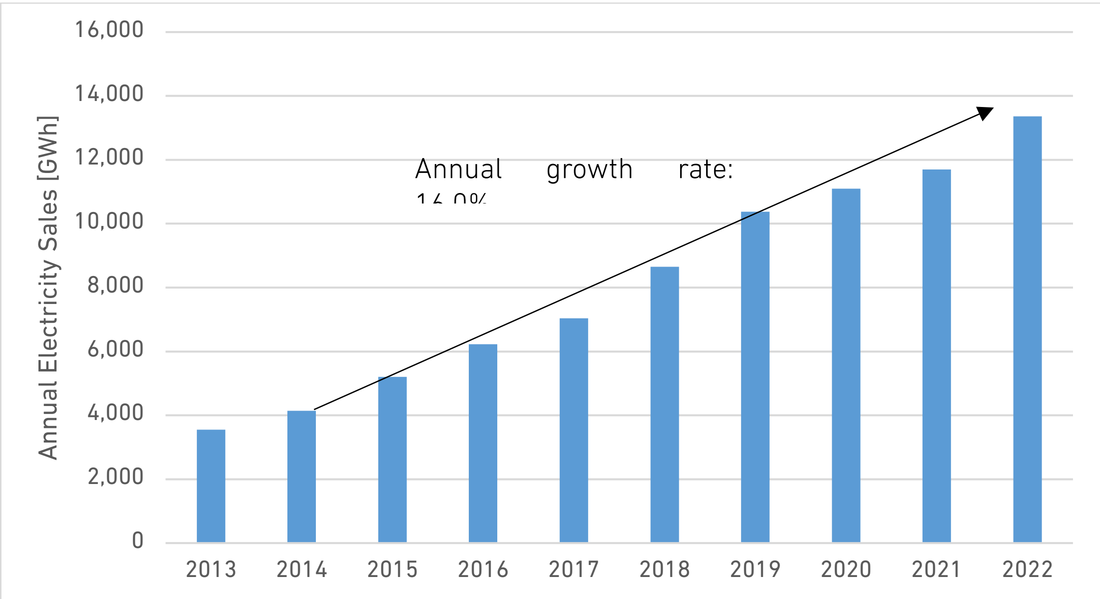
# Impact Analysis of Cambodia's Power Sector

## 1. The Current Situation of the Power Sector in Cambodia

### 1.1 Power Demand

Figure 4.1 shows annual electricity sales to consumers in Cambodia, based on data from annual reports published by the Electricity Authority of Cambodia (EAC). Electricity sales have increased from 3,553 GWh in 2013 to 13,362 GWh in 2022. The annual growth rate of electricity sales from 2013 to 2022 was about 16.0% (EAC, n.d.).

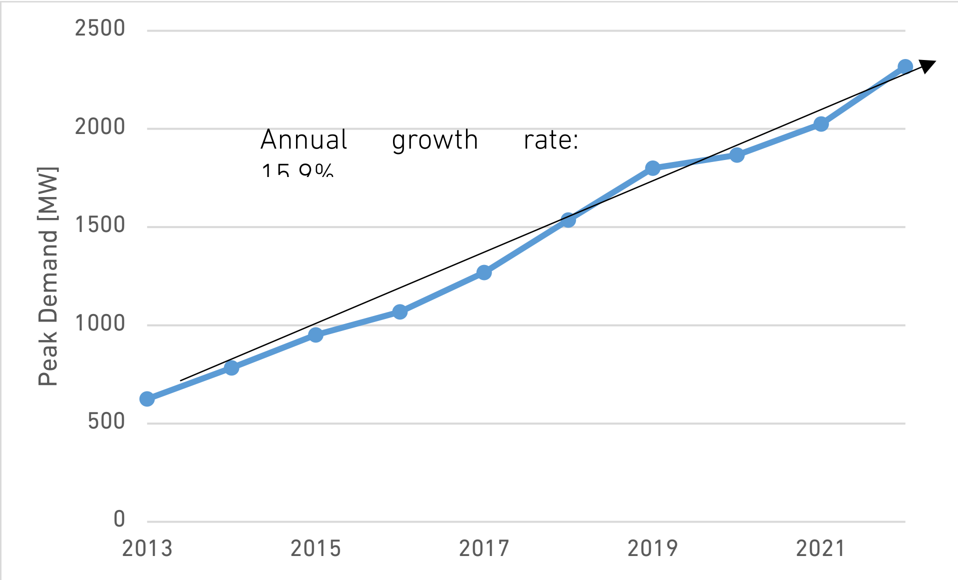
Figure 4.1 Annual Electricity Sales in Cambodia




% = percent, GWh = gigawatt-hour.
Source: EAC (n.d.), modified by the author.

Figure 4.2 shows the changes in peak demand in Cambodia from 2013 to 2022, based on data from the annual reports published by Electricité du Cambodge (EDC) (EDC, 2018) and the Japan International Cooperation Agency report (JICA, 2024). Peak demand has also increased from 625 GWh in 2013 to 2,317 GWh in 2022. The annual growth rate for electricity sales from 2013 to 2022 is about 15.9%.

Figure 4.2 Changes in Peak Demand in Cambodia

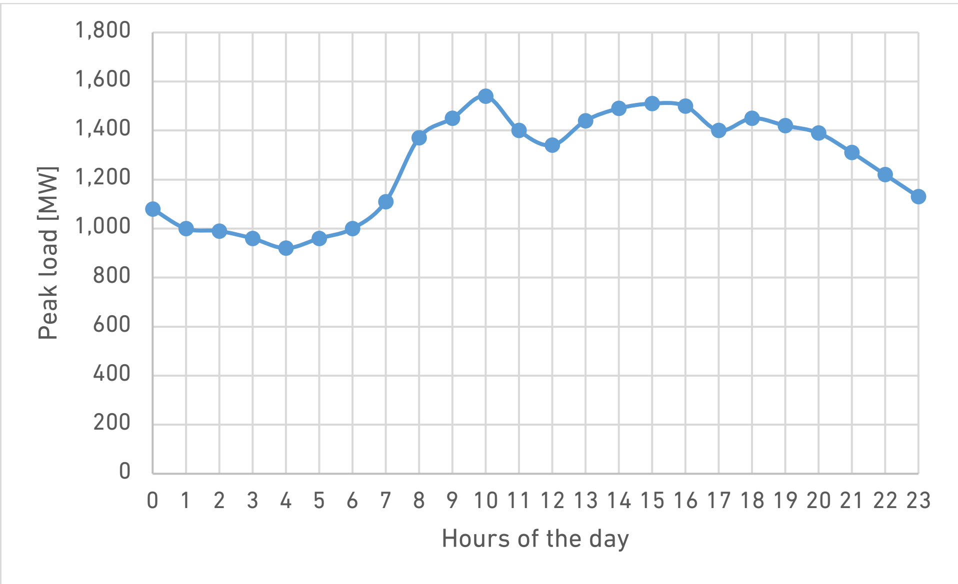



% = percent, GWh = gigawatt-hour.

Source: EDC (2018) and JICA (2024), modified by the author.

Figure 4.3 shows the daily peak load curve of the national grid in 2018, based on data from the annual report published by the EDC (EDC, 2018). The peak load curve in Cambodia is low in the early morning and gradually increases towards noon, peaking at 10:00 am. It then fluctuates between 1,300 and 1,500 megawatts (MW) into the evening and gradually decreases at night.

Figure 4.3 Daily Peak Load Curve of the National Grid in 2018




MW = megawatt.

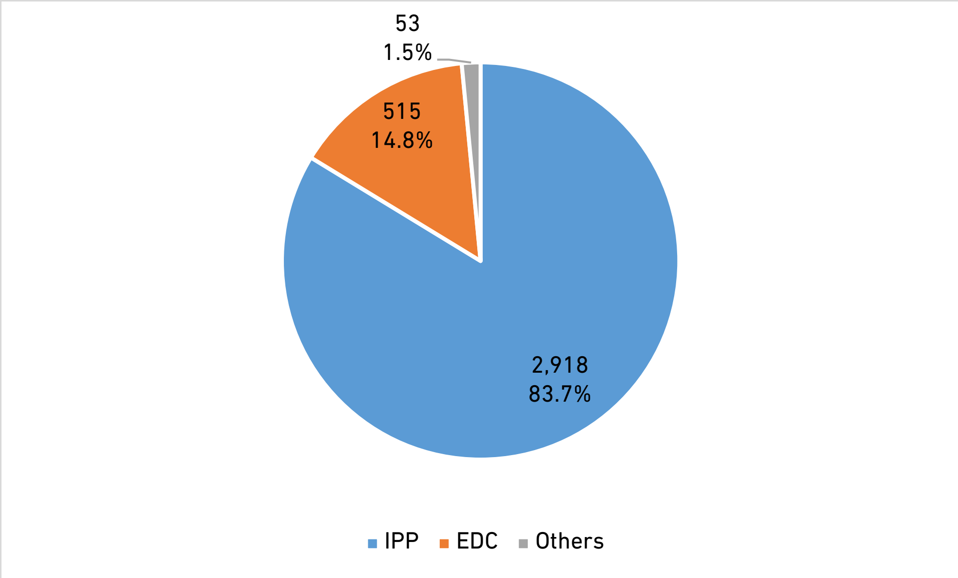
Source: EDC (2018), modified by the author.

## 1.2 Power Generation

Figure 4.4 shows the installed capacity by type of power producers in 2022. The total installed capacity is 3,486 MW and independent power producers own 83.7% of the total, or 2,918 MW. The rest is owned by EDC with 14.8 % or 515 MW and others with 1.5 % or 53 MW.

Figure 4.4 Installed Capacity by Type of Power Producers in 2022

(Megawatt and percentage)

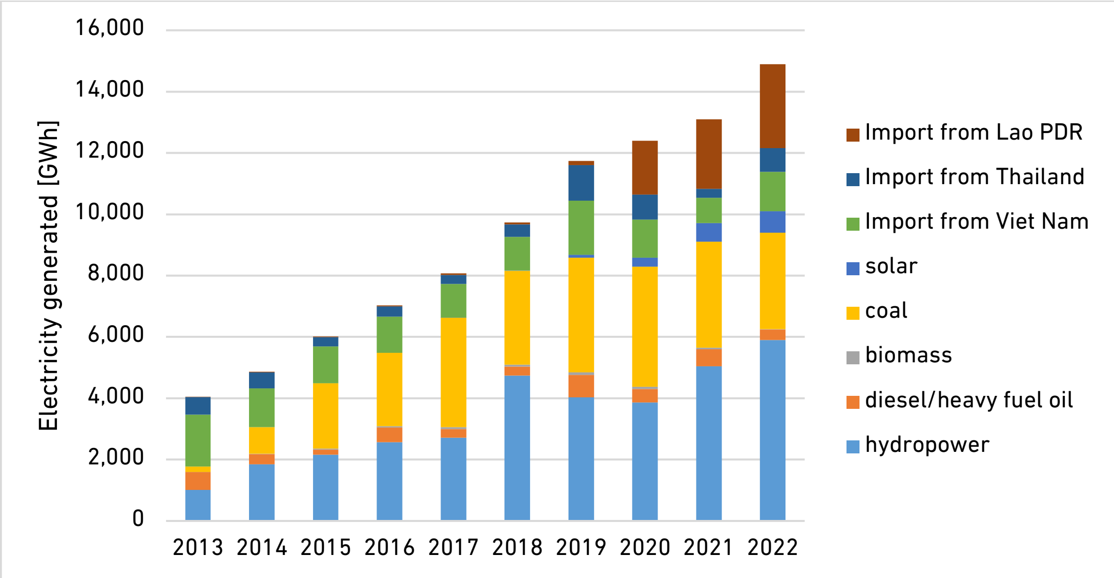



% = percent, MW = megawatt. IPP= independent power producer, EDC = Electricité du Cambodge.
Source: EAC (2022), modified by the author.

Figure 4.5 shows the amount of electricity generated by type in Cambodia. Electricity generation and electricity demand have increased steadily from 2013 to 2022. Hydropower was the main generation source for domestic power plants in 2013, followed by diesel/heavy fuel oil. The number of hydropower plants have progressively increased, and their generation capacity has also increased since 2013. Diesel/heavy oil, on the other hand, has not changed significantly, but instead, coal-fired power generation has increased. Also notable are imports from neighbouring countries. In 2013, approximately 56% of total electricity generation was imported from the Lao People's Democratic Republic (Lao PDR), Thailand, and Viet Nam. Since 2014, the share of electricity imports from neighbouring countries in total electricity generation has decreased due to the operation of domestic coal-fired power plants. However, supply availability is secured against increased electricity demand from 2019 onwards through increased electricity imports from neighbouring countries, particularly Lao PDR, indicating that electricity imports from neighbouring countries still contribute to a stable supply of electricity in

Cambodia. Solar photovoltaic power generation has been gradually increasing since 2019, but its share of the total is still not large.

Figure 4.5 Amount of Electricity Generated by Type




GWh = gigawatt-hour, Lao PDR = Lao People's Democratic Republic.
Source: EAC (2022), modified by the author.

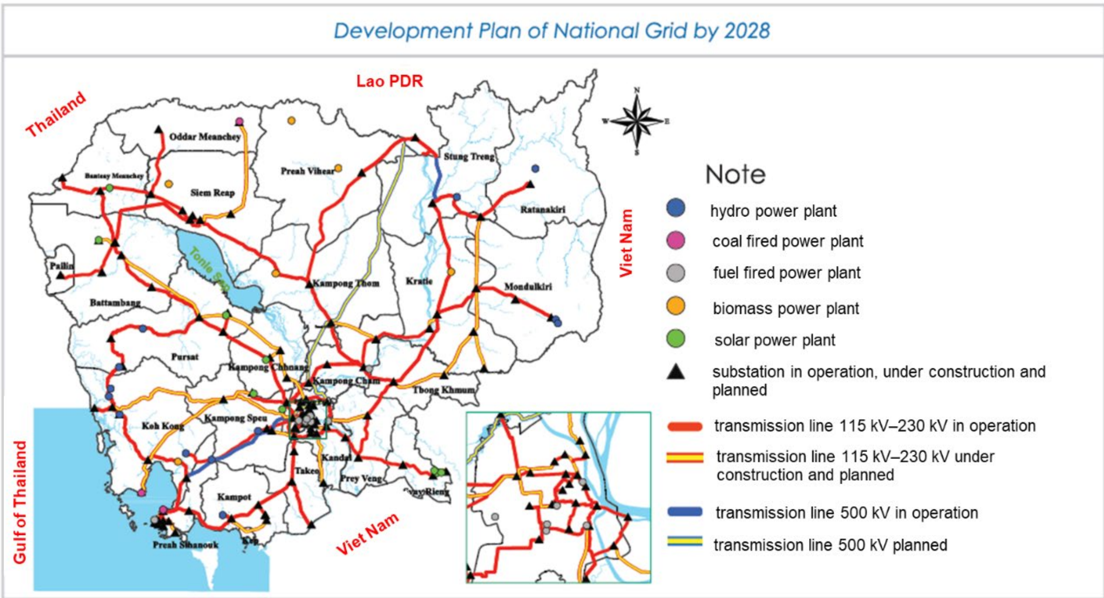
## 1.3 Overview of the National Grid

Cambodia's power sector has seen substantial growth, fuelled by factors such as rising urbanisation, economic development, and a concerted effort by the Government of Cambodia to achieve comprehensive nationwide electrification. As of 2023, around 98.9% of the country's villages had access to electricity, a remarkable increase from just over 24.2% in 2009. This significant improvement reflects the country's commitment to expanding electrical access and infrastructure.

According to the EAC, the national grid development plan, detailed in the report Salient Features of Power Development in the Kingdom of Cambodia (EAC, 2023) outlines the strategic direction for the sector until 2028. As of December 2023, Cambodia's power transmission network included lines operating mainly at 230 kilovolts (kV) and 115 kV, which facilitated the distribution of electricity across the country. Additionally, there are existing 500 kV transmission lines designed for importing electricity from Lao PDR and Thailand, crucial for meeting the country's energy needs. The development plan shows ambitious infrastructure projects, notably the planned construction of a new 500 kV transmission line extending from around Phnom Penh to the Lao PDR border by 2028. This project aims to enhance the capacity and reliability of the electricity grid, further integrating Cambodia into the regional power market and improving the overall stability of the national grid (Figure 4.6).

Whilst Cambodia's electricity supply reliability has seen significant improvements in recent years, challenges persist, especially in rural areas. Issues with voltage fluctuations and power quality have arisen, largely because rapid demand growth has outstripped the development of the electricity infrastructure. Nevertheless, the combined efforts of the government and private sector have been gradually addressing and improving these issues.

Figure 4.6 Development Plan for the National Grid by 2028

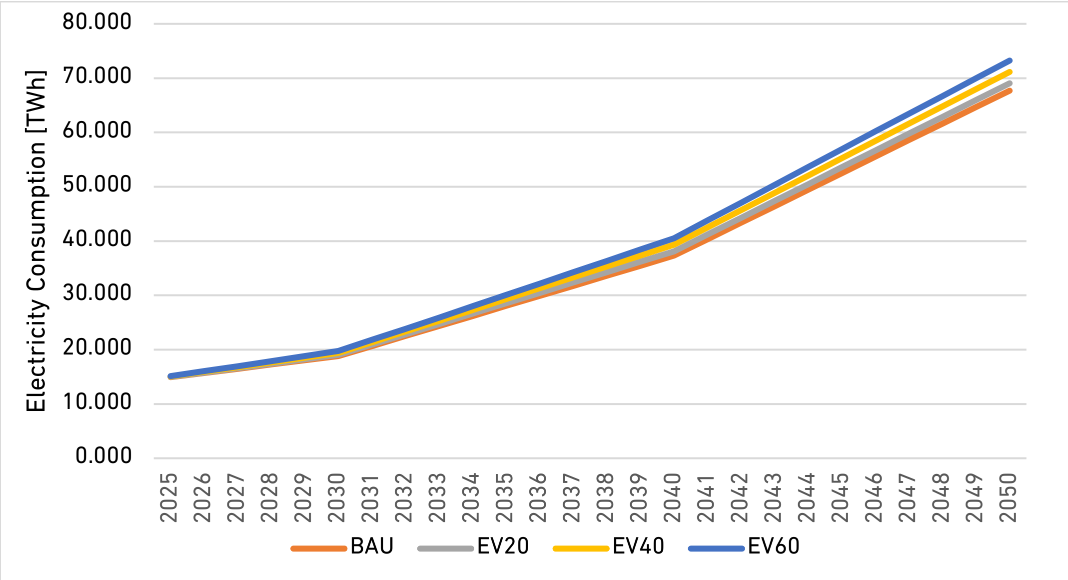



kV =kilovolt, Lao PDR = Lao People's Democratic Republic.
Source: EAC (2023).

## 2. Electricity Consumption

Chapter 1 explored a scenario where 20%, 40%, and 60% of vehicles in Cambodia would be converted to EVs by 2050. It assessed the impact on gasoline consumption and the rise in electricity demand due to EV charging. Figure 4.7 presents the forecast for electricity consumption until 2050 based on the level of EV adoption, as determined in Chapter 1. We touch on the peak demand forecast in Section 4.3.2.

Figure 4.7 Forecast for Electricity Consumption Until 2050




BAU = business-as-usual, EV20 = electric vehicle 20% penetration scenario, EV40 = electric vehicle 40% penetration scenario, EV60 = electric vehicle 60% penetration scenario, TWh =terawatt hour.
Source: Authors' calculations.

## 3. Electric Vehicle Charging Demand

Tables 4.1 to 4.3 show the annual, monthly, and daily demand for charging electricity. These are those presented in Chapter 1. EV charging demand will fluctuate monthly and particularly daily due to human behavioural shifts, but in this scenario, it is averaged by the number of months and days with our objective of roughly analysing the impact of EV penetration on the electricity sector in Cambodia.

Table 4.1 Annual Charging Demand

(Gigawatt-hour)

| | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|
| BAU | 26.8 | 126.3 | 267.1 | 425.4 | 581.9 | 732.3 |
| EV 20 | 74.4 | 358.5 | 761.1 | 1,213.7 | 1,661.7 | 2,092.4 |
| EV 40 | 147.7 | 715.7 | 1,520.9 | 2,426.6 | 3,323.0 | 4,184.9 |
| EV 60 | 221.0 | 1,072.9 | 2,280.8 | 3,639.4 | 4,984.3 | 6,277.3 |

BAU = business-as-usual, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario GWh = gigawatt-hour.
Source: Author's calculations.

Table 4.2 Monthly Charging Demand

(Gigawatt-hour)

| | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|
| BAU | 2.2 | 10.5 | 22.3 | 35.4 | 48.5 | 61.0 |
| EV 20 | 6.2 | 29.9 | 63.4 | 101.1 | 138.5 | 174.4 |
| EV 40 | 12.3 | 59.6 | 126.7 | 202.2 | 276.9 | 348.7 |
| EV 60 | 18.4 | 89.4 | 190.1 | 303.3 | 415.4 | 523.1 |

BAU = business-as-usual, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario, GWh = gigawatt-hour.
Source: Author's calculation.

Table 4.3 Daily Charging Demand

(Megawatt-hour)

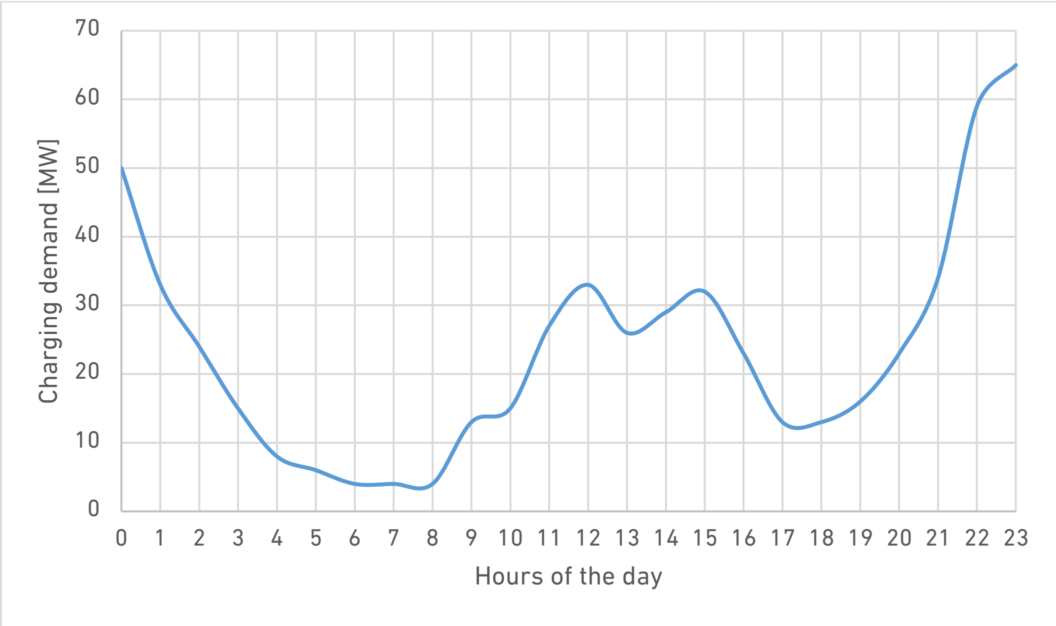
| | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|
| BAU | 73.5 | 346.0 | 731.9 | 1,165.4 | 1,594.3 | 2,006.4 |
| EV 20 | 204.0 | 982.1 | 2,085.1 | 3,325.3 | 4,552.7 | 5,732.7 |
| EV 40 | 404.8 | 1,960.7 | 4,166.9 | 6,648.1 | 9,104.1 | 11,465.3 |
| EV 60 | 605.6 | 2,939.4 | 6,248.7 | 9,971.0 | 13,655.5 | 17,198.0 |

BAU = business-as-usual, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario.
Source: Author's calculation.

### 3.1. Daily Charging Demand Profile

This subsection describes EV charging demand as a preparation for estimating future daily load curves in Cambodia, considering EV charging demand. The hourly charging demand of EVs varies according to their intended use. If the EV is mainly used for private purposes, it is operated during the day and recharged after returning home in the evening or at night. If the EV is used as a company car or as a commuter car, it is assumed that it is often recharged after work in the evening or at night as well, as the EV operates from morning to evening, but if the company has recharging facilities, the demand for recharging electricity may increase during the day as well. ERIA's previous studies on EV penetration in Lao PDR have created hourly charging electricity demand profiles as shown in Figure 4.8 (Kimura et al, 2022). This was based on the results of a study conducted by Chen, Yang, and Ma (2020) in Hefei, China. Figure 4.8 shows the hourly charging demand profile.

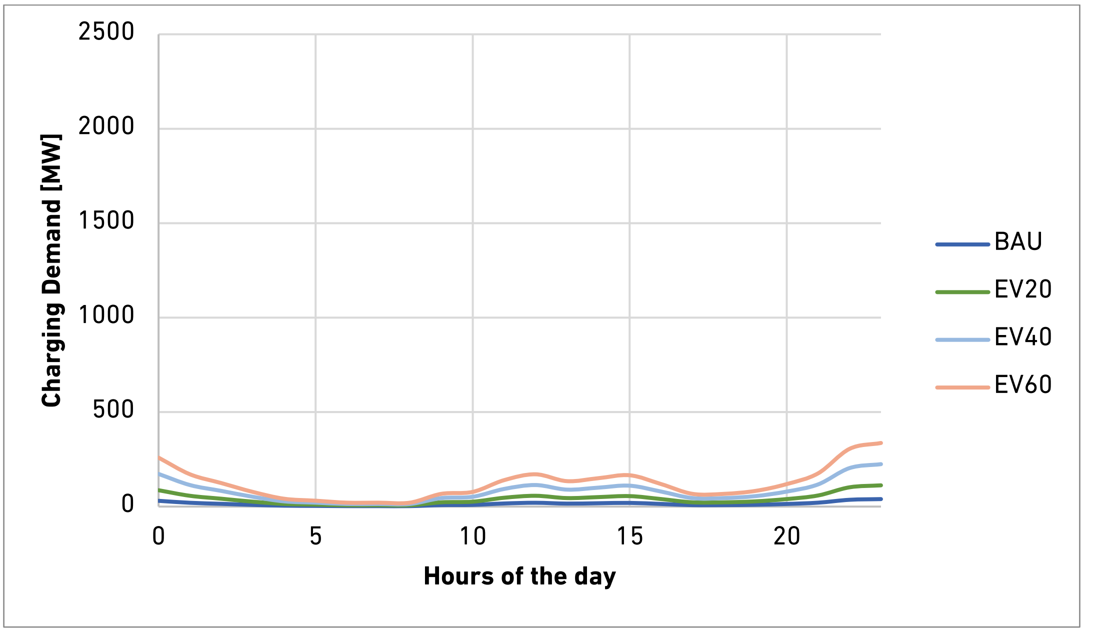
Figure 4.8 Charging Demand Profile




MW = megawatt.
Source: Chen, Yang, and Ma (2020), modified by the authors.

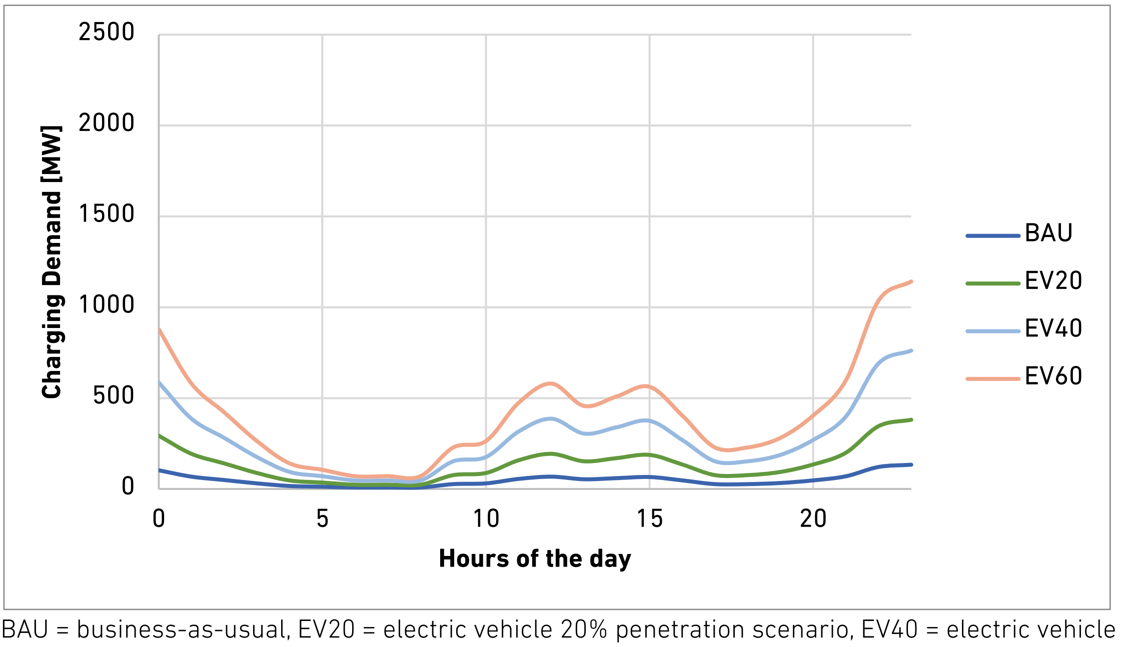
Based on Figure 4.8 and the daily EV charging demand calculated in Table 4.3, we calculated charging electricity demand profiles in Cambodia for the period 2025–2050. Figure 4.9 shows electricity demand profiles for 2030, Figure 4.10 shows the profiles for 2040, and Figure 4.11 shows the profiles for 2050. As the penetration of EVs increases, the demand for charging electricity increases, amounting to approximately 2,000 MW at the peak in 2050.

Figure 4.9 Charging Demand Profile in 2030



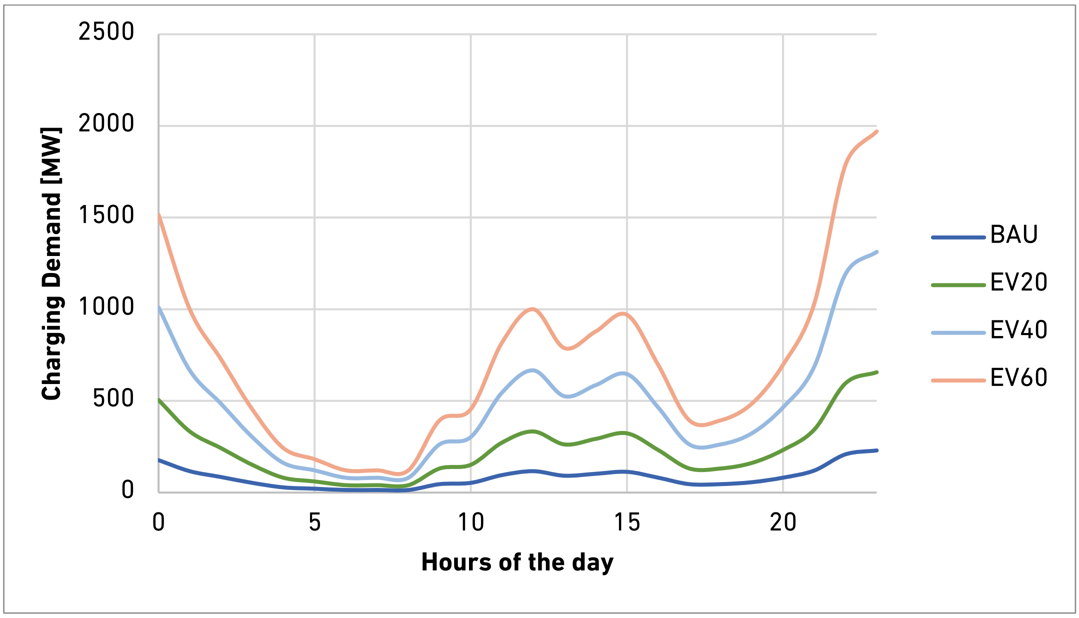

BAU = business-as-usual, EV20 = electric vehicle 20% penetration scenario, EV40 = electric vehicle 40% penetration scenario, EV60 = electric vehicle 60% penetration scenario, MW = megawatt.
Source: Authors' calculations.

Figure 4.10 Charging Demand Profile in 2040




BAU = business-as-usual, EV20 = electric vehicle 20% penetration scenario, EV40 = electric vehicle 40% penetration scenario, EV60 = electric vehicle 60% penetration scenario, MW = megawatt.
Source: Authors' calculations.

Figure 4.11 Charging Demand Profile in 2050

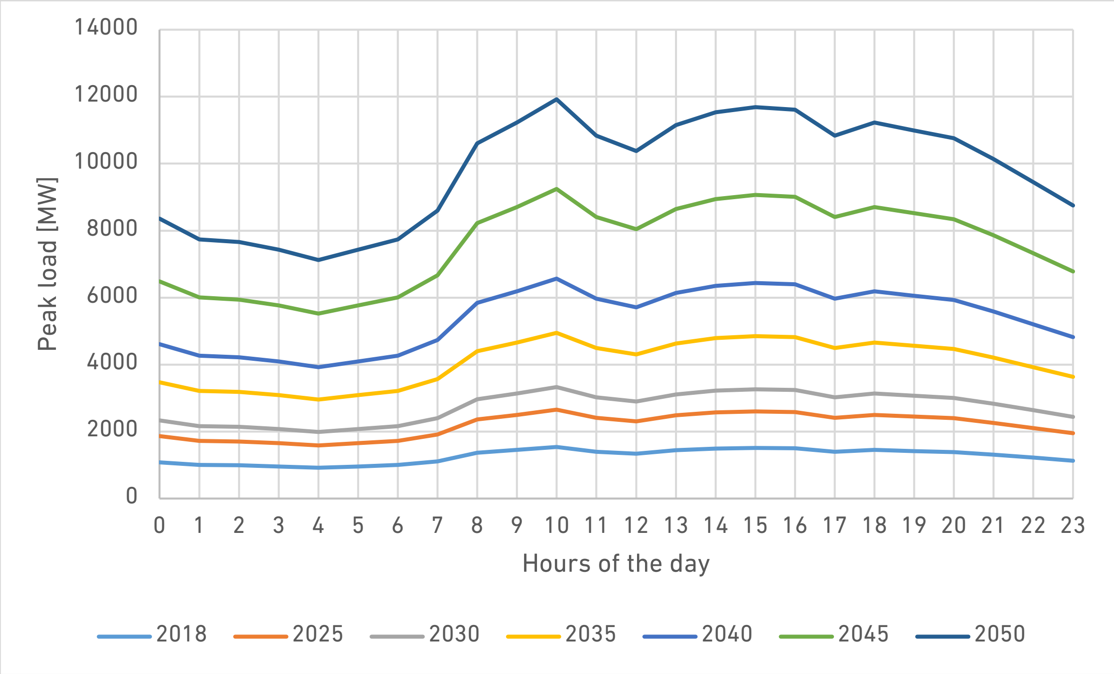



BAU = business-as-usual, EV20 = electric vehicle 20% penetration scenario, EV40 = electric vehicle 40% penetration scenario, EV60 = electric vehicle 60% penetration scenario, MW = megawatt.
Source: Authors' calculations.

## 3.2. Forecast of the Daily Demand Curve Including Electric Vehicle Charging Demand

This subsection draws on the results of Section 3.1 to estimate the future daily power demand curve considering EV charging demand. Figure 4.12 shows the forecast of peak demand without EV charging demand up to 2050. It was calculated by multiplying the daily peak load curve in 2018 shown in the Figure 4.3 by the growth rate of power demand in Cambodia, based on the assumption that there was almost no demand for EV charging in 2018. It should be noted here that Figure 4.12 does not include EV charging demand.

Figure 4.12 Forecast for Peak Demand Without Electric Vehicle Charging Demand up to 2050

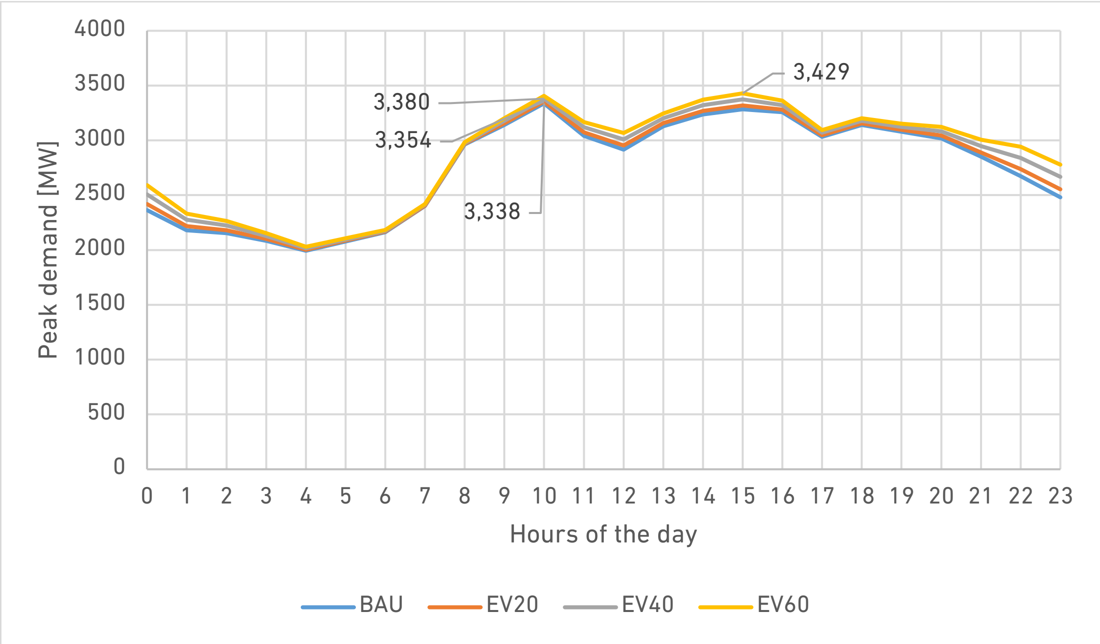



MW = megawatt.
Source: Authors' calculations.

Figure 4.13–Figure 4.15 show the result of overall daily peak demand forecast including EV charging demand in 2030 (Figure 4.13), 2040 (Figure 4.14), and 2050 (Figure 4.15). These were calculated by adding the EV charging demand shown in Figure 4.9, Figure 4.10, and Figure 4.11 to the overall power demand in Cambodia excluding the EV charging demand shown in Figure 4.12.

Figure 4.3 and Figure 4.12 show that the highest demand in Cambodia is at around 10.00 am. Figure 4.13–Figure 4.15 show that the trend remains the same in projected scenarios where EV penetration is not high, but as EV penetration increases, the peak hour changes to around 03.00 pm. This is because, as can be seen in Figure 4.9–Figure 4.11, EV charging demand tends to be low at 10:00 am but high at 03.00 pm. It can also be seen that EV charging demand is highest late at night rather than during the day, but this does not significantly affect peak demand as other electricity demand is low during this time.

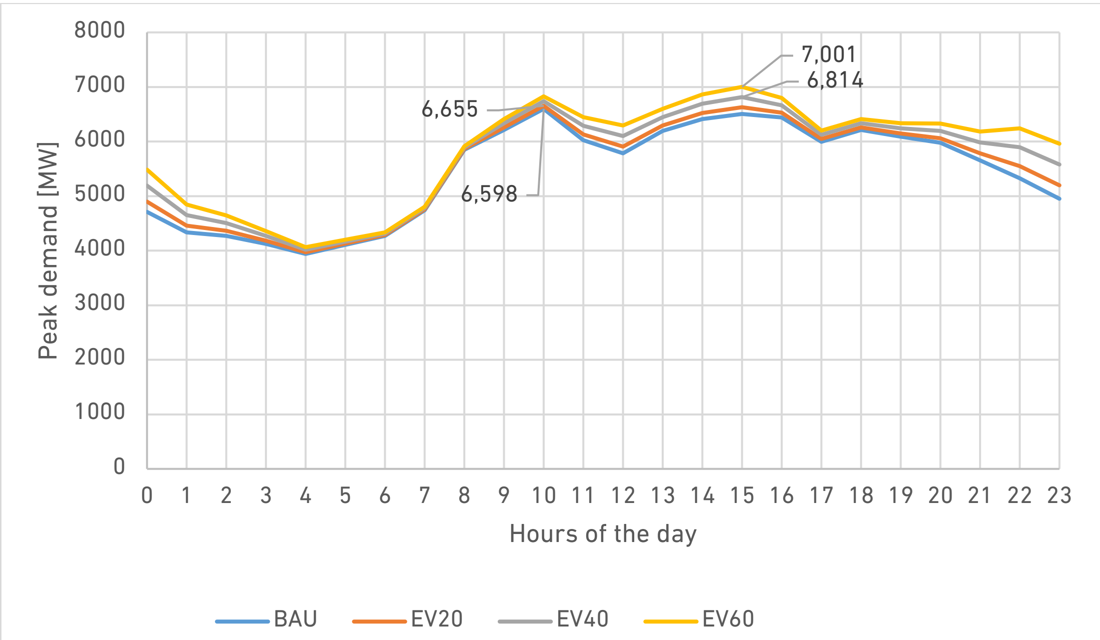
Figure 4.13 Forecast for Daily Peak Demand in 2030




BAU = business-as-usual, EV20 = electric vehicle 20% penetration scenario, EV40 = electric vehicle 40% penetration scenario, EV60 = electric vehicle 60% penetration scenario, MW = megawatt.

Source: Authors' calculations.

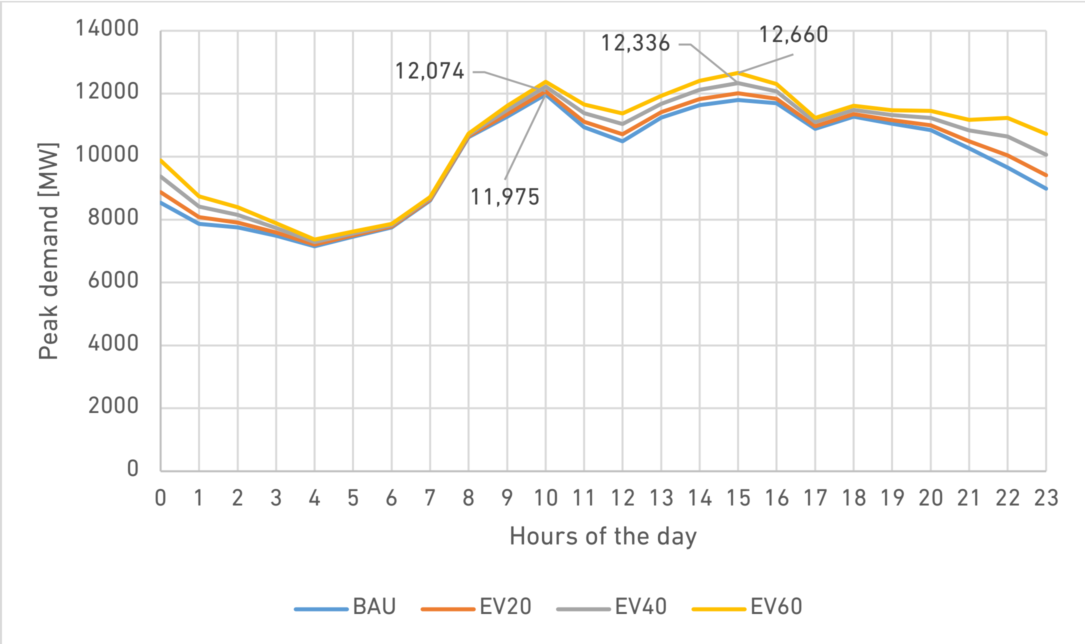
Figure 4.14 Forecast for Daily Peak Demand in 2040




BAU = business-as-usual, EV20 = electric vehicle 20% penetration scenario, EV40 = electric vehicle 40% penetration scenario, EV60 = electric vehicle 60% penetration scenario, MW = megawatt.

Source: Authors' calculations.

Figure 4.15 Forecast of Daily Peak Demand in 2050




BAU = business-as-usual, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario, MW = megawatt.
Source: Authors' calculations.

## 4. Impact Analysis on the Power Sector by Electric Vehicle Penetration

The impact on the power sector by EV penetration in Cambodia has been analysed in terms of the required generation capacity and its cost, as well as the cost of the necessary transmission and distribution network.

### 4.1. Required Generation Capacity and Cost Estimation

The monthly demand per scenario for EV penetration was shown in Table 4.2. This report focuses on hydropower to calculate the generation capacity needed to meet this demand, since hydropower has a lot of potential in Cambodia. To gauge the generation capacity required, the number of additional hydropower plants needed to meet the demand must be calculated. For the information required for the calculation, the capacity factor for hydropower plants is assumed to be 35% (MME and ERIA, 2019). The capacity factor of hydropower plants varies with the season (dry and wet season) and is generally higher in the wet season and lower in the dry season. Therefore, assuming that if power generation can be ensured in the dry season, it can be ensured in the wet season as well, this report uses the dry season capacity factor to assess the required power generation capacity. The assessment also considers transmission and distribution losses. The value is set at 3.8% based on the actual performance of the Japanese electricity company, TEPCO Power Grid, in 2022 (TEPCO, 2022). The current transmission and distribution losses in Cambodia are around 10%, which is higher than this, but the value is used in this report as it is expected to be lower in the future.

Table 4.4 shows the calculation of the hydropower development required. In the EV60 scenario, the required capacity in 2050 reaches 2,154.7 MW. This figure suggests that many hydropower plants will need to be developed, but this is possible given Cambodia's hydropower potential. According to ADB, Cambodia's technical hydropower potential is estimated at 10,000 MW (ADB, 2018). In addition, according to the development plan of the Ministry of Mines and Energy of Cambodia (MME), the capacity of hydropower plants in 2040 is envisaged to be 2,973 MW (MME, 2022). The remaining potential is approximately 7,000 MW. Thus, in terms of potential, the development of 2,154.7 MW is feasible.

### Table 4.4 Hydropower Development That Will Be Required

(Megawatts)

| | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|
| BAU | 9.1 | 43.3 | 91.9 | 145.8 | 199.8 | 251.3 |
| EV20 | 25.5 | 123.2 | 261.1 | 416.4 | 570.5 | 718.4 |
| EV40 | 50.7 | 245.5 | 521.9 | 832.9 | 1,140.6 | 1,436.3 |
| EV60 | 75.8 | 368.2 | 783.0 | 1,249.3 | 1,711.1 | 2,154.7 |

BAU = business-as-usual, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario.
Source: Authors' calculations.

The cost of installing hydropower plants in this scenario is also roughly estimated. According to the MME's development plan, the increase in hydropower plant capacity from 2022 to 2040 is 1,645 MW at a capital investment cost of $4,137 million, which translates into a unit cost per MW of $2.51 million/MW. Table 4.5 shows the installation costs of a hydropower plant to meet EV charging demand.

### Table 4.5 Hydropower Installation Costs Required

($ million)

| | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|
| BAU | 22.7 | 108.6 | 230.6 | 366.0 | 501.4 | 630.7 |
| EV20 | 64.1 | 309.1 | 655.5 | 1,045.3 | 1,431.9 | 1,803.1 |

| | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|
| EV40 | 127.2 | 616.2 | 1,309.9 | 2,090.5 | 2,862.8 | 3,605.1 |
| EV60 | 190.2 | 924.3 | 1,965.4 | 3,135.8 | 4,294.7 | 5,408.2 |

$ = United States dollar, BAU = business-as-usual, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario.
Source: Authors' calculations.

## 4.2. Estimation of Transmission and Distribution Network Costs

For the electricity from the developed power plants to reach EV-owning consumers, reinforcement of the national grid will also be required. Section 4.4.2 describes the cost of the necessary transmission and distribution network reinforcement for this purpose. Please note, however, that we could not obtain data on existing transmission and distribution capacity, therefore rough estimations are used in this report.

According to MME's Power Development Masterplan (MME, 2022), peak demand growth from 2022 to 2040 is estimated at 6,180 MW and the total cost of transmission network upgrades over that period is estimated at $1,796 million. This cost includes not only 230 kV and 500 kV transmission lines but also transformers, reactive plants, series capacitors, and resilience upgrades. From the above values, the cost per MW of transmission network reinforcement is calculated at $0.3 million/MW. On the other hand, Table 4.6 shows the increase in peak demand due to EV charging demand calculated by the authors. This was derived by comparing the maximum peak demand excluding EV charging demand in a day, as derived in Figure 4.12, with the maximum peak demand including EV charging demand in a day, as estimated in Figure 4.13–Figure 4.15. Then, based on Table 4.6 and the cost per MW of transmission network reinforcement, the cost of the transmission network required to meet EV charging demand is shown in Table 4.7. It should be noted that the results only estimate the cost of the transmission network needed to meet EV charging demand and do not consider the electricity demand from other factors that will increase by 2050.

Table 4.6 Increase in Peak Demand Due to Electric Vehicle Charging Demand

(Megawatts)

| | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|
| BAU | 2.2 | 9.6 | 19.0 | 30.7 | 41.7 | 53.1 |
| EV20 | 5.6 | 26.4 | 54.8 | 87.8 | 119.9 | 151.6 |
| EV40 | 10.9 | 52.3 | 138.3 | 246.9 | 332.8 | 414.4 |
| EV60 | 16.3 | 101.4 | 255.7 | 434.2 | 589.4 | 737.6 |

BAU = business-as-usual, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario
Source: Authors' calculations.

Table 4.7 Transmission Network Costs Required

($ million)

| | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|
| BAU | 0.7 | 2.9 | 5.7 | 9.2 | 12.5 | 15.9 |
| EV20 | 1.7 | 7.9 | 16.4 | 26.3 | 36.0 | 45.5 |
| EV40 | 3.3 | 15.7 | 41.5 | 74.1 | 99.8 | 124.3 |
| EV60 | 4.9 | 30.4 | 76.7 | 130.3 | 176.8 | 221.3 |

$ = United States dollar, BAU = business-as-usual, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario.
Source: Authors' calculations.

Table 4.8 gives information on the electricity distribution network in December 2023, as published by the EAC (EAC, 2023). The table indicates that a total of $2,090 million has been invested in the distribution network so far. In addition, using peak demand in 2022 (2,317 MW), since peak demand data for 2023 was not available, it can be estimated that the cost per MW of distribution network reinforcement is about $0.9 million/MW. The cost of the distribution network required to meet EV charging demand is shown in Table 4.9. As with the estimation of the transmission network costs, it should be noted that the results only estimate the cost of the distribution network needed to meet EV charging demand and do not consider the electricity demand from other factors that will increase by 2050.

Table 4.8 Distribution Network Developed by December 2023

($ million)

| Type of facility | Unit | Invested by EDC | Invested by licensee | Total |
|---|---|---|---|---|
| Middle voltage line | km | 25,438 | 24,214 | 49,652 |
| Transformer | Unit | 14,880 | 14,020 | 28,900 |
| Low voltage line | km | 10,466 | 36,945 | 47,411 |
| Connectivity device | Connection | 1,382,795 | 2,322,712 | 3,705,507 |
| Invested Fund | $ million | 864 | 1,226 | 2,090 |

$ = United States dollar, BAU = business-as-usual, EDC = Electricité du Cambodge, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario, km = kilometre.
Source: EAC (2023), modified by the authors.

Table 4.9 Distribution Network Costs

($ million)

| | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|
| BAU | 2.0 | 8.6 | 17.1 | 27.7 | 37.5 | 47.8 |
| EV20 | 5.1 | 23.8 | 49.3 | 79.0 | 107.9 | 136.5 |
| EV40 | 9.8 | 47.1 | 124.4 | 222.2 | 299.5 | 372.9 |
| EV60 | 14.6 | 91.2 | 230.1 | 390.8 | 530.5 | 663.9 |

$ = United States dollar, BAU = business-as-usual, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario
Source: Authors' calculations.

## 5. Conclusion

Section 4 has analysed the impact of EV penetration on the power sector. Based on recent trends, Cambodia's electricity demand will increase steadily until 2050. Furthermore, the demand will continue to increase with EV penetration. We estimate that the annual EV charging demand will reach about 6.2 terawatt hours in 2050 in the EV 60 scenario. This would represent a significant change in Cambodia's electricity demand. For example, Cambodia's daily peak demand is currently around 10:00 a.m., but our study showed that this peak would shift to around 15:00 p.m. as EVs become more widely available.

Our study also estimated the generation, transmission, and distribution network costs required to meet EV charging demand. In terms of generation, Cambodia has a high potential for hydropower, so the study assumed that all EV charging demand would be met by new hydropower generation. In this case, the required capacity reaches up to 2,154.7 MW by 2050. This figure suggests that many hydropower plants will need to be developed, but this is possible given Cambodia's technical hydropower potential of 10,000 MW. Investment costs also reach $5,408.2 million. For transmission and distribution network costs, our study estimated that a maximum of $221.3 million would be needed for the transmission network and a maximum of $663.9 million for the distribution network to meet the EV charging demand. The maximum total cost, including generation, transmission, and distribution networks, is then up to $6,293.4 million. This amount is so large that the government should be prepared to systematically invest funds for this purpose. According to MME's Master Plan for Power Development (MME, 2022), however, a total of $3,355 million has been committed for the generation and transmission network from 2022 to 2025, so it would not be impossible given this amount.

On the other hand, external financial support and the use of private investment could also be an effective solution to the financial issues. Institutions such as the World Bank and ADB provide low interest loans and technical assistance to help countries transition to cleaner energy sources. Furthermore, climate finance mechanisms such as the Green Climate Fund and funding from developed nations enable developing countries to invest in renewable energy projects. Through such international support, developing countries can build the foundation needed to progress with their decarbonisation efforts. Moreover, the deployment of independent power producers is also a key strategy for accelerating decarbonisation by leveraging private sector capital and technology. In cases where it is difficult for the government to directly fund all infrastructure development, private companies taking on the role of building and operating power plants offers an effective model. Independent power producers attract private investment, reducing the financial burden on governments and promoting the rapid and efficient development of energy infrastructure. Independent power producers often operate within a Public-Private Partnership model, where governments provide policy and regulatory support, whilst private companies handle the construction and operation of power plants. This collaboration allows for efficient decarbonisation, whilst also promoting economic growth in developing countries. The synergy between public and private sectors can help these nations transition towards decarbonisation whilst fostering sustainable development.

Finally, it should be noted that each of the analyses in this study is only rough research based on limited data. Therefore, if EVs are to become widespread in Cambodia, detailed analysis will be required for power system planning and cost estimation.

# Chapter 5

# The Impact of Electric Vehicles on Energy Consumption and Carbon Dioxide Emissions in Cambodia

This chapter assesses the impact of BEV penetration on energy consumption and carbon dioxide ($CO_2$) emissions in Cambodia. Theoretically, BEV penetration increases the demand for electricity and decreases the demand for petroleum products, such as gasoline.

## 1. The Energy Balance Table of Cambodia in 2021

In 2022, the MME, with the support of ERIA estimated Cambodia's EBTs for 2020 and 2021, basing their estimates on Cambodia Energy Statistics 2000-2019 (ERIA, 2022), however, there were some inconsistencies with the figures.

## Table 5.1 Cambodia's Energy Balance Table, 2021

(million tonnes of oil equivalent)

| | Coal (sub bituminous) | Petroleum products | Gasoline | Jet kerosene | Diesel oil | Residual oil | LPG | Lubricant | Hydro | Solar | Electricity | Biomass | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Indigenous production | - | - | - | - | | | | | 0.439 | 0.036 | | 1.983 | 2.458 |
| Import | 1.387 | 3.240 | 0.875 | 0.062 | 1.744 | 0.067 | 0.413 | 0.079 | | | 0.348 | | 4.974 |
| Export | - | - | - | - | | | | | | | | | - |
| International bunker oil | | 0.060 | | 0.060 | | | | | | | | | 0.060 |
| Total primary energy supply | 1.387 | 3.180 | 0.875 | 0.002 | 1.744 | 0.067 | 0.413 | 0.079 | 0.439 | 0.036 | 0.348 | 1.983 | 7.372 |
| Power generation | -0.893 | -0.111 | | | -0.083 | -0.028 | | | -0.439 | -0.036 | 0.869 | -0.011 | -0.621 |
| Transmission & distribution losses | - | - | | | | | | | | | -0.202 | | -0.202 |
| Total transformation | -0.893 | -0.111 | | | -0.083 | -0.028 | | | -0.439 | -0.036 | 0.667 | -0.011 | -0.823 |
| Statistics difference | - | -0.000 | - | -0.000 | - | - | - | - | - | - | -0.001 | -0.001 | -0.002 |
| Total final energy consumption sector | 0.494 | 3.069 | 0.875 | 0.002 | 1.661 | 0.039 | 0.413 | 0.079 | - | - | 1.016 | 1.973 | 6.551 |
| Industry | 0.494 | 0.226 | | | 0.187 | 0.039 | | | | | 0.366 | 1.390 | 2.476 |
| Transport | - | 2.152 | 0.875 | 0.002 | 1.184 | | 0.091 | | | | | | 2.152 |
| Road | - | 2.150 | 0.875 | - | 1.184 | | 0.091 | | | | | | 2.150 |
| Rail | - | - | | - | | | | | | | | | - |
| Air | - | 0.002 | | 0.002 | | | | | | | | | 0.002 |
| Inland waterways | - | - | | | | | | | | | | | - |
| Other sector | - | 0.612 | | | 0.290 | | 0.322 | | | | 0.650 | 0.583 | 1.845 |
| Commercial | - | 0.312 | | | 0.032 | | 0.280 | | | | 0.286 | | 0.598 |
| Residential | - | 0.062 | | | 0.020 | | 0.042 | | | | 0.364 | 0.583 | 1.009 |
| Agriculture | - | 0.149 | | | 0.149 | | | | | | | | 0.149 |
| Other | - | 0.089 | | | 0.089 | | | | | | | | 0.089 |
| Non-energy use | - | 0.079 | | | | | | 0.079 | | | | | 0.079 |

LPG = liquified petroleum gas.
Source: Authors' calculations based on ERIA (2022), prepared by Ministry of Mines and Energy, Cambodia, with the support of ERIA.

The total final energy consumption (TFEC) of Cambodia in 2021 was 6.551 Mtoe and its fuel shares were coal at 7.5%, petroleum at 46.9%, electricity at 15.5% and biomass at 30.1%. It is notable that 30% of TFEC still came from biomass and 47% of TFEC was accounted for by petroleum products, mainly diesel oil (25%) and gasoline (13%). In terms of sectors, industry was dominant at 37.8%, followed by transport at 32.8% (mainly roads), residential at 15.4%, commercial at 9.1% and others at 4.9%. Power generation was 0.869 Mtoe (10.1 terawatt hours) and hydropower was dominant, followed by coal, solar, oil, and biomass. As a result, total primary energy supply (TPES) was 7.372 Mtoe and its fuel shares were coal at 18.8%, petroleum products at 43.1%, hydropower at 6.0%, solar at 0.5%, electricity at 4.7% (the import of electricity from neighbouring countries) and biomass at 26.9%. Import dependency defined as import divided by TPES was 67.5% and diesel oil showed dominant share at 35.1%, followed by coal, gasoline, liquefied petroleum gas, and electricity.

## 2. The Impact on Petroleum Products

We analysed the impact that BEV penetration would have on petroleum product consumption. To analyse the EV impact (Table 5.1), we set out two scenarios to simplify the calculations. EV50 assumes a 50% EV penetration rate in 2021 and EV0 assumes a 0% EV penetration ratio in 2021, acting as a baseline.

Gasoline consumption in 2021 was 875,000 kilotonnes of oil equivalent (ktoe) (0.875 Mtoe). This amount is defined as the following formula:

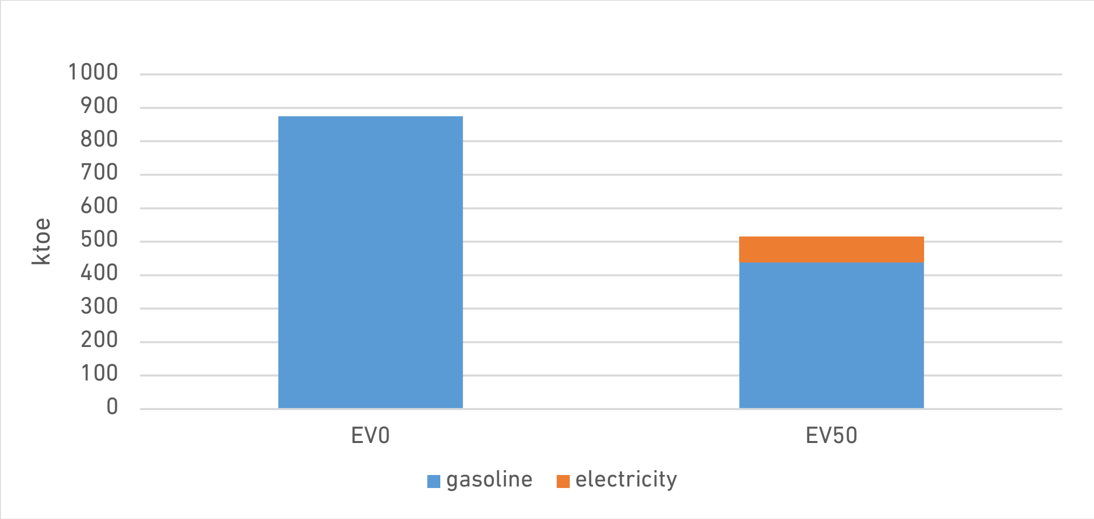
Number of gasoline vehicles x driving distance (km/year) x fuel economy (km/litre) x heat content (kcal/litre) / 10,000,000 (kcal/toe) / 1,000 (kilo) = 875 ktoe

If we assume a driving distance of 12,000 km/year, fuel economy at 10km/litre and heat content at 8,000 kcal/litre, the number of gasoline vehicles is estimated at 911,458. If half of the gasoline vehicles are replaced by BEVs, the electricity demand is estimated as the following formula:

Number of BEV x driving distance (km)/fuel economy (km/kWh) x heat content (kcal/kWh) / 10,000,000 (kcal/toe) / 1,000 (kilo)

If we assume the number of BEVs as 455,729 (half of 911,458), driving distance at 12,000 km, fuel economy (6 km/kWh) and heat content at 860 kcal/kWh, electricity demand is estimated at 78 ktoe. If Cambodia applies an EV penetration policy which replaces gasoline cars with BEVs at 50%, gasoline consumption decreases to 437.5 ktoe. On the other hand, electricity demand increases to 78 ktoe. Thus, an EV penetration policy brings energy savings of around 360 ktoe compared to a gasoline-oriented society.

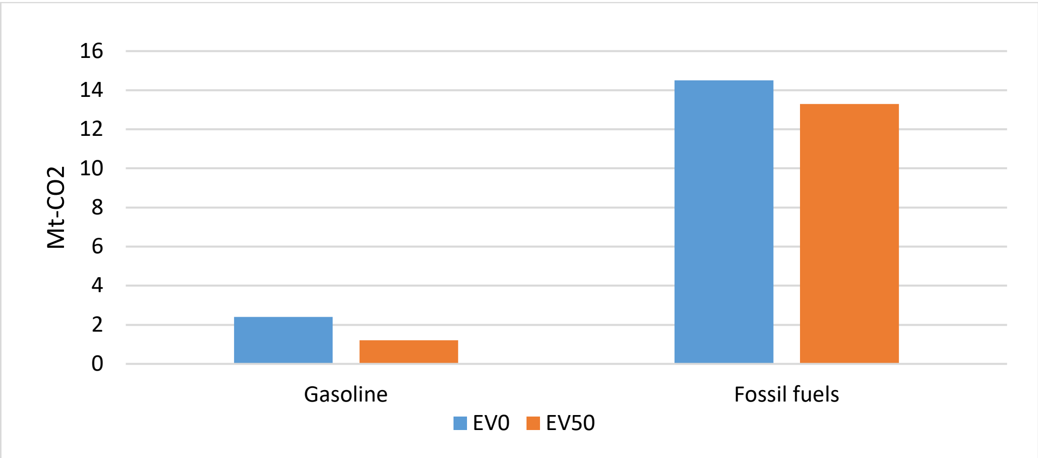
Figure 5.1 The Impact of Electric Vehicle Penetration on Energy Consumption in Cambodia in 2021




EV0 = 0% electric vehicle penetration, EV50 = 50% electric vehicle penetration, ktoe = kilotonnes of oil equivalent.
Source: Authors' calculations.

$CO_2$ emissions from gasoline consumption also decreases from 2.4 Mt- $CO_2$ to 1.2 Mt-$CO_2$ due to EV penetration. Total $CO_2$ emissions from fossil fuel combustion (coal and oil) was 14.5 Mt- $CO_2$ in 2021, so EV penetration (50%) contributed to an 8% reduction in $CO_2$ emissions in Cambodia (Figure 5.2).

Figure 5.2 The Impact of Carbon Dioxide Emissions in 2021




EV0 = 0% electric vehicle penetration, EV50 = 50% electric vehicle penetration, Mt-$CO_2$ = million metric tonnes of carbon dioxide.
Source: Authors' calculations.

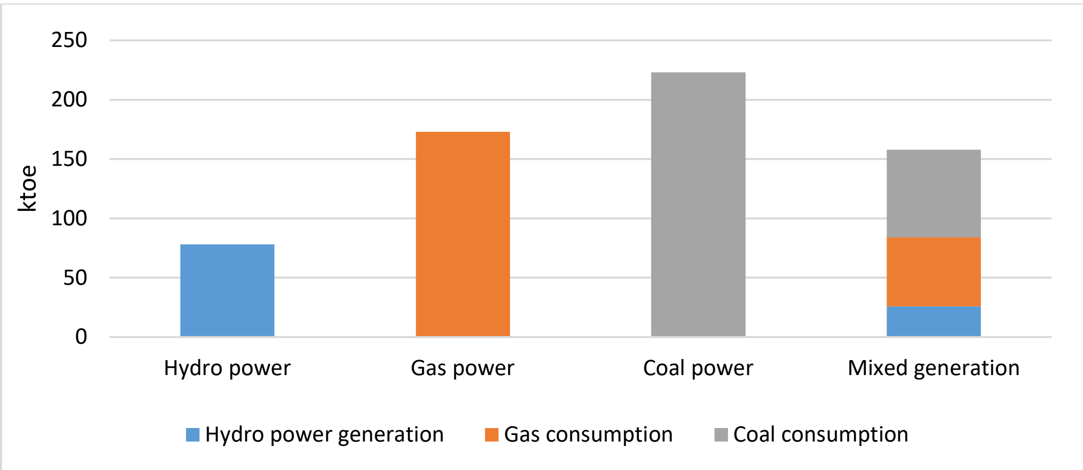
## 3. Impact on the Power Sector

EV penetration leads to an increase in electricity demand and the need to generate additional electricity. Cambodia's electricity demand in 2021 was 1,016 ktoe, so the electricity demand increased about 8% due to the EV penetration ratio of 50%. The equivalent to 78 ktoe is 911,458 megawatt-hours and there are four power generation options for Cambodia: (i) hydropower, (ii) gas, (iii) coal, and (iv) mixed generation. In case of (ii), (iii), and (iv), we need to estimate fossil fuel consumption as follows;

i. No fuel consumption because of hydropower generation.
ii. If we assume thermal efficiency of gas power generation at 45%, gas consumption is estimated at 173 ktoe.
iii. If we assume thermal efficiency of coal power generation at 35%, coal consumption is estimated at 223 ktoe.
iv. If we assume 1/3 per each power source as share of power generation mix and the same thermal efficiency of gas and coal power generation, gas and coal consumption are estimated at 58 ktoe (gas) and 74 ktoe (coal).

If the additional electricity demand reflected by EV penetration (50%) is generated by coal power plants, energy consumption is highest at 223 ktoe, followed by gas at 173 ktoe, mixed generation at 158 ktoe, and hydropower at 78 ktoe. Thus, hydropower is recommended for EV penetration (Figure. 5.3).

### Figure 5.3 Increased Energy Consumption due to the Penetration of Electric Vehicles into the Power Sector



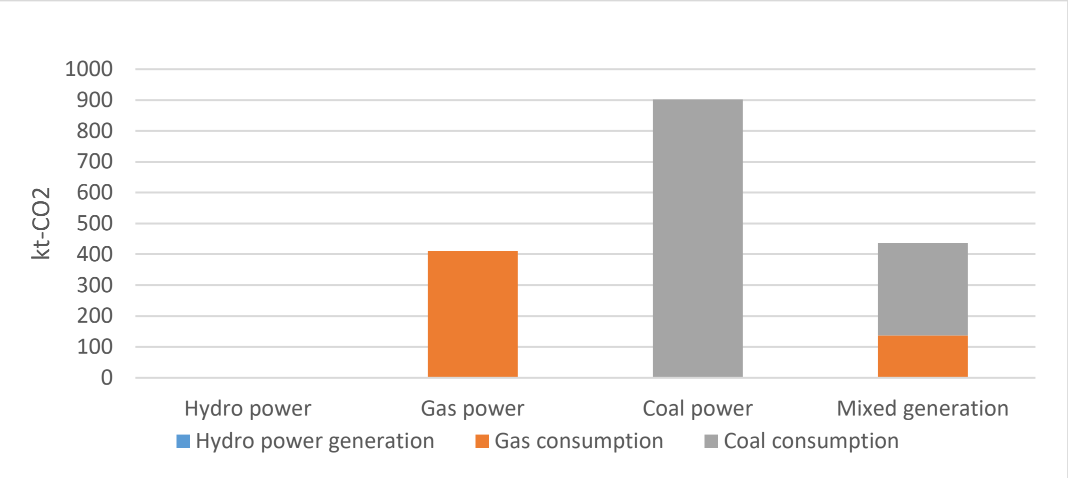

ktoe = kilotonnes of oil equivalent

Source: Author' calculations.

Fossil fuel consumption for power generation emits $CO_2$, so next we estimate the increase in $CO_2$ emissions resulting from the EV penetration:

i. No $CO_2$ emissions due to hydropower generation.
ii. If we assume the thermal efficiency of gas power generation at 45%, gas consumption is estimated at 410,000 tonnes of $CO_2$.
iii. If we assume the thermal efficiency of coal power generation at 35%, coal consumption is estimated at 902,000 tonnes of $CO_2$.
iv. If we assume 1/3 per each power source as a share of the power generation mix and the same thermal efficiency of gas and coal power generation, gas and coal consumption are estimated at 138 ktoe (gas) and 299 ktoe (coal), making a total of 437,000 tonnes of $CO_2$.

Figure 5.4 The Increase in Carbon Dioxide Emissions in The Power Sector

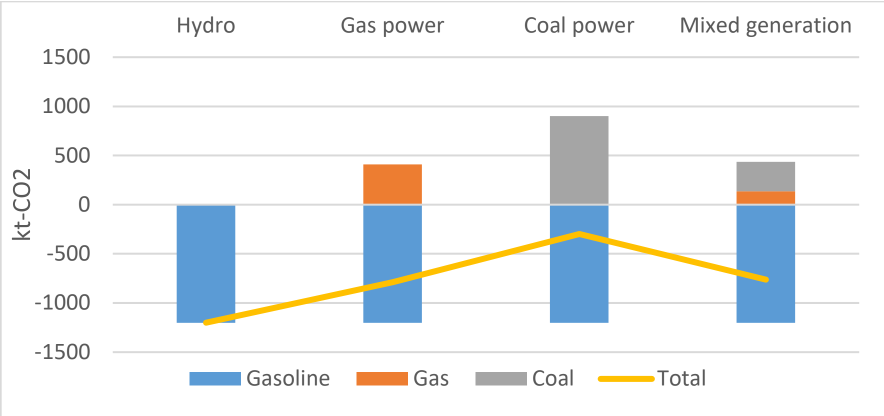



Kt-$CO_2$ = kilotonne of carbon dioxide.
Source:

## 4. Overall Impact

EV penetration reduces $CO_2$ emissions due to a decrease in gasoline consumption. However, it increases power generation due to the additional electricity demand. Thus, levels of $CO_2$ emissions in the power sector are dependent on the power source selected. If Cambodia generates electricity by hydropower to meet the additional electricity demand created by EV penetration, no $CO_2$ emissions are expected. But, if Cambodia selects thermal power generation, $CO_2$ will be emitted. However, gas power generation is much better than coal power generation, Thus, in terms of $CO_2$ emissions, renewable power generation such as hydropower is strongly recommended, followed by gas power generation, mixed generation, and coal power generation (Figure 5.5).

Figure 5.5 The Overall Impact of Electric Vehicle Penetration on Carbon Dioxide Emissions




Kt-$CO_2$ = kilotonne of carbon dioxide.
Source: Authors' calculations.

## 5. The Impact on the Energy Balance Table of Cambodia in 2021

If we assume 50% EV penetration and 1/3 power generation by hydro, coal, and gas power generation, the EBT of Cambodia in 2021 (Table 5.1) must be changed. Import and consumption of gasoline are reduced, however, hydropower generation, coal imports and coal consumption at coal power plants, and gas imports and gas consumption at gas power plants are increased. But TPES and TFEC are less than the original EBT. In the case of EV penetration, TPES is 6.763and TFEC is 6.194. On the other hand, TPES is 7.372 and TFEC is 6.551 if there is no EV penetration. Thus, EV penetration brings energy savings and the mitigation of $CO_2$ emissions, but renewable energy and gas power generation are recommended.

Table 5.2 Cambodia's Revised Energy Balance Table including Electric Vehicle Penetration, 2021

| | Coal (sub bituminous) | Petroleum products | Gasoline | Jet kerosene | Diesel oil | Residual oil | LPG | Lubricant | Gas | Hydro | Solar | Electricity | Biomass | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Indigenous production | - | - | - | - | | | | | | 0.465 | 0.036 | | 1.983 | 2.484 |
| Import | 1.461 | 2.802 | 0.437 | 0.062 | 1.744 | 0.067 | 0.413 | 0.079 | 0.058 | | | 0.348 | | 4.669 |
| Export | - | - | - | - | | | | | | | | | | - |
| International bunker oil | | 0.060 | | 0.060 | | | | | | | | | | 0.060 |
| Total primary energy supply | 1.461 | 2.742 | 0.437 | 0.002 | 1.744 | 0.067 | 0.413 | 0.079 | 0.058 | 0.465 | 0.036 | 0.348 | 1.983 | 7.093 |
| Power generation | -0.967 | -0.111 | | | -0.083 | -0.028 | | | -0.058 | -0.465 | -0.036 | 0.947 | -0.011 | -0.701 |
| Transmission & distribution losses | - | - | | | | | | | | | | -0.202 | | -0.202 |
| Total transformation | -0.967 | -0.111 | | | -0.083 | -0.028 | | | | -0.465 | -0.036 | 0.745 | -0.011 | -0.845 |
| Statistics difference | -0.000 | -0.000 | - | -0.000 | - | - | - | - | | - | - | -0.001 | -0.001 | -0.002 |
| Total final energy consumption sector | 0.494 | 2.631 | 0.437 | 0.002 | 1.661 | 0.039 | 0.413 | 0.079 | | - | - | 1.094 | 1.973 | 6.192 |
| Industry | 0.494 | 0.226 | | | 0.187 | 0.039 | | | | | | 0.366 | 1.390 | 2.476 |
| Transport | - | 1.714 | 0.437 | 0.002 | 1.184 | | 0.091 | | | | | 0.078 | | 1.792 |
| Road | - | 1.712 | 0.437 | - | 1.184 | | 0.091 | | | | | 0.078 | | 1.790 |
| Rail | - | - | | - | | | | | | | | | | - |
| Air | - | 0.002 | | 0.002 | | | | | | | | | | 0.002 |
| Inland waterways | - | - | | | | | | | | | | | | - |
| Other sector | - | 0.612 | | | 0.290 | | 0.322 | | | | | 0.650 | 0.583 | 1.845 |
| Commercial | - | 0.312 | | | 0.032 | | 0.280 | | | | | 0.286 | | 0.598 |
| Residential | - | 0.062 | | | 0.020 | | 0.042 | | | | | 0.364 | 0.583 | 1.009 |
| Agriculture | - | 0.149 | | | 0.149 | | | | | | | | | 0.149 |
| Other | - | 0.089 | | | 0.089 | | | | | | | | | 0.089 |
| Non-energy use | - | 0.079 | | | | | | 0.079 | | | | | | 0.079 |

- = negative number, LPG = liquified petroleum gas.

Source: Authors calculations.

# Chapter 6

# The Support System for Electric Vehicles in Cambodia

## 1 Introduction

ICE vehicle users benefit from a widespread and convenient refuelling station network. But EV charging infrastructure is in its early development stage, especially in ASEAN countries.

In principle, an EV can be plugged into a home wall-mounted box, which is the simplest EV service equipment, but home charging is not as simple as it seems, and the long charging time is its main inconvenience. Moreover, increasing grid pressure is a risk as home charging takes place mainly in the late afternoon after working hours, when household electricity demand is peaking. These are the main reasons for developing different types of chargers and installing them in public spaces such as parking lots, workplaces, petrol stations, and motorway rest areas.

### 1.1. Charger Types

Chargers on the market can be divided into slow and fast. Slow chargers use an alternating current (AC) under 400 volts, whilst fast chargers use a direct current (DC) of 400 volts and above. Most charging stations are slow and more than 88% have 22 kilowatt (kW) power or lower. This category includes 2.3 kW household plugs that take about 9 hours to completely recharge a common EV. Most EVs can be home-charged via an AC outlet of 3.3 kW–11 kW.

Slow chargers are Level 1 (120 volts) and Level 2 (200 volts–240 volts) and suitable for short trips, whilst DC fast chargers, most often found in public locations such as motorway rest areas, are best for longer journeys (Hall and Lutsey, 2017). Both recharging times are significantly longer than ICE vehicle refuelling times.

Table 6.1 classifies chargers into four modes, corresponding to a specific charging speed, required voltage, electric current, and level of communication between vehicle and power outlet.

Slow chargers are also often grouped into slow and semi-fast. It takes 6–8 hours to fully charge a pure BEV using slow chargers with a single-phase 3.3 kW of power and 120 volts–240 volts. This practice corresponds to home charging using a shared circuit without any safety protocol.

## Table 6.1 Different Modes of Plug-in Electric Vehicle Charging

| Mode | Name | Power (kilowatt) | Current | Phase | Charging time | Place | Voltage (volt) | Power Range (ampere) | Communication level | Further description |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Slow | 3.3 | AC | Single | 6–8 hours | Household, workplace wall box | 120–240 | Up to 16 | NANA | Shared circuit without safety protocols |
| 2 | Slow, semi-fast | 7.4 | AC | Single | 3–4 hours | Household, workplace wall box and public charging poles | 120–240 | Over 16 and up to 32 | Semi-active connection to vehicle to communicate for safety purpose | Shared or dedicated circuit with safety protocols, including grounding detection, overcurrent protection, temperature limits, and a pilot data line |
| 3 | Slow, semi-fast, or fast | 10 | AC | Three | 2–3 hours | | 240 | Any | Active connection between charger and vehicle | Wired-in charging station on a dedicated circuit, mode-two safety protocols, active communication line with the vehicle, i.e. smart charging suitability |
| | | 22 | AC | Three | 1–2 hours | Mostly public charging poles | | | | |
| 4 | Fast | 50 | DC | – | 20–30 minutes | Motorway service area or dedicated charging stations in urban areas (current standard) | 400 | | Active connection between charger and vehicle | Mode-three features with more advanced safety and communication protocols |
| | | 120 | DC | | 10 minutes | Motorway service area or dedicated charging stations in urban areas (future standard) | | | | |

AC = alternating current, DC = direct current, NA = not applicable.
Sources: Bakker (2013), Hall and Lutsey (2017), Spöttle et al. (2018).

With slow to semi-fast chargers, charging time should be reduced from 4 hours to 1 hour. Facilities with power greater than 3.3 kW but less than 22 kW can be found in households, workplaces, and public spaces. Chargers with power lower than 22 kW allow a maximum speed up to 2 hours of charging and can be applied to shared or dedicated circuits with safety protocols. Facilities with power higher than 22 kW reduce charging time down to 1 hour. Semi-fast chargers are installed mostly in public charging facilities often equipped with an active communication line between the charging point and the vehicle.

Finally, the DC fast chargers are often installed in motorway service areas or in urban dedicated charging stations where long charging time is less tolerated.

The situation is, however, complicated. Compatibility between EVs and charging point technology standards is an issue as there are at least five technology standards or connector types:

- Type-1 AC. Amongst the most popular EV connectors in this category are some produced by the Japanese manufacturer Yazaki, following the North American SAE J1772 standard. They are mostly slow chargers and can be found in North America and Japan.
- Type-2 AC. Most are fabricated by the German company Mennekes, following the AC charging technology standard gaining market share in Europe and China. This type is compatible with most EVs and AC chargers and can facilitate only single-phase and three-phase AC charging.
- Type-3 AC. Built by the EV Plug Alliance, mostly in Italy and in France, and used only up to 2012, when the Type-2 AC became dominant in Europe.
- Type-4 DC. Also known as the Japanese standard, CHAdeMO. It was the first widespread technical standard for DC fast charging developed by a Japanese consortium. This type is found not only in Japan but also in European countries, mostly in France.
- Combined Charging System (CCS). The combined AC and DC fast charging plugs are CCS Combo 1, preferred by the US car manufacturers, and CCS Combo 2, preferred by German manufacturers.
- Tesla supercharger infrastructure. This DC fast charger is used mostly in North America.

### 1.2. Standardisation and Interoperability

Charging stations are considered interoperable if they can serve a large variety of EV models and offer payment methods accessible to all EV drivers (Spöttle et al., 2018). Standardisation guarantees interoperability, provides clarity to manufacturers, allows for economies of scale, and ensures compliance with safety standards. EV charging interoperability means that EV users can charge their cars at any charging point using their usual choice of authorisation and payment method.

Charging infrastructure – at least the physical equipment, payment systems, and charging protocol – must be standardised. In Europe, for example, Type-2 AC and Type-3 AC coexisted, as did CHAdeMO and CCS Combo 2. In 2014, European Commission Directive 2014/94/EU required that all providers of public chargers include a Type-2 AC connector where Level 2 or fast AC charging is available, and a CCS connector where Level 3 charging is provided. In Southeast Asia, charging infrastructure is still in its development phase, but some trends are visible: Type-2 connectors are available for AC charging, and CCS Combo connectors are also available for DC charging in Malaysia, Singapore, and Thailand. CHAdeMO is available in Malaysia and Thailand.

Many charging station network operators in the early years of EV penetration developed their own payment systems. EV users normally subscribe to a charging station operator and cannot always charge or pay at a station belonging to another operator. A simple solution is for the user to subscribe to more than one operator. A more sophisticated solution is to allow roaming between operators as mobile phone network operators have been doing for years.

Finally, charging activity needs protocols that standardise the communication interface between the car, the charging stations, and the system that oversees monitoring and managing of the charging station, including the roaming platforms. That system is usually referred to as the charge point operator or charging service operator. For example, Europe has the open clearing house protocol supported by national charging infrastructure providers in Austria, Belgium, Germany, Ireland, Luxembourg, the Netherlands, and Portugal; open charge point protocol, initiated by ElaadNL, which is also involved in open clearing house protocol; and open charge point interface, supported by European operators.

### 1.3. Current Electric Vehicle Charging Infrastructure in Cambodia and Neighbouring Countries

The type of EV charging plug should be carefully considered when developing an EV framework, as it may affect the compatibility and design of future EV charging stations. By selecting the appropriate plug type, the infrastructure can serve a wide variety of vehicles, meet increasing demand, and align to local and industry requirements. As a comparison, we may draw insights from neighbouring countries that have made more advanced progress in the EV ecosystems.

Thailand, a leading country in ASEAN's EV ecosystem, recorded over 150,000 EVs by 2023 and 3,746 EV charging points (P3 Group, 2024). Of these, 64% are Type-2 (GB/T or Mennekes), 29% are CCS Combo-2 type, and the remaining 7% are Type-4 (CHAdeMO). This distribution aligns with Thailand's EV market, which is dominated by ORA vehicles (42.2%) that mainly uses Type-2 or CCS Combo-2 plugs, and MG vehicles (31.2%) – another Chinese brand – that also relies on these plug types (P3 Group, 2024) (Table 6.2). Similarly, in Viet Nam, the ecosystem includes approximately 3,000 charging stations or 15,000 charging points, (KPMG, 2024). With Vinfast leading the market, it is likely that most of their vehicles use Type-2 or CCS Combo-2 plugs, which are compatible with Chinese EV models.

Table 6.2 Electric Vehicle Charging Infrastructure Based on Plug Type (Points)

| EV Plug Type | Thailand (*) | Phnom Penh, Cambodia (**) |
|---|---|---|
| Type-1 (J1772) | - | 2 |
| Type-2 / GB/T / Mennekes | 2,404 | 31 |
| Type-3 | - | 1 |
| Type-4 / CHAdeMO | 263 | 2 |
| CCS Combo 2 | 1,079 | - |
| Tesla Supercharger | - | 1 |
| **Total** | **3,746** | **37** |

EV = electric vehicle
Source: *P3 Group, 2024, and **EVChargingStops, 2024.

Whilst the data about EV charging points in Thailand has been detailed according to its plug type, similar detailed data is lacking in Viet Nam. In Cambodia, there is also limited information on EV charging points. However, available data indicates that in Phnom Penh, 84% are for Type-2, 5% are for both Type-1 and Type-4, and 3% are for both Type-3 and Tesla supercharger (EVChargingStops, 2024) (Table 6.2). The EV charging plugs standards in Cambodia will be the CCS-2 standard, and thus all EVs in Cambodia must be fully compatible with the nationwide standard to ensure seamless accessibility and interoperability.

There are two reasons why the interoperability of charging points and stations is a key issue that Cambodia needs to consider when designing its strategy and plan for charging infrastructure deployment. First, the interoperability of charging facilities should allow smooth cross-border EV trips between the Mekong countries. Different plug types in the different countries should not create a constraint to road transport mobility in the region. Second, developing interoperable charging systems should encourage greater penetration of EVs as it will be easier to find charging points, thereby reducing driver anxiety.

### 1.4. Cost of Charging Infrastructure

Simple home charging can compete with more efficient gasoline cars and is even significantly cheaper when a time-of-use (TOU) electricity tariff with lower prices in off-peak periods is in place. More powerful home charging is sensitive to capital cost but competitive with moderately efficient ICE vehicles and would be substantially cheaper under a TOU regime (Lee and Clark, 2018).

The issue, however, is how to develop non-home-based charging points or stations as home charging has limitations. Developing such stations needs significant investment, supporting regulations, an adequate business model, and, in many places, central government intervention or initiatives.

China's central government, for instance, has funded a programme in 88 pilot cities, led by Beijing, Shanghai, and Shenzhen, to provide one charging point for every eight EVs. The charging points are grouped into stations, which must be no more than 1 kilometre from any point within the city centre (Hall and Lutsey, 2017).

The 13th Five-Year Plan (2016–2020) states that China shall build a nationwide charging station network that will fulfil the power demand of five million EVs by 2020 (Xin, 2017). The State Grid Corporation of China, the state-owned electric utility monopoly, had built more than 40,000 charging stations by 2016 and was planning to build a network of 120,000 public-individual charging points for electric cars by 2020, throughout major regions in China (Chen et al., 2018). China's National Energy Administration says that the country had a total of 450,000 stationary charging points in 2017, including around 210,000 publicly accessible units (Ying and Xuan, 2018).

Singapore's Land Transport Authority, announced in 2016 that it would install 2,000 charging points, and in 2017 reached an agreement with a private company, BlueSG Pte Ltd., to launch a nationwide car-sharing programme with a fleet of 1,000 PHEVs. The company planned to install and operate the charging points. Singapore Power Group, the state-owned electricity and gas distribution company, planned to roll-out 1,000 charging points by 2020, of which 250 would be 50 kW fast DC chargers able to fully charge a car in 30 minutes. Normal slow chargers cost around $3,700, whilst fast chargers cost $48,000. By September 2018, HEVs made up 4.3% of the total of around 615,000 registered vehicles, PHEVs made up 0.06%, and BEVs made up 0.08% (Tian, 2018). Many industrial players think the lack of charging facilities has been a main cause of slow EV penetration.

In Japan, the government created the massive Next Generation Vehicle Charging Infrastructure Deployment Promotion Project to fund charging stations around cities and highway rest stations in 2013 and 2014 (CHAdeMO, 2016). The nationwide Nippon Charge Service, a joint project of the state-owned Development Bank of

Japan with Nissan, Toyota, Honda, Mitsubishi, and Tokyo Electric Power Company, operates almost 7,500 stations.

In the US, by 2017, around 47,000 charging outlets had been built all over the country. The General Services Administration had installed EV charging stations for federal employees and other authorised users, and more than 10 states were offering rebates and tax credits to commercial customers and homeowners for installing charging stations (Lu, 2018).

In several EV front-runner countries in Europe, the public sector and private investors financed early charging infrastructure when the use of chargers was not yet high enough to be profitable, with public subsidies being phased out in 2020–2025. Technological acceptance and spread and economies of scale should stimulate similar developments in other European countries (T & E, 2018).

What follows is a summary of public charging facility costs in EV front-runner countries. We focus on the top priority for ASEAN countries, which is to develop slow or semi-fast Level 2 charging facilities, and on fast charging infrastructure, installation of which will be much more limited, depending on mobility purposes and needs.

### *1.4.1 Slow to Semi-fast AC Charging Facility Costs*

Table 6.3 shows that the hardware costs of slow to semi-fast charging facilities are comparable, even between Europe, India, and the US.

**Table 6.3 Examples Purchase and Installation Costs of Slow and Semi-Fast Charging Facilities**

| Countries (currency) | Application | Costs | Included items |
|---|---|---|---|
| US ($, 2017) | L2 – home | 450–1,000 (50–100) | Charging station hardware (additional electrical material costs in parentheses) |
| | L2 – parking garage | 1,500–2,500 (210–510) | |
| | L2 – kerb side | 1,500–3,000 (150–300) | |
| France, Germany, Italy, Netherlands, Spain, UK (€ 2017)* | 3.7 kW new residential building | 1,170 | Materials (for installation, including cables); wall box (hardware of charging station, excluding cables); and labour (around 20% of total costs) |
| | 3.7 kW operating residential building | 1,280 | |
| | 7.4 kW new non-residential building | 1,760 | |
| | 7.4 kW operating non-residential building | 2,025 | |

| Countries (currency) | Application | Costs | Included items |
|---|---|---|---|
| Germany (€, 2017)** | >3.7 kW – one charging point | 1,200 | Complete hardware, including communication and smart meter |
| | 11 kW or 22 kW – two charging points | 5,000 | |
| India ($, 2019)*** | Bharat charger AC 001-1 point(s)-3 phase 415 volt-3 x 3.3 kW | 980 | Approximate cost, including goods and services tax at 18% |
| | Type-2 AC Charger-1 point(s)-7.2 kW | 1,050 | |
| | CCS-2-1 point(s)-3 phase 415 volt-25 kW | 9,800 | |
| EU 28 average (€, 2018)**** | AC mode 2 – home (up to 11 kW) | <800 | Purchase cost for a single charging point, not installation, grid connection, or operational costs |
| | AC mode 2 – commercial (up to 19.4 kW) | <2,000 | |
| | AC mode 3 – fast (22 kW of 43 kW) | 1,000–4,000 | |

$ = US dollar, € = euro, AC = alternating current, EU = European Union, kW = kilowatt, UK = United Kingdom, US = United States.
Source: Authors' research based on *CREARA Analysis (2017), ** NPE (2015), *** Pillai et al. (2018), and **** Spöttle et al. (2018).

In the US, a simple home 3.7 kW charger costs only around $500, whilst a 7.2 kW charger that can fully charge a EV in around 4 hours costs around $1,000 – almost the same as in Europe and India – which shows that local content of charger production in India is low. For chargers of 22 kW or more, costs in India are much higher than in the US or Europe, which means India still does not enjoy economies of scale for charging hardware production.

The charger's power, electric power phases, and number of charging points are amongst the factors that determine the cost of EV charger hardware and materials.

Home installations are used less intensively, have lower safety requirements, and are therefore less costly than public stations, which are more sophisticated and might include liquid-crystal display screens, advanced payment and data tracking communication, and dual-port power routing capabilities (Fitzgerald and Nelder, 2017).

Installation methods significantly affect total installation costs: installation from scratch is always cheaper than from partially make-ready facilities such as those that are pre-piped or pre-cabled. Several European governments stimulate development of partially make-ready charging facilities by the private sector, e.g. building or utility owners (CREARA Analysis, 2017).

*6.1.4.2 Fast DC Charging Facility Costs*

DC Level 3 charging stations reduce charging time, but they cost significantly more than a Level 2 charger because of two factors: expensive equipment and the frequent need to install a 480 volt transformer. Fast charger hardware is significantly more expensive than Level 2, and in the US a transformer might cost another $10,000–$20,000 (Fishbone, Shahan, and Badik, 2017). Installing DC fast charging stations in the US typically costs as much as $50,000. Inclusion of project development, design, permits, and system upgrades can raise the total cost of DC fast charging deployment as high as $300,000 each (Fitzgerald and Nelder, 2018) (Table 6.4).

Table 6.4 Examples of Fast Charging Facility Purchase and Installation Costs

| Countries (currency) | Application | Costs | Included items |
|---|---|---|---|
| US ($, 2017)* | DC fast charging | 12,000–35,000<br>(300–600) | Charge station hardware (plus extra electrical materials) |
| Germany (€, 2017)** | 50 kW | 25,000 | Complete hardware, including communication and smart meter |
| EU 28 average (€, 2018)*** | DC fast – standard (20 kW–50 kW) | 20,000 | Purchase cost for a single charging point, not installation, grid connection, or operational costs |
| | DC high power – fast (100 kW–400 kW) | 40,000–60,000 | |

$ = US dollar, € = euro, DC = direct current, EU = European Union, kW = kilowatt, US = United States.
Source: Authors' research from *Fitzgerald and Nelder (2017), ** NPE (2015), and *** Spöttle et al. (2018).

## 2. Electric Vehicles and Their Charging Infrastructure: A Chicken And Egg Issue

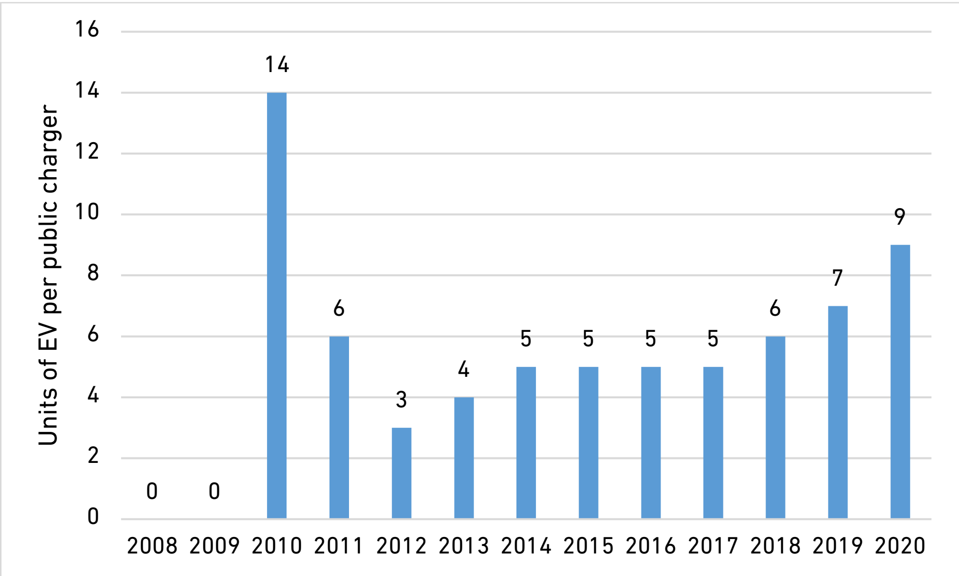
Fast charging stations need to achieve a sufficiently high utilisation ratio to compensate for the high total cost of installation and operation where grid impact will be low. DC fast charging hubs should serve high-usage fleets and ride-hailing vehicles, ideally along high-usage corridors and commuting routes around major cities, and rest areas for interurban trips on major highways (Lee and Clark, 2018).

Since 2011, we have witnessed the unprecedented growth of EV sales and charging infrastructure points across the world.

The European Alternative Fuels Observatory (EAFO) (EAFO, 2021) database shows that in the European Union (EU-27) and in six non-EU countries (Iceland, Lichtenstein, Norway, Switzerland, Turkey, and the United Kingdom), total road EV sales have increased from only 1,792 units in 2010 to 1,117,546 units in 2020, i.e. more than 620-fold during the 10-year period. Around 93% of the total road EV sales in 2020 consisted of passenger cars (M1 category). The EAFO database reveals that recharging infrastructure points in Europe have increased from 400 in 2010 to 224,237 in 2020 – more than 560-fold during the same period. In 2020, almost 89% of recharging points were normal chargers with power equal or less than 22 kW. The other 11% were fast chargers with power higher than 22 kW.

The ratio of the number of EV units per charger has fluctuated between 2008 and 2020 in the EAFO countries, i.e. EU-27 plus the Iceland, Lichtenstein, Norway, Switzerland, Turkey, and the United Kingdom. As shown in Figure 6.1, there was practically no public charging in 2008 and 2009. In 2010 around 400 chargers were built and operated. A massive installation of chargers in those countries reduced the ratio from 14 in 2010 to three in 2012. The ratio went up again afterwards to reach around nine EVs per public charger in 2020.

Figure 6.1 The Number of Electric Vehicle Units per Public Charger in European Alternative Fuels Observatory Countries




EV = electric vehicle.
Source: EAFO (2021).

Public charging infrastructure is key to EV market growth. Rough apparent patterns are observed between EV uptake and charging infrastructure availability, with substantial variability across markets. The development of a robust charging infrastructure network is a key requirement for large-scale transition to electromobility, but there is no universal benchmark for the number of EVs per public charge point (Hall and Lutsey, 2017).

Table 6.5 shows that the average ratios of EVs to charging stations in EV front-runners vary greatly between, or even within, regions.

Table 6.5 Average Ratios of Electric Vehicles per Public Charge Point

| Country | Region | EV/Public Charge Point Ratio |
|---|---|---|
| China* | China average | 8 (pilot cities)<br>15 (other cities) |
| World* | Worldwide | 8 (2015))<br>15 (2016) |
| United States* | US average | 7–14 |
| | | 24 |
| | California | 27 |
| EU | EU average* | 10 |
| | The Netherlands** | 3.6 |
| | Norway** | 15.2 |
| | Germany** | 6.7 |
| | UK** | 9.7 |
| | France** | 7.6 |

EU = European Union, UK = United Kingdom, US = United States.
Source: Authors' research from * Hall and Lutsey (2017) and *** Spöttle et al. (2018).

EU data show that the EV market share of new registrations rises as the vehicle to charging point ratio drops from 25 to 5. A low ratio would benefit EV uptake but infrastructure coverage denser than one charging point per 10 EVs would be inefficient: sales numbers become insensitive with a decreasing ratio. The high costs of additional charging infrastructure, therefore, do not justify high investments (Harrison and Thiel, 2017).

A study on the relationship between the number of EVs and publicly accessible charging points in Europe (EU 28 + Norway) demonstrates two interesting findings. First, with some variation in the countries' national context, the density of charging infrastructure generally correlates positively with EV adoption. A range of other factors are proven or suspected to be correlated with EV uptake, such as model availability, financial incentives, urban density, etc. Charging infrastructure is necessary but not enough for EV adoption. Most front-runner countries have applied a demand-oriented approach to rolling out charging infrastructure. Second, the ideal ratio of EVs per charging point will, in the long run, lie between 10 and 16 (Spöttle et al., 2018).

The roll-out of charging infrastructure may be oriented towards demand or coverage. The demand-oriented approach assumes that charging infrastructure should be constructed where existing and future demand can be determined and aims for optimal allocation and utilisation of all charging points, thereby avoiding redundancies. The coverage-oriented approach is premised on public infrastructure guaranteeing a minimum standard of service to the widest possible public by minimising the distance between the charging points. None of the front-runner countries take the coverage-oriented approach, except the US, with its designated alternative fuel corridors; China, which has required 88 pilot cities to install a charging network with charging points positioned no farther than 1 kilometre from any point within the city centre; and Norway, where the government financed the deployment of at least two fast charging stations every 50 kilometres on all main roads by 2017 (Figenbaum, 2019).

A study for Thailand by Thananusak et al. (2020) proposed two types of policies to deal with the 'chicken and egg' issue. The first type of policy – the 'demand pull' – deals with boosting demand for EVs. This type might consist of providing rebates and tax credits for consumers, increasing the demand for EVs through government procurement activities, establishing regulations and standards that facilitate demand growth, and building consumer awareness. The second type of policy – the 'technology pull' – might consist of policies that aim to give favourable loans with low interest rates for investors; providing public co-funding charging stations; setting up preferential electricity selling rates; providing financial support for chargers and equipment purchase; providing rebates, investment subsidies, tax incentives, tax holidays, etc; and creating EV charging consortia to lay the foundation of interoperability.

## 3. Public Charging Supply-Cost Model

In this chapter we have implemented a methodology of public charging supply-cost model to Cambodia. The method was developed by Transport and Environment (2020) and can be used to calculate the number of public EV chargers needed at an aggregated level as well as the costs needed to roll-out those chargers.

This implementation is nevertheless a mere exercise as it involved many assumptions that are based on literature or practices in other countries. A more proper implementation of the method should include an in-depth series of consultations and surveys with many stakeholders in Cambodia which is beyond the scope of this study.

### 3.1. Methodology

The public charging supply-cost model considers the determination of the number of public charging stations from both the demand and supply sides.

Basically, the number of EV chargers per charger type in the model is calculated by dividing the electric energy needed per charger type, which represents the demand side, by the electric energy to be delivered by each charger type, which represents the supply side.

Therefore, from the **demand** side we need to have at least four main inputs:

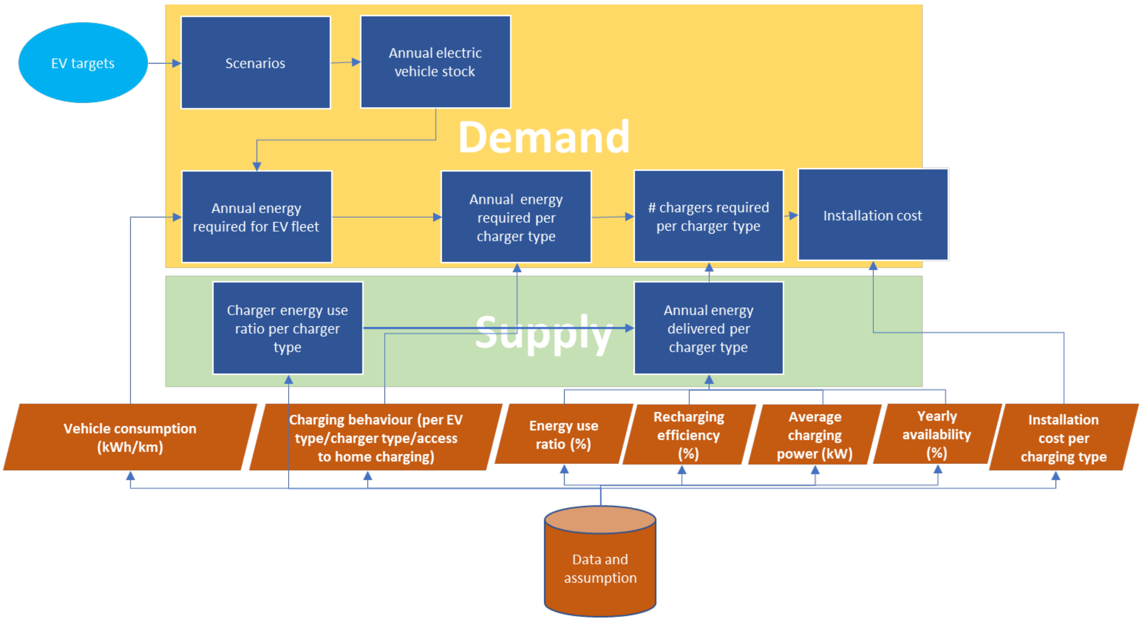
- the energy required by the EV fleet,
- the number of EVs,
- charging behaviour, and
- the battery efficiencies of the EVs.

From the **supply** side, we need to have the following inputs at charger type level:

- charger energy use ratio,
- recharging efficiency,
- charging power, and
- periodical charger availability.

Figure 6.2 shows the flowchart summarising the public charging supply-cost model. The detailed calculations of the model are then explained. In line with Chapter 1, the time period of this exercise for Cambodia is between 2018 and 2050 with calculation done on a yearly basis.

Figure 6.2 Flowchart of the Public Charging Supply-Cost Model




# = number, % = percent, EV = electric vehicle, km = kilometre, kW = kilowatt, kWh= kilowatt hour.
Source: Authors' adaptation of the model from Transport and Environment (2020).

*3.1.1 Demand Side*

Calculated at the level of EV type, as given in Equation 2, the annual electricity required by the EV fleet is calculated by multiplying the number of EVs, the average battery efficiency, and the average kilometres travelled of the corresponding year. The total electricity needed by all EV is simply the sum of electricity needed for all EV types (Equation 3).

Equation 2. $\boldsymbol{ENEREQEV_{ev\,type} = VEHTOT_{ev\,type}.BATTEFF_{ev\,type}.MILEAGE_{ev\,type}}$

Where

$ENEREQEV_{ev\,type}$: annual energy required for each EV type (kWh)

$VEHTOT_{ev\,type}$: total stock of EV per EV type

$BATTEFF_{ev\,type}$: average battery efficiency for each EV type (kWh/km)

$MILEAGE_{ev\,type}$: average annual travelled kilometre for each EV type (km)

Equation 3. $\boldsymbol{ENEREQTOT = \sum_{evtype} ENEREQ_{evtype}\,.\,10^{-6}}$

Where

$ENEREQTOT$: annual total energy required for all EVs (GWh)

The annual energy required for each charger type is calculated by multiplying the total electric energy required to feed EVs by the usage percentage of each charger type and the access to chargers as given in Equation 4.

The usage percentage of each charger type represents the charging behaviour, i.e. how power is distributed across the different charger types in a particular region and period. Since public chargers have usually been rolled out starting from the slow types, it is logical to assume high-usage percentages of slow chargers at the beginning of the period. With time, semi-fast and fast chargers should be quantitatively more available and therefore the usage percentages should also shift gradually from the slow to semi-fast and fast charger types.

Equation 4. $\boldsymbol{ENEREQCHAR_{charger\,type} = ENERQTOT.CHARBHV_{charger\,type}.CHARACC_{charger\,type}}$

Where

$ENEREQCHAR_{charger\,type}$: annual energy required for each charger type (GWh)

$CHARBHV_{charger\,type}$: charging behaviour or usage percentage amongst the different charger types (%)

$CHARACC_{charger\,type}$: access to charger (home charger: 95%, the rest of chargers: 100%)

### *3.1.2 Supply Side*

Annual electric energy delivered by each charger type is calculated using Equation 5 as the result of multiplying recharging efficiency or losses from plug to battery, the availability of each charger during the day, the ratio of total electric energy delivered to the total maximum energy capacity (charger at maximum power of 24 hours in a 7-day period), and the average power level than can be delivered by a charger in one hour.

Equation 5. $\boldsymbol{ENERDLVCHAR_{charger\ type} = CHAREFF_{charger\ type}.AVAILYEAR_{charger\ type}.ENERATIO_{charger\ type}.}$

$\boldsymbol{CHARPWR_{charger\ type}.24.3654}$

Where

$ENERDLVCHAR_{charger\ type}$: annual electric power delivered by each type of charger (GWh)

$CHAREFF_{charger\ type}$: recharging efficiency or losses from plug to battery (%)

$AVAILYEAR_{charger\ type}$: availability or uptime during the day (%)

$ENERATIO_{charger\ type}$: energy use ratio (%) or the ratio of total energy delivered to the total max power capacity (charger at maximum power of 24 hours in 7-day period)

$CHARPWR_{charger\ type}$: average power level can be delivered by a charger in one hour (kW)

As shown in Equation 6, the number of chargers needed is calculated by dividing the annual power required for each charger type, obtained by the Equation 4, by the annual power delivered by each charger type obtained in Equation 5. The number of public chargers is the sum of all chargers that belong to public charger categories as given in the Equation 7.

Equation 6. $\boldsymbol{NBCHAR_{charger\ type} = \frac{ENEREQCHAR_{charger\ type}}{ENERDLVCHAR_{charger\ type}}}$...

where

$NBCHAR_{charger\ type}$: number of chargers needed by charger type (GWh)

$ENEREQCHAR_{charger\ type}$: annual energy required for each charger type (GWh)

$ENERDLVCHAR_{charger\ type}$: annual energy delivered by each type of charger (GWh)

Equation 7. $\boldsymbol{TOTNBCHAR = \sum_{charger\ type \in public} NBCHAR_{charger\ type \in public}}$

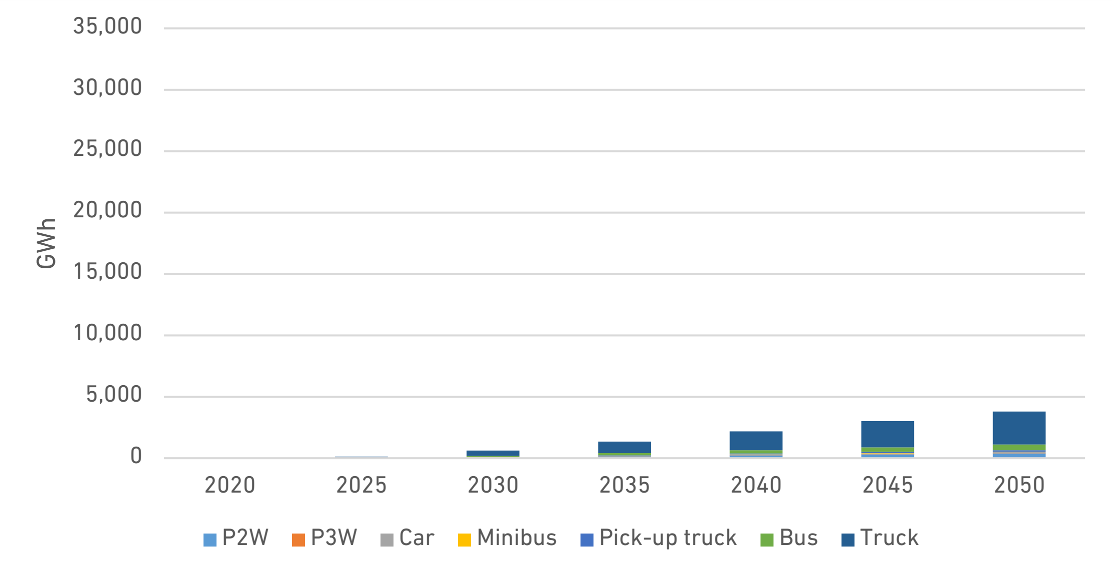
## 3.2. Results

### *3.2.1 Electricity Demand of Road Transport Vehicles*

The demand for electric power to feed EVs in four scenarios, i.e. BAU, EV20, EV40, and EV60 was calculated in Chapter 2. Figure 6.3–Figure 6.5 show the electricity needed in the four scenarios differentiated by EV types, i.e. two-wheelers, three-wheelers, car, minibus, pickup truck, bus, and heavy-duty truck (or simply 'truck').

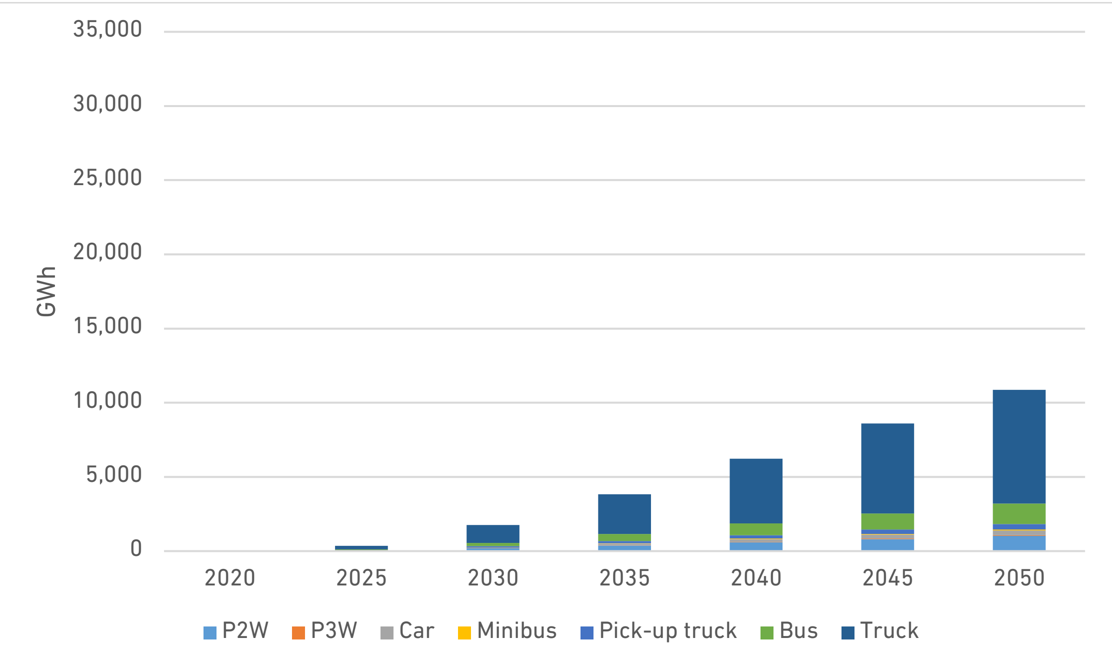
In the four scenarios we can see that electric trucks would need almost 70% of the total electric power and therefore have the lion's share of the electricity for EVs. With around 13%, electric buses' electricity demand share would be the second highest, whilst electric two-wheelers' share would be the third highest (around 9%-10%), followed by pickup trucks (4%) and cars (3%).

Figure 6.3 The Electricity Demand of Road Transport Vehicles in the Business-as-Usual Scenario




GWh = gigawatt-hour, P2W = powered two-wheeler, P3W = powered three-wheeler.
Source: Authors' calculations.

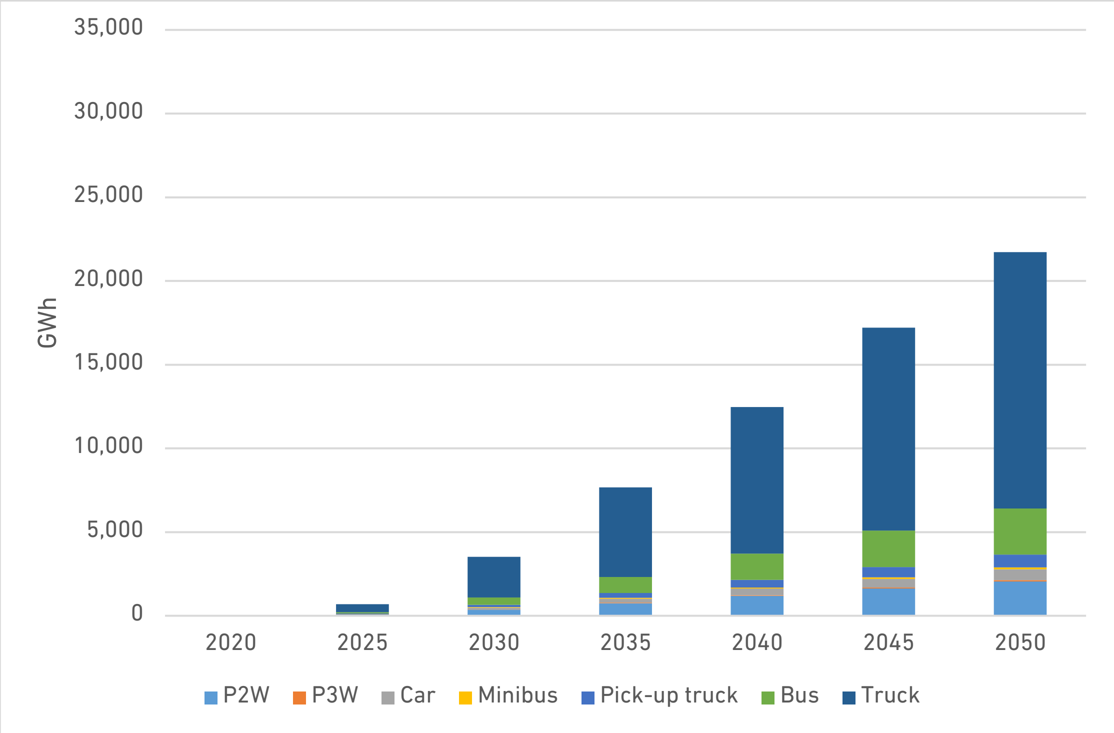
Figure 6.4 The Electricity Demand of Road Transport Vehicles in the Electric Vehicle 20% Penetration Scenario




EV20 = electric vehicle 20% penetration scenario, GWh = gigawatt-hour, P2W = powered two-

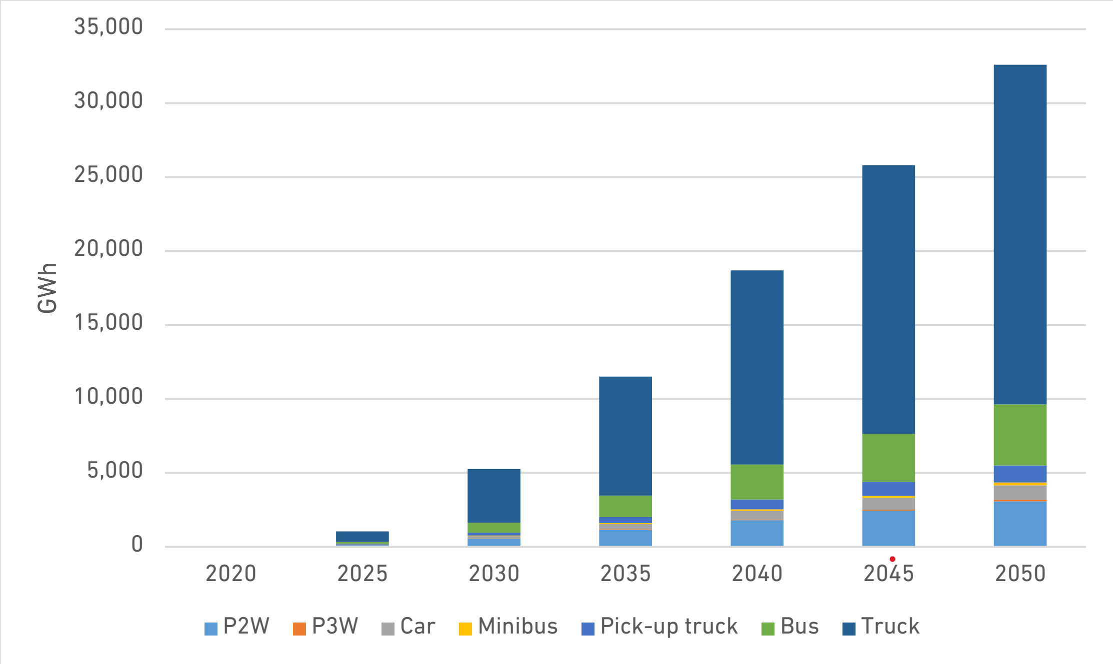
wheeler, P3W = powered three-wheeler.
Source: Authors' calculations.

Figure 6.5 The Electricity Demand of Road Transport Vehicles in the Electric Vehicle 40% Penetration Scenario




EV20 = electric vehicle 20% penetration scenario, GWh = gigawatt-hour, P2W = powered two-wheeler, P3W = powered three-wheeler.
Source: Authors' calculations.

Figure 6.6 The Electricity Demand of Road Transport Vehicles in Electric Vehicle 60% Penetration Scenario




EV20 = electric vehicle 20% penetration scenario, GWh = gigawatt-hour, P2W = powered two-wheeler, P3W = powered three-wheeler.
Source: Authors' calculations.

The high share of electric power needed to run electric heavy-duty trucks should be one of the considerations for Cambodia in its electrification programme, i.e. to include or not to include heavy-duty trucks in the programme. Heavy-duty trucks will need more superfast chargers as will be explained in the following sections.

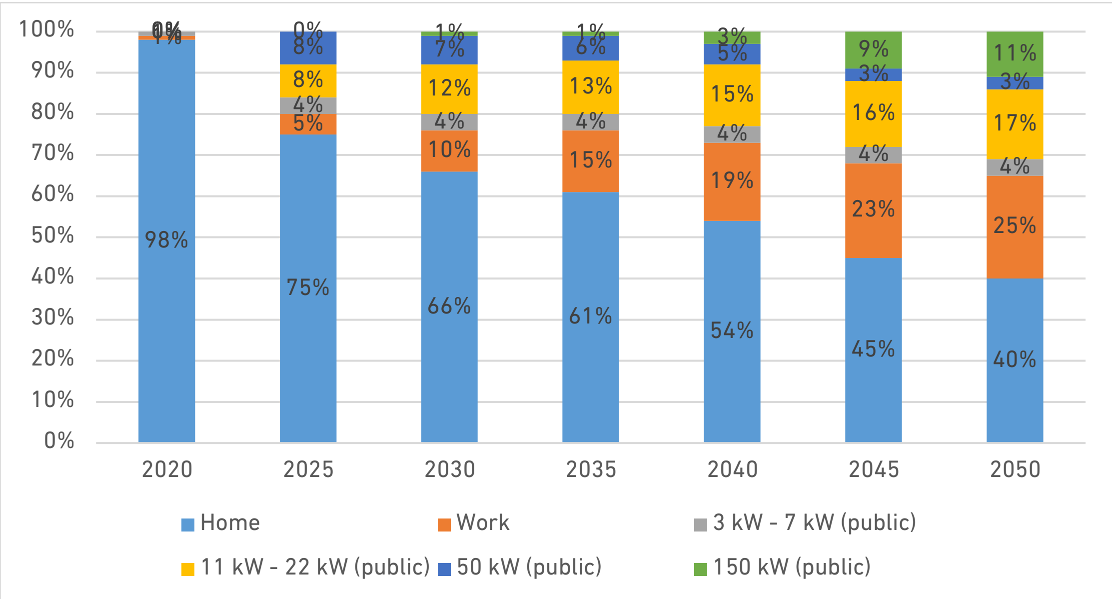
### *3.2.2 Electricity Demand by Charger Type*

To calculate the electricity demand by charger type, as determined by equation (3) we need to have charging behaviour, i.e. the distribution of energy shares amongst the different charger types. As shown in Figure 6.7, we assume that in Cambodia, home charging would constitute 98% of the total electricity used in 2020. By 2025, we assume that this share becomes 75% and would decrease to reach only 40% of the share by 2050. By this time, the power share of faster charger types should grow, and we assume that by 2050, 25% of power would be obtained at work, 4% at 3 kW–7 kW public chargers, 17% in 11 kW–22 kW public chargers, 3% in 50 kW public chargers, and 11% in 150 kW public chargers. The total private (home and work) power share would decrease then from 80% in 2025 to 65% in 2050, whilst that of public charging would increase from 20% in 2025 to 35% in 2050.

For comparison, in 2020, the average charging behaviour in EU countries, as reported in Transport and Environment (2020), consisted of around 45% home charging, 15% charging at work, 10% 3 kW–7 kW public chargers, almost 15% 11 kW–12 kW public chargers, and around 1% 150 kW superfast chargers. By 2030, the estimated average charging behaviour in the EU countries as reported in the same study would consist of around 60% home charging, 30% charging at work, 10% 3 kW–7 kW public chargers, almost 20% 11 kW–12 kW public chargers, and around 3% 150 kW superfast chargers.

The average charging behaviour in Cambodia in 2050 was then assumed to be just slightly better than that of the EU countries in 2020 in terms of share of private chargers (home and work) and the penetration of superfast 150 kW chargers. The assumption of strong use of 150 kW chargers was based on the high electricity demand arising from the penetration of heavy-duty EVs, especially e-trucks, in Cambodia as shown in Figure 6.3–Figure 6.6. E-trucks should be equipped with big batteries that would need to be charged rapidly using superfast chargers.

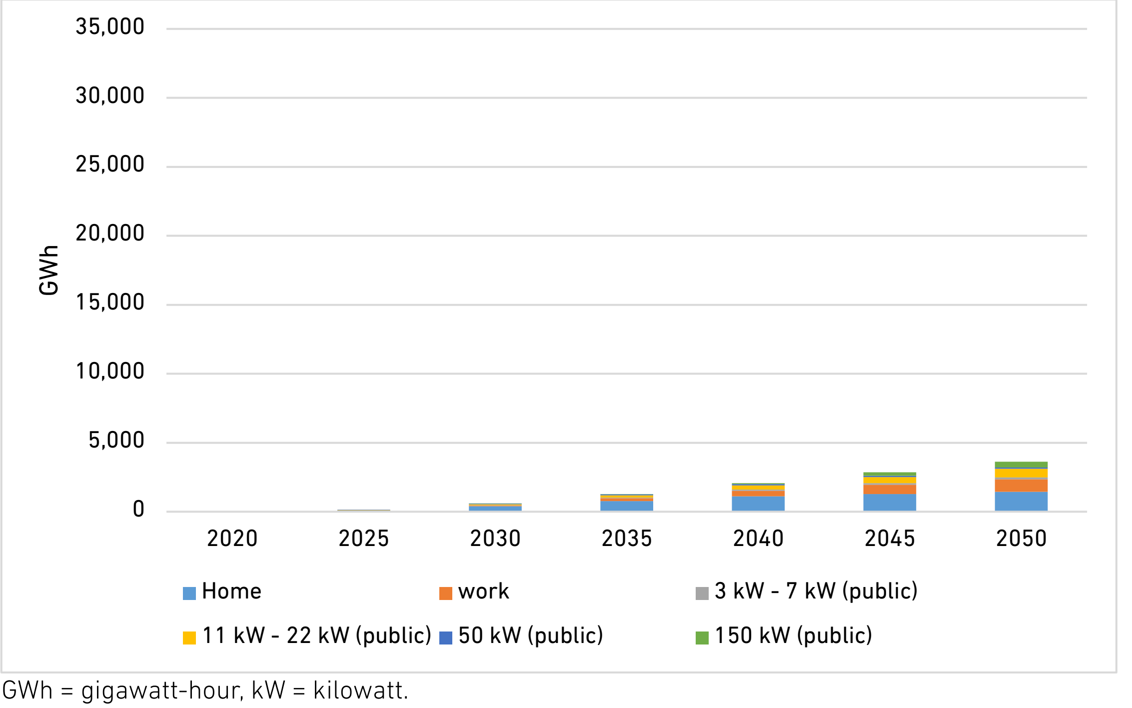
Figure 6.7 Charging Behaviour Assumptions




% = percent, kW = kilowatt.
Source: Authors' calculations.

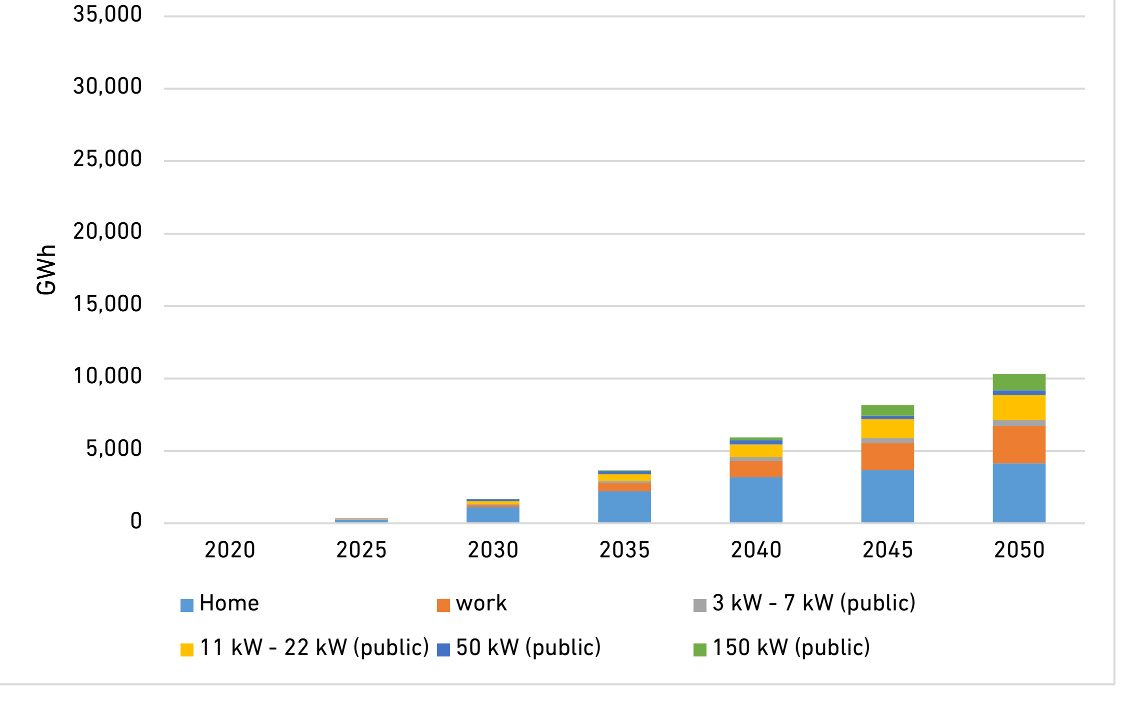
Assuming that public chargers would be 100% accessible and private chargers 95%, the electricity demand by charger types in the four scenarios are given in Figure 6.8–Figure 6.11.

Figure 6.8 The Electricity Demand by Charger Type in the Business-as-Usual Scenario



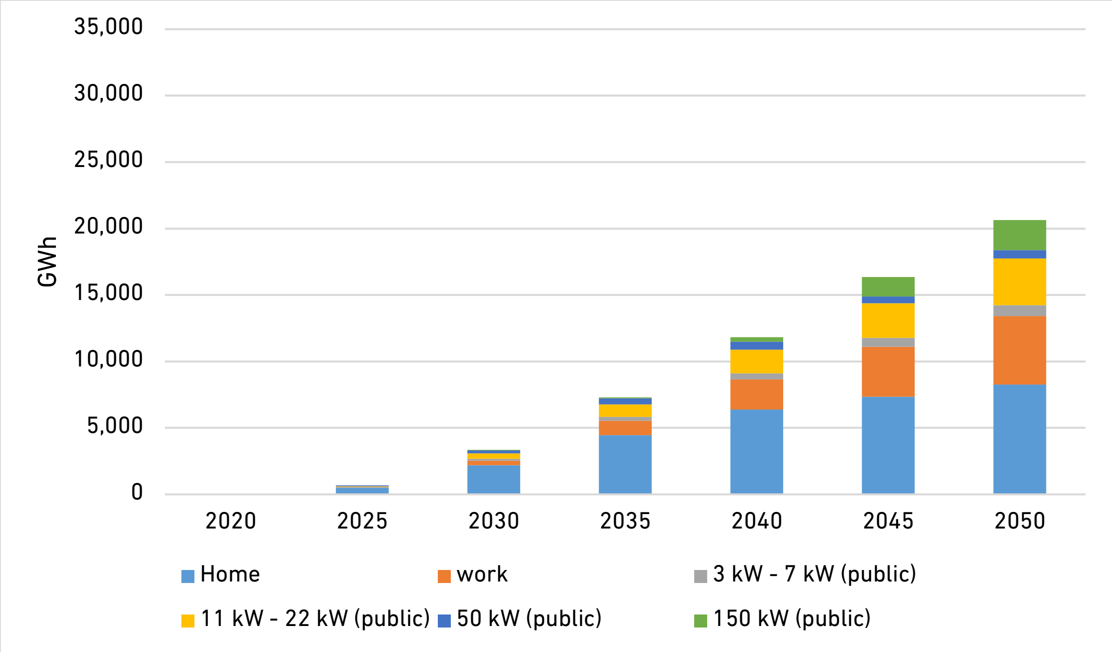

GWh = gigawatt-hour, kW = kilowatt.
Authors' calculations.

Figure 6.9 Electricity Demand by Charger Type in Electric Vehicle 20% Penetration Scenario



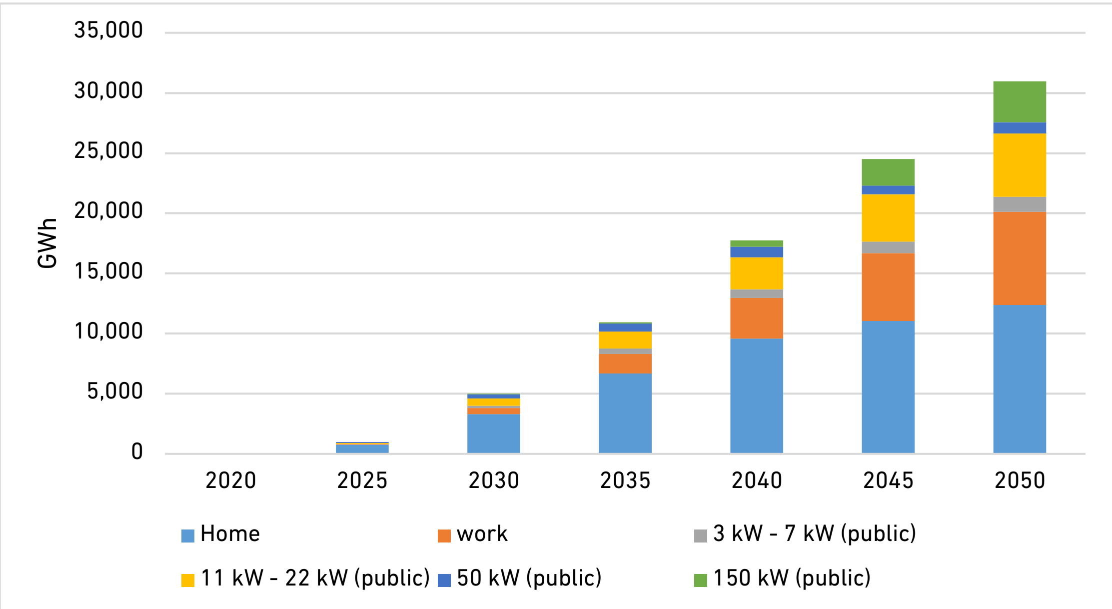

GWh = gigawatt-hour, kW = kilowatt.
Source: Authors' calculations.

Figure 6.10 The Electricity Demand by Charger Type in the Electric Vehicle 40% Penetration Scenario




GWh = gigawatt-hour, kW = kilowatt.
Source: Authors' calculations.

Figure 6.11 Electricity Demand by Charger Type in the Electric Vehicle 60% Penetration Scenario




GWh = gigawatt-hour, kW = kilowatt.
Source: Author's calculation.

The 95% accessibility assumption for private home chargers means that not all users live in dwellings where the garages are equipped with electric plugs that can be used to charge their EVs. Users who do not have a garage or live in flats without individual indoor parking spaces are assumed amongst the 5%. In consequence, the total electric power needed by the EV fleet given in Figure 6.3–Figure 6.6 are then slightly higher than the total electricity needed by chargers.

Table 6.6 shows three other important assumptions from the supply side, i.e. the availability or uptime of chargers; recharge efficiency, or losses from plug to battery; and the average charging power of each charger type.

Uptime of chargers is assumed to increase from 95% in 2020 to 99% in 2050, whilst recharge efficiency is assumed to be constant at 95% during the analysed period.

Table 6.6 Assumptions on Availability, Efficiency, and Charging Power

| | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| Availability (or uptime) | 95% | 96% | 97% | 98% | 99% | 99% | 99% |
| Recharge efficiency (losses from plug to battery) | 95% | 95% | 95% | 95% | 95% | 95% | 95% |
| Average charging power (kW) | | | | | | | |
| Home | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| Work | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 3–7 kW (public) | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 11–22 kW (public) | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| 50 kW (public) | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 |
| 150 kW (public) | 150.0 | 150.0 | 150.0 | 150.0 | 150.0 | 150.0 | 150.0 |

% = percent, kW = kilowatt.
Source: Author's estimation based on Transport and Environment (2020).

Table 6.7 and Table 6.8 show two distinct assumptions of energy use ratio, which is the ratio of total energy delivered with the total maximum energy capacity, i.e. charger at the maximum power 24 hours x 7 days. Assumption 1 (Table 6.7) supposes that energy ratios of all public chargers would increase gradually from 2020 to 2050. Assumption 2 (Table 6.8) supposes that energy use ratios of public chargers will only increase between 2025 and 2035. From 2025 onwards the energy use ratios of public chargers stay constant.

Table 6.7 Assumption 1: Increasing Energy Use Ratio in Public Charging from 2020 to 2050

| | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| Home | 12.0% | 12.0% | 12.0% | 12.0% | 12.0% | 12.0% | 12.0% |
| Work | 12.0% | 12.0% | 12.0% | 12.0% | 12.0% | 12.0% | 12.0% |
| 3–7 kW (public) | 0.0 | 3% | 5% | 7% | 10% | 14% | 15% |
| 11–22 kW (public) | 0.0 | 1% | 2% | 3% | 7% | 9% | 12% |
| 50 kW (public) | 0.0 | 1% | 2% | 4% | 4% | 5% | 7% |
| 150 kW (public) | 0.0 | 0% | 1% | 2% | 3% | 4% | 5% |

% = percent, kW = kilowatt.
Source: Author's assumptions.

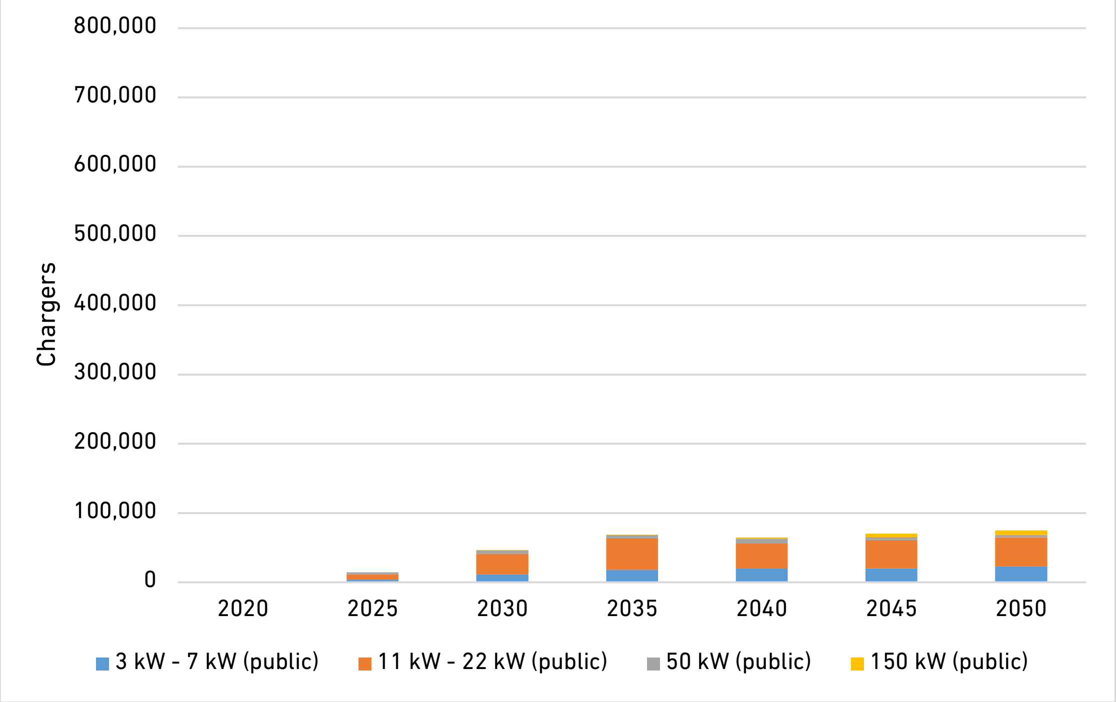
Table 6.8 Assumption 2: Constant Energy Use Ratio in Public Charging from 2020 to 2040

| | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| Home | 12.0% | 12.0% | 12.0% | 12.0% | 12.0% | 12.0% | 12.0% |
| Work | 12.0% | 12.0% | 12.0% | 12.0% | 12.0% | 12.0% | 12.0% |
| 3–7 kW (public) | 0.0 | 3% | 5% | 5% | 5% | 5% | 5% |
| 11–22 kW (public) | 0.0 | 1% | 2% | 2% | 2% | 2% | 2% |
| 50 kW (public) | 0.0 | 1% | 2% | 2% | 2% | 2% | 2% |
| 150 kW (public) | 0.0 | 0% | 1% | 1% | 1% | 1% | 1% |

% = percent, kW = kilowatt.
Source: Author's assumptions.

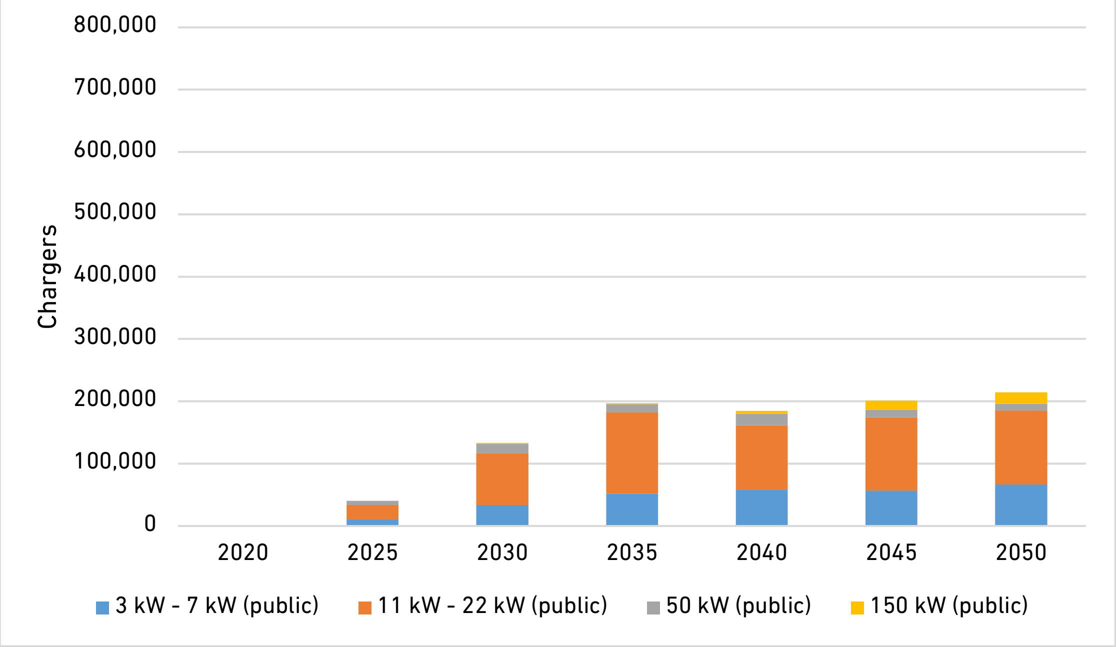
The effects of the two assumptions are seen in the calculated number of public chargers (Figure 6.12–Figure 6.15) under Assumption 1 where the energy use ratios increase gradually from 2020 to 2050 and where the total number of public charging points would reach between 75,000 (BAU) to 643,000 (EV60) in 2050.

Figure 6.12 The Number of Public Chargers in the Business-as-Usual Scenario – Energy Use Ratio Assumption 1



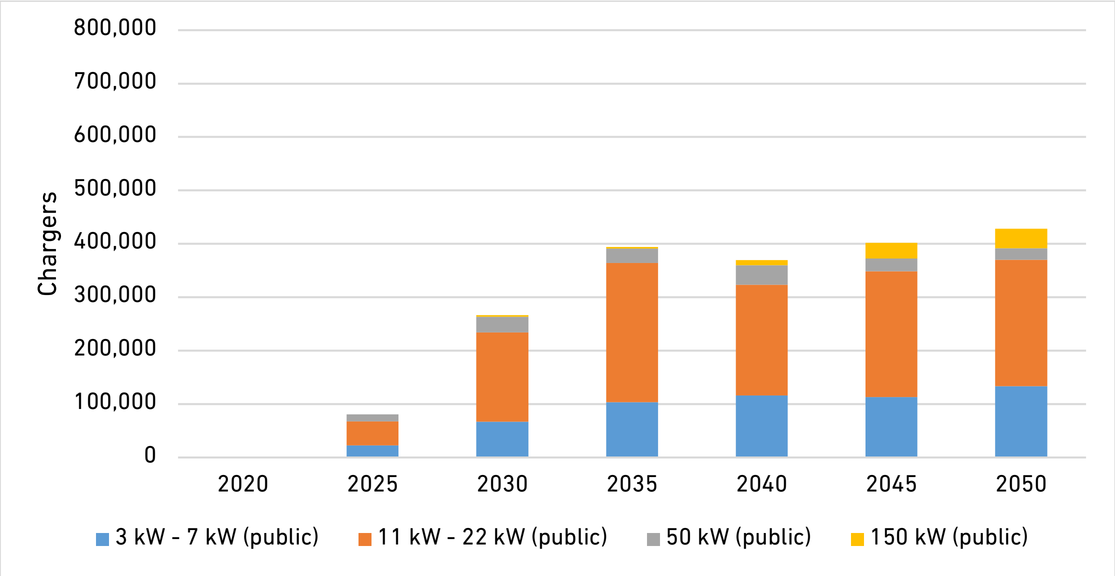

kW = kilowatt.
Source: Authors' calculations.

Figure 6.13 The Number of Public Chargers in the Electric Vehicle 20% Penetration Scenario – Energy Use Ratio Assumption 1



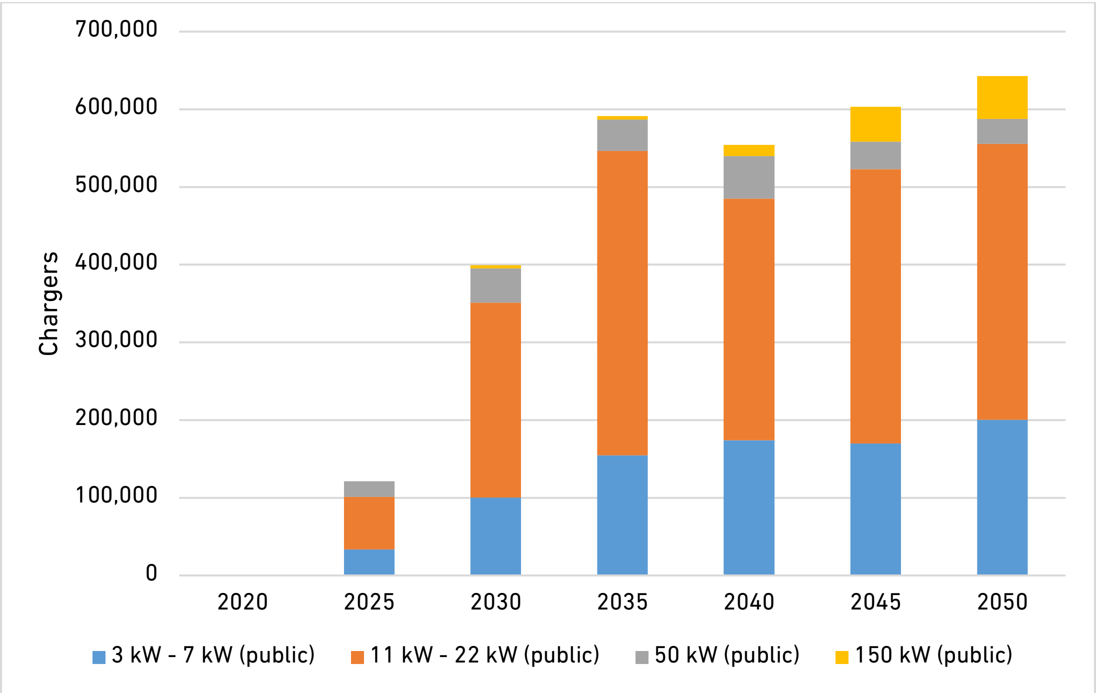

% = percent, kW = kilowatt.
Source: Authors' calculations.

Figure 6.14 The Number of Public Chargers in the Electric Vehicle 40% Penetration Scenario – Energy Use Ratio Assumption 1




kW = kilowatt.
Source: Author's calculation.

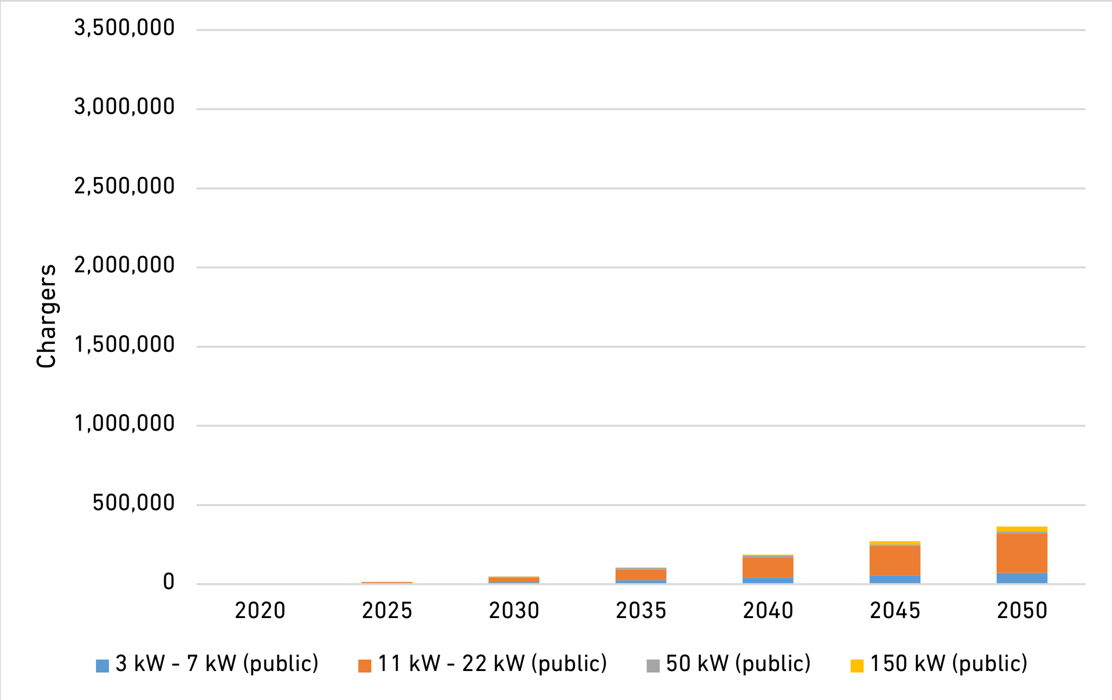
Figure 6.15 The Number of Public Chargers in the Electric Vehicle 60% Penetration Scenario – Energy Use Ratio Assumption 1




kW = kilowatt.
Source: Author's calculation.

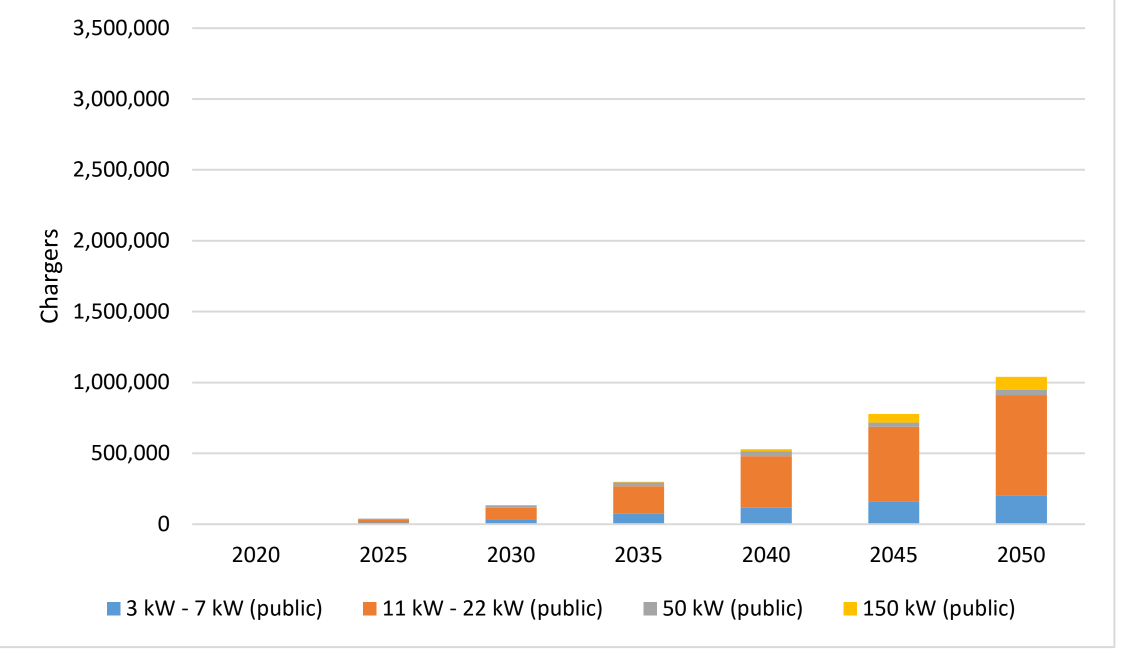
As shown in Figure 6.16–Figure 6.19, under Assumption 2 where the energy use ratios are assumed to remain the same between 2035 to 2050, the total number of public chargers would grow at a faster rate in the four scenarios than that of Assumption 1. By 2050, under this assumption the number of charging points by 2050 will range from almost 364,000 (BAU) to more than 3,100,000 points (EV60).

Figure 6.16 The Number of Public Chargers in the Business-as-Usual Scenario –Energy Use Ratio Assumption 2



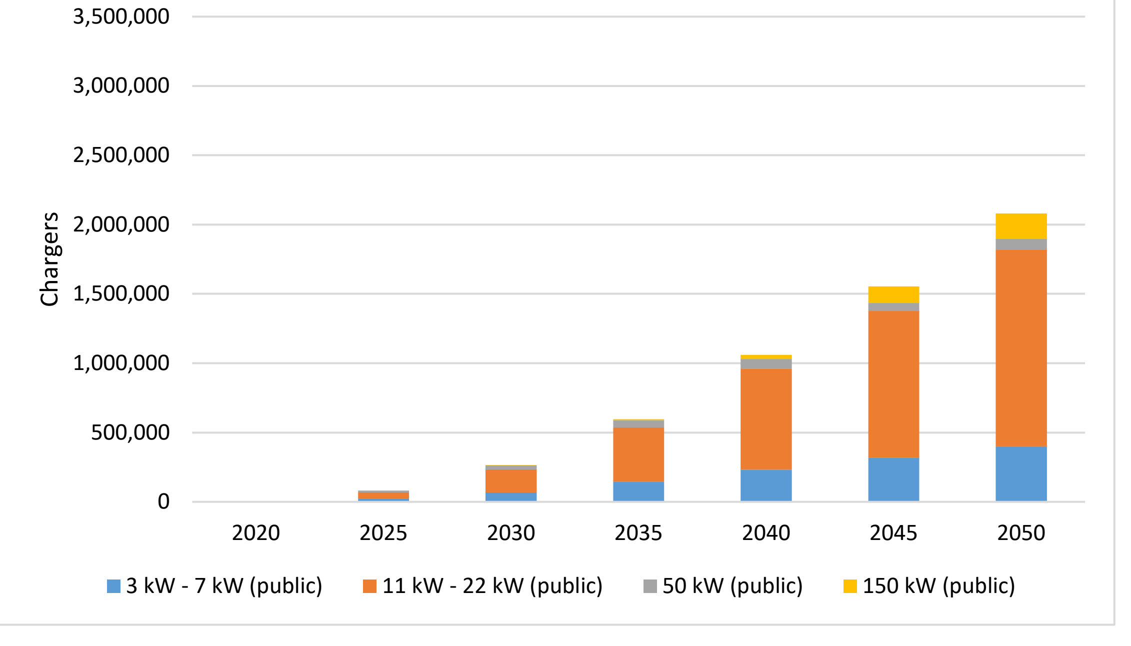

kW = kilowatt.
Source: Authors' calculations.

Figure 6.17 The Number of Public Chargers in the Electric Vehicle 20% Penetration Scenario – Energy Use Ratio Assumption 2



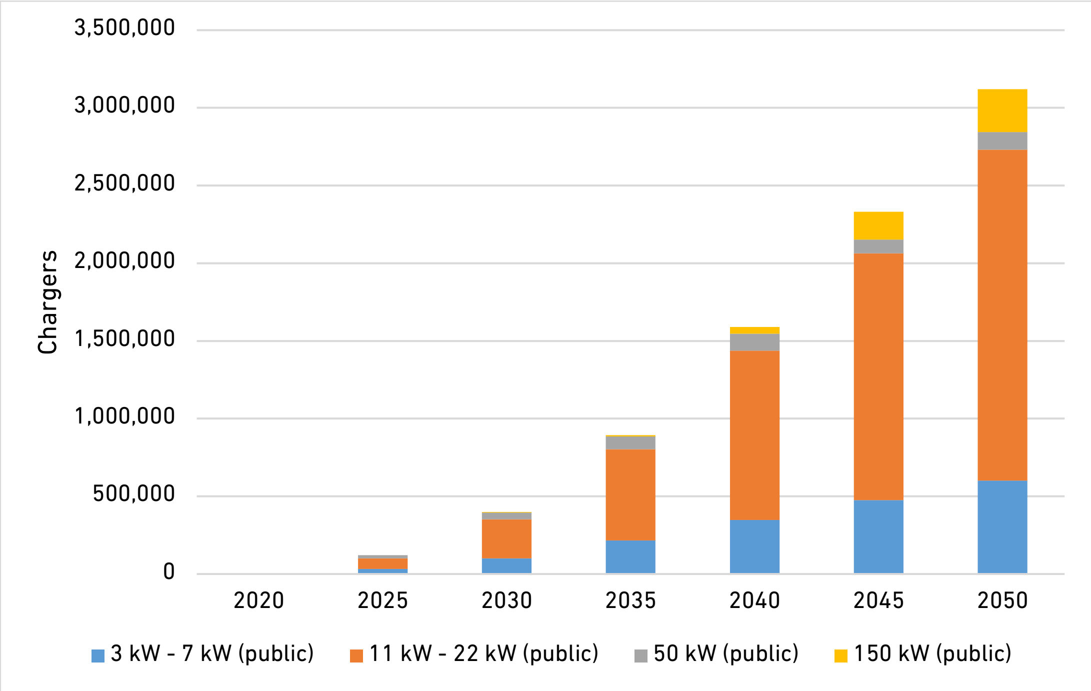

kW = kilowatt.
Source: Authors' calculations.

Figure 6.18 The Number of Public Chargers in the Electric Vehicle 40% Penetration Scenario – Energy Use Ratio Assumption 2




kW = kilowatt.
Source: Authors' calculations.

Figure 6.19 The Number of Public Chargers in the Electric Vehicle 60% Penetration Scenario – Energy Use Ratio Assumption 2

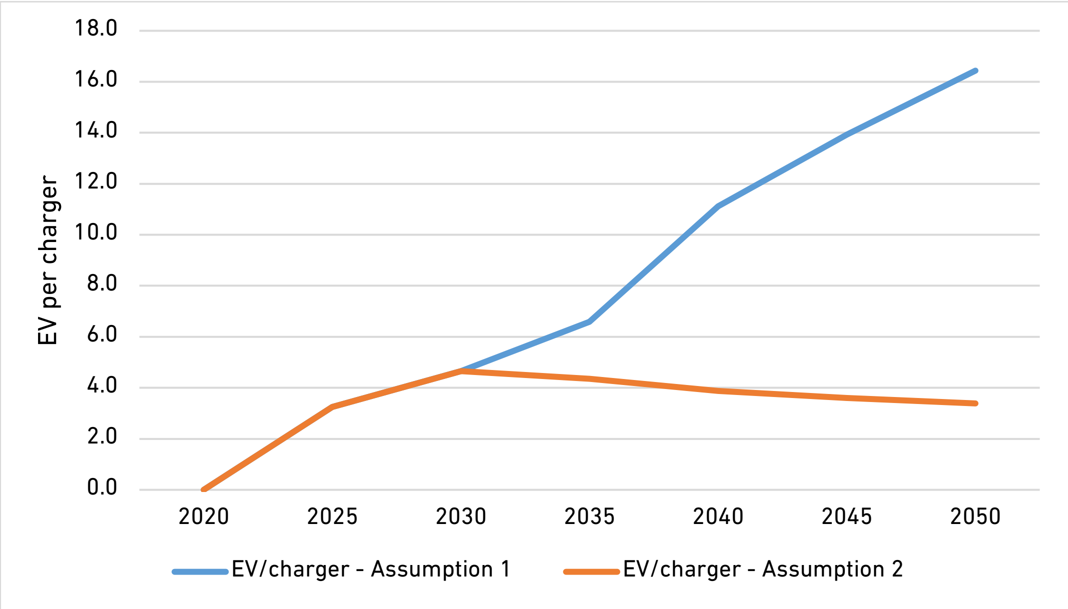



kW = kilowatt.
Source: Authors' calculations.

Figure 6.20 and Figure 6.21 show two additional indicators, i.e. the ratio of EVs to chargers and the ratio of electric power consumption to charger. The increasing energy use ratios in Assumption 1 keep the number of chargers relatively low, therefore the ratio of EVs to the number of chargers in this assumption would increase from around 4.7 units of EV per charger in 2030 to around 16.4 units of EV per charger in 2050. In contrast, the stable energy use ratios between 2035 and 2050 in Assumption 2 means faster growth of the number of chargers and automatically the ratio of the number of EVs to the number of charges remain relatively low, i.e. 4.7 in 2030 to 3.4 in 2050.

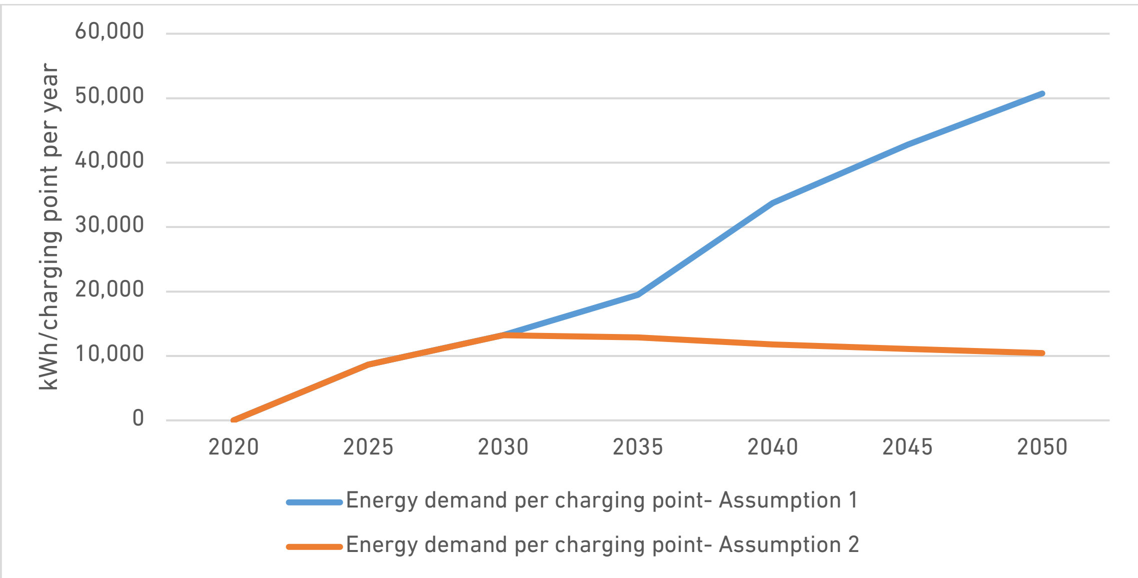
The ratio of electric power per charger would also increase in Assumption 1, from around 13,200 kWh per charger per year in 2030 to around 50,711 kWh per charger per year in 2050. In contrast, under Assumption 2, the ratio of consumed power would remain relatively constant, i.e. 13,209 kWh per charger per year in 2030 to 10,450 kWh per charger per year in 2050.

Figure 6.20 Electric Vehicles per Charging Points in the Two Assumptions




EV = electric vehicle, kWh = kilowatt hour.
Source: Authors calculations.

Figure 6.21 Electricity Delivered (kWh) per Charging Point per Year in the Two Assumptions




EV = electric vehicle, kWh = kilowatt hour.
Source: Authors' calculations.

Increasing energy use ratios would avoid the need for constructing more charging infrastructure. However, fewer chargers would also mean more power load on each charger, and this might also trigger less comfort for users such as longer waiting times or longer queues in charging stations or even longer travel distances and times to reach those stations.

On the other hand, building more chargers would avoid high power load on chargers and increase comfort for users. However, building more chargers means the need for more costly investment.

We took some installation costs per charger from various sources in Table 6.9 to calculate the total costs of installing chargers in the two assumptions for each of the three scenarios.

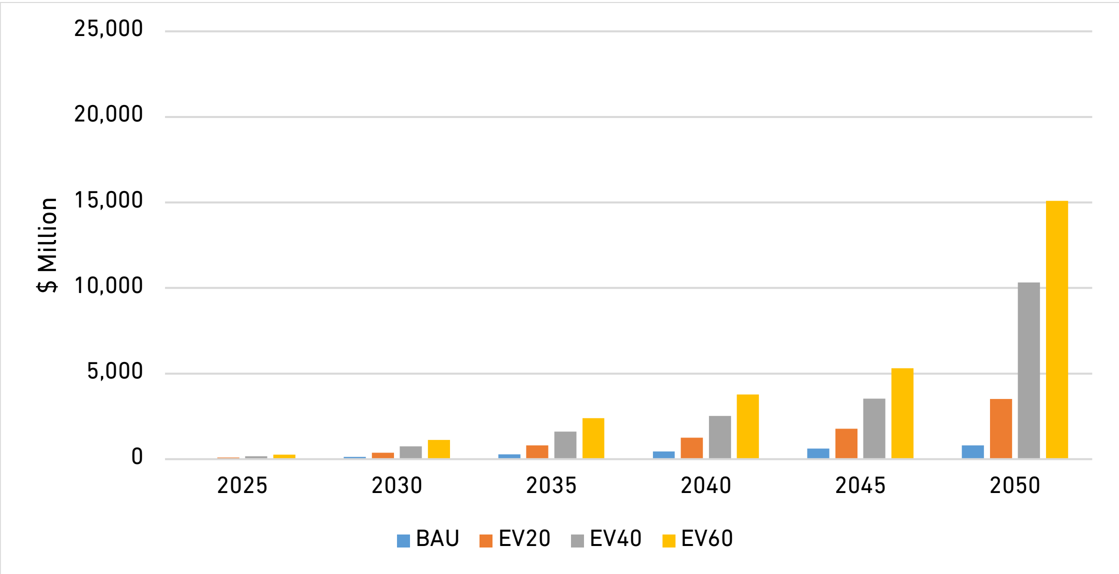
Table 6.9 Assumed Installation Costs

| Power (kW) | Installation cost per charging point | Currency | Country | Cost ($) |
|---|---|---|---|---|
| 7.2* | 69,000 | baht | Thailand | 2,154 |
| 22* | 95,000 | baht | Thailand | 2,966 |
| 50** | 25,000 | euros | Germany | 29,769 |
| 150*** | 50,000 | euros | EU | 59,538 |

$ = US dollar, EU = European Union, kW = kilowatt.
Source: Authors' calculations from *FutureCharge (2024), **NPE (2015), and ***Spöttle et al. (2018).

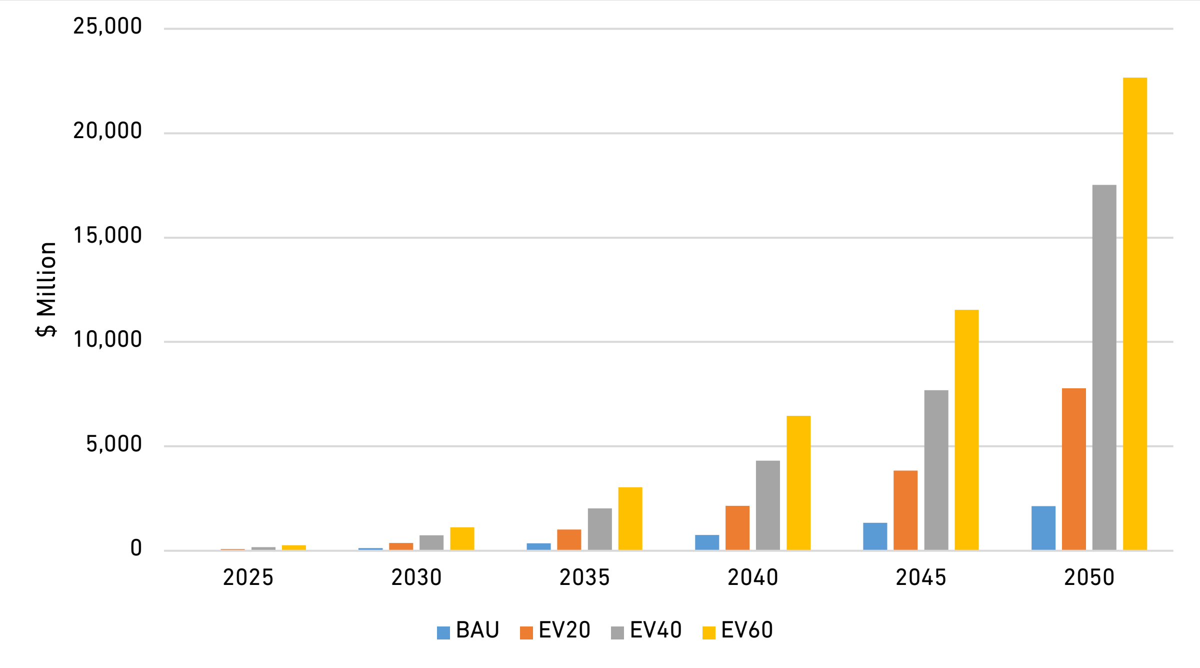
Under Assumption 1 where energy ratios are increased to keep the number of chargers relatively low, the accumulative costs might reach from around $809 million to $15,102 million by 2050 (Figure 6.22). Under Assumption 2 as shown in Figure 6.23, where the number of chargers increases, total cumulative costs by 2050 would reach between $2,135 million to $22,668 million.

Figure 6.22 Accumulative Cost–Energy Ratio Assumption 1




$ = US dollar, BAU = business-as-usual, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario
Source: Authors' calculations.

Figure 6.23 Accumulative Cost-Energy Ratio Assumption 2




$ = US dollar, BAU = business-as-usual, EV20 = electric vehicles 20% penetration scenario, EV40 = electric vehicles 40% penetration scenario, EV60 = electric vehicles 60% penetration scenario
Source: Authors' calculations.

## 4. Optimal Deployment of Charging Infrastructure

The public charging supply-cost model as demonstrated in Section 6.3 is a simple method to determine the number of chargers needed in a region at a highly aggregated spatial level such as country, the type of charger needed, and the impacts of the possible solutions to the demand side as indicated by the ratio of EVs per charger, to the supply side as indicated by the electricity consumption per charger, and to the cost of charger roll-out.

To deploy EV charging infrastructure at the lower spatial level such as cities or municipalities, we need to determine not only the number of chargers and their required type, but also the spatial distribution of those chargers in a determined period. The research questions are then how many chargers should be built, the required type, and where.

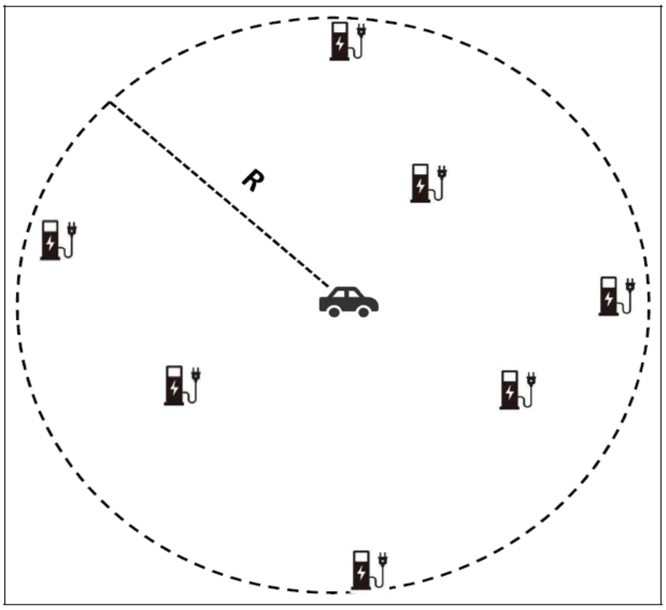
There are many approaches to locate and optimise EV charge point locations that answer the above questions. Most studies focus on demand modelled by demographics, traffic, or individual trip data. Two methods are usually combined to answer those questions. The first is the transportation approach that focuses on the issues such as mobility flows, road network configuration, and travel demand. The second is the electric approach that considers factors such as demand from EVs, user behaviour patterns, and electric grid infrastructure, with the aim to locate charging stations in power systems such that their capacity and security requirements are satisfied and the investment costs needed to upgrade them are minimised.

Some recent research has looked at optimally deploying EV charging infrastructure. Wagner, Götzinger, and Neumman (2013), for example, take a transportation approach. Using data from Amsterdam, which is one of the cities with the highest number of EV users, the research first investigated the influence of possible local trip destinations on charging point usage by EV owners. The trip destinations, so called ‘points of interest’ (POI), were grouped into 92 different categories, and the research proved that these POIs have a significant influence on the actual charging behaviour of EV owners in Amsterdam. A ranking structure was developed to rate individual POIs based on the surrounding charge point usage behaviour. The individual POI ranking was used to assess the ‘charge point attractiveness’ of selected urban areas.

Finally, a location model was built to provide city planners with the optimal locations for new charging point infrastructure based not only on POI locations but also on demand coverage.

Tian et al. (2018) proposed an optimisation model for charging stations that was based on waiting time. The target of this optimisation model was to minimise the time cost to EV drivers. Even if their main objective related to the transportation perspective, i.e. reduction of driver’s time cost, Tian et al. (2018) showed the need to use EV driver behaviour prediction, i.e. estimating whether drivers choose to charge EVs at a certain time. When EV drivers choose to charge their vehicles, they have a choice of several charging stations in the vicinity that they can reach with the power remaining in their EV (Figure 6.24).

Figure 6.24 Selection of Charging Stations by Drivers of Electric Vehicles



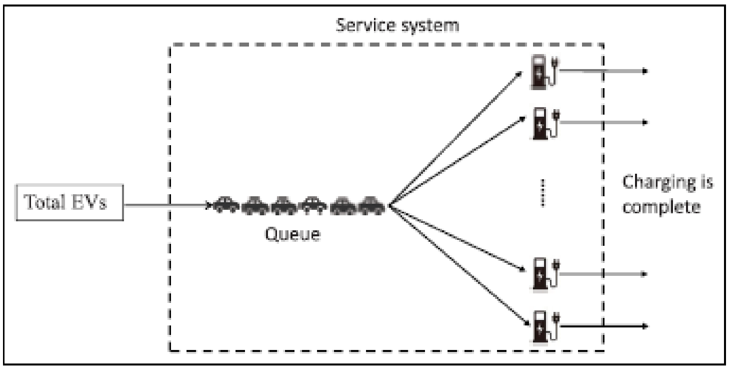

R = remaining power of electric vehicle.
Source: Tian et al. (2018).

EV drivers might go to the nearest charging station, but they might need to wait to charge. The waiting time might be lower if they chose to go to the second nearest and the total time cost for charging would be less than that for the nearest station.

The total time cost without the behaviour prediction of EV drivers is 27.28% more than the total time cost in driver behaviour prediction mode, and the average waiting time is 1.68 minutes more.

Tian et al. (2018) built a queuing model based on the number of drivers (vehicles) that are predicted to go to each station and the station capacity, therefore the waiting time is calculated as shown in Figure 6.25. Finally, an optimisation model is built to determine the location of charging stations based on the minimised charging time cost.

Figure 6.25 Queuing System for Electric Vehicles at a Charging Station




EV = electric vehicle.
Source: Tian et al. (2018).

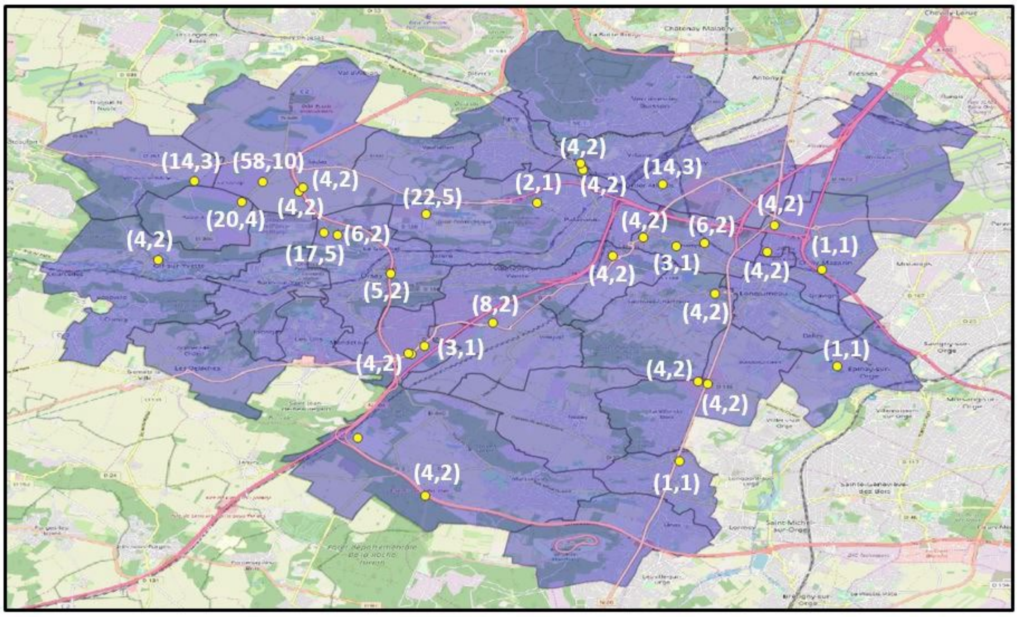
Finally, Mourad and Hennebel (2020) developed a mathematical formula to maximise the covered recharging demand, whilst respecting investment budget limits and the available capacities provided by the electric grid. With the objective to find the optimal locations for deploying EV charging stations and to find the number of chargers that need to be installed at each charging station, they considered the different mobility flows and recharging demands as well as the constraints imposed by the available electric grid and the availability of alternative energy sources, i.e. photovoltaic.

With the objective function being to maximise the total covered charging demand based on the covered paths, Mourad and Hennebel's mathematical model had several constraints:

- The sum of location costs and charger installation costs does not exceed total budget limit;
- A minimum of the overall charging demand must be satisfied;
- Charging demands for vehicles and trucks at each path must be satisfied;
- The number of fast chargers (for vehicles and trucks) to be installed must be within the specified limits at each charging location; and
- The electric power required to operate the installed chargers does not exceed the available electric capacity at the charging locations.

Mourad and Hennebel (2020) started by defining a set of coupling nodes, a set of potential charging locations, and a set of mobility paths that represented EV flows and their recharging demands. Through a case study on the Paris Saclay area in the Île-de-France region in France, the research obtained the optimal locations for deploying EV charging stations as well as the number of chargers that need to be installed at each charging station as given in Figure 6.26.

Figure 6.26 Number of Chargers per Station, Saclay Area, Paris




Note:
The number of fast chargers to be installed at each selected charging point is given in parenthesis, i.e. (light vehicle chargers, truck chargers)
Source: Mourad and Hennebel (2020).

## 5. Facilitating Charging Infrastructure Investment

Developing charging infrastructure needs significant investment. The public sector cannot bear the total burden and needs to attract private investors. The main challenge is convincing investors that the investment will be profitable as there are not yet enough EVs on the road.

Some strategies employed by EV front-runner countries for rolling out charging facilities are summarised below.

### 5.1 China

The world leader in the number of EVs sold, China began in 2009 with the '10 cities, 10,000 vehicles' business model to promote EV development, but established targets only in June 2012: 500,000 vehicles by 2015 and 5 million by 2020.

The programme's first step was top-down selection of experimental sites where the central government could either test policy or try out innovative practices. The second step – evaluation and absorption – combined bottom-up and top-down approaches. Central government agents evaluated the performance of pilot projects, whilst local participants reported their progress to the central authorities, documenting the most advanced practices for wider diffusion. The third step – diffusion by the central government – popularised successful practices through the media and endorsement by leading politicians. The final step was the learning and feedback loop (Marquis, Zhang, and Zhou, 2013).

Five models were created in the pilot cities: state leadership in Beijing based on public sector support; platform-led business in Shanghai replicating international models; cooperative commercialisation in Shenzhen based on a leasing model through strategic partnership; flexible rental in Hangzhou; and fast charging models in Chongqing, which is close to the Three Gorge Power Grid.

The city-based pilot programmes, however, focused on local goals and firms rather than a long-term national agenda. Competition for central government support eroded cities' willingness to cooperate with each other on setting national or international standards and goals; manufacturers or players were barred from entering other cities.

## 5.2 United States

EVs are becoming more popular in the US. California leads with 2% EV share of total road vehicles, followed by Hawaii (1.20%), Colorado (0.56%), Texas (0.23%), and Ohio (0.15%). Measures in urban areas that promote EV charging facilities include:

- development of make-ready locations by utilities that would support a variety of third-party charging stations (California, Colorado);
- implementation of TOU rates that encourage users to charge during off-peak periods (California, Hawaii, Ohio);
- provision of significant charging development rebates for the private sector (Colorado, Texas); low interest loans for businesses, non-profit organisations, public schools, and local governments for installing charging stations (Ohio); and grants to build stations (Texas);
- legal frameworks that favour private ownership of charging stations by allowing private companies to resell electricity supplied by a public utility to charge EVs (Colorado);
- partnerships between public utilities and private companies to develop and operate charging stations (Texas); and
- explicit right to site charging on premises for multifamily dwellings and townhouses (Hawaii) (Fitzgerald and Nelder, 2017).

## 5.3 Europe

Measures taken by two EV front-runner European countries – the Netherlands and Germany – are summarised below:

- The Netherlands. Between 2010 and 2014, seven grid operators (state-owned and regional) invested in developing charging infrastructure (Living Lab Smart Charging, 2017), which was later included in the Green Deal Electric Driving Programme (2016–2020) backed by a consortium of central and regional governments, grid operators, the automotive sector, and universities. The programme provides funding for public charging poles that comes equally from government, municipalities, and market players, and for the installation of the Netherlands Knowledge Platform on Public Charging Infrastructure (Hamelink, 2016). The programme not only develops charging facilities but also the roaming system and implements international protocol standards.

- Germany. The country has several financial support programmes at different government levels. The Federal Ministry of Transport's programme for EV charging infrastructure and the regional model of electromobility finance and/or subsidise the development of charging infrastructure that requires local or private investment.

In other European countries – front-runners or followers – state-owned agencies, with or without big private partners such as grid operators, first financed or organised deployment of charging infrastructure. Agencies or consortia then offered financing programmes to the private sector or local government to develop charging infrastructure.

## 6. Charging Scheme Strategy

The expansion of EVs and their demand for charging facilities have become increasingly important. The associated electricity demand will affect energy markets and the grid infrastructure. Studies on Portugal (Nunes, Farias, and Brito, 2015) and the EU (Kasten et al., 2016) show the impact of EVs once they make up 5%–10% of total road vehicles.

The amount of electricity needed to meet additional demand and the GHG emissions produced to generate electric power are calculated based on the average of total power plant mix. EVs' environmental performance would be better than conventional vehicles' performance if additional demand was met by a low-carbon intensive energy mix. Even if there were 300 million electric cars, if power generation was not decarbonised, $CO_2$ emissions would be insignificantly reduced by less than 1% (Sauer, 2019). EVs may reduce local pollution but not global emissions.

China, the EV front-runner in Asia, is struggling to curb the share of coal-fired-based electric energy from 75% to 50% and to increase that of renewable sources from 25% to 50% by 2030. This would bring down power generation carbon intensity by one-third and ensure that EVs will be less carbon intensive than they are now. China uses more electricity from coal-fired generating plants during fast charging peak demand periods and after working hours in the evening. Slow charging during off-peak hours, when energy from renewables such as wind turbines is available, would reduce $CO_2$ emissions (Chen et al., 2018).

When and how EVs are charged determines which generation plants satisfy additional electricity demand and have an impact on emissions. Depending on their total system and marginal costs, different types of power plants may increase production. Including this charging scheme in the analysis might change the calculation results.

Uncontrolled or user-driven charging occurs mostly after work in the evening, when electricity demand is already high, increasing system load and the costs of utilities (Brandmayr et al., 2017).

User-driven charging would raise severe concerns about generation adequacy and may jeopardise the stability of the power system (Schill and Gerbaulet, 2015). Fast charging stations use large amounts of power for short periods of time, meaning that expensive upgrades will be needed for a relatively low use rate (Hall and Lutsey, 2017). In the US, if EVs constitute 25% of all road vehicles, uncontrolled charging would increase electricity peak demand by 19%, but spreading charging over the evening hours would increase demand by only 6% (Fitzgerald and Nelder, 2017).

Reducing carbon emissions and the load on the local grid will be solved only by charging management schemes, some of which are described below.

- Off-peak or network-oriented charging. This includes policies and structures that encourage off-peak-period charging, including workplace or daytime charging and night-time home charging, to avoid network congestion and physical capacity constraints. This strategy should increase system stability and grid functioning but producing electricity during low demand periods using conventional energy sources might have negative environmental effects.
- Cost-oriented charging. This aims to reduce EV charging cost by shifting the charging time to periods of low energy prices. EV owners could benefit from low energy costs, and load patterns might be smoothed as the low charging cost period coincides often with low demand. Additional conventional production during low-cost periods could have negative environmental effects. Schill and Gerbaulet (2015) made the following findings. First, cost-driven charging promotes renewable energy more than user-driven charging, but cost-driven charging might also increase the use of the emissions-intensive lignite power generation. Germany, for example, has the lowest marginal costs for thermal technology and uses more hard coal than user-driven strategies. Second, cost-driven charging reduces unused generated power more than uncontrolled charging. The opposite happens in countries with a high share of renewables, such as Denmark,

which has a low share of emissions-intensive generators and a high share of wind power. Using a cost-driven charging system, Germany and the ASEAN countries will reduce $CO_2$ emissions only if they build more renewable energy generators. Cost-driven charging will work only if emissions externalities are correctly priced.

- Smart charging. This includes controlled charging and demand response. A simpler solution such as the use of in-vehicle timers to take advantage of TOU rates could help minimise stress on the electrical grid, whilst also saving money for consumers. Smart charging strategies are less practical for DC fast charging than for Level 2 charging as drivers expect fast charging to be available on demand (Hall and Lutsey, 2017). As the fast-changing market continues to grow, fast chargers should be placed near adequate high-capacity electrical infrastructure.
- Combined smart and cost-oriented charging. Decreasing real time price increases renewable energy share, such as wind, as it is available during that period. The variability of wind power drops as its share increases. In this situation, $CO_2$ emissions could be higher than the average of the total power plant energy mix, if coal, for example, due to its low marginal costs, dominates the lower price part of the merit order (Dallinger, Wietschel, and Santini, 2012).
- Renewable energy-oriented charging or low emissions-oriented charging. This aims to increase environmental performance or avoid the negative impact of GHG and air pollutant emissions. The measure shifts charging times to periods of high or surplus renewable energy generation, resulting in reduced additional production by conventional plants. However, conditions vary in different energy systems and this strategy requires sufficient renewable power generation to meet additional electricity demand.

In Cambodia, MME is responsible for leading the development of EV charging stations, as outlined on the National Policy on the Development on Electric Vehicles 2024–2030 (MME, 2024). MME has set strategic directions for the development of EV charging stations across the country.

EDC will start assessing the feasibility of charging infrastructure in private, semi-public, and public places. For the private charging points for home use, it will use Level 2 charging with an AC power supply (single-phase or three-phase from 3.3 kW to 19.2 kW) and will be integrated to a centralised management system for electricity bill incentives. For semi-public charging points for workplaces, schools, etc, EDC will encourage site owners to invest in the charging stations. Meanwhile, for public charging points (shopping malls, gas stations, etc), installation will be prioritised in cities and towns and charging points will be equipped with fast chargers to accommodate higher demand.

On the other hand, MME will focus on regulatory frameworks. This includes establishing permit and licensing procedures, setting the technical and safety standards, streamlining the application process, implementing fair and appropriate charging tariffs, developing management software and mobile applications, and conducting training for EV charging station technicians. MME will implement fair and appropriate charging tariffs to balance affordability for consumer and operational sustainability. It will do this by considering investment in medium voltage networks and transformers, employing various charging methods (including solar integration), and implementing time-of-use tariffs to manage peak load demand.

# Chapter 7

# Conclusions and Recommendations

## 1. Conclusions

**Chapter 1** reviewed the current situation of BEV penetration in Cambodia. The Government of Cambodia assists BEV penetration in the country with various incentives for BEV importers and customers through reducing the import and acquisition tax on BEVs. But BEV penetration is still low due to their high price, insufficient BEV charging stations (infrastructure), and a lack of awareness of BEVs amongst Cambodian citizens. However, it is recognised that BEVs could mitigate air pollution and climate changes issue in Cambodia

**Chapter 2** forecast the BEV penetration ratio in Cambodia until 2050, applying a scenario approach of 20%, 40%, and 60%. It is assumed that ICE vehicles, including all road transport modes, will be replaced by BEVs. The assumption is made because there is no historical data on BEV penetration rates to use as a basis for projections. First, we forecast the number of vehicles in Cambodia until 2050 applying Gompertz curve and second, we forecast the number of BEVs using the assumed penetration ratios. Based on the fuel consumption formula which is defined as fuel economy x driving distance x number of vehicles, the amount of fuel savings for BEVs in the 60% scenario in 2050 is estimated: 1.3 million kilolitres of gasoline and less than 4 million kilolitres of diesel oil. On the other hand, the additional electricity demand for BEVs is estimated at more than 6,000 GWh in 2050.

**Chapter 3** analysed the impact of EV penetration on the macro economy and oil industry. As mentioned in Chapter 2, BEV penetration brings a decrease in gasoline and diesel consumption until 2050. Historically, Cambodia imports 100% of its petroleum products from its neighbouring countries (Singapore, Thailand and Viet Nam), thus Cambodia can reduce the import of petroleum products through BEV penetration. GDP is defined as consumption + investment + stock change + export – import, so if Cambodia decreases the import of petroleum products, its GDP increases. In the EV60% scenario, Cambodia's GDP could increase 2.9%, showing the positive impact BEV penetration could have on the macro economy. The Government of Cambodia has been charging import tax on imported petroleum products, so its revenue would decrease, having a negative impact on Cambodia's fiscal condition. However, if the Government could charge sales tax on electricity for BEVs, this negative impact could be eliminated. In the EV60% scenario, the demand for petroleum products, such as gasoline and diesel oil will be slightly larger in 2050 than their demands in 2020. This means that the existing oil companies can maintain their current oil market volume but cannot expect as high an income growth as BAU. However, the oil companies have opportunities to challenge EV charging businesses and this may cover revenue gaps between BAU and the EV60% scenario.

Chapter 4 analysed the impact of BEV penetration on the power sector. Chapter 2 forecast additional electricity demand for BEVs at 6,277.3 GWh in 2050 in the case of the EV60% scenario. If this electricity demand is covered by hydropower plants due to green electricity, 2,154,7 MW of hydropower capacity will be needed, and its investment cost is estimated at $5,408.2 million. In addition, the capacity of transmission lines and the distribution network must be upgraded to respond to the increase in peak demand. In the EV60% scenario, the investment cost of the transmission line is estimated at $221.3 million, and the cost of the distribution network is estimated at $663.9 million. Thus, a total additional investment of $6,293.4 million will be needed in the power sector to support EV penetration in Cambodia.

Chapter 5 analysed the impact of EV penetration on energy consumption and $CO_2$ emissions in Cambodia. If the same number of ICE vehicles and BEV travel similar distances, the electricity consumption of BEVs (based on the tonne of oil equivalent basis) is lower than the fuel consumption of ICE vehicles because of the different heat content of electricity at 860kcal/kWh and gasoline at around 8,000 kcal/litre. Thus, we can expect energy savings from BEV penetration. $CO_2$ emissions will reduce due to saving from lower transport fuel consumption. On the other hand, levels of $CO_2$ emissions by power sector depend on the power generation mix. If Cambodia generates electricity for EVs by renewable energy such as hydropower, $CO_2$ will not be emitted, but if the country depends on thermal power plants such as coal and gas, $CO_2$ emissions will increase due to fossil fuel combustion. However, $CO_2$ emissions from gas power plants are almost half those from coal power plant.

Chapter 6 analysed electric charging stations. There are several types of charging plugs developed by China (influenced by BYD), the EU, Japan (influenced by NISSAN), and the US (influenced by Tesla). Thus, Cambodia must consider which type of charging plug will be the global standard. To save on the charging time for EVs, high voltage charging stations will be necessary in Cambodia, but they are costly. Cambodia could start to increase the number of lower volage charging stations at offices and shopping centres and after that, increase high voltage charging stations in private facilities and along roads and highways.

## 2 Policy Recommendations

Based on the conclusions mentioned above, the following recommendations are extracted:

- EV is an option for Cambodia to promote decarbonisation in the final energy consumption sector because Cambodia has significant hydropower and solar photovoltaic potential.
- EV penetration brings Cambodia opportunities to save energy through replacing ICE vehicles with EVs, as well as macroeconomic benefits (an increase of GDP) through a decrease in transport fuel imports.
- Cambodia should recognise the negative impact to the oil industry of EV penetration. The MME must consider ways to mitigate this impact such as through encouraging the oil industry to develop electricity charging and battery recycling businesses.
- $CO_2$ emissions will be reduced due to saving on transport fuel consumption but if electricity for EV is generated by coal power plant, this $CO_2$ reduction will be offset by the increase of $CO_2$ emissions by coal power generation. Thus, power generation for the electricity demand of EVs should be clean, such as renewable energy or gas power generation.
- Much investment will be needed to increase renewable energy capacity or gas power capacity and to upgrade transmission and distribution lines due to the increase in peak demand for electricity. Financial schemes for the power sector are important.
- In addition to investment in the power sector, investment in EV support systems, such as charging stations, will also be needed for EV penetration.

# References


Alternative Fuel Data Centre (2021), *Light-Duty All-Electric Vehicles Registered in the United States Weighted by Vehicle Class Registered* Figures'. Unted States Department of Energy (DOE). https://afdc.energy.gov/data (Accessed 21 March 2025)

Asian Development Bank (ADB) (2018), *Cambodia Energy Sector Assessment, Strategy, and Road Map*. Manila: ADB. https://www.adb.org/sites/default/files/institutional-document/479941/cambodia-energy-assessment-road-map.pdf

——— (2023), *Key Indicators for Asia and the Pacific 2022*. Manila: ADB. https://www.adb.org/publications/key-indicators-asia-and-pacific-2022

Bakker, S (2013), *Standardization of EV Recharging Infrastructures, Report Written Within the Framework of Activity 4.4 of the Interreg IVB Project E-Mobility NSR*. North Sea Region Electric Mobility Network. http://archive.northsearegion.eu/files/repository/20140805153226_StandardizationofEVRecharginginfrastructure.pdf

Brandmayr, C., D. Benton, A. George, and C. Kumar (2017), *People Power: How Consumer Choice Is Changing the UK Energy System*. London: Green Alliance. https://www.green-alliance.org.uk/people_power_consumer_choice.php

Cambodia Investment Board and Ministry of Economy and Finance (CIB and MOEF) (2023), *Incentives for Green Technologies in Cambodia*. Phnom Penh: CIB.

Cambodia National Petroleum Authority (CNPA) (2023), *Taxation and Import Duty Policies on Hybrid and Electric Vehicles*. Phnom Penh: CNPA.

CHAdeMO Association (2016), *2015 Activity Report (1 April 2015–31 March 2016*). https://www.chademo.com/wp2016/wp-content/uploads/2016/06/FY2015ActivityReport_en.pdf

Chen, X., H. Zhang, Z. Xu, C.P. Nielsen, M.B. McElroy, J. Lu (2018), 'Impacts of Fleet Types and Charging Modes for Electric Vehicles on Emission under Different Penetrations of Wind Power', *Nature Energy*, 3, pp.413–21. https://doi.org/10.1038/s41560-018-0133-0

Chen, J., F. Li, R. Yang, and D. Ma (2020), 'Impacts of Increasing Private Charging Piles on Electric Vehicles' Charging Profiles: A Case Study in Hefei City, China', *Energies 2020*, 13(17), 4387. https://doi:10.3390/en13174387

Chhem, R. (2022). *Electric Vehicles in Cambodia: Opportunities and Challenges*. Phnom Penh: Cambodian Institute for Sustainable Development.

CREARA Analysis (2017), *EUE 67 – Cost of EV Charging Infrastructure*. Madrid: Creara Energy Experts.

Dallinger, D., M. Wietschel, and D. Santini (2012), 'Effect of Demand Response on the Marginal Electricity Used by Plug-In Electric Vehicles', *World Electric Vehicle Journal*, 4(3), 2766–74. https://www.researchgate.net/publication/286567709_Effect_of_demand_response_on_the_marginal_electricity_used_by_plug-in_electric_vehicles

Dargay, J., D. Gately, and M. Sommer (2007), 'Vehicle Ownership and Income Growth, Worldwide: 1960–2030', *The Energy Journal*, 28(4), pp.143-70. https://www.researchgate.net/publication/46523642_Vehicle_Ownership_and_Income_Growth_Worldwide_1960-2030

European Alternative Fuels Observatory (EAFO) (2021), *EAFO Database*, https://www.eafo.eu/vehicles-and-fleet/m1 Accessed 16 August 2021

Electricity Authority of Cambodia (EAC) (2022), *Report on Power Sector of the Kingdom of Cambodia*, Phnom Penh: EAC. https://www.eac.gov.kh/site/annualreport?lang=en

——— (2023), *Salient Features of Power Development in the Kingdom of Cambodia Until December 2023*. Phnom Penh: EAC. https://eac.gov.kh/site/index?lang=en, Accessed 13 August 2024.

———. (n.d). Annual Report. Phnom Penh: EAC. https://www.eac.gov.kh/site/annualreport?lang=en

Electricité du Cambodge (EDC) (2018), *Annual Report 2018*. Phnom Penh: EDC. https://admin.edc.com.kh/images/annuallyreport/a4969d005440f67a4e57ebf240c48d85.pdf

Economic Research Institute for ASEAN and East Asia (ERIA) (2022), *Cambodia Energy Statistics 2000–2019*. Jakarta: September. https://www.eria.org/publications/cambodia-energy-statistics-20002019

———. (2023), *Energy Outlook and Energy Saving Potential in East Asia 2023*. Jakarta: 31 August 2023. https://www.eria.org/publications/energy-outlook-and-energy-saving-potential-in-east-asia-2023

EVChargingStops (2024), *EV Charging Stations In Phnom Penh, Cambodia*. https://www.evchargingstops.com/cambodia/phnom-penh, Accessed 2 December 2024

Figenbaum, E. (2019), *Summary: Charging into the Future – Analysis of Fast Charger Usage*. Oslo: Institute of Transport Economics Norwegian Centre for Transport Research. https://www.toi.no/getfile.php/1349745-1551449575/Publikasjoner/T%C3%98I%20rapporter/2019/1682-2019/1682-2019-sum.pdf

Fishbone, A., Z. Shahan, and P. Badik (2017), *Electric Vehicle Charging Infrastructure: Guidelines for Cities*. Warsaw: Clean Technica and Greenway. https://cleantechnica.com/wp-content/uploads/2024/02/EV-Charging-Infrastructure-Guidelines-for-Cities.pdf

Fitzgerald G., and C. Nelder (2017), *From Gas to Grid: Building Charging Infrastructure to Power Electric Vehicle Demand*. Basalt, CA: Rocky Mountain Institute. https://rmi.org/insight/from_gas_to_grid/

FutureCharge (2024), *Explore Our Products: Siemens EV Charger*. https://futurecharge.co.th/

General Department of Transport (2024), Phnom Penh: Land Transport Department of Cambodia, https://mpwt.gov.kh/en/home, Accessed April 2024

General Department of Customs and Excise: International Merchandise Trade Statistics (2024), *Total Trade Statistics of Last 5 Years*. Phnom Penh: General Department of Customs and Excise https://stats.customs.gov.kh/en, Accessed July 2024

Hall, D. and N. Lutsey (2017), 'Emerging Best Practices for Electric Vehicle Charging Infrastructure', *White Paper*. Washington, DC: The International Council on Clean Transportation. https://theicct.org/publication/emerging-best-practices-for-electric-vehicle-charging-infrastructure/

Hamelink, M. (2016), *Dutch Vision Charging Infrastructure*. The Hague: Ministry of Economic Affairs (The Netherlands).

Harrison, G. and C. Thiel (2017), 'An Exploratory Policy Analysis of Electric Vehicle Sales Competition and Sensitivity to Infrastructure in Europe', *Technological Forecasting & Social Change*, 114, pp.165–78. https://www.sciencedirect.com/science/article/pii/S0040162516302104

International Energy Agency (IEA) (2019), *IEA Global EV Outlook 2019: Scaling up the Transition to Electric Mobility*, Paris: IEA. https://www.iea.org/reports/global-ev-outlook-2019

IEA (2021), Global EV Outlook 2021, Paris: IEA. https://www.iea.org/reports/global-ev-outlook-2021

International Trade Centre (ITC) (2024), *Trade Map*. Geneva: ITC. https://www.trademap.org/Index.aspx, Accessed July 2024

Japan International Cooperation Agency (JICA) (2024), *Cambodia Electricity Overview*, Tokyo: JICA. https://www.jica.go.jp/overseas/cambodia/information/investment/__icsFiles/afieldfile/2024/03/12/20240312electric_power_202402_2.pdf, Accessed 24 June 2024 (no longer available).

Kasten, P., J. Bracker, M. Haller, and J. Purwanto (2016), *Assessing the Status of Electrification of the Road Transport Passenger Vehicles and Potential Future Implications for the Environment and European Energy Systems. Final Report – Task 2. Specific Contract under Framework Contract EEA/ACC/13/003*, Rotterdam: Trinomics VBV. https://www.oeko.de/en/publications/assessing-the-status-of-electrification-of-the-road-transport-passenger-vehicles-and-potential-future-implications-for-the-environment-and-european-energy-system/

Kimsay, T. (2023), 'Cambodia's Policy Shift toward Electric Vehicles', *The Phnom Penh Post*. https://www.phnompenhpost.com

Kimura, S., A.J. Purwanto, K. Ueda, and T. Hiruma (2022), *Assessment of Electric Vehicle Penetration in the Lao People's Democratic Republic*. Jakarta: Economic Research Institute for ASEAN and East Asia (ERIA). https://www.eria.org/research/assessment-of-electric-vehicle-penetration-in-the-lao-peoples-democratic-republic/

Kimura, S., H. Phoumin, and A.P. Purwanto (2023), *Energy Outlook and Energy Saving Potential in East Asia 2023*. Jakarta: ERIA. https://www.eria.org/research/energy-outlook-and-energy-saving-potential-in-east-asia-2023/

KPMG (2024), *The EV 2024 Report: Vietnam's Market: Driven by Voltage: Navigating the EV Landscape*, Amstelveen: KPMG, https://kpmg.com/vn/en/home/insights/2024/07/the-ev-landscape-in-vietnam.html

Lee, H. and A. Clark (2018), 'Charging the Future: Challenges and Opportunities for Electric Vehicle Adoption', *Faculty Research Working Paper Series*, Harvard Kennedy School, John F. Kennedy School of Government, RWP18--026. https://projects.iq.harvard.edu/files/energyconsortium/files/rwp18-026_lee_1.pdf

Living Lab Smart Charging (2017), *Smart Charging and Electromobility: Driving on Solar and Wind Power!* Netherlands: Living Lab Smart Charging. https://s3.eu-central-1.amazonaws.com/z3r2zxopa4uuqpw5a4ju/livinglab/files/Smart%20Charging%20boek/170701_Book%20Smart%20Charging%20UK-WEB.pdf

Lu, J. (2018), *Comparing US and Chinese Electric Vehicle Policies*. Washington, DC: Environmental and Energy Study Institute. https://www.eesi.org/articles/view/comparing-u.s.-and-chinese-electric-vehicle-policies

Martins, J., F.P. Brito, D. Pedrosa, V. Monteiro,and J.L. Afonso (2013), Real-Life Comparison Between Diesel and Electric Car Energy Consumption', in *Grid Electrified Vehicles: Performance, Design and Environmental Impacts'*, New York: Nova Science Publishers, pp. 209–32. ISBN 978-1-62808-839-7, https://core.ac.uk/download/pdf/55627041.pdf

Marquis, C., H. Zhang, and L. Zhou (2013), 'China's Quest to Adopt Electric Vehicles', *Stanford Social Innovation Review*, Spring. https://www.hbs.edu/ris/Publication%20Files/Electric%20Vehicles_89176bc1-1aee-4c6e-829f-bd426beaf5d3.pdf

Ministry of Mines and Energy of Cambodia (MME) (2022), *Power Development Masterplan 2022–2040*, Phnom Penh: MME. https://data.opendevelopmentcambodia.net/laws_record/national-policy-on-the-development-of-the-electric-vehicle-sector-2024-2030version.pdf

———, (2024), National Policy on the Development of Electric Vehicles 2024–2030, Phnom Penh: MME.

MME and ERIA (2019), *Cambodia Basic Energy Plan*. https://www.eria.org/publications/cambodia-basic-energy-plan/

Ministry of Public Works and Transport, Lao PDR (MPWT) (2019), *Data on Road Transport Vehicles.*

Ministry of Public Works and Transport, Cambodia (MPWT) (2023), *EV Policy and Development Plan*. Phnom Penh: MPWT.

——— (2024), *Electric Vehicle Roadmap for Charging Stations*. Phnom Penh: MPWT.

Mourad, A., and M. Hennebel (2020), 'The Optimal Deployment of Recharging Stations for Electric Vehicles Based on Mobility Flows and Electric Grid Specifications'. *2020 IEEE PES Innovative Smart Grid Technologies Europe (ISGT-Europe)*, October 2020, The Hague, Netherlands. https://hal.archives-ouvertes.fr/hal-02958645

National Platform for Electric Mobility (NPE) (2015), *Charging Infrastructure for Electric Vehicles in Germany: Progress Report and Recommendations for Action*. Berlin: NPE. https://www.plattform-zukunft-mobilitaet.de/en/2download/charging-infrastructure-for-electric-vehicles-in-germany-status-report-and-recommendations-for-action/

Ned, S. (2022), 'Sustainable Transportation in Cambodia: The Role of Electric Vehicles', *Cambodia Green Growth Journal*, 5(1), pp. 24–30.

Nunes, P., T. Farias, and M.C. Brito (2015), 'Day Charging Electric Vehicles with Excess Solar Electricity for A Sustainable Energy System', *Energy*, 80, pp. 263–74. https://www.researchgate.net/publication/270008022_Day_charging_electric_vehicles_with_excess_solar_electricity_for_a_sustainable_energy_system

P3 Group (2024), *Assessing Thailand's Readiness for Electric Mobility: Evaluating the Charging Experience of Different Charge Point Operators and Their EV Charging Services*. https://www.p3-group.com/wp-content/uploads/2024/04/P3-EV-Report-Thailand.pdf,

Pillai, R.K., R. Suri, S. Kundu, H. Singh, S.S. Roy, and S. Dhuri (2018), 'Electric Vehicle Charging Stations Business Models for India', *India Smart Grid Forum (ISGF) White Paper*. https://indiaesa.info/media/downloadfiles/ISGF_White_Paper_-_EVSE_Business_Models_for_India._485350084.pdf

Sauer, N. (2019), 'Electric Cars Won't Stop Rising Oil Demand', *Ecologist*. 25 January. https://theecologist.org/2019/jan/25/electric-cars-wont-stop-rising-oil-demand,

Schill, W-P. and C. Gerbaulet (2015), 'Power System Impacts of Electric Vehicles in Germany: Charging with Coal or Renewables?', *Applied Energy*, 156, pp.185–96. https://www.sciencedirect.com/science/article/abs/pii/S0306261915008417

Sok, H. (2024). 'Cambodia's Electric Vehicle Infrastructure: Current Developments and Future Plans'. The Khmer Times. https://www.khmer-times.com

Spöttle, M. et al. (2018), *Research for TRAN Committee – Charging Infrastructure for 'Electric Road Vehicles*. Brussels: European Parliament, Policy Department for Structural and Cohesion Policies. https://www.europarl.europa.eu/RegData/etudes/STUD/2018/617470/IPOL_STU(2018)617470_EN.pdf

TEPCO, (2022), *Power Supply Equipment*. Tokyo: TEPCO. https://www.tepco.co.jp/corporateinfo/illustrated/electricity-supply/transmission-distribution-loss-j.html, Accessed 3 December 2024

Thananusak, T., P. Punnakitikashem, S. Tanthasith, and B. Kongarchapatara (2020), 'The Development of Electric Vehicle Charging Stations in Thailand: Policies, Players, and Key Issues (2015–2020)', *World Electric Vehicle Journal 2021*, 12(1). https://doi.org/10.3390/wevj12010002,

Tian, Z., W. Hou, X. Gu, F. Gu, and B. Yao (2018), 'The Location Optimization of Electric Vehicle Charging Stations Considering Charging Behaviour', *Simulation*, 94(7), pp.625–36. https://doi.org/10.1177/0037549717743807

Transport and Environment (T&E) (2018), *Roll-out of Public EV Charging Infrastructure in the EU: Is the Chicken and Egg Dilemma Resolved?* Brussels: T&E https://www.transportenvironment.org/uploads/files/Charging20Infrastructure20Report_September202018_FINAL.pdf

——— (2020), *Recharge EU: How Many Charge Points will Europe and its Member States Need in the 2020s*. Brussels: T&E, 7 January. https://www.transportenvironment.org/articles/recharge-eu-how-many-charge-points-will-eu-countries-need-2030

Wagner, S., M. Götzinger, and D. Neumman (2013), 'Optimal Location of Charging Stations in Smart Cities: A Point of Interest Based Approach', *Thirty-Fourth International Conference on Information Systems, Milan 2013*.

https://www.researchgate.net/publication/287014278_Optimal_location_of_charging_stations_in_smart_cities_A_point_of_interest_based_approach

World Bank (2024), *World Development Indicators*. Washington, DC: World Bank. http://data.worldbank.org. Accessed 1 August 2024.

Xin, Z. (2017), 'State Grid Scales Up Charging', *China Daily*, 26 January. www.chinadaily.com.cn/business/2017-01/26/content_28058742.htm,

Xu, Y., S. Çolak, E.C. Kara, S.J. Moura, and M.C. González (2016), 'Planning for Electric Vehicle Needs by Coupling Charging Profiles with Urban Mobility', *Nature Energy*, 3, pp.484–93. https://www.researchgate.net/publication/324842722_Planning_for_electric_vehicle_needs_by_coupling_charging_profiles_with_urban_mobility

Ying, X. and T.J. Xuan (2018), 'China's Electric Vehicle Charging Stations Idle 85% of Time', *Caixin*, 22 January. https://www.caixinglobal.com/2018-01-22/chinas-electric-vehicle-charging-stations-idle-85-of-time-101201234.html

Zhang, K., T. Gong, K. Shi (2019) 'Method for evaluating user-side flexible device access to power grid' IOP Conf. Ser.: Earth Environ. Sci. 295 042065, DOI 10.1088/1755-1315/295/4/042065