Ministry of Public Works and Transport
General Department of Land Transport

Roadmap for the Development of an Electric Vehicle Charging Stations Network in Cambodia

2023

Preface

I am pleased to present this essential document, the "Roadmap for the Development of an Electric Vehicle Charging Stations Network in Cambodia." As Cambodia's Minister of Public Works and Transport, I understand the crucial role that sustainable transportation plays in our nation's progress to achieving the 2050's target of becoming a high-income country under the wise and visionary leadership of **Samdech Moha Borvor Thipadei HUN MANET, Prime Minister of Cambodia**. Adopting eco-friendly technologies is not just an option; it is a responsibility we owe to our environment, our people, and future generations.

This roadmap is a vital guide for Cambodia's transport future. It outlines a clear plan to create a reliable electric vehicle charging network across the country, paving the way for cleaner and more efficient transportation. Electric Vehicle have the potential to reduce pollution, enhance energy security, and position Cambodia as a leader in green technology. However, for this vision to materialize, a strong charging infrastructure must be in place.

I commend the authors for their meticulous work and extend my sincere gratitude to UNDP for their steadfast support in making this roadmap materialized. This roadmap provides valuable insights into different scenarios of electric vehicle adoption and the necessary investments in charging infrastructure. It also identifies lessons from global practices and outlines practical steps for the government, businesses, and other stakeholders.

As policymakers, it is our responsibility to assess and act upon these recommendations. We must collaborate across sectors to bring this roadmap to life. Our aim is to create a modern, sustainable transportation sector that benefits all Cambodians. Accessible charging infrastructure is key to making electric vehicle a reality. With collective effort, Cambodia can lead Southeast Asia's shift toward electric mobility.

I invite everyone, regardless of background, to explore this roadmap. Let's engage in discussions and partnership that will drive the implementation of this roadmap. Under the admirable leadership of **Samdech Thipadei Prime Minister,** we can redefine transportation, embracing innovation for Cambodia's brighter future.

Phnom Penh, 29 December 2023

Minister of Public Works and Transport

PENG Ponea

Acknowledgements

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We would like to thank all those who contributed to this study through their respective activities.

Many thanks to the top management and officials of the Ministry of Public Works and Transport, as well as the General Department of Land Transport, for taking the time to guide and provide valuable input in organizing this work.

We would also like to thank the UNDP team for their support in preparing this document.

This report has benefited from technical inputs and valuable comments from esteemed members of the GDLT, colleagues from line ministries and other public institutions, as well as representatives from the private sector, who gave some of their valuable time to help ensure that this work is contextualised and impactful.

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December 2022, Phnom Penh, Cambodia

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Table of Acronyms

AC	Alternative Current
ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
BAU	Business-as-usual
BEV	Battery Electric Vehicle
BMS	Battery Management System
CAPEX	Capital Expenditure
CDC	Council for the Development of Cambodia
CUF	Capacity Utilisation Factor
DC	Direct Current
DOD	Depth of Discharge
EAC	Electricity Authority of Cambodia
EDC	Electricité Du Cambodge
EPC	Engineering, Procurement, Construction
EV	Electric Vehicle
EVCS	Electric Vehicle Charging Station
FCEV	Fuel-cell Electric Vehicle
GDLT	General Department of Land Transport
GDP	Gross Domestic Product
HEV	Hybrid Electric Vehicle
HV	High Voltage
ICEV	Internal Combustion Engine Vehicle
IEA	International Energy Agency
IEA	International Energy Agency
IEC	International Electrotechnical Commission
ISO	International Organisation for Standardisation
LCOE	Levelised Cost of Energy
LEV	Light Electric Vehicle
LIB	Lithium-Ion Battery
LV	Low Voltage
MISTI	Ministry of Industry Science Technology and Innovation
MME	Ministry of Mines and Energy
MPWT	Ministry of Public Works and Transport
MRD	Ministry of Rural Development
MV	Medium Voltage
NR	National Road
NSC	National Standards Council
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditure
PHEV	Plug-in Hybrid Electric Vehicle
PWM	Pulse Width Modulation
RGC	Royal Government of Cambodia
SOC	State of Charge
TC8	Technical Committee 8
TWG	Technical Working Group
UNDP	United Nations Development Programme
UNR	United Nations Regulation
UPTD	Urban Public Transport Department
USD	United States Dollars

Foreword

The Royal Government of Cambodia (RGC) is fully committed to fulfilling its climate change mitigation objectives as outlined in its Nationally Determined Contributions (NDC) and Long-Term Strategy for Carbon Neutrality (LTS4CN). Clean mobility has been identified as a key priority to strive towards carbon neutrality.

The Government is in the process of adopting a set of policies, action plans, and concrete measures to foster the emergence of a dynamic market for Electric Vehicles (EVs). In 2016, the introduction of the battery reprocessing and recycling regulation by the Ministry of Environment paved the way for the necessary development of this sector. More recently, import duties on four-wheeler electric vehicles have been cut by half compared to internal combustion engine vehicles.

The efforts of the RGC are focused on creating a strong enabling environment for the emergence and scaling-up of the EV market, which entails the development of a nation-wide network of charging infrastructure. EV uptake and Electric Vehicle Charging Stations (EVCS) development are intrinsically correlated. Wide EV uptake without an EVCS network would confine clean mobility to a niche market and would not allow for economy-wide and cross-country usage.

This roadmap embodies the Government's vision for clean mobility in Cambodia. Its main objectives are to (i) define clear targets for ECVS network development in coherence with EV market projections and uptake goals, (ii) set priorities in terms of infrastructure development to meet the specific needs of the Cambodian people, (iii) identify regulatory development pathways, and (iv) assess financial and capacity building needs amongst stakeholders to enable the emergence of a self-sufficient market in the long run.

The partnership with the private sector is crucial for accelerating change, promoting innovation and new technologies. This roadmap will increase the projection capacity of private actors involved in the development of the network and help them build a strategy on this nascent market. Public actors, on the other hand, will be able to anticipate the needs for capacity building and the implementation of market-enabling measures. This document is structured as follows:

- **Background** examines the technical and financial basics of EVs and EVCS, discusses the current development of the EV and EVCS market worldwide, in the region, and in Cambodia.
- **Future Scenarios Modelling** details an analysis of electric vehicle uptake scenarios in Cambodia, and draws conclusions regarding the need for charging infrastructure.
- **Situation Analysis of EVCS in Cambodia** dives into the current situation of the EVCS market of Cambodia by discussing market prospects, identifying key players, and describing existing roadblocks.
- **Action Plan** proposes guiding principles for the charging infrastructure, and details an action plan that is to guide the Government in developing a robust institutional framework.
- The multiple **Annexes** allow to delve deeper into the intricacies of charging infrastructure.

ខ្លឹមសារសង្ខេប

សាវតារ

ឆ្នាំ២០២១ ជាឆ្នាំពិសេសមួយរបស់ទីផ្សារសកលនៃយានយន្តអគ្គិសនី។ ចំនួនលក់យានយន្តអគ្គិសនីបានកើនដល់ ៤២% នៃចំនួនលក់សរុប សម្រាប់ប្រភេទទោចក្រយានយន្តអគ្គិសនី និងត្រីចក្រយានយន្តអគ្គិសនី ៨,២% សម្រាប់ប្រភេទរថយន្តអគ្គិសនីដឹកអ្នកដំណើរ និង ៤៤% សម្រាប់ប្រភេទរថយន្តក្រុងអគ្គិសនី។ បច្ចុប្បន្ននេះ រថយន្តអគ្គិសនីធុនស្រាលចំនួនលើសពី ២៧០ លានគ្រឿងកំពុងចរាចរណ៍នៅលើដងផ្លូវ ក្នុងនោះមានរថយន្តអគ្គិសនីដែលប្រើប្រាស់ជាលក្ខណៈគ្រួសារ ១៨លានគ្រឿង រថយន្តក្រុងអគ្គិសនី ៦៨៥.០០០ គ្រឿង រថយន្តទេសចរណ៍អគ្គិសនី និងរថយន្តដឹកទំនិញអគ្គិសនីចំនួន ៦១៣.០០០ គ្រឿង។ ជាពិសេស ការព្យាករណ៍បានរំពឹងថា ការលក់រថយន្តអគ្គិសនីនឹងកើនឡើងលើសពីការលក់យានយន្តម៉ាស៊ីនចំហេះក្នុង នៅតាមទីផ្សារតំបន់ភាគច្រើនចន្លោះពីឆ្នាំ២០២៥ ដល់២០៤០។

នៅតំបន់អាស៊ីអាគ្នេយ៍ ទំនោរទៅប្រើប្រាស់យានយន្តអគ្គិសនីនឹងមានការកើនឡើងខ្លាំងជារួម ដែលដើរតួយ៉ាងសំខាន់នៅក្នុងគោលនយោបាយអាកាសធាតុក្នុងតំបន់ និងក្លាយជាប្រធានបទយុទ្ធសាស្ត្រ សម្រាប់ឧស្សាហកម្មរថយន្តក្នុងស្រុកផងដែរ។ ទោះបីជាទីផ្សារយានយន្តអគ្គិសនីក្នុងតំបន់បានបង្ហាញសញ្ញានៃការពង្រីកវិសាលភាពរបស់ខ្លួននាពេលអនាគតក៏ដោយ ក៏ការកើនឡើងនៃការប្រើប្រាស់យានយន្តអគ្គិសនីនៅតែស្ថិតក្នុងដំណាក់កាលដំបូងនៅឡើយក្នុងតំបន់អាស៊ាន ដោយដណ្តើមបានចំណែកទីផ្សារតែប៉ុន្មានភាគរយប៉ុណ្ណោះនៅតាមប្រទេសភាគច្រើន។ ឧបសគ្គចម្បងៗក្នុងការអភិវឌ្ឍទីផ្សារនេះ ត្រូវបានកំណត់យ៉ាងច្បាស់ ដូចជា៖

- **ភាពអាចរកបាន៖** នាពេលបច្ចុប្បន្ន មានម៉ូដែលយានយន្តអគ្គិសនីពីរ ឬបីប្រភេទដែលអាចស្វែងរកបានក្នុងតំបន់ និងពឹងផ្អែកខ្លាំងទៅលើការនាំចូល។
- **តម្លៃ៖** តម្លៃមានការប្រកួតប្រជែងជាមួយប្រភេទយានយន្តប្រើម៉ាស៊ីនចំហេះក្នុង ជាពិសេសទីផ្សារយានយន្តមួយទឹក ដែលនៅតែជាឧបសគ្គដ៏ធំ។
- **ភាពងាយស្រួល៖** កង្វះហេដ្ឋារចនាសម្ព័ន្ធស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនី ដែលបង្កជាការព្រួយបារម្ភចំពោះអ្នកប្រើប្រាស់ដែលមានសក្តានុពល និងជាការរាំងដល់ការលក់យានយន្តអគ្គិសនី។
- **ការយល់ដឹង៖** យានយន្តអគ្គិសនី ត្រូវបានរួមបញ្ចូលតិចតួចទៅក្នុងចំណេះដឹងសង្គម ហើយប្រជាពលរដ្ឋភាគច្រើននៅមិនទាន់មានទំនុកចិត្តក្នុងការប្រើប្រាស់នៅឡើយ។
- **សមត្ថភាពបច្ចេកទេស៖** កង្វះបណ្តាញទូទាំងប្រទេសលើប្រតិបត្តិការជួសជុល ដំណើរការ និងការថែទាំ។

ទោះបីជាការបញ្ចូលថាមពលយានយន្តអគ្គិសនីភាគច្រើនធ្វើឡើងនៅតាមផ្ទះក៏ដោយ ការអភិវឌ្ឍហេដ្ឋារចនាសម្ព័ន្ធស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនី ដែលមានគុណភាពខ្ពស់នៅតែមានភាពចាំបាច់ ក្នុងការធានាបានលទ្ធភាពសេដ្ឋកិច្ចក្នុងការទទួលយកយានយន្តអគ្គិសនីមកប្រើប្រាស់។

ហេដ្ឋារចនាសម្ព័ន្ធស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនីត្រូវបានបែងចែកជាបួនប្រភេទចម្បង រួមមាន i) **ការបញ្ចូលថាមពលតាមផ្ទះ** ជាការបញ្ចូលថាមពលមានអានុភាពទាប ដែលធ្វើឡើងនៅក្នុងផ្ទះ ឬកន្លែងធ្វើការ ii) **ការបញ្ចូលថាមពលអគ្គិសនីចរន្តឆ្លាស់ (AC) សាធារណៈ** ដែលស្ថានីយបញ្ចូលថាមពលអគ្គសនីត្រូវបានដំឡើងក្នុងទីប្រជុំជន បើកឱ្យប្រើប្រាស់ជាសាធារណៈ និងសម្រាប់តែការបញ្ចូលថាមពលប្រើប្រាស់រយៈពេលខ្លី iii) **ការបញ្ចូលថាមពលអគ្គិសនីចរន្តជាប់ (DC) ល្បឿនលឿន** ដែលដំណើរការដោយអានុភាពខ្ពស់ និងចាំបាច់ក្នុងការធានាដល់ការធ្វើដំណើរទូទាំងប្រទេស និង iv) **ស្ថានីយផ្លាស់ប្តូរអាគុយ** គឺជាគំរូប្តូរអាគុយរបស់យានយន្ត និងផ្តោតទៅលើតែយានយន្តធុនស្រាល (ទោ-ត្រីចក្រយានយន្ត) ប៉ុណ្ណោះ។

ជាទូទៅ សមាមាត្រនៃស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនីមួយត្រូវបានណែនាំឱ្យប្រើប្រាស់បានជាសាធារណៈសម្រាប់រថយន្តអគ្គិសនី ១០ គ្រឿង ដែលចរាចរណ៍នៅលើដងផ្លូវ។ ជាធម្មតា ស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនីត្រូវបានបែងចែកជា ៤០% សម្រាប់ការបញ្ចូលថាមពលអគ្គិសនីចរន្តជាប់ល្បឿនលឿន និង ៦០% សម្រាប់ការបញ្ចូលថាមពលអគ្គិសនីចរន្តឆ្លាស់ល្បឿនយឺត។ ម្យ៉ាងទៀត សម្រាប់យានយន្តអគ្គិសនីធុនស្រាល គំរូផ្លាស់ប្តូរអាគុយគឺជាដំណោះស្រាយដ៏មានប្រសិទ្ធភាពក្នុងរយៈពេលខ្លី ដើម្បីឆ្លើយតបទៅនឹងកង្វះខាតនៃហេដ្ឋារចនាសម្ព័ន្ធ ឬឆ្លើយតបទៅនឹងតម្រូវការរបស់ប្រភេទយានយន្តដឹកជញ្ជូន តាមភាពចាំបាច់។

ការដំឡើងស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនី ទាមទារឱ្យមានការវិនិយោគដើមទុនដំបូង សម្រាប់សម្ភារៈឧបករណ៍ ការរចនា ការដំឡើង និងការធ្វើបច្ចុប្បន្នភាពហេដ្ឋារចនាសម្ព័ន្ធអគ្គិសនី (ខ្សែ បណ្តាញតភ្ជាប់ ត្រង់ស្វូម៉ាទ័រ ជាដើម)។

គំរូស្តង់ដារនៃតម្លៃហេដ្ឋារចនាសម្ព័ន្ធស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនី			
ប្រភេទយានយន្ត	កង់បួន		កង់ពីរ
ហេដ្ឋារចនាសម្ព័ន្ធស្ថានីយ	ប្រព័ន្ធបញ្ចូលថាមពលចរន្តឆ្លាស់	ប្រព័ន្ធបញ្ចូលថាមពលចរន្តជាប់ល្បឿនលឿន	ទូប្តូរអាគុយ
ទំហំអានុភាព	4 ដល់ 40 គីឡូវ៉ាត់	40 ដល់លើសពី 400 គីឡូវ៉ាត់	10 ដល់ 20 គីឡូវ៉ាត់
តម្លៃក្នុងមួយទូបញ្ចូលថាមពល	$2,000 ដល់ $10,000	$30,000 ដល់ $100,000	$5,000 ដល់ $10,000

ជាទូទៅ សេវាបញ្ចូលថាមពលយានយន្តអគ្គិសនី គឺជាការវិនិយោគទទួលបានប្រាក់ចំណេញទាប ដែលទាមទារឱ្យមានអត្រាប្រើប្រាស់ខ្ពស់ ដើម្បីធានាការទទួលបានប្រាក់ចំណេញ។ ទោះបីជាមានការឧបត្ថម្ភធនក៏ដោយ ស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនី គឺកម្រទទួលបានផលចំណេញក្នុងរយៈពេលខ្លីដោយខ្លួនឯងណាស់។

ការវិភាគស្ថានភាពអំពីស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនីនៅកម្ពុជា

ការផ្គត់ផ្គង់យានយន្តដឹកជញ្ជូនផ្លូវគោកនៅកម្ពុជាបាននិងកំពុងកើនឡើងក្នុងអត្រាពិសេសពី ១០% ទៅ ១៥% ក្នុងមួយឆ្នាំ គិតចាប់តាំងពីចុងទសវត្សរ៍ឆ្នាំ១៩៩០ មក។ យានយន្តចុះបញ្ជីមានជាង ៦,៣ លានគ្រឿង គិតត្រឹមឆ្នាំ២០២១ ដែលក្នុងនោះ ៨៥% ជាទោចក្រយានយន្ត។ ទោះបីជាការប្រើប្រាស់រថយន្តផ្ទាល់ខ្លួននឹងបន្តកើនឡើងក្នុងពេលប៉ុន្មានឆ្នាំខាងមុខទៀតក៏ដោយ ទោចក្រយានយន្តត្រូវបានគេរំពឹងថានឹងនៅតែជាមធ្យោបាយធ្វើដំណើរតាមផ្លូវគោកច្រើនជាងគេ។

ក្នុងឆ្នាំ២០២០ យានយន្តអគ្គិសនីដំណើរការដោយអាគុយត្រូវបានគេប៉ាន់ប្រមាណថាមានចំនួនតិចជាង ០,១% នៃការលក់យានយន្តគ្រប់ប្រភេទទាំងអស់ក្នុងព្រះរាជាណាចក្រកម្ពុជា។ គិតត្រឹមខែកក្កដា ឆ្នាំ២០២២ មានរថយន្តអគ្គិសនីចំនួន ២៣១ គ្រឿង ដែលបានចុះបញ្ជីនៅក្រសួងសាធារណការ និងដឹកជញ្ជូន រួមជាមួយស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនី ចំនួន ៧ កន្លែង បានដាក់ឱ្យប្រើប្រាស់ជាសាធារណៈទូទាំងប្រទេស។

គ្រប់ដៃគូពាក់ព័ន្ធដែលមានសក្តានុពលទាំងអស់នៅក្នុងទីផ្សារយានយន្តអគ្គិសនី និងស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនី បានត្រៀមខ្លួនជាស្រេចក្នុងការវិនិយោគ សហការ និងមានគំនិតផ្តួចផ្តើមជាច្រើនត្រូវបានរៀបចំជាមូលដ្ឋានសម្រាប់ការអភិវឌ្ឍនាពេលអនាគតនៅកម្ពុជា។ វឌ្ឍនភាពរបស់យានយន្តអគ្គិសនីមានសក្តានុពលខ្លាំង ក្នុងការពង្រាយខ្លួនទូទាំងប្រទេស និងឆាប់រហ័ស ដោយការជំរុញគាំទ្រពេញលេញពីគ្រប់ក្របខ័ណ្ឌច្បាប់ និងគោលនយោបាយ។

ការអភិវឌ្ឍហេដ្ឋារចនាសម្ព័ន្ធស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនីនឹងត្រូវចាប់ផ្តើមជាដំបូង ដោយការជំរុញពីវិស័យឯកជន ជាមួយនឹងធនធានហិរញ្ញវត្ថុដែលផ្តោតទៅលើបរិស្ថាន សង្គម អភិបាលកិច្ច និងមូលនិធិនៃផលប៉ះពាល់សង្គមដែលមានស្រាប់។ ដូច្នេះ រាជរដ្ឋាភិបាល ដែលរួមបញ្ចូលដោយក្រុមការងារបច្ចេកទេស បូកផ្សំនឹងអន្តរក្រសួង និងស្ថាប័នពាក់ព័ន្ធ ត្រូវបានគេរំពឹងថានឹងដើរតួនាទីជានិយ័តករសំខាន់ក្នុងការលើកកម្ពស់វិធីសាស្ត្រផ្អែកលើតម្រូវការ ដោយអនុវត្តវិធានការទីផ្សារ។

មកដល់ពេលនេះ ឧបសគ្គមួយចំនួនដែលបានរារាំងដល់ការអភិវឌ្ឍហេដ្ឋារចនាសម្ព័ន្ធ មានដូចជា i) ការលំបាក និងការចំណាយទាក់ទងនឹងការធ្វើឱ្យប្រសើរឡើងបណ្តាញតភ្ជាប់ នៅទីតាំងដែលមានសក្តានុពល ii) កង្វះស្តង់ដារបច្ចេកទេសសម្រាប់ឧបករណ៍ រួមទាំងគុណភាព សុវត្ថិភាព និងការតភ្ជាប់ចំណុចបញ្ចូលថាមពល iii) កង្វះព័ត៌មានលម្អិតថ្នាក់ជាតិក្នុងការកំណត់គោលដៅនៃយានយន្តអគ្គិសនី និងស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនី iv) នៅមិនទាន់មានភាពច្បាស់លាស់លើច្បាប់ក្នុងការអនុញ្ញាតឱ្យដំណើរការស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនីដោយសារវិសាលភាពនៃច្បាប់អគ្គិសនី ដែលគ្រប់គ្រងការលក់ និងទិញថាមពលនៅកម្ពុជា។

គំរូសេណារីយ៉ូនាពេលអនាគត

សេណារីយ៉ូចំនួនបីត្រូវបានលើកឡើង សម្រាប់កំណើនយានយន្តអគ្គិសនីនៅក្នុងប្រទេសកម្ពុជាចាប់ពីក្រោយឆ្នាំ២០២២ ដល់ឆ្នាំ២០៥០ ត្រូវប្រើប្រាស់ និងគណនា ដើម្បីធ្វើការព្យាករណ៍តម្រូវការហេដ្ឋារចនាសម្ព័ន្ធស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនីសម្រាប់ពេលអនាគត។ សេណារីយ៉ូ អ៊ីវី១ (EV1) គឺជាសេណារីយ៉ូអភិរក្ស។ សេណារីយ៉ូ អ៊ីវី២ (EV2) គឺជាសេណារីយ៉ូនៃចំនួនប្រាកដនិយម ហើយនិងសេណារីយ៉ូ អ៊ីវី៣ (EV3) គឺជាសេណារីយ៉ូដែលស្របជាមួយកម្មវត្ថុរបស់យុទ្ធសាស្ត្រអភិវឌ្ឍន៍រយៈពេលវែងប្រកបដោយអព្យាក្រឹតកាបូន (LTS4CN)។

វាមិនមែនជារឿងប្លែកនោះទេដែលទោចក្រយានយន្ត និងត្រីចក្រយានយន្តនឹងក្លាយជាទីផ្សារយានយន្តអគ្គិសនីធំជាងគេក្នុងប្រទេសកម្ពុជា។ សេណារីយ៉ូទាំងបីនេះបង្ហាញថា យានយន្តទាំងនេះនឹងមានចំនួនលើសពីមួយលានគ្រឿង ចរាចរនៅលើដងផ្លូវនៅចន្លោះឆ្នាំ២០៣០ ដល់ ២០៤០ នឹងឈានដល់ចន្លោះពី ២,១ លាន ទៅ ៧,៣ លានគ្រឿងត្រឹមឆ្នាំ២០៥០។

ដោយចំនួនរថយន្តនៅកម្ពុជានៅតែកើនឡើងគួរឱ្យកត់សម្គាល់ ការផ្គត់ផ្គង់អគ្គិសនីទៅតាមកំណើនយានយន្តគឺជាឱកាសដ៏ច្បាស់លាស់មួយ ដើម្បីជៀសវាងការងាកត្រលប់ទៅប្រើប្រាស់យានយន្តម៉ាស៊ីនប្រើចំហេះក្នុងវិញ។ សេណារីយ៉ូទាំងនេះបង្ហាញថានឹងមានរថយន្តអគ្គិសនីលើសពី ១០ម៉ឺនគ្រឿងនៅកម្ពុជាចន្លោះឆ្នាំ២០៣៥ ដល់២០៤២ ហើយកើនចន្លោះពី ៣០ម៉ឺនទៅជាង១លានគ្រឿងត្រឹមឆ្នាំ២០៥០។

ផ្ទុយទៅវិញ រថយន្តអគ្គិសនីដឹកទំនិញធុនធំ រំពឹងថានឹងកើនឡើងតែពីរបីពាន់គ្រឿងប៉ុណ្ណោះ ដែលធ្វើចរាចរលើដងផ្លូវត្រឹមឆ្នាំ២០៥០។ ជារួម ការផ្គត់ផ្គង់អគ្គិសនីសម្រាប់រថយន្តអគ្គិសនីធុនធំ នឹងបង្កជាឧបសគ្គ ជាពិសេសទាក់ទងនឹងការប្រើប្រាស់បណ្ដាញអគ្គិសនីជាតិ និងការបន្តនៃកំណើនយានយន្តជាថ្មីម្តងទៀត។

ការប្រើប្រាស់ថាមពលអគ្គិសនី ដោយយានយន្តអគ្គិសនី នឹងមានអត្រាចន្លោះពី ០,៧% ទៅ ២,៨% នៃការប្រើប្រាស់ថាមពលអគ្គិសនីក្នុងស្រុកសរុបនៅកម្ពុជាត្រឹមឆ្នាំ២០៤០ ដែលពាក់កណ្ដាលនៃអត្រានេះត្រូវរំពឹងថាប្រើប្រាស់ដោយរថយន្តអគ្គិសនីធុនស្រាល។

ការរៀបចំកន្លែងរក្សាទុកសំណល់អាគុយ ដើម្បីគ្រប់គ្រងបរិមាណដ៏ច្រើនសន្ធឹកសន្ធាប់នៃអាគុយដែលត្រូវបានប្រើអស់អាយុកាល គឺជាកត្តាចំបាច់ដែលមិនអាចខ្វះបាន។ គិតត្រឹមឆ្នាំ២០៣០ តម្រូវការអាគុយនឹងស្ថិតនៅកម្រិតទាប ពោលគឺតិចជាង ពីរ ឬបីមេហ្គាវ៉ាត់ម៉ោង (MWh) ក្នុងមួយឆ្នាំ។ ត្រឹមឆ្នាំ ២០៤០ អាគុយជាច្រើនរយមេហ្គាវ៉ាត់ម៉ោងនឹងត្រូវផ្លាស់ប្ដូរចេញ និងបន្តយកប្រើប្រាស់ដោយត្រង់ជាលើកទីពីរ។ ត្រឹមឆ្នាំ២០៥០ បរិមាណចន្លោះពី ០,៧ ទៅ ២,៥ ជីហ្គាវ៉ាត់ម៉ោង (GWh) នឹងត្រូវឈប់ឱ្យប្រើប្រាស់សារឡើងវិញសម្រាប់ការប្រើប្រាស់លើកទីពីរជារៀងរាល់ឆ្នាំ ហើយចន្លោះពី ០,៣ ទៅ ១,៤ ជីហ្គាវ៉ាត់ម៉ោងនឹងត្រូវការកែច្នៃប្រើប្រាស់ឡើងវិញ ស្មើនឹងប្រមាណពី ៦ ទៅ ៩% នៃតម្រូវការអាគុយថ្មី។ នៅក្នុង

ប្រទេសកម្ពុជា ម៉ូតូអគ្គិសនីមួយគ្រឿងត្រូវបានព្យាករណ៍ថាបំភាយឧស្ម័នផ្ទះកញ្ចក់ ៥៥% តិចជាងម៉ាស៊ីនចំហេះក្នុងដែលមានទំហំសមមូលគ្នា គិតក្នុងពេលមួយវដ្តជីវិត ខណៈដែលរថយន្តលក្ខណៈគ្រួសារអាចកាត់បន្ថយបានត្រឹមតែ ២២% តែប៉ុណ្ណោះ។ ការប្រើប្រាស់អគ្គិសនីជំនួសឱ្យអ៊ីដ្រូកាបូន មានតួនាទីយ៉ាងសំខាន់ក្នុងកាត់បន្ថយការបំភាយឧស្ម័នផ្ទះកញ្ចក់សម្រាប់ដំណើរការយានយន្ត និងរួមជាមួយការកាត់បន្ថយការបំភាយឧស្ម័នផ្ទះកញ្ចក់ចេញពីការផលិតអគ្គិសនីនៅកម្ពុជាទៀតនោះ ការកាត់បន្ថយការបំភាយទាំងនេះនឹងមានបរិមាណច្រើនគួរឱ្យកត់សំគាល់។ ការប្រើប្រាស់យានយន្តអគ្គិសនីអាចកាត់បន្ថយការចំណាយលើប្រេងឥន្ធនៈសម្រាប់អ្នកប្រើប្រាស់បានជាមធ្យម ១៣៣ ដុល្លារសហរដ្ឋអាមេរិកសម្រាប់ម៉ូតូអគ្គិសនី និង ១.០៦៩ ដុល្លារសហរដ្ឋអាមេរិក សម្រាប់រថយន្តអគ្គិសនី ក្នុងមួយឆ្នាំ។ គិតត្រឹមឆ្នាំ២០៣០ សក្តានុពលនៃការកាត់បន្ថយការចំណាយសម្រាប់គ្រួសារនៅកម្ពុជានឹងមានទំហំចន្លោះពី ១៤ លាន ទៅ ៧៨ លានដុល្លារសហរដ្ឋអាមេរិក ក្នុងមួយឆ្នាំ។ ត្រឹមឆ្នាំ២០៥០ ទំហំនៃការកាត់បន្ថយចំណាយនេះមានចន្លោះពី ៥០៩ ទៅ ១.៧៦៦ លានដុល្លារសហរដ្ឋអាមេរិក ជារៀងរាល់ឆ្នាំ។

ចំនួនហេដ្ឋារចនាសម្ព័ន្ធដែលត្រូវការចំបាច់ ដើម្បីជួយគាំទ្រដល់កំណើននៃយានយន្តអគ្គិសនី នឹងប្រែប្រួលចន្លោះពី ៩.៩០០ ទៅ ៣៣.៨០០ ទូ ដោយរាប់បញ្ចូលគ្រប់ប្រភេទនៃការបញ្ចូលថាមពលអគ្គិសនីត្រឹមឆ្នាំ២០៥០។ ដោយឡែក ទីតាំងយុទ្ធសាស្ត្រសម្រាប់ស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនីចរន្តជាប់ល្បឿនលឿនមានចន្លោះពី ២៥ ទៅ ១០០ ទីតាំង ដែលអាចធ្វើការតភ្ជាប់ការធ្វើដំណើរទៅគ្រប់ខេត្តក្រុងទូទាំងប្រទេសកម្ពុជាគិតត្រឹមឆ្នាំ២០៣០ ហើយនៅត្រឹមដំណាច់ឆ្នាំ២០៥០ តម្រូវការនឹងកើនឡើងចន្លោះពី ១.៧០០ ទៅ ៥.៩០០ ទីតាំង។

ការដាក់ពង្រាយហេដ្ឋារចនាសម្ព័ន្ធស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនីនេះត្រូវការដើមទុនវិនិយោគចន្លោះពី ១៦៨ ទៅ ៥៧៦ លានដុល្លារសហរដ្ឋអាមេរិកនៅត្រឹមឆ្នាំ២០៥០ គិតជាមធ្យមមានចន្លោះពី ០,៥ ទៅ ២ លានដុល្លារសហរដ្ឋអាមេរិកក្នុងមួយឆ្នាំ ចន្លោះពីឆ្នាំ២០២២ ដល់ ២០៣០។

ដើមទុនវិនិយោគប្រចាំឆ្នាំសម្រាប់ហេដ្ឋារចនាសម្ព័ន្ធស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនី

	សម្រាប់រថយន្តអគ្គិសនី						សម្រាប់ទោចក្រយានយន្តអគ្គិសនី		
	ប្រភេទបញ្ចូលថាមពលល្បឿនយឺត			ប្រភេទបញ្ចូលថាមពលល្បឿនលឿន			ស្ថានីយប្តូរអាគុយ		
រយៈពេល /សេណារីយ៉ូ	EV1	EV2	EV3	EV1	EV2	EV3	EV1	EV2	EV3
2022 - 2025	$50k	$100k	$180k	$90k	$180k	$310k	$70k	$130k	$440k
2025 - 2030	$130k	$270k	$460k	$240k	$480k	$810k	$210k	$420k	$1.3m
2030 - 2040	$1.3m	$2.6m	$4.3m	$2.3m	$4.5m	$7.7m	$1.4m	$2.7m	$5.2m
2040 - 2050	$3.4m	$6.8m	$11.5m	$6.0m	$12.1m	$20.5m	$1.7m	$3.3m	$4.6m

ផែនទីបង្ហាញផ្លូវ

ផែនការសកម្មភាពបានបង្កើតឡើង ដើម្បីត្រួសត្រាយផ្លូវសម្រាប់សកម្មភាពរបស់រដ្ឋាភិបាល ក្នុងការគាំទ្រដល់ការអភិវឌ្ឍបណ្តាញហេដ្ឋារចនាសម្ព័ន្ធស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនី។

អនុសាសន៍ត្រូវបានផ្តល់ក្នុងការបង្កើតក្របខ័ណ្ឌច្បាប់ ដែលអនុញ្ញាតឱ្យមានការដំឡើងទីតាំងបញ្ចូលថាមពលយានយន្តអានុភាពទាបដោយសេរីនៅតាមទីតាំងឯកជន ព្រោះថាការដំឡើងទាំងនេះនឹងមានការប៉ះពាល់តិចតួចបំផុតទៅលើហេដ្ឋារចនាសម្ព័ន្ធបណ្តាញអគ្គិសនីជាតិ ព្រមទាំងការធ្វើនិយ័តកម្មសម្រាប់ការដំឡើងដែលមានអានុភាពខ្ពស់ដូចជា ស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនីចរន្តជាប់ល្បឿនលឿន ដោយមានការកំណត់និយមន័យ និងនីតិវិធីច្បាស់លាស់។ ការកំណត់ និងបង្ហាញពីស្តង់ដារបច្ចេកទេសនឹងជំរុញដល់កំណើនការប្រើប្រាស់ និងធានាបានសុវត្ថិភាពអ្នកប្រើប្រាស់។

ផែនទីបង្ហាញផ្លូវត្រូវបានបែងចែកការអនុវត្តជាបីដំណាក់កាល (២០២៥២០២៧ ២០៣០)។ដំណាក់កាលទី១ មានសកម្មភាពអាទិភាពខ្ពស់បំផុតសម្រាប់ការអភិវឌ្ឍស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនីរួមមាន៖

- **ការបង្កើតក្រុមការងារបច្ចេកទេសអន្តរក្រសួង៖** ក្រុមការងារនេះ នឹងមានសមាសភាពពីមន្ត្រីបច្ចេកទេសជំនាញរបស់ក្រសួងដែលនឹងធានាដល់ការសម្របសម្រួលរវាងដៃគូពាក់ព័ន្ធ និងបង្កើតប្រព័ន្ធច្រកចេញចូលរួមមួយ ដើម្បីជៀសវាងការទាក់ទងទៅច្រើនកន្លែង និងច្រើនស្ថាប័ន។
- **ការអនុម័តគោលដៅថ្នាក់ជាតិនៃកំណើនយានយន្តអគ្គិសនី និងស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនី៖** វិធីសាស្ត្រលម្អិតរបស់រាជរដ្ឋាភិបាលសម្រាប់ការដាក់ឱ្យប្រើប្រាស់យានយន្តអគ្គិសនី និងការបង្កើនទីតាំងស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនីនឹងបង្ហាញពីការប្តេជ្ញាចិត្តយ៉ាងមុតមាំក្នុងការគាំទ្រឱ្យប្រើប្រាស់បច្ចេកវិទ្យាថ្មីទាំងនេះ។
- **ការរៀបចំផែនការជំរុញដំណាក់កាលដំបូង៖** ដើម្បីចាប់ផ្តើមការអភិវឌ្ឍបណ្តាញស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនីល្បឿនលឿន ដោយបង្ហាញលក្ខខណ្ឌចាំបាច់សម្រាប់ការអភិវឌ្ឍទីផ្សារដំណាក់កាលដំបូង។
- **គាំទ្រការបង្កើតសមាគមធុរកិច្ច៖** ដើម្បីនាំយកតួអង្គសំខាន់ៗទាំងអស់រួមគ្នាក្រោមឆ័ត្រតែមួយ និងបង្កើតបណ្តាញក្រុមពិភាក្សាជាប្រចាំ ដើម្បីជំរុញកំណើន និងសម្រួលដល់ការអភិវឌ្ឍហេដ្ឋារចនាសម្ព័ន្ធ។
- **ការបង្កើតក្រុមការងារដំណើរការនីតិវិធីសម្រាប់ហេដ្ឋារចនាសម្ព័ន្ធស្ថានីយបញ្ចូលថាមពលអានុភាពខ្ពស់៖** ដើម្បីដោះស្រាយផ្នែកច្បាប់ ដែលបង្កើតឡើងដោយវិសាលភាពនៃច្បាប់ស្តីពីអគ្គិសនី។
- **ការកំណត់ និងអនុវត្តនៃស្តង់ដារបច្ចេកទេស៖** ជាពិសេសតំណរភ្ជាប់សម្រាប់ការបញ្ចូលថាមពល (ក្បាលដោត) រួមទាំងគុណភាពនៃឧបករណ៍ និងសុវត្ថិភាពនៃការដំឡើងផងដែរ។

តារាង១ កាលវិភាគនៃផែនទីបង្ហាញផ្លូវសម្រាប់សកម្មភាពដែលគួរអនុវត្ត

សកម្មភាពដែលគួរអនុវត្ត		2022	ដំណាក់កាលទី 1 2025	ដំណាក់កាលទី 2 2027	ដំណាក់កាលទី 3 2030
ប្រធានបទទី1 - ការសម្របសម្រួល និងគាំទ្រ					
1.1 ការបង្កើតក្រុមការងារបច្ចេកទេសអន្តរក្រសួង (TWG)	*(MPWT)*				
1.2 រៀបចំគោលដៅថ្នាក់ជាតិ និងការចេញយុទ្ធសាស្ត្រអភិវឌ្ឍន៍	*(MPWT)*				
1.3 ផែនការជំរុញដំណាក់កាលដំបូងសម្រាប់ស្ថានីយបញ្ចូលថាមពលល្បឿនលឿន	*(MPWT)*				
1.4 រៀបចំគោលដៅត្រួតពិនិត្យ និងរាយការណ៍	*(MPWT)*				
1.5 គាំទ្រការបង្កើតសមាគមធុរៈកិច្ចយានយន្តអគ្គិសនី និងស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនី	*(MPWT)*				
ប្រធានបទទី2 – ការអភិវឌ្ឍក្របខ័ណ្ឌច្បាប់ និងគោលនយោបាយ					
2.1 ការរៀបចំនីតិវិធីសម្រាប់ហេដ្ឋារចនាសម្ព័ន្ធស្ថានីយបញ្ចូលថាមពលអានុភាពខ្ពស់	*(MPWT, EAC, MME, EDC)*				
2.2 ការរៀបចំក្របខ័ណ្ឌលទ្ធកម្មសម្រាប់ទីតាំងសាធារណៈ	*(MPWT)*				
2.3 ការបង្កើតស្តង់ដារគុណភាព និងសុវត្ថិភាពសម្រាប់ឧបករណ៍បញ្ចូលថាមពល	*(MPWT / MISTI)*				
2.4 ការបង្កើតស្តង់ដារសម្រាប់តំណរបញ្ចូលថាមពល (ក្បាលដោត)	*(MPWT / MISTI)*				
2.5 ការលើកទឹកចិត្តការដំឡើង និងបំផុសអាជីវកម្មទាក់ទងនឹងស្ថានីយបញ្ចូលថាមពលយានយន្តអគ្គិសនី	*(MEF)*				
ប្រធានបទទី3 – ការរួមបញ្ចូលជាមួយបណ្តាញអគ្គិសនី					
3.1 សម្រួលដល់ការធ្វើបច្ចុប្បន្នភាពហេដ្ឋារចនាសម្ព័ន្ធសម្រាប់ទីតាំងស្ថានីយ	*(MME)*				
3.2 រួមបញ្ចូលហេដ្ឋារចនាសម្ព័ន្ធស្ថានីយបញ្ចូលថាមពលក្នុងផែនការអភិវឌ្ឍថាមពលរយៈពេលវែង	*(MME)*				
3.3 រៀបចំផែនការបច្ចុប្បន្នភាពសម្រាប់បច្ចេកវិទ្យាទំនើប	*(MME)*				
ប្រធានបទទី4 – ការអភិវឌ្ឍសមត្ថភាព និងលើកកម្ពស់ការយល់ដឹង					
4.1 យុទ្ធនាការអនុវត្តជាគំរូ	*(RGC)*				
4.2 បង្កើតគោលការណ៍ណែនាំនៃការអនុវត្តល្អបំផុត	*(MPWT)*				
4.3 បង្កើតជំនាញបច្ចេកទេសថ្មី	*(RGC)*				

Executive Summary

Scope and Approach

The key objective of this document is (i) to assess the need for EVCS network development in Cambodia, in coherence with EV market projections, (ii) to help set priorities in terms of infrastructure development to meet the specific needs of the Cambodian people, (iii) to identify regulatory development pathways, with recommended actions and players, and finally (iv) to assess financial and capacity building needs amongst stakeholders to enable the emergence of a self-sufficient market in the long run.

The recommended course of actions described here is specifically targeting the development of the charging infrastructure, not the adoption of electric vehicles more broadly. It will be important to ensure synchronisation between these proposed activities and other initiatives that are more directly related to EVs.

The development of this document was supported in particular by extensive desk research, multiple interviews with key stakeholders (financial institutions, EV suppliers, EVCS suppliers, government, etc.), and a country-wide field work. The results and recommendations formulated here were validated in a series of workshops with representatives of the private sector and line ministries.

Background

2021 was an exceptional year for the global electric vehicle (EV) market. Electric vehicle sales reached 42% of total sales for two- and three-wheelers, 8.2% for passenger cars, and 44% for urban buses. There are now more than 270 million light electric vehicles on the road, 18 million cars, 685,000 buses, and 613,000 vans and trucks. In particular, it is expected that electric car sales will surpass Internal Combustion Engine Vehicles (ICEV) sales in most markets between 2025 and 2040.

In Southeast Asia, electric mobility is becoming an increasingly central issue, which is expected to play a crucial role in the climate policies of the region, whilst being a strategic topic for the local automotive industries. Although the regional EV market has shown signs of future expansion, EV uptake is still at its early stage in ASEAN, capturing only a few percent of market share in most countries. The key barriers to the development of this market are clearly identified:

- **Availability**: few EV models are currently available in the region, which still relies heavily on imports.
- **Affordability**: cost competition with ICEVs, especially from the second-hand market, remains a major barrier.
- **Convenience**: lack of sufficient charging infrastructure creates range anxiety amongst potential users, hampering EV sales.
- **Awareness**: EVs are still hardly integrated into the Cambodian landscape; misconceptions regarding their operation and reliability remain common.
- **Technical capacity**: there is a lack of nation-wide network operators and maintenance personnel.

Although the vast majority of charging takes place at home, developing a high-quality charging infrastructure will be critical to ensure economy-wide adoption of electric vehicles. Charging infrastructure is divided into four main types: (i) **home charging**, charging carried out in the home or workplace at low power, (ii) **away-from-home AC charging**, stations installed in urban areas and open to the public, used in particular for short top-up charges, (iii) **DC fast charging**, carried out at high power and essential to ensure cross-country travel, and (iv) **battery swapping stations**, Battery-as-a-Service models targeted at light vehicles.

Generally, a ratio of 1 charging station open to the public for every 10 electric cars on the road is recommended, with Electric Vehicle Charging Stations (EVCS) usually divided into 40% DC fast chargers and 60% AC slow chargers. On the other hand, battery swapping models for light electric vehicles are short-term effective solutions to compensate for the lack of infrastructure or to respond to specific transport needs.

Installing a charging station requires significant initial capital investment: hardware, design, installation, and upgrading the electrical infrastructure (grid connection, transformer, etc.).

Benchmark of charging infrastructure cost			
Vehicle segment	Four-wheelers		Two-wheelers
Charging infrastructure	AC charger	DC fast charger	Battery swapping cabinet
Power capacity	4 to 40 kW	40 to over 400 kW	10 to 20 kW
Cost per charging point	$2,000 to $10,000	$25,000 to $100,000	$5,000 to $10,000

Generally speaking, charging services are low-margin investments which require a high equipment use rate to ensure profits. Even with significant subsidies, EV charging stations are rarely short-term profitable ventures on their own.

Situation Analysis of EVCS in Cambodia

Cambodia's stock of motorised land vehicles has been growing at an exceptional rate of 10 to 15% per year since the late 1990s. There were over 6.3 million registered motorised vehicles in the Kingdom in 2021, of which 85% are motorcycles. Although the use of personal cars will continue to grow in the coming years, motorcycles are expected to remain the predominant means of road transport.

In 2020, battery electric vehicles were estimated to account for less than 0.1% of vehicle sales across all segments in the Kingdom. As of September 2022, there were 295 2-3 electric wheelers and 262 electric vehicles registered with MPWT, as well as 7 open to the public EVCS implemented in the country.

All key potential stakeholders of the EV and EVCS markets are ready to invest and cooperate; multiple initiatives have prepared the ground for future development in Cambodia. There is strong potential for rapid and country-wide deployment of EVs, which will be enabled by an adequate and supportive regulatory and policy framework.

The development of the charging infrastructure will be primarily a private sector-driven initiative, with financial resources already readily available through Environment, Social, Governance (ESG) and impact funds. Therefore, the Government, embodied by a Technical Working Group bringing together key line ministries and public organisations, is expected to play a regulatory role, promoting a market-based approach by implementing market-enabling measures.

A number of roadblocks have so far hampered the development of the infrastructure and will need to be addressed, particularly (i) the difficulty and cost associated with upgrading connection points at potential host sites, (ii) the absence of technical standards for components regarding quality, safety, and charging connectors, (iii) the absence of detailed national EV and EVCS uptake targets, (iv) the existing legal void regarding authorisation to operate charging equipment, due in particular to the Law of Electricity which regulates the sale and purchase of energy in the Kingdom.

Future Scenario Modelling

Three scenarios for the adoption of electric vehicles in Cambodia were modelled, from 2022 to 2050 period, and are used to draw conclusions about the associated vehicle charging infrastructure needed. Scenario EV1 is the conservative scenario, EV2 the more realistic uptake scenario, and EV3 is the aspirational scenario aligned with LTS4CN objectives.

Unsurprisingly, two- and three-wheelers will constitute by far the largest market segment of electric vehicles in the Kingdom. All three scenarios suggest that there will be over a million of them on the roads sometime between 2030 and 2040, reaching between 2.1 and 7.3 million units by 2050.

Given that Cambodia's car stock is still growing significantly, there is a clear opportunity to electrify it as it grows, thus avoiding the inertia related to retiring ICEVs. The scenarios provide that there will be over 100,000 electric cars in Cambodia sometime between by 2035 and 2042, and by 2050 between 300 thousand and more than a million.

In contrast, only an expected few thousand electric heavy vehicles will be on the road by 2050. Overall, electrifying the heavy-vehicle stock will raise particularly complex challenges in terms of grid integration and vehicle stock renewal.

Electricity consumption generated by the EVs will represent between 0.7% and 2.8% of Cambodia's national electricity consumption by 2040, half of which is expected to come from electric cars.

It will be paramount to set up battery disposal facilities in order to manage the orderly end-of-life of these significant volumes of batteries. By 2030, the capacity needed will remain particularly low, below a few MWh per year. By 2040, several hundreds of MWh of batteries will need to be decommissioned and directed to secondary applications. By 2050, between 0.7 and 2.5 GWh will need to be decommissioned each year for secondary uses, and between 0.3 and 1.4 GWh will need to be recycled, covering 6 to 9% of the demand for new batteries.

In Cambodia, an electric motorcycle will emit an estimated 55% less GHG than an equivalent ICEV during its lifetime, whilst for cars this benefit is only 22%. The use of electricity instead of hydrocarbons significantly reduces the operational emissions of vehicles; with the decarbonisation of the Cambodian electricity grid, these savings will become more significant.

The use of an electric vehicle makes it possible to reduce fuel expenditure for users by an average $133 per year for electric motorcycles, and $1,069 for electric car. The potential savings for households will amount to between $14 and $78 million per year by 2030. By 2050, these savings may represent between $509 and $1,766 million every year.

The resulting infrastructure needed to support the growth of the electric vehicle stock will vary between 9,900 and 33,800 individual charging points by 2050, all types combined. In particular, by 2030, between 25 and 100 strategically located DC fast chargers will be needed to fully interconnect Cambodia's provinces; by 2050, 1,700 to 5,900 will be required – a similar amount to the approximately 3,000 gas stations contained in Cambodia.

The deployment of the charging infrastructure will require a cumulative capital investment between $168 and $576 million by 2050, averaging $0.5 to $2 million per year in the 2022 to 2030 period.

Yearly capital investment in charging infrastructure									
	For electric cars						For electric motorcycles		
	Slow chargers			Fast chargers			Battery swapping stations		
Period / Scenario	EV1	EV2	EV3	EV1	EV2	EV3	EV1	EV2	EV3
2022 - 2025	$50k	$100k	$180k	$90k	$180k	$310k	$70k	$130k	$440k
2025 - 2030	$130k	$270k	$460k	$240k	$480k	$810k	$210k	$420k	$1.3m
2030 - 2040	$1.3m	$2.6m	$4.3m	$2.3m	$4.5m	$7.7m	$1.4m	$2.7m	$5.2m
2040 - 2050	$3.4m	$6.8m	$11.5m	$6.0m	$12.1m	$20.5m	$1.7m	$3.3m	$4.6m

Action Plan

An action plan has been developed to guide Government in supporting the development of a charging infrastructure network.

It is recommended to develop a legal framework that freely allows the installation of low-power charging outlets on private premises as these will have very little impact on the national power infrastructure, whilst regulating the implementation of high-power installations such as DC fast chargers through clearly defined policy. The introduction of technical standards will align initiatives and help ensure user safety.

The roadmap follows a three-phase timeline (2025, 2027, 2035). Phase 1 contains the highest priority actions for the development of charging stations, namely:

- **The establishment of an inter-ministerial Technical Working Group (TWG)**. The TWG will be composed of ministerial technical staff that will ensure coordination between initiatives and create a single window system to avoid interaction with multiple government contact points.
- **The adoption of national uptake targets for EVs and for EVCS.** Detailing the Government's approach for EV adoption and EVCS deployment will show a strong and holistic commitment to support these new technologies
- The set-up of an **Early Incentive Programme** to kick-start the development of a network of fast charging stations, by bringing the necessary conditions for the early development of the market.
- Assisting in the **establishment of business associations** to bring all key players together under one roof, and setting up regular discussion channels to foster initiatives and facilitate infrastructure development.
- Development of an **authorisation process for high-power charging infrastructure** to address the legal void created by the Law on Electricity.

- The **adoption and enforcement of a defined set of technical standards**, in particular for charging connectors (plugs), but also in terms of component quality and installation safety.

Table 1. Roadmap timeline for recommended actions.

Recommended actions	Lead and cooperating ministries	2022	Phase 1 2025	Phase 2 2027	Phase 3 2035
Topic #1 - Coordination and Support					
1.1 Establishment of an inter-ministerial Technical Working Group (TWG)	*(TWG)*	■	■		
1.2 Set-up of national uptake targets and issuance of a development strategy	*(TWG)*	■	■		
1.3 Developing an Early Incentive Programme for fast chargers	*(TWG)*	■	■		
1.4 Supporting the establishment of business associations pertaining to EV and EVCS	*(TWG)*	■	■		
1.5 Developing a vehicle battery disposal action plan	*(TWG)*	■	■	■	
1.6 Building a monitoring and reporting framework for EVCS	*(TWG)*	■	■	■	
Topic #2 – Regulatory and Policy Framework Development					
2.1 Development of an authorisation process for high-power charging infrastructure	*(TWG)*	■	■		
2.2 Developing of a procurement framework for public locations	*(MPWT)*	■	■	■	
2.3 Assessment of safety risks and requirements for AC charging	*(TWG)*	■	■	■	
2.4 Issuing quality and safety standards for charging equipment	*(MPWT / MISTI / TC8)*	■	■		
2.5 Definition of regulatory approach for low-power charging infrastructure	*(TWG)*	■	■	■	
2.6 Issuing technical standards for charging connectors (plugs)	*(MPWT / MISTI / TC8)*	■	■		
2.7 Incentivising EVCS installation and the emergence of EVCS-related businesses	*(MEF)*	■	■	■	
2.8 Setting requirements to the installation of EVCS in new constructions	*(TWG)*	■	■	■	
Topic #3 – Grid Integration					
3.1 Facilitating infrastructure upgrades for site hosts	*(MME)*	■	■	■	
3.2 Country-wide assessment of EVCS installation risks and necessary upgrades	*(MME)*	■	■	■	
3.3 Including charging infrastructure in long-term power development plans	*(MME)*	■	■	■	
3.4 Planning for cutting-edge approaches	*(MME)*	■	■	■	■
Topic #4 – Capacity Building and Awareness Raising					
4.1 Campaign for leading by example	*(RGC)*	■	■	■	■
4.2 Developing best-practices guidelines	*(MPWT)*	■	■	■	
4.3 Building the new technical skillsets	*(RGC)*	■	■	■	■

Background

Basics of Electric Vehicle Charging Stations

Note: Additional information can be found in **Annex 1**, which dives deeper into the technical basics of electric vehicle charging stations.

Classification of Electric Vehicles

An electric vehicle (EV) is a vehicle which is propelled by one or more electric motors, powered by a battery pack – commonly, the term EV encompasses both battery electric vehicles (BEVs) and plug-in hybrid vehicles (PHEVs). Road vehicles are classified according to their powertrain as follows:

Table 2. Classification of vehicle power trains.

Type	Acronym	Definition
Battery Electric Vehicle	**BEV**	**Fully electric vehicle without a combustion engine.** (Main focus of this document).
Hybrid Electric Vehicle	HEV	Vehicle with an internal combustion engine and an electric powertrain that can be run in pure electric mode for a limited range and benefits from regenerative braking.
Plug-in Hybrid Electric Vehicle	PHEV	HEV that has a larger battery and can be plugged in and charged.
Fuel Cell Electric Vehicle	FCEV	Hydrogen-fuelled vehicles, which includes a fuel cell and a battery-powered electric motor.
Internal Combustion Engine Vehicle	ICEV	Conventional fossil powered vehicle which uses diesel, gasoline, or gaseous fluids.

Electric alternatives exist for all transport modes and vehicle categories, from two-wheelers to heavy-duty trucks. The following table provides a standard classification and typical specifications of BEV segments.

Table 3. Main BEV segments and associated battery characteristics.
Compiled from market data of available EV models.

<table>
<tr><th>Category</th><th>Type</th><th>kWh per km</th><th>Battery size</th><th>Battery voltage</th></tr>
<tr><td rowspan="3">Two-wheelers</td><td>Bicycle</td><td rowspan="3">~ 0.03</td><td>0.25 – 1 kWh</td><td rowspan="2">36 - 48 V</td></tr>
<tr><td>Scooter</td><td>~ 1 kWh</td></tr>
<tr><td>Motorcycle</td><td>3 – 20 kWh</td><td>48 - 72 V</td></tr>
<tr><td>Three-wheelers</td><td>Tuk-tuk</td><td>~ 0.06</td><td>3.6 – 8 kWh</td><td>48 – 72 V</td></tr>
<tr><td rowspan="2">Cars</td><td>1st gen. BEV</td><td rowspan="2">0.1 – 0.3</td><td>~ 20 kWh</td><td>72 V</td></tr>
<tr><td>2nd gen. BEV</td><td>30 – 150 kWh</td><td rowspan="5">350 – 500 V</td></tr>
<tr><td rowspan="4">Heavy duty vehicles</td><td>Urban bus</td><td rowspan="4">0.5 – 1.2</td><td rowspan="2">80 – 300 kWh</td></tr>
<tr><td>Urban truck</td></tr>
<tr><td>Inter-urban bus</td><td rowspan="2">> 300 kWh</td></tr>
<tr><td>Long-haul truck</td></tr>
</table>

The average driving range of new BEVs has been steadily increasing: the weighted average range for a new battery electric car increased from 200 km in 2015 to over 350 km in 2022 (IEA, 2022).

Electric Vehicle Charging Equipment

Charging stations are commonly classified into **four power levels**:

Table 4. Power range definition of charging levels of EVCS.

EVCS power level	Charging power	Range delivery *(for cars)*	Type
Level #1	< 3.7 kW	< 20 km per hour	Slow charger
Level #2	3.7 to 22 kW	< 150 km per hour	
Level #3	22 to 120 kW	150 to 600 km per hour	Fast charger
Level #4	> 120 kW	> 600 km per hour	

The charging level needs to be adapted to the type of EV and the user behaviour in order to be completed in a reasonable amount of time and without incurring damage to the battery. For instance, light electric vehicles, since they have small battery packs, mostly need a low-power supply, whereas heavy-duty vehicles need a high-power delivery. Alternatively, instead of charging the battery directly, some manufacturers favour a Battery-as-a-Service (BaaS) or battery swapping approach. In these models, depleted batteries are removed from the vehicle and replaced with fully-charged ones by a third-party operator for a fee. Annex 3 - describes battery swapping models in more detail.

The following table summarises charging levels that are commonly used for different electric vehicle segments.

Table 5. Main BEVs segments and associated appropriate charging levels.
Compiled from market data of available EV models.

EV segment	Type	Level #1 < 3.7 kW	Level #2 3.7 – 22 kW	Level #3 - #4 > 22 kW	Battery swapping
Two-wheelers	Bicycle	•			•
	Scooter	•			•
	Motorcycle	•	*Rarely*		•
Three-wheelers	Tuk-tuk	•	•		•
Cars	1st gen. BEV	•	•	•	*Rarely*
	2nd gen. BEV	•	•	•	
Heavy duty vehicles	Urban bus			•	
	Urban truck			•	
	Inter-urban bus			•	
	Long-haul truck			•	

Cost of Electric Vehicle Charging Stations

The cost of a given charging point is dependent on the specific requirements and constraints of the station and its users. Therefore, the costs associated with installing and operating EVCS can vary extensively, depending on the power rating of the station, the desired charging point features, the site location, the existing electrical infrastructure, and the necessary civil work. The main costs can be broken down as follows:

i. **Hardware costs.**
   - EVCS unit.
   - Material for connecting the station to the electrical service (cables, electrical panels, trenching, boring, repaving, metering, etc.).
   - Payment system.

- Additional EVCS equipment (advertising platform, energy monitoring, etc.).

ii. **Installation costs.**
- Design and engineering review.
- Contractor labour and materials.
- Licensing and inspection.

iii. **Additional capital costs.**
- Potential electrical infrastructure upgrades (breakers, transformer, cabling, etc.).
- Civil work (lighting, signage, painting, parking space, etc.).
- Hardware and installation warranty.
- Land/parking space purchase or lease.

iv. **Operation and maintenance costs.**
- Electricity consumption and demand charges.
- Subscription to EVCS online monitoring systems.
- Management time.
- Billing transaction costs.
- Preventative and corrective maintenance.

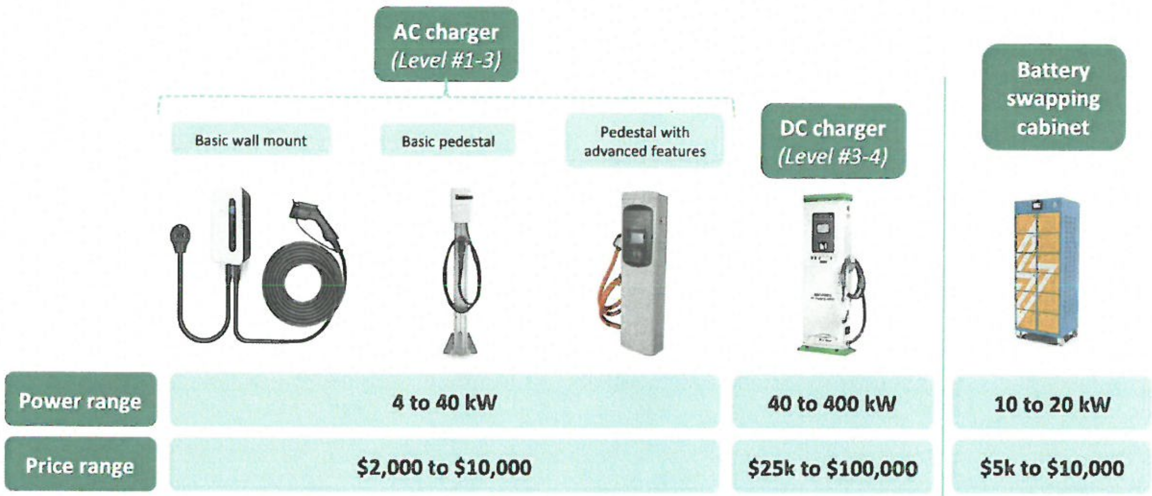

Figure 1. Benchmark price of different types of EVCS in 2022.
Compiled from market data of available EVCS models; costs are given as an indication and may vary significantly between components, locations, and project specifics. Battery swapping cabinet costs do not include batteries.

Benefits of Electric Vehicle Charging Stations

Note: Additional information pertaining to EVCS financial modelling and business models can be found in Annex 4 and Annex 5.

Ensuring the profitability of charging equipment is of primary concern to potential investors. Proper financial forecasting can be challenging, as it has to account for factors such as EV user on-site dwell time, charging fee structure, charging station utilisation rate, and indirect benefits for the site host.

Generally speaking, charging services are low-margin investments which require a high equipment use rate to ensure profit. Even with significant subsidies, **EV charging stations are rarely short-term profitable ventures on their own.**

By installing open-to-the-public EVCS within their ground, site hosts can attract or retain BEV-driving visitors, employees, and customers. Benefits induced by the equipment include:

- **Revenue generation.**
    - **Direct**: fees paid by EV users to use the charging equipment.
    - **Indirect**: (i) sales revenue from customers either coming to a site for the purpose of using the charging station or spending longer time at the location whilst waiting for their vehicle to charge (ii) revenue from on-site advertising boards.
- **Corporate branding and increased attractivity.** Hosting EV charging stations can signal commitment of the host site to advancing sustainability goals.

Global Context of EVs and EVCS

Electric Car Market

2020 and 2021 were pivotal years for the global electric vehicle market. Despite the COVID-19 crisis and a 15.3% contraction of the global automotive industry, the stock of PHEV and BEV cars grew by an exceptional **40% between 2019 and 2020**. An even stronger acceleration took place in 2021, with an additional 6.7 million new BEV and PHEV being added to the global stock. Overall, in 2021, **EVs accounted for 8.2% of new car sales worldwide** (IEA, 2022).

Table 6. Overview of the development of EV market segments in 2022. (BNEF, 2022).

Segment	Two- and three-wheelers	Passenger cars	Urban buses	Vans and trucks
EV sale share	42%	8.2%	44%	1%
Global stock	230 million (bicycles) 35 million (motorcycles)	18 million	685,000	613,000

In 2022, the more than 18 million electric cars worldwide represent approximately 1% of the global motorised vehicle stock. **Electric car sales could surpass ICEV sales in most markets between 2025 and 2040** (BNEF, 2022). However, few countries and urban areas disproportionally concentrate most EV sales, with 80% of all EVs sold in China, Europe, and the United States in 2021 (IEA, 2022).

Whilst over the past decade, the global electric vehicle market had been dominated by Plug-in Hybrid Electric Vehicles (PHEVs), BEVs have been continuously gaining momentum against PHEVs; **in 2022, BEVs represented 70% of EV sales worldwide** (BNEF, 2022).

In the last few years, the available EV offer has grown significantly: **there are 450 electric car models currently available worldwide**, 60% more than in 2019. All the largest Original Equipment Manufacturers (OEM) groups have announced ambitious targets in terms of sales of electric vehicles, and the development of new models.

Governments have continued to strengthen the promotion of the uptake of EVs through direct purchase incentives and tax deductions. In 2021, the global expenditure on incentives increased by 25%, reaching $14 billion, over $2,000 per electric car sold (IEA, 2022).

Electric Micromobility

Electric micromobility - encompassing electric scooters, bicycles, and tuk-tuks – has also experienced sturdy growth in 2021, fuelled in particular by the increasingly widespread deployment of shared mobility services in urban areas around the world. The International Energy Agency estimates that there are nearly **35 million electric motorcycles and scooters on the road worldwide, and close to 230 million electric bicycles** – making two-wheelers by far the main market segment for electric vehicles. Whilst the European and American markets are currently experiencing strong growth, Asia, and particularly China, continues to account for the vast majority of the market.

Electric Heavy-vehicles

The market for heavy-duty electric vehicles has also been growing rapidly; global sales of electric buses experienced a 40% increase in 2021. However, the market share of electric models is still small: **only 0.3% of total heavy-vehicle registrations in 2021, 90% of which were concentrated in China**. Globally, battery electric buses account for 4% of the total fleet and trucks for only 0.1%. The masses involved require high power and large-capacity batteries, which affect the economic viability of such vehicles. Nevertheless, short-distance use cases such as urban buses and last mile freight are favourable to electrification. Slow overnight charging in depots is the common solution for commercial vehicles but a public charging infrastructure could help foster the development of longer distance applications. Electrification for long distance transport, which requires very high-power charging facilities (> 350 kW), is still uncertain due to high costs (IEA, 2022).

Electric Vehicle Charging Infrastructure

The development of the EV market has naturally come hand-in-hand with a boom in the deployment of charging stations. In 2021, there were **17 million charging points installed worldwide** - nearly as many as electric cars deployed worldwide (IEA, 2022).

Remarkably, **the vast majority of the vehicle charging happens either at home or at workplaces**. As a consequence, only a fraction of the global charging station stock constitutes publicly accessible charging points: the IEA estimates that **88% of EVCS are low-power and installed within private premises** (IEA, 2022).

EV owners tend to rely as much as possible on their own private chargers, and make use of public chargers only when absolutely needed (e.g., for long distance travel, or unexpected trips). The typology of public charging points varies greatly between countries, and depends on charging behaviour, EV uptake and types, demographics, urbanisation, and policy landscapes. There were over **2 million publicly accessible chargers for cars in 2021, 40% of which are fast chargers** (IEA, 2022).

Comparing the evolution of the stock of public charging stations and the uptake of electric vehicles in different countries shows that various strategies are being implemented, both in terms of the ratio of EVs per public charging station, but also in terms of preference between low- and high-power charging points. Nevertheless, **a ratio of at least 1 publicly accessible EVCS per 10 electric cars is commonly recommended** to ensure the away-from-home charging requirements from EV-users.

Energy Shift

The uptake of electric vehicles modifies the final energy consumption mix of the transport sector, causing **a shift from fossil fuels towards electricity**. Therefore, the deployment of charging stations comes with significant infrastructure challenges to accommodate this new demand for energy, both in terms of **power delivery capacity** (transmission, distribution) and **electricity generation**. These technical barriers become all the more complex when it comes to faster, higher-power chargers.

Nevertheless, the percentage of electricity consumption attributable to EVs remains marginal even in countries with the highest EV uptake: 0.5% in China, 0.2% in the USA, 0.3% in Europe. However, it has been estimated that these countries could see **the share of electricity consumption from EV charging reach 3 to 7% by 2030**, thereby inducing significant and growing pressure on power systems (IEA, 2022). By 2050, **consumption from EVs will represent an estimated 27% of global electricity demand** (BNEF, 2022).

Electric Mobility in Southeast Asia

Regional Automotive Market

In line with the stark economic development of the ASEAN region, **the stock of registered motorised vehicles increased every year at a 6% to 10% rate** over the last decade, exceeding 300 million individual vehicles in 2020, thus representing close to one vehicle per two inhabitants (ASEANStatsDataPortal, 2022).

Although passenger cars have been gaining significant momentum, the market remains overwhelmingly dominated by light-duty vehicles: **motorcycles account for approximately 75% of all road vehicles - the highest penetration rate of two-wheelers in the world**. Since 2006, the road infrastructure of member countries has increased by an average 62 thousand kilometres per year; the overall road density now exceeds 0.5 kilometres of road per square kilometre (ASEANStatsDataPortal, 2022).

The ASEAN region plays a key role within the global motorcycle industry, being **the third largest market in terms of production and sales** after India and China. Indonesia, Thailand, and Vietnam alone accounted for more than 11 million units in 2019 out of the total sales of 13.7 million in the region (ABeam, 2021).

Motorcycles remain the key transportation method in ASEAN, thanks to their low cost, their efficient fuel consumption, and their workability around traffic congestion. However, as incomes increase, and with the establishment of policy initiatives and the expansion of infrastructure, the market of developing ASEAN countries tends to shift increasingly towards passenger cars. As a result, the vehicle market of ASEAN member states is often divided into three phases (ABeam, 2021):

i. **The motorcycle market phase**. Economic growth correlates with an increase in the number of motorcycles on the road.
ii. **The car market phase.** Economic growth with lifestyle change leads to increasing passenger car sales over motorcycle sales. The tipping point differs from country to country, and may depend on inequality levels and overall road infrastructure.

iii. **The premium market phase.** Beyond a certain development threshold, the ratio of motorcycles to cars no longer decreases and may even increase again. This is due to the availability of new transport offers such as electric vehicles, luxurious motorcycles, or public transports, that reshape the transport market.

Regional Electric Mobility Context

Electric mobility is an increasingly central topic across the ASEAN region. Electric vehicle fleets are expected to play an important role in addressing traffic-related localised air pollution in growing urban areas, and related climate benefits will keep increasing as the region decarbonises its electricity production.

The increase in fuel prices since mid-2021 linked to the global commodity crisis has highlighted the exposure of Southeast Asian economies to fossil fuel price fluctuations, and further emphasised the potential economic benefits of electric vehicles for both end-users and governments.

Nevertheless, as with emerging economies in other regions, EV uptake is at its early stage in the ASEAN region. Electric vehicle sales remain marginal, but several markets have been showing early signs of a future scale up since 2020:

Table 7. Sales share of electric vehicles in ASEAN in 2020. (ICCT, 2022)

Sales share of electric vehicles in 2020		
	Two-wheelers	**Cars**
Vietnam	8.3%	< 0.1%
Philippines	1.4%	0.2%
Indonesia	1.1%	< 0.1%
Malaysia	0.8%	< 0.1%
Thailand	< 0.1%	0.4%
Cambodia	< 0.1%	< 0.1%
Singapore	< 0.1%	1.1%

In 2021, **the cost of electric vehicles still largely dominated the concerns of potential EV owners in ASEAN** (AIDIC, 2021), illustrating the low level of market maturity in the region. The regional market is still largely focussed on the two- and three-wheeler segments. However, due in part to a lack of governmental policy regarding these new vehicles, the vast majority of electric two-wheelers remains unregistered. The United Nations Environmental Programme (UNEP) indicated in 2021 that there were already 1.35 million registered electric two-wheelers in Vietnam, whilst Malaysia, Thailand, Indonesia, and the Philippines are estimated to have a few thousand each (UNEP, 2020).

These numbers are expected to grow significantly over the next few years, in line with the expansion of the available offer, the wider adoption of these new technologies by the general public, as well as the increasing pressure from fuel costs due to the ongoing global energy crisis. The International Renewable Energy Agency estimated that by 2025, close to **20% of all vehicles in Southeast Asia could be electric**, including **59 million two- and three-wheelers and 8.9 million passenger cars** (IRENA & ACE, 2016). Retrospectively, these early estimates seem quite optimistic. However, they show that a vast untampered potential lies within the region. BloombergNEF, in their Economic Transition Scenario, **forecasts that EV cars could reach a 55% market share in Southeast Asia by 2040** (BNEF, 2022).

Electric Mobility Development Strategies in the Region

Despite constituting the second largest potential market for electric micromobility and having a significant regional automotive industry, **the vast majority of electric vehicles and their components is still imported into the ASEAN**, especially from China. ASEAN manufacturers and governments are willing to step up and meet the increased demand for electric mobility. Existing major automotive hubs such as Thailand and Indonesia are taking steps to spur EV manufacturing and battery production through policy measures, such as tax incentives and production or export targets.

Within the region, electric mobility has so far received various levels of attention and support from local governments. The individual national contexts in terms of industry, energy, environment, economy, and transportation strongly influence objectives, eagerness, and capacity to promote the uptake of EVs. Appendix 1 provides an updated overview of the level of development of the EV market in ASEAN, in terms of the stock of EVs and public EVCS, government targets, support mechanisms, and EVCS regulation in force.

In addition to the common barriers that all countries have to overcome in order to promote the uptake of electric vehicles such as availability, affordability, convenience, and awareness. The emerging markets within the ASEAN face a whole additional set of constraints. The International Council on Clean Transportation (ICCT) identified the following main barriers to the development of the ASEAN EV market (ICCT, 2022):

- **Lack of regulations.** A strong and holistic policy signal to the private sector is needed to promote investment in infrastructure, manufacturing, and product deployment so as to spur an adequate available offer.
- **Price competition with low-cost ICEVs.** The average cost of ICEVs within the ASEAN remains lower or comparable to equivalent electric vehicles. Moreover, individuals in the ASEAN rely heavily on second-hand markets, and the massive imports of inexpensive used ICEVs further increases the upfront cost difference between EVs and traditional vehicles. Meanwhile, the EV second-hand market is still nascent. A combination of regulatory and demand-based policies is required to provide cost parity between EVs and ICEVs in the long term.
- **Lack of e-mobility-based businesses.** The available offer is still limited in the ASEAN, therefore restricting options for mass uptake of EVs. In addition, because of the early stage of the market, in Cambodia there is no resale value for EVs. But in the future, it will play a significant role in shaping the evolution of the ASEAN market.
- **Insufficient charging infrastructure.** As driving range and charging time remain strong concerns of potential EV owners, the development of the charging infrastructure needs to be adequate and country-wide.
- **Lack of local technical expertise.** As these technologies are still quite new, local expertise is largely unavailable, resulting in underdeveloped supply chain capability, insufficient network of mechanics trained on EV repairs, and poor establishment and implementation of technical standards for vehicle and charging infrastructure.

- **Limited public awareness.** ICEVs are massively embedded within local culture, whilst electric vehicles still suffer from misconceptions and misunderstanding from the general public.

Electric Mobility in Cambodia

Cambodia's Road Transport Sector

The development of the road transport sector has come hand-in-hand with the expansion of the Cambodian economy, playing a key role in the development of the tourism, manufacturing, and agriculture sectors.

Particularly, the land transport sector holds a fundamental position within the national strategic goals of promoting growth, employment, equity, and efficiency, set in the Cambodian Rectangular Strategy Phase IV (RSIV). Under the RSIV Rectangle 2. Side 1., the Government aims to improve the infrastructure through enhanced transport connectivity and internal integration, and the expansion of the coverage of energy and digital connectivity so as to contribute to the competitiveness and diversification of the economic growth base (RGC, 2018).

Road transport is overwhelmingly the largest transport subsector of the Kingdom, representing an estimated **modal share of more than 90% for passenger and freight**. Over the past decade, Cambodia undertook a significant road construction and rehabilitation process as the Kingdom seeks to facilitate faster transportation within and between provinces. Roads are vital to the country's economic development, being the only source of transportation in most rural areas. Main priorities for the infrastructure development include (i) improving rural connectivity, (ii) enhancing connectivity access between cities, (iii) promoting connectivity and trade with neighbouring countries and within the ASEAN.

The management of roads infrastructure is divided into three government authorities:

- **The Ministry of Public Works and Transport (MPWT)** is the competent authority for the transport sector in the Kingdom of Cambodia and manages the expressways, national roads, and provincial roads. Within the MPWT, two main Directorates relate to national and provincial road transport. Additionally, MPWT is responsible for the construction and maintenance of the transport infrastructure of the Kingdom, including roads, bridges, sewage systems, solid waste treatment systems, ports, railways, and waterways.
- **The Ministry of Rural Development (MRD)** is in charge of rural roads and other roads as assigned by the RGC.
- **The sub-national administrations** are the competent authorities to manage roads within urban areas through the assignment of duties from the MPWT and the MRD and approved by the RGC.

Overall, the **road transport network of Cambodia has more than doubled since 2008**, comprised in 2022 of over 65,000 kilometres of roads, of which 19% are paved (ADB, 2019). The road infrastructure is administratively divided into:

- **1-digit national roads** (2,254 km). Most important, multiple lane road infrastructure, connecting the country's main cities.

- **2-digits national roads** (5,007 km). Interconnecting secondary cities, 1-digit national roads, as well as border crossings. Half have two lanes.
- **3-4 digits provincial roads** (9,031 km). Mainly unpaved, providing interconnection at district level.
- **Rural roads** (45,242 km). Under the responsibility of the MRD, allowing transport at the communal level, and largely unpaved.

In 2020, whilst the borders were closed because of the COVID-19 crisis, several major road construction projects were commissioned by the RGC. In particular, two expressways are being developed to serve the growing extent of economy and trade. The first connecting Phnom Penh to the Preah Sihanouk province, with a total length of 230 km. The second, still under negotiation, will lead Phnom Penh to Ho Chi Minh City with a total length of 213 km.

Cambodia's Motorised Vehicle Stock

In line with the economic development of Cambodia, the demographic expansion, and the migration of population from rural to urban areas, the overall stock of motorised land vehicles has been growing at an exceptional rate of **10 to 15% per year** since the late 1990s. Today, it is estimated that there are **over 6.3 million motorised vehicles** in the Kingdom, of which more than **85% are motorcycles**. The stock was increased by approximately **500,000 motorcycles and 70,000 cars per year** since pre-Covid times according to the MPWT (MPWT, 2022).

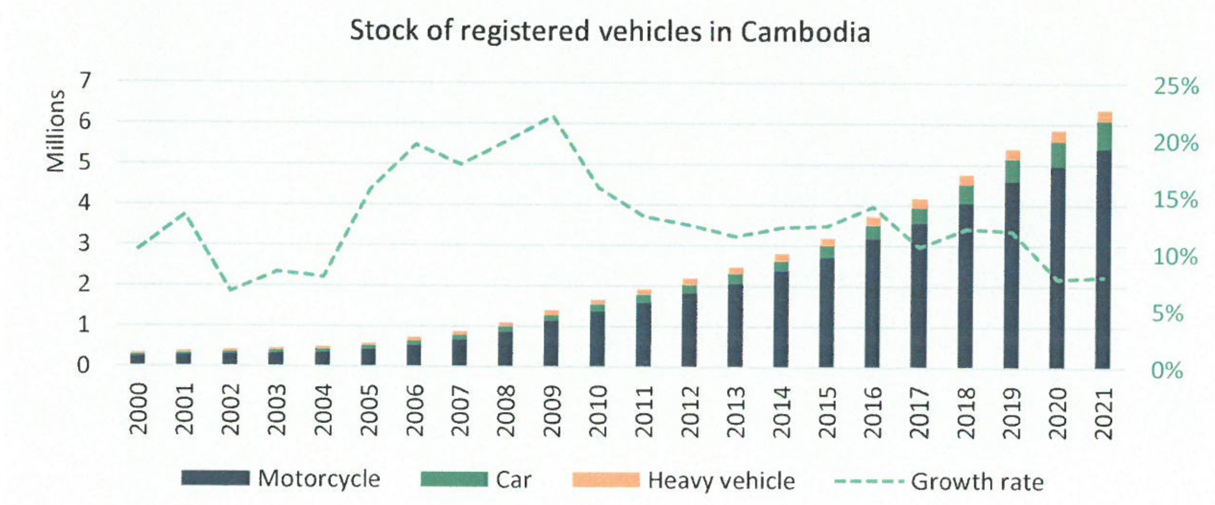

Figure 2. Vehicle registrations per year and per type of vehicle.
(MPWT, 2022)

In 2019, 85% households in urban areas and 77% in rural areas owned a motorcycle. Only 10% of households owned a car or van (NIS, 2019).

Table 8. Ownership of motorised vehicles by Cambodian households in 2014 and 2019.
(NIS, 2020)

Percentage of households owning at least one					
		Cambodia	Phnom Penh	Other urban	Rural areas
Motorcycle	2014	**66%**	90%	74%	61%
	2019	**83%**	90%	87%	80%
Car	2014	**5%**	20%	9%	2%
	2019	**10%**	27%	14%	10%

The domestic automotive industry is still quite unstructured, and is vastly dominated by second-hand reconditioned and imported vehicles, which account for 70 to 80% of all sales in the Kingdom according to the Cambodia Automotive Industry Federation (CAIF). However, the last few years have seen an increase in the market share of new vehicles, both (i) through the development of a dozen vehicle assembly plants mostly targeted at the domestic market, and (ii) through the development of a supply of affordable Chinese vehicles benefiting from favourable import conditions.

Automotive component manufacturers and vehicle assemblers, including car manufacturers, have been gaining significant momentum in the Kingdom. The Council for the Development of Cambodia (CDC) identified the development of the automotive industry as a priority sector.

Vehicle import taxes are divided into the customs duty, the special tax, and the VAT. Depending on the type of vehicle, its engine power, and its energy source, **the overall import tax may vary from 50 to over 90%** (see **Appendix 4**). Since 2022, imported battery electric vehicles benefit from a reduced special tax.

Imports and Consumption of Oil Products for Transport

Cambodian oil demand is fully met with imports: Cambodia has attempted to exploit offshore oil and gas deposits in the Gulf of Thailand since the 1990s, with no success thus far. There are no operating oil refineries in the country yet, although some projects have been considered. Overall, 15 local and international oil companies import petroleum products from abroad and distribute them to consumers through over 3,000 licensed petrol stations and 29 petroleum terminals.

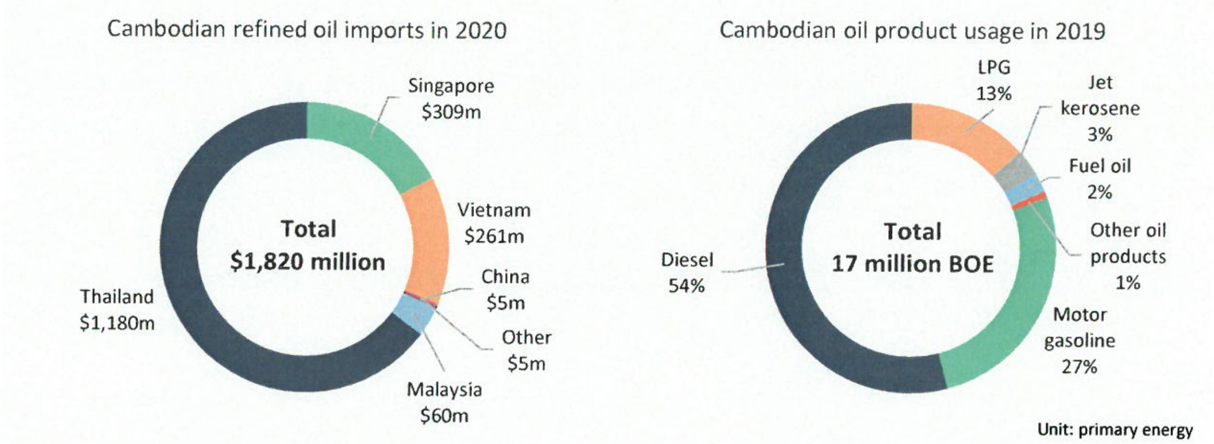

Figure 3. Statistics of Cambodia's oil products imports.
BOE = Barrel of Oil Equivalent (1 BOE = 1,700 kWh)
(OEC, 2022) (IEA, 2022).

The expansion of the Cambodian vehicle stock has led to a **10% yearly growth of fuel consumption from the transport sector** during the last decade (UNFCCC, 2019). In 2019, **the transport sector as a whole utilised 72% of the oil products imported in Cambodia** (energy-wise), accounting for over 12 million barrel of oil equivalent in primary energy consumption (IEA, 2022).

Environmental Externalities of the Cambodian Transport Sector

Overall, **the transport sector is estimated to account for more than 50% of the greenhouse gas emissions from the energy sector of Cambodia**, representing 5 million equivalent tonnes of CO_2 in 2016, more than electricity generation and industrial processes combined (UNFCCC, 2019).

The sprawl of inefficient, old, and second-hand vehicles has led to a deterioration of air quality throughout the country, and most notably in urban areas. In particular, concentrations of PM2.5 particles in the air in Phnom Penh, coming partly from vehicle emissions, have been found to regularly exceed WHO recommended air quality standards. No vehicle age limit is currently imposed on imported second-hand vehicles, meaning that most lack pollutant mitigation technology, although imposing higher import tax on older vehicles (more than 10 years) has been agreed.

Several policies have been recently introduced and ambition to reduce the environmental impact of the transport sector, such as:

- **Cambodia's Updated Nationally Determined Contribution** (NCSD/MOE, 2020). By 2030, pledge to reduce energy-associated GHG emissions - including transport - by 40% compared to business-as-usual.
- **Long-term Strategy for Carbon Neutrality** (MoE, 2021). By 2050, EVs to represent 70% of motorcycles and 40% of cars and urban buses.
- **Draft National Energy Efficiency Policy 2021-2035** (MME, 2022). By 2030, reduce the final energy consumption of the transport sector by 5% compared to business-as-usual.

EV and EVCS Market in Cambodia

In 2020, **battery electric vehicles were estimated to represent less than 0.1% of vehicle sales across all segments in the Kingdom** (ICCT, 2022). As of September 2022, there were 295 2-3 electric wheelers and 262 electric vehicles registered, as well as **7 publicly open EV charging stations** implemented in the country (MPWT, 2022).

The registration of electric vehicles with the MPWT, especially in the two- and three-wheeler segments, is neither widespread nor systematic, making it difficult to obtain quality data on the development of the market. The usual estimates given by the private sector are of a few hundred electric tuk-tuks, and a few thousand electric motorbikes currently on the roads, mainly in Phnom Penh. The EV and EVCS markets are not yet specifically regulated in Cambodia, although a number of initiatives are under development, especially pertaining to technical and safety standards.

The current available electric car offer in Cambodia is still relatively limited, although an increasing number of players are starting to take an interest in the market. With the notable exception of Jaguar and Tesla, no large European, Japanese, Korean, or American OEMs are importing battery electric vehicles into Cambodia at the moment. Three reasons are generally put forward to explain this reluctance: (i) the low maturity of the market, (ii) the lack of charging infrastructure, (iii) the absence of a proper battery recovering channel. This latter aspect constitutes a major blocking point for some manufacturers: in the absence of regulations and of existing services to ensure the proper reprocessing and recycling of batteries, international OEMs tend to consider that importing BEVs is too risky. For the time being, the segment of available electric cars is largely limited to Chinese-made vehicles.

Nevertheless, there is a surprisingly large number of hybrid vehicles in Cambodia; some estimates suggest that more than one in six car sales (including imported second-hand vehicles) is a hybrid. In particular, Toyota does not officially import hybrid vehicles into Cambodia, but there are numerous reconditioned and second-hand Toyota Camrys, Harriers, and Priuses on the roads.

In recent years, the two- and three-wheeler markets have seen a growing number of electric scooter and electric tuk-tuk importers, some working towards developing a local manufacturing activity. Some of these initiatives have addressed the absence of existing charging infrastructure by setting up their own network of battery swapping stations.

Additionally, multiple development projects have recently provided support to this market, such as:

- **SMMR.** Sustainable Mobility in Medium-Sized Metropolitan Regions (SMMR) is a German-funded project implemented by GFA Group under the ASEAN Secretary of Transport. The main objective of this project is to support national ministries in developing their strategies around sustainable transport. Their work focuses on medium-size cities (i.e., not capital cities). Their main activity is to provide capacity building, and develop technical working groups with line ministries, providing guidance and helping develop plans and visions for potential initiatives. SMMR then assist the ministries in fund sourcing. Their main topics are SUMP (Sustainable Urban Mobility Planning), transport executives, LEVs, logistics, smart mobility, and active mobility.
- **World Bank.** As part of its support to the development of Cambodia, the World Bank has commissioned a study on the deployment of electric vehicles. This study will be conducted in partnership with the Ministry of Mines and Energy, and aims to (i) provide a list of suggested policies and fiscal structures/incentives viable for Cambodia situation and each of the market segments, (ii) make an overview of the transport market in Cambodia and entry points for e-mobility, (iii) set up a stakeholder mapping and suggest investment models and partnerships for e-mobility implementation of charging infrastructure, (iv) analyse the gender/differently-abled gaps in the transport sector and make recommendations for improvements as e-mobility is deployed, (v) establish a roadmap for e-mobility implementation in Cambodia.
- **Global Green Growth Institute.** In 2019 and 2020, GGGI conducted a GCF readiness project which aimed to promote the switch from gasoline to electric motorcycles. Project deliverables include a market and technical assessment, communication needs assessment, a policy gap analysis, followed by the design of a financial incentive scheme and investment concept note. Activities of this project include (i) support to the development of selected regulatory measures to promote e-motorcycle use, (ii) demonstration of a switch from gasoline to electric motorcycles for the fleet of a high-profile institution through a subsidy scheme, (iii) pre-feasibility study for the deployment of clean buses in the city of Siem Reap including the World Heritage Site of Angkor, (iv) investment facilitation.
- **Energy Lab – CCCA.** Energy Lab and the Cambodia Climate Change Alliance have recently collaborated to improve the perception of electric vehicles amongst the Cambodian public. This initiative included a series of events and awareness raising campaigns.

- **DFAT – CAP-RED.** The Australian Department of Foreign Affairs and Trade recently issued a tender for their new project CAP-RED, which will focus primely on e-mobility. This new initiative is still at tendering stage and will aim to support the private sector in developing e-mobility infrastructure, through the provision of flexible technical and financial support.

Future Scenarios Modelling

1. Scenario Architecture

In this section, three different scenarios for the adoption of electric vehicles in Cambodia are analysed over the 2022 to 2050 period – a conservative one, a more realistic one, and an aspirational one which corresponds to LTS4CN targets. Each scenario corresponds to a different share of electric vehicles in total yearly vehicle sales by 2050.

Table 9. Architecture of the scenarios. [1]

Market share of EVs in new vehicles sales in 2050			
	Motorcycles	**Cars**	**Heavy vehicles**[2]
	Category A1 and A2 vehicles: two-wheelers below or above 125 cc, motorcycle trailers, and three-wheelers (tuk-tuks).	Category B vehicles: passenger cars, pick-up trucks, and other vehicles below 9 passengers and 3.5 tonnes.	Category C and D vehicles: all trucks above 3.5 tonnes, and buses above 9 passengers.
Baseline	0%	0%	0%
Scenario EV1	30%	15%	1%
Scenario EV2	60%	30%	3%
Scenario EV3 *(LTS4CN)*	90%	51%	5%

The scenarios were deliberately designed to cover a broad spectrum of potential market growth:

- **EV1** is a conservative scenario, wherein 30% of new motorcycle sales and 15% of new car sales are electric vehicles, which corresponds to an electrification rate of 20% of motorcycles (2.1 million) and 12% of cars (316 thousand) by 2050.
- **EV2** is a more realistic scenario, which was designed in line with existing market analyses conducted in the region. It would result in a stock of 4.1 million electric motorcycles (40%) and 631,000 electric cars (24%) on the road by 2050.
- **EV3** is an aspirational scenario: it has been calibrated so as to be consistent with the Long-term Strategy for Carbon Neutrality (LTS4CN) set out by the Ministry of the Environment, which calls for 70% of motorcycles, and 40% of cars on the road to be electric by 2050 (MoE, 2021). This amounts to respectively 7.3 million electric motorcycles and 1.1 million electric cars.

[1] The vehicles segments ("Motorcycles, Cars, Heavy-vehicles") are based on the classification used by MPWT to determine the categories of driving licences as well as the registration of motorised vehicles. Three-wheelers are not treated separately in this analysis due to a lack of available market data but can be interpreted as included in the "Motorcycles" segment.

[2] Although heavy-duty vehicles are included in this analysis in order to highlight the challenges inherent to electrifying this segment of vehicles - particularly in terms of their significant energy consumption - this exercise does not dive deeper into the associated charging infrastructure. Indeed, the market of electric heavy vehicles is evolving rapidly, and it is considered that they should be the subject of a separate study focusing on their specific problematics (logistics, public transport, tourism, regional commerce, etc.), which are outside the scope of this work.

2. Methodology and Key Assumptions

In order to characterise the need for charging infrastructure, a projection of electric vehicle sales as well as a modelling of future user behaviour were built. These allow conclusions to be drawn regarding the requirement for and locations of charging infrastructure, as well as the associated energy consumption and capital investment volumes.

In addition, this modelling allows the estimation of the battery demand that will be generated by the adoption of electric vehicles, as well as the associated reprocessing capacity requirements. Finally, avoided CO_2 emissions as well as fuel saving benefits are estimated. The methodology and the assumptions used are greater discussed in **Appendix 2**.

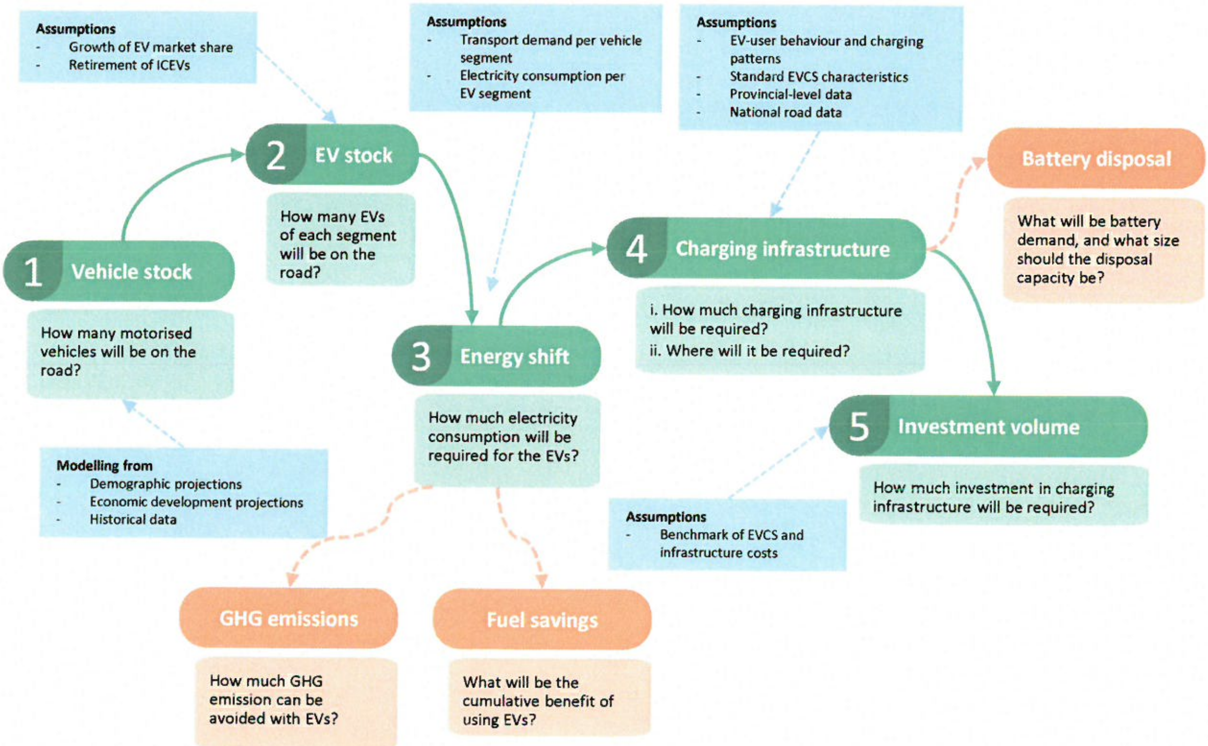

Figure 4. Schematic modelling assumptions and approach.

The growth of the Cambodian vehicle stock (given below) was estimated based on economic and demographic projections, and is assumed to be the same in each scenario. The motorcycle stock is expected to stabilise at approximately 10 million vehicles by 2050, whilst the stocks of cars and heavy vehicles are anticipated to experience uninterrupted and steep growth.

Table 10. Modelling of the stock of motorised vehicles in Cambodia.

Size of the vehicle stock and ratio of vehicles per person						
	Motorcycles		Cars		Heavy vehicles	
2021 *(actual)*	5.4m	*0.28*	0.6m	*0.03*	0.26m	*0.01*
2025 *(estimated)*	6.5m	*0.38*	0.8m	*0.05*	0.28m	*0.01*
2030 *(estimated)*	7.9m	*0.44*	1.0m	*0.07*	0.31m	*0.02*
2040 *(estimated)*	9.6m	*0.50*	1.6m	*0.08*	0.39m	*0.02*
2050 *(estimated)*	10.4m	*0.50*	2.7m	*0.13*	0.50m	*0.02*

In order to estimate the transport demand associated with electric vehicles, it was assumed that motorcycle users drive an average of 5,000 km per year; whilst cars and heavy vehicles are driven 10,000 km and 90,000 km respectively. The energy demand generated per electric vehicle is then estimated by combining the transport demand with the typical energy consumption of electric vehicles.

Table 11. Key assumptions on EVs.

Key assumptions on EVs	Motorcycles	Cars	Heavy vehicles
Lifespan of batteries	10 years	15 years	5 years
Battery size	2.8 kWh	55 kWh	300 kWh
Distance travelled per year	5,000 km	10,000 km	90,000 km
Electricity consumption of EVs	0.025 kWh per km	0.2 kWh per km	1.0 kWh per km
Yearly electricity consumption	125 kWh per EV	2,000 kWh per EV	90,000 kWh per EV

In line with current benchmarks, batteries are supposed to have a lifespan of 10 years for motorcycles, and 15 and 5 years for cars and heavy vehicles respectively. Beyond this period, it is assumed that batteries are used for 5 years in secondary stationary use, before they need to be recycled.

Because of the inherent inertia of vehicle stocks which take decades to renew, high sales of EVs do not immediately translate into substantial numbers of EVs. The market share of electric vehicles amongst new vehicle sales is modelled to follow a logistic S-curve from 2020 to 2050; a significant acceleration of sales is expected from 2030 onwards. In the median EV2 scenario, 25% of new motorcycle sales are electric in 2033, whilst for cars, the 25% market share is reached in 2040. In all three scenarios, heavy vehicle sales are largely driven by internal combustion vehicles, even by 2050.

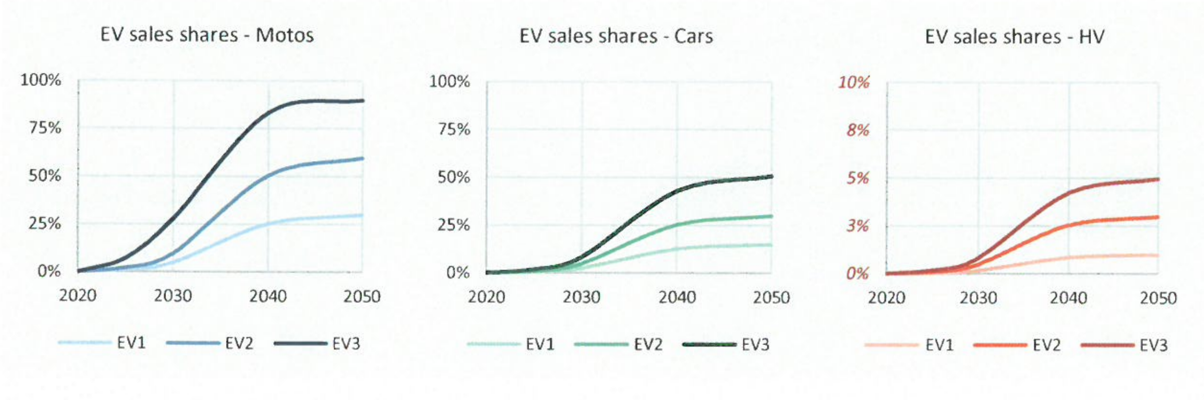

Figure 5. Assumptions of EV market share of new vehicle sales per segment and per scenario.

The model distinguishes between four types of EV charging methods:

(i) **Home charging.** Accounts for 85% of charging for motorcycles and cars. It consists of slow charging at night or during the working day, taking place either at home or at workplaces. It does not require any significant investment in infrastructure or upgrades to electrical systems.

(ii) **Away-from-home charging.** Accounts for 9% of electric car charging. It consists of slow top-up charges done whilst the user runs errands in a public location within urban areas (e.g., coffee shops, malls, hotels, touristic sites, etc.). Capital investment required for a typical 10-kW AC charger is approximately $7,500.

(iii) **Fast charging.** Accounts for 6% of electric car charging. It consists of DC fast charging used during long journeys. The station is located directly on a national road connecting urban areas (e.g., gas stations). Capital investment required for a typical 50-kW charging station is between $30,000 to $50,000.

(iv) **Battery swapping.** Battery swapping is assumed to be a partial solution, used for electric motorcycles mostly by logistics companies, delivery services, or shared mobility services. In terms of infrastructure, battery swapping is modelled by the installation of decentralised $10,000 battery charging cabinets, each containing 6 battery packs, solely within urban areas (e.g., at convenience stores).

3. Results

The full results for the three scenarios are included in the **Appendix 6**.

Adoption of Electric Vehicles

Electric Motorcycles

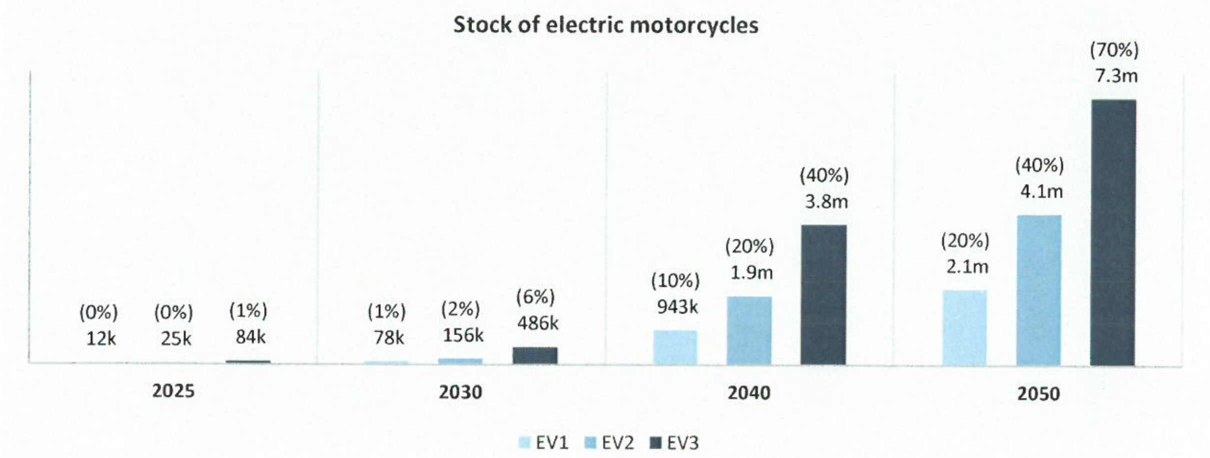

Figure 6. Stock of electric motorcycles.
The percentages in parenthesis represent the percentage of EVs within the motorcycle stock.

Motorcycles will constitute by far the largest market segment of electric vehicles in Cambodia. All three scenarios suggest that there will be a million electric motorcycles on the road sometime between by 2040. Furthermore, reaching 70% electric two-wheelers by 2050, as called for in the Long-term Strategy for Carbon Neutrality (MoE, 2021), will require selling an average of 190,000 electric motorcycles per year over that period.

Electric Cars

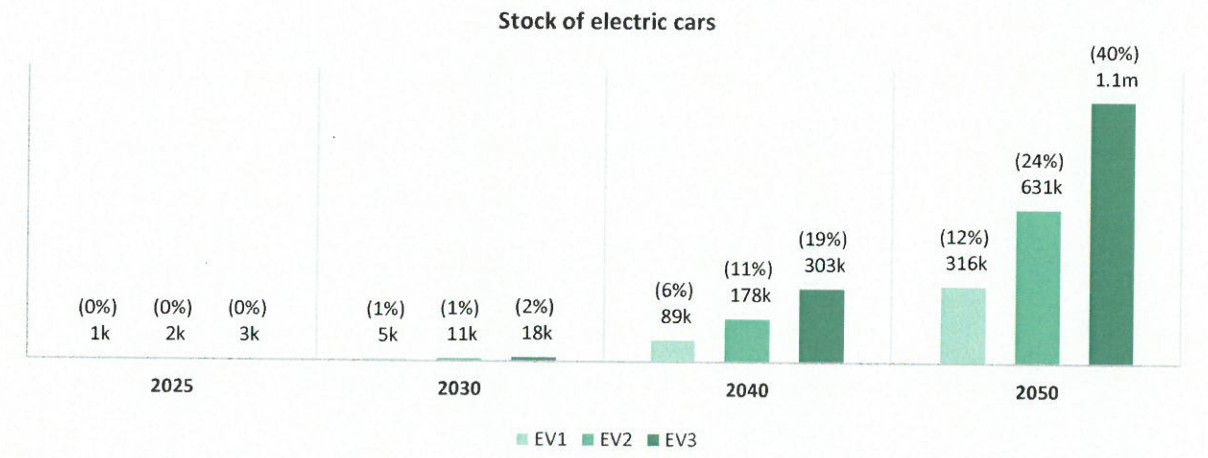

Figure 7. Stock of electric cars.
The percentages in parenthesis represent the percentage of EVs within the car stock.

The scenarios provide that there will be over 100,000 electric cars in Cambodia sometime between by 2035 and 2042. Given that Cambodia's car stock is not yet fully built up (the modelling suggests that it will increase more than fivefold by 2050), there is a clear opportunity to electrify it as it grows, thus avoiding the inertia related to retiring ICEVs.

Electric heavy vehicles

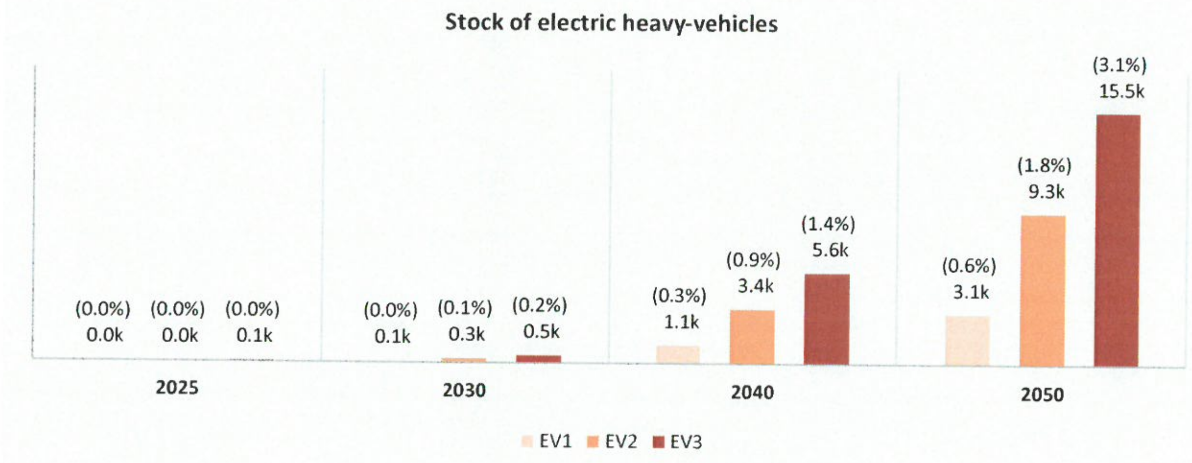

Figure 8. Stock of EVs in each scenario.
The percentages in parenthesis represent the percentage of EVs within the heavy vehicle stock.

Heavy vehicles will be by far the smallest market segment for electric vehicles in Cambodia, with an estimated few thousand electric heavy vehicles on the road by 2050.

Electricity Demand

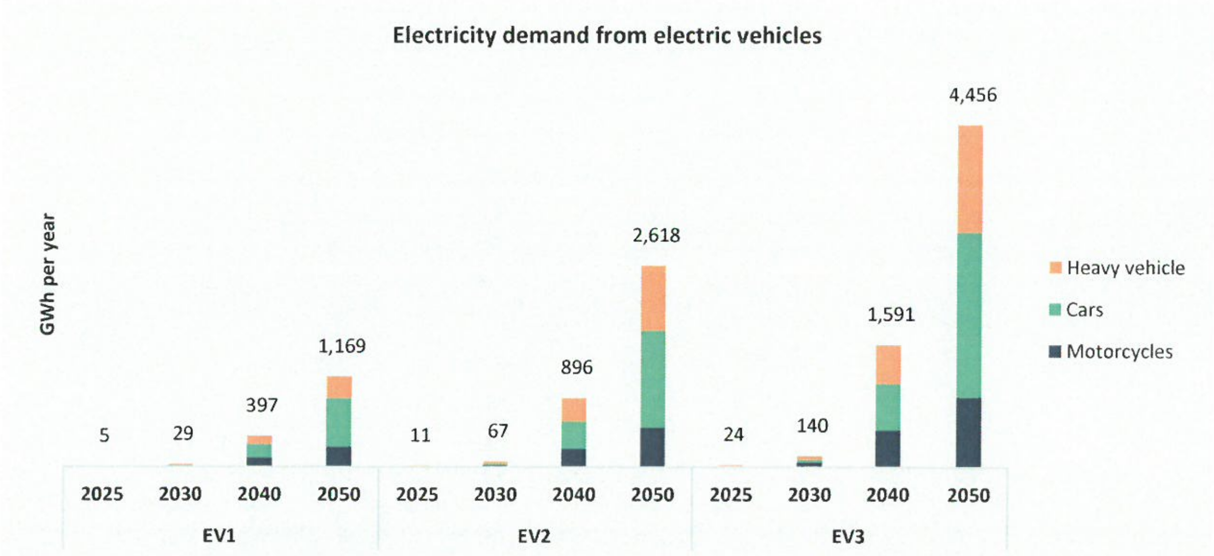

Figure 9. Electricity demand generated by the EVs.

Electricity consumption from EVs will reach between 1,169 and 4,456 GWh per year by 2050 - equivalent to 9% to 36% of the 12,400 GWh of electricity consumed nationally in 2021. Making use of the modelling of the growth of the national electricity consumption done by the ADB and the MME as part of the draft National Power Development Plan 2022 – 2040 (ADB, MME, 2022), it can be estimated that the electricity consumption from EVs will account for 0.7% to 2.8% of Cambodia's electricity consumption by 2040.

Overall, this shift from refined petroleum products towards electricity will reduce the yearly national consumption of gasoline, diesel, and LPG by 680,000 to 2,600,000 barrels of oil equivalent by 2050.

Due to their high energy consumption and large distance covered per year, and despite their relatively small number, electric heavy vehicles will account for a significant share of the electricity consumption attributable to EVs – between 300 and 1,500 GWh per year by 2050. This highlights the significant challenges that will come with the electrification of the heavy vehicle fleet.

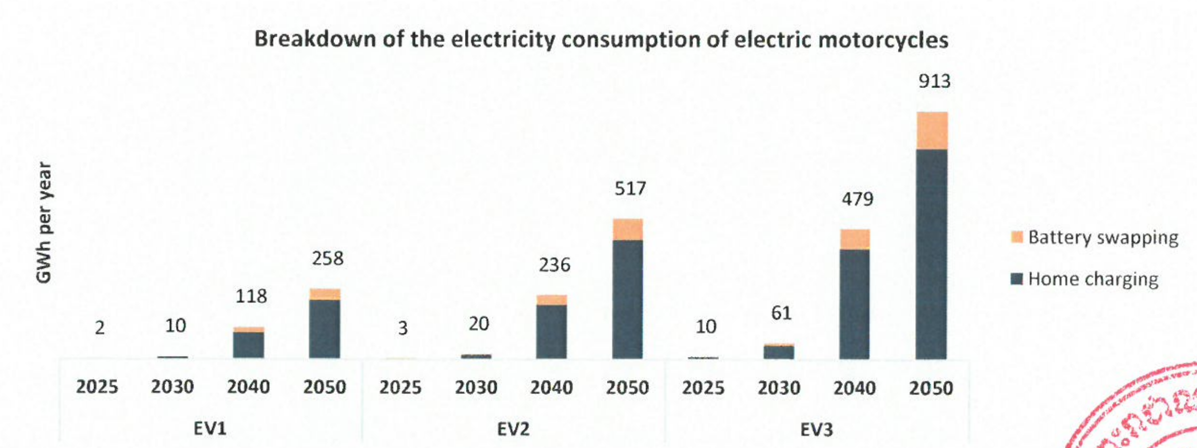

Figure 10. Electricity demand generated by the electric motorcycles.

Although motorcycles will be by far the largest EV segment, their energy consumption will be significantly lower than that of electric cars. Electric motorcycles will account for an estimated fifth of total electricity consumption from EVs.

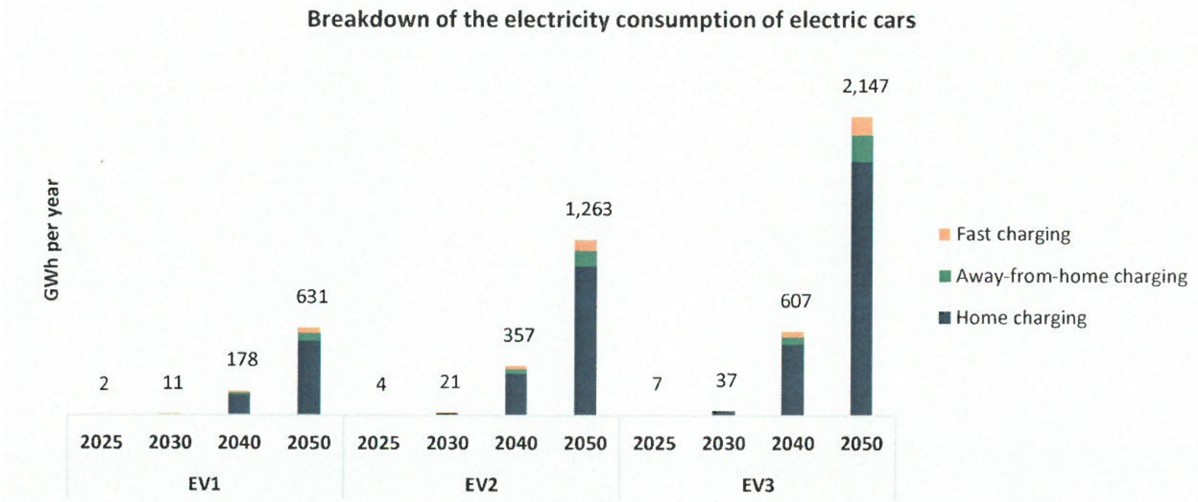

Figure 11. Electricity demand generated by the electric cars.

Electric cars will account for over half of the total electricity consumption from EVs. In line with international benchmarks, the vast majority of the charging will be done at low-power and within private premises.

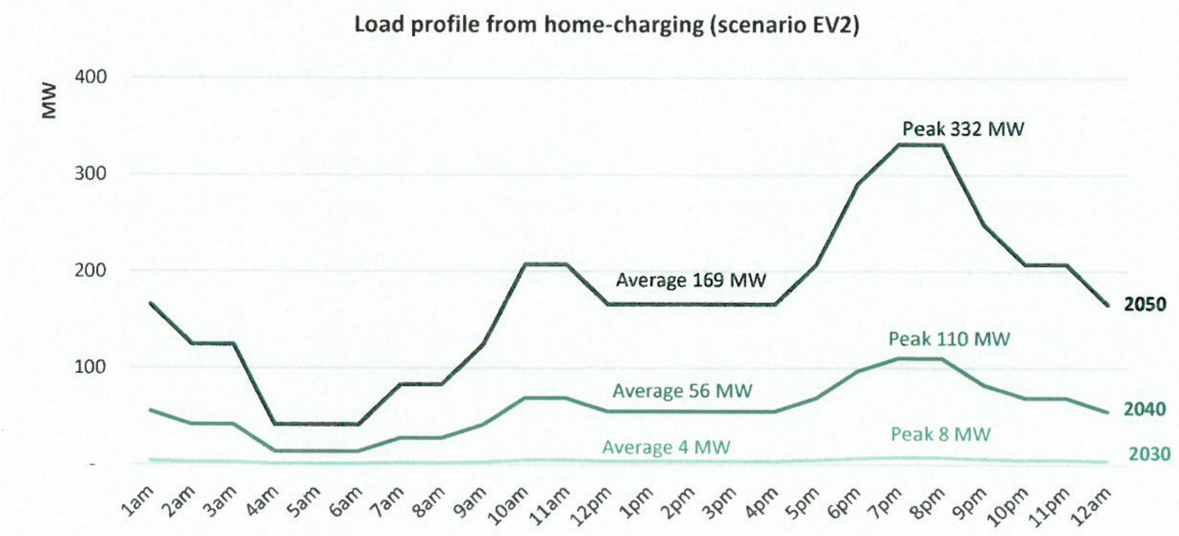

Figure 12. Estimated load profile from home charging of electric cars and motorcycles in scenario EV2.
Does not include away-from-home charging, DC fast charging, and battery swapping. Does not include heavy vehicles.

In the median EV2 scenario, the power demand created by residential charging of electric vehicles is expected to remain negligible by 2030, accounting for a few megawatts overall. In 2040, the peak load will reach 110 MW, and upwards of 300 MW by 2050.

Battery Demand and Disposal

In order to support the adoption of electric vehicles, the demand for batteries will reach between 137 and 620 MWh per year by 2030. As EV adoption accelerates between 2030 and 2040, battery demand is expected to exceed a GWh per year during this period, reaching 2.6 to 8.9 GWh per year by 2050.

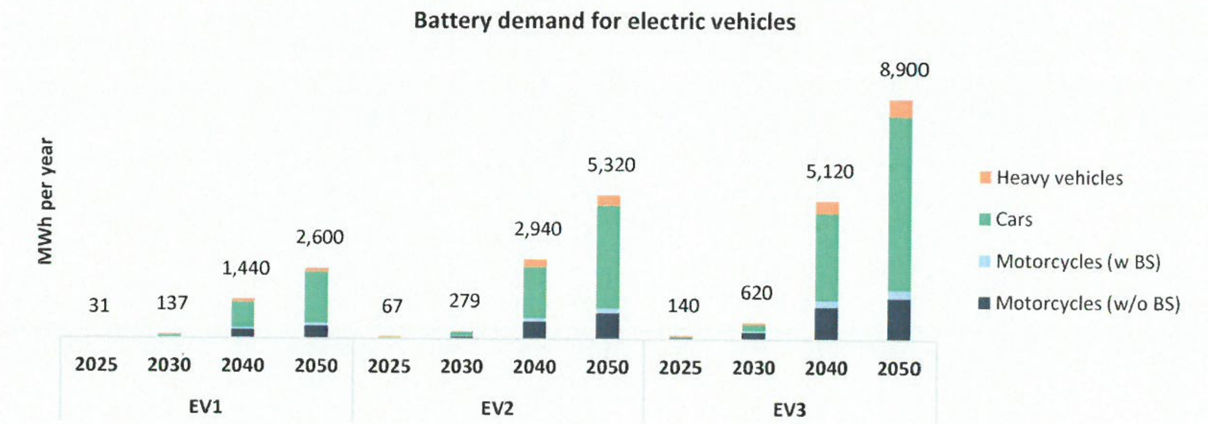

Figure 13. Breakdown of the demand for battery.
"BS" = battery swapping

Because of the high battery capacity they incorporate, electric cars will account for 40 to 70% of the battery demand. On the other hand, the use of battery swapping for 15% of two- and three-wheelers will not generate a significant excess of batteries.

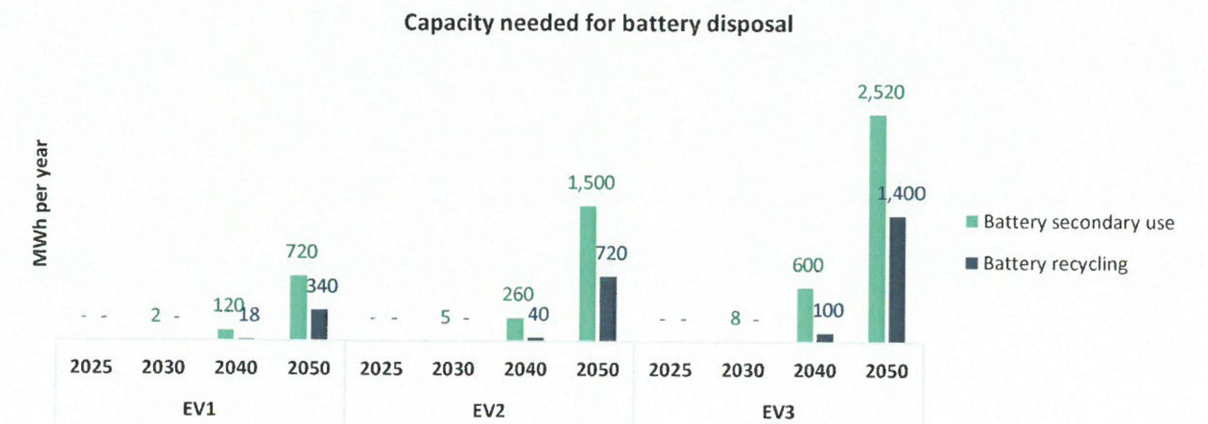

Figure 14. Capacity needed for battery disposal.
"Secondary use" encompasses the decommissioning of battery packs whose capacity degraded below 80%. They are sent to stationary uses that extend their lifetime - i.e., grid stabilisation, back-up systems, off-grid electrification, etc. "Recycling" on the other hand encompasses the dismantlement of batteries whose capacity degraded below 50%.

It will be paramount to set up battery disposal facilities in order to orderly manage the end-of-life of these significant volumes of batteries. By 2030, the capacity needed will remain particularly low, below a few MWh per year. By 2040, several hundred MWh of batteries will need to be decommissioned and directed to secondary applications. By 2050, between 0.7 and 2.5 GWh will need to be decommissioned each year for secondary uses, and between 0.3 and 1.4 GWh will need to be recycled, covering 6 to 9% of the demand for new batteries.

Greenhouse Gas Emissions

In Cambodia, an electric motorcycle will emit an estimated 55% less GHG than an equivalent ICEV during its lifetime, whilst for cars this benefit is only 22%. The use of electricity instead of hydrocarbons significantly reduces the operational emissions of vehicles; however, the manufacture of the electric vehicles generates a sizeable additional carbon footprint. With the decarbonisation of the Cambodian electricity, these savings will become more significant.

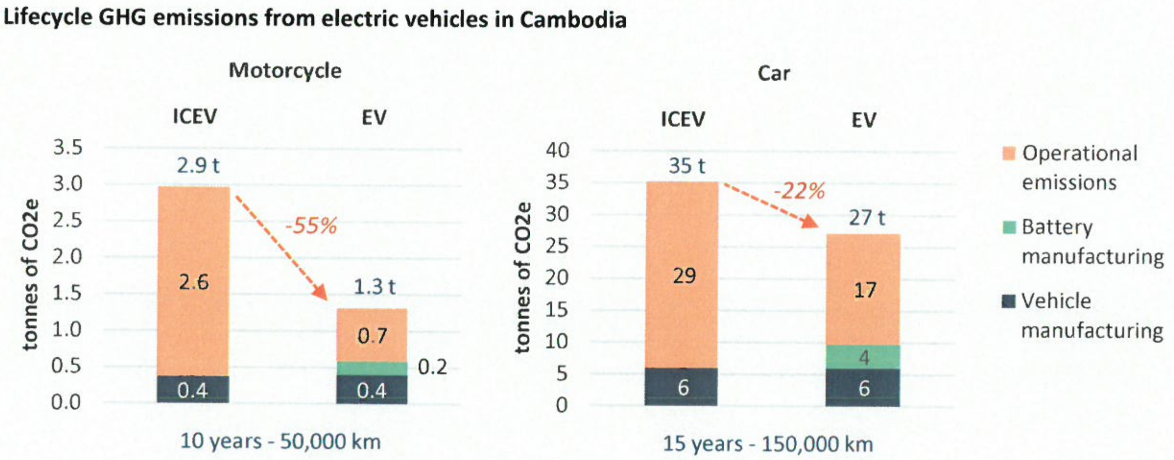

Figure 15. Lifecycle GHG emissions from electric vehicles in Cambodia.
"CO_2e" = carbon dioxide equivalent. Results may vary greatly between different vehicles depending on their design, their production, and their use. "Vehicle manufacturing" = emissions attributable to the production of the vehicle. "Battery manufacturing" encompass the production of the vehicle's battery pack. "Operational emissions" represents emissions either from the combustion of hydrocarbons (gasoline, diesel, LPG) or from the production of electricity used to power EVs. Emissions from battery dismantling and recycling are not considered. The grid factor adopted is considered constant and taken as recommended by the UNFCCC: 0.58 kg CO_2e per kWh.

In scenario EV3 and by 2030, avoided fuel-related GHG emissions will reach 104,000 tonnes of CO_2 equivalent per year. By 2050, 2.2 million tonnes of CO_2 equivalent will be avoided every year; further decarbonation of the electricity production could help increase these savings significantly.

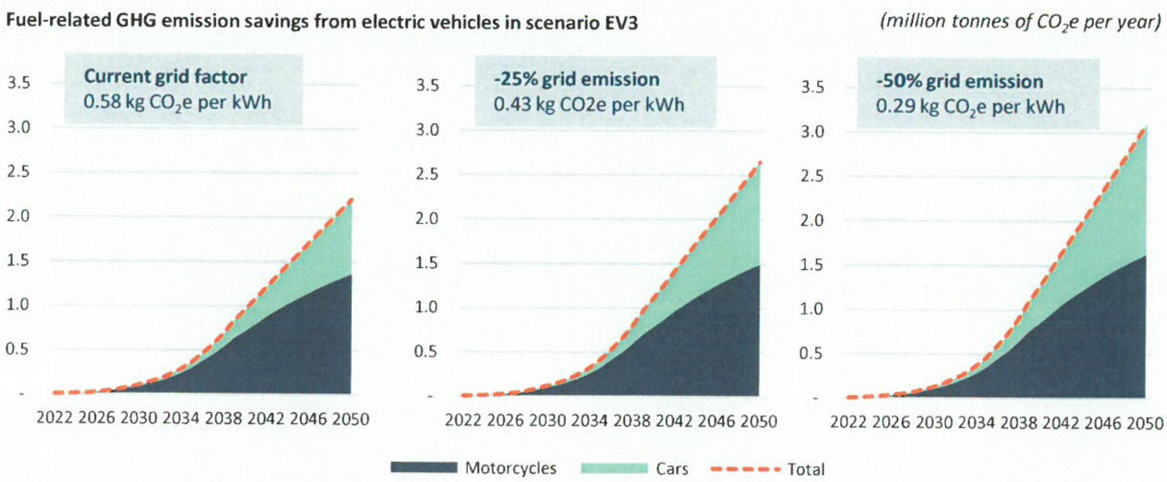

Figure 16. Fuel-related GHG emissions savings from electric vehicle adoption in EV3.
"CO_2e" = carbon dioxide equivalent. Includes only the reduction of emissions due to fuel switching: from hydrocarbon to electricity. Savings are calculated with respect to the baseline situation where all vehicles are ICEV.

Fuel Expense Savings

The use of an electric vehicle makes it possible to reduce fuel expenditure for users. With the assumptions used and current fuel prices, it appears that on average an electric motorcycle user saves $133 per year, and an electric car user $1,069 per year on average.

Table 12.Fuel savings by switching to EVs, point of view of the user.
This calculation is adapted from a modelling prepared by GGGI and the Ministry of Environment, assessing the fuel savings of EV users.

Electricity tariff		0.18	$ per kWh
Fuel tariff			
Gasoline		1.4	
Diesel		1.4	$ per litre
LPG		0.6	
Fuel usage	**Motorcycle**	**Car**	
Gasoline	100% - 45 km per litre	80% - 12 km per litre	
Diesel		10% - 14 km per litre	
LPG		10% - 9 km per litre	
Savings by switching to EV	**Motorcycle**	**Car**	
	$0.03 per km	**$0.11 per km**	
	$133 per year	**$1,064 per year**	

Extrapolated to the number of electric vehicles on the road, the potential savings for households will amount to between $14 and $78 million per year by 2030. By 2050, these savings may represent between $509 and $1,766 million every year.

Figure 17. Cumulated expense savings from electric vehicle adoption.
Current US Dollar. This calculation is made at constant energy price.

Charging Infrastructure

Stock of Charging Infrastructure

The three scenarios are based upon a wide range of market uptake assumptions. As a result, infrastructure needs vary greatly as well - between 9,900 and 33,800 individual charging points by 2050, all types combined.

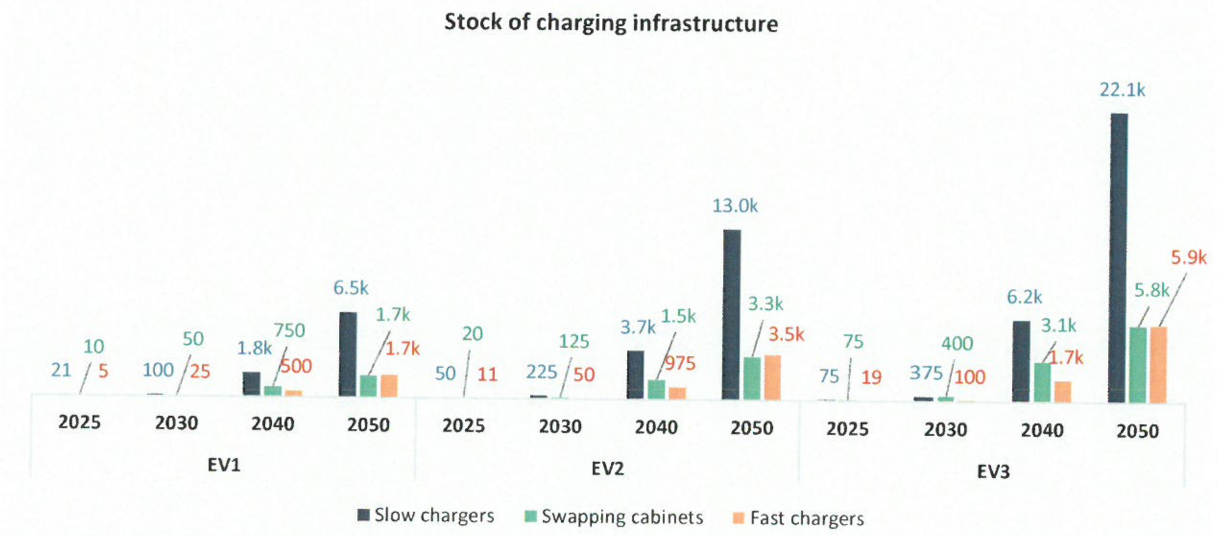

Figure 18. Stock of charging infrastructure.
The swapping cabinets considered here have a capacity of six 2.8 kWh battery packs. Slow chargers are assumed to have a 10-kW power rating, whilst fast chargers are rated at 50 kW. A particular charging station could potentially have more than one charging point or swapping cabinet.

Despite the fact that only a fraction of electric motorbikes will employ battery swapping models (mostly logistics companies, company fleets, delivery services, or shared mobility services), vast infrastructure will be needed to accommodate these particular needs - reaching a few thousand swapping cabinets by 2040. This suggests that relying too heavily on a Battery-as-a-Service model would be highly challenging in the long-term.

Approximately one open-to-the-public charging point will be required for every 38 electric cars on the road in Cambodia. Slow chargers for four-wheelers will be the bulk of this infrastructure (an estimated 80% of total charging points). Overall, several thousand AC charging stations will be needed in urban areas by 2040, and between 6,500 and 22,100 will be required country-wide by 2050. Due to the limited per-site investment required for these devices, it is expected that their deployment will be organic and closely linked with the deployment of electric vehicles without requiring specific support.

The number of fast chargers needed is expected to grow from 25 to 100 in 2030, to 1,700 to 5,900 by 2050 depending on the scenario. Achieving such deployment volumes will require specific support and guidance for their development, in order to facilitate the high demand in terms of capital investment, electrical infrastructure upgrades, and energy consumption.

Swapping Stations

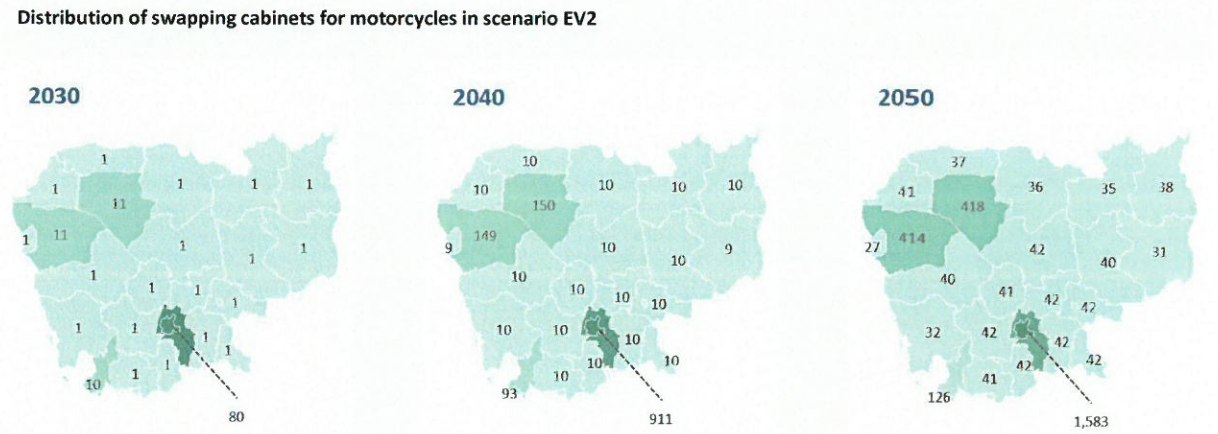

Figure 19. Provincial distribution of battery swapping cabinets.
*Results are presented here for scenario EV2; full detail of all three scenarios is included in **Appendix 6.** The swapping cabinets considered here have a capacity of six 2.8 kWh battery packs. A particular swapping station could potentially have more than one cabinet and/or larger cabinets.*

The vast majority of swapping stations will be needed in urban areas, mainly in Phnom Penh, Kandal, Preah Sihanouk, Siem Reap, and Battambang. In other rural areas, a small number of cabinets - from 1 per province in 2030 to approximately 40 in 2050 in scenario EV2 - will be sufficient to cover the battery swapping needs of these provinces. This is due to a combination of two factors: (i) it is expected that EV penetration will initially be largely concentrated in large urban areas, and (ii) rural areas have lower vehicle ownership altogether (see **Table 7.**).

Slow Chargers

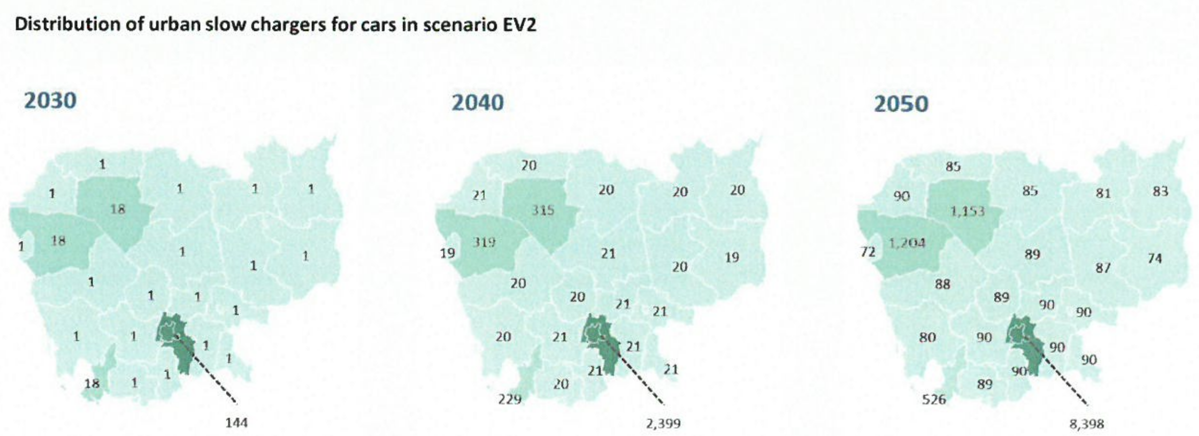

Figure 20. Provincial distribution of slow chargers.
*Results are presented here for scenario EV2; full detail of all three scenarios is included in **Appendix 6.** Slow chargers are assumed to have a 10-kW power rating. A particular charging station could potentially have more than one charging point.*

Similarly, it is expected that the majority of slow chargers for electric cars will be concentrated in dense urban areas where the majority of EVs will be introduced.

Fast Chargers

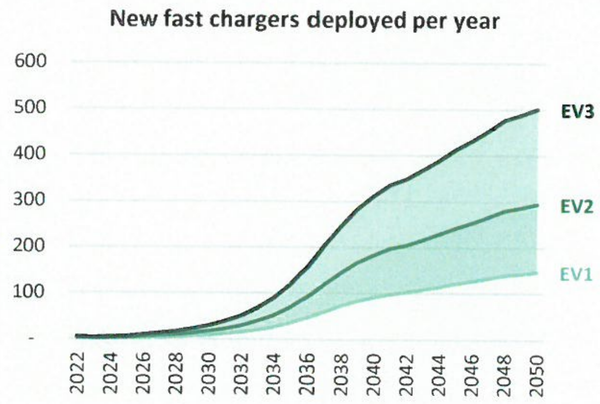

Figure 21. Deployment of fast chargers.
Fast chargers are assumed to have a 50-kW power rating. A particular charging station could potentially have more than one charging point.

The development of the fast charger network is critical to address the range anxiety of potential users, which remains amongst the key concerns of potential EV users (AIDIC, 2021). As depicted in **Figure 15.**, the development of the fast charger network is expected to undergo two phases:

- **By 2030**, between 25 and 100 strategically located fast chargers will be needed to fully interconnect Cambodia's provinces, thereby facilitating country-wide travel with electric cars. This represents one charging point every 70 to 300 km of national road.

- **By 2050**, and in line with the growing stock of EV cars, between 1,700 and 5,900 fast chargers will be needed to adequately cover the growing travel needs of EV users. To do so, the deployment rate of fast chargers will need to accelerate significantly after 2035, allowing the installation of several hundred charging points per year.

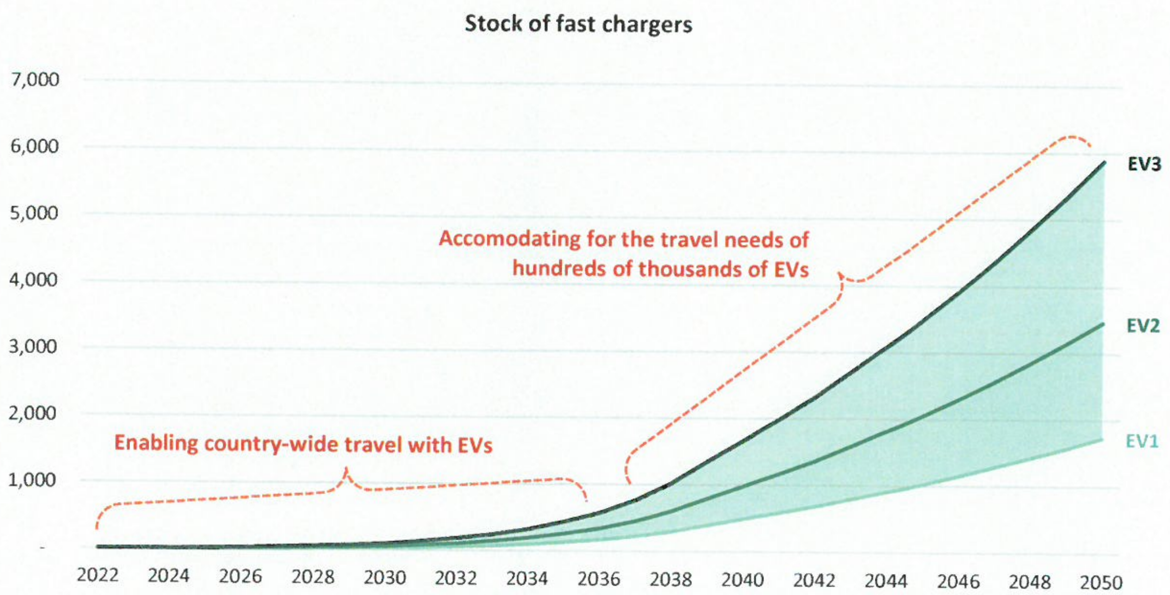

Figure 22. Details of the stock of fast chargers.
Fast chargers are assumed to have a 50-kW power rating. A particular charging station could potentially have more than one charging point.

The results of the modelling of the distribution of fast chargers on national roads for scenario EV2 is given in **Figure 16.**

Distribution of the EV fast chargers in scenario EV2

		Number of fast chargers in EV2			
	Length (km)	2025	2030	2040	2050
NR1	169	1	3	54	190
NR11	105	0	0	5	17
NR2	140	0	3	44	157
NR3	254	1	5	81	286
NR31	98	0	0	4	16
NR4	271	2	8	138	487
NR48	158	0	0	7	26
NR5	429	2	13	218	772
NR56	152	0	0	7	25
NR57	104	0	0	5	17
NR6	426	2	13	216	766
NR62	147	0	0	7	24
NR64	302	0	1	14	49
NR66	140	0	0	6	23
NR68	164	0	0	7	26
NR7	424	2	8	135	477
NR71	59	0	0	3	10
NR78	207	0	1	9	33
NR76	206	0	1	9	33
NR8	172	0	0	8	28

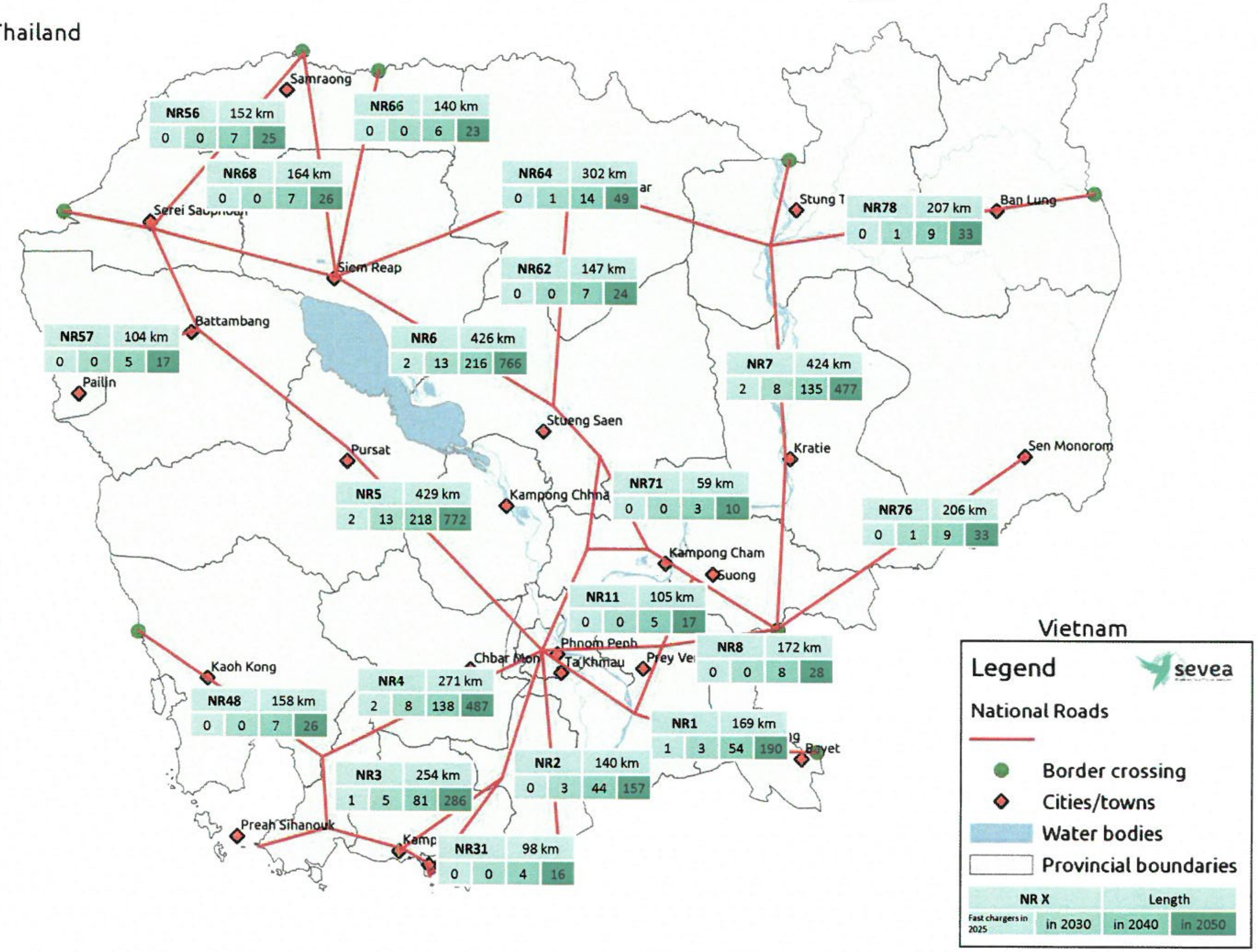

Figure 23. Distribution of EV fast chargers in scenario EV2.

*Results are presented here for scenario EV2; full detail of all three scenarios is included in **Appendix 6.** Fast chargers are assumed to have a 50-kW power rating. A particular charging station could potentially have more than one charging point.*

Assessment of Financing Needs for Charging Infrastructure

The development of the EVCS network will require a cumulative capital investment of $168 to $576 million by 2050. Whilst these investment volumes may seem particularly high when taken at face value, they amount to $430 per electric car and $16 per electric motorcycle on the road.

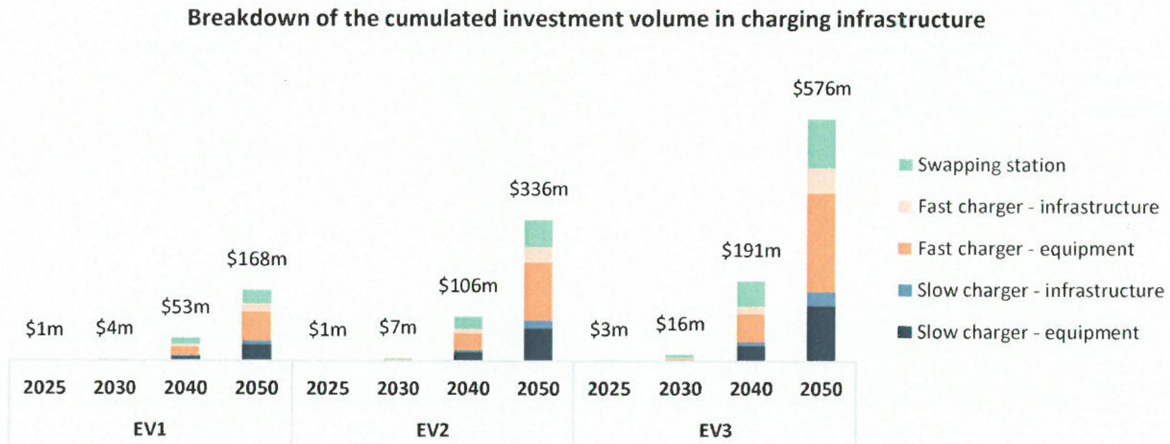

Figure 24. Cumulated investment volume in charging infrastructure for motorcycles and cars.
*Current US dollars. "Equipment" = charging equipment, "Infrastructure" = upgrade of the grid connection and the electrical installation at a given location (transformers, breakers, distribution panels and cables, etc.) – does not include investment in electricity generation, transmission, or distribution. "Swapping station" does not include battery packs. Infrastructure for charging electric heavy vehicles is not included. All items include capital expenditure and do not include operational expenditure. Full detail of all three scenarios is included in **Appendix 6.***

DC fast chargers will require a substantial share of total charging infrastructure investments, amounting to an average 45% of total investments, compared to 25% for slow chargers. The deployment of the fast charger network will require between $220,000 and $740,000 of capital investment per year nation-wide until 2030. After 2040, and in order to accommodate the needs of an ever-increasing number of users, the fast charger network will require $6 to $20.5 million capital investment per year.

Table 13. Yearly capital investment in charging infrastructure.
Current US dollars. Does not include investment in electricity generation, transmission, or distribution. "Swapping station" does not include battery packs. Only includes capital expenditure and does not include operational expenditure.

Yearly capital investment in charging infrastructure									
	For electric cars						For electric motorcycles		
	Slow chargers			**Fast chargers**			**Battery swapping stations**		
Period / Scenario	EV1	EV2	EV3	EV1	EV2	EV3	EV1	EV2	EV3
2022 - 2025	$50k	$100k	$180k	$90k	$180k	$310k	$70k	$130k	$440k
2025 - 2030	$130k	$270k	$460k	$240k	$480k	$810k	$210k	$420k	$1.3m
2030 - 2040	$1.3m	$2.6m	$4.3m	$2.3m	$4.5m	$7.7m	$1.4m	$2.7m	$5.2m
2040 - 2050	$3.4m	$6.8m	$11.5m	$6.0m	$12.1m	$20.5m	$1.7m	$3.3m	$4.6m

Situation Analysis of EVCS in Cambodia

This chapter dives into the current situation of the charging infrastructure market of Cambodia by discussing market prospects, identifying key players, and describing existing roadblocks, thus highlighting required market-enabling measures and course of actions.

1. Lessons Learnt

Key Specificities of the Cambodian Context

1. Prevalence of the two- and three-wheeler markets.

There were over 6.3 million registered motorised vehicles in the Kingdom in 2021, of which 85% are motorcycles (see **Figure 2.**). Although the use of personal cars will continue to grow in the coming years, motorcycles are expected to remain the predominant means of road transport and to represent the largest market for electric vehicles.

2. Low urbanisation rate.

Cambodia's urbanisation rate stands at 24% (WB, 2022); urban centres are limited in number and size in the country (see **Figure 22.**). Whilst this should facilitate the deployment of charging stations within urban areas, intermediary locations on the road between major cities experience significant road traffic and are therefore potential locations for fast charging equipment.

3. Reliance on second-hand vehicle imports.

The domestic automotive industry is still quite unstructured and is vastly dominated by imported vehicles; second-hand vehicles account for 70 to 80% of sales in the Kingdom according to Cambodia's Automotive Industry Federation (CAIF), while there is no resale value nor second hand market for EVs.

4. High import taxes on vehicles.

Vehicle and automotive equipment import taxes are high when compared to other countries in the region and although major import tax incentives are provided compared to ICEVs, EV import taxes are still significant in absolute term (see **Table 18.**).

5. Quality, price, and sale of electricity.

Although the electricity tariffs have continuously decreased over the last few years, electricity prices remain the highest in the region, especially in residential areas (see **Table 17.**). Furthermore, the quality of the electricity supply and distribution may notably constrain the implementation of charging equipment. In addition, the Law on Electricity of Cambodia prohibits the sale of electricity by consumers which prevents charging stations from charging fees for their utilisation (EAC, 2015), unless they are able to secure a sub-license, a relatively rare type of license that enables them to purchase electricity from a licensee and resell it under predefined conditions to end-users (e.g.: markets are an example of consumers that have a sub-license).

6. Opportunity to fast-track projects.

All key potential stakeholders of the EV and EVCS markets are ready to invest and cooperate; multiple initiatives have prepared the ground for future development in Cambodia. There is

strong potential for rapid and country-wide deployment of EVs, which will be enabled by an adequate and supportive regulatory and policy framework.

EVCS Ecosystem

The EV charging ecosystem brings together a wide range of actors, from public institutions to private companies; there is a strong need for coordination of the ecosystem to ensure the effective and orderly development of an EV charging station network. In particular, it is expected that the RGC, embodied by a Technical Working Group bringing together key line ministries and public organisations, will play a regulatory role and will frame the installation of charging equipment by the private sector. The figure below describes the expected structure of the EVCS ecosystem in Cambodia:

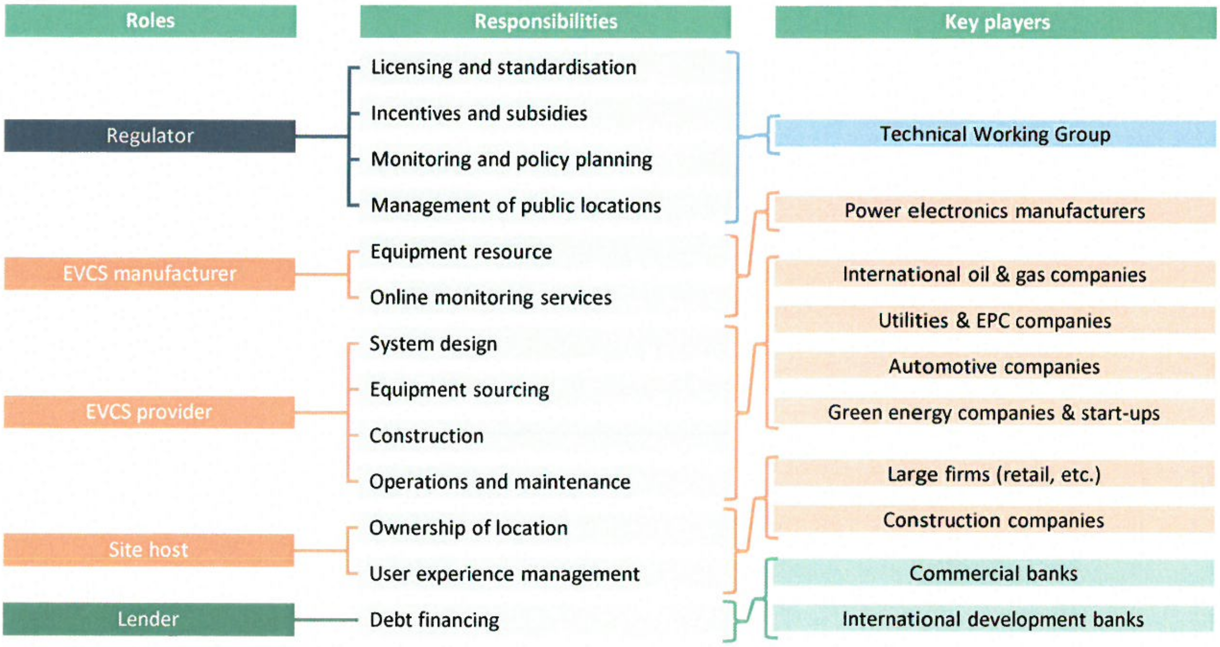

Figure 25. Mapping of key players of the EVCS value chain.

The development of the charging infrastructure will primarily be a private sector-driven initiative. Private initiatives are already largely organised, and await the development of a regulatory framework to kick-start large-scale infrastructure investments. In addition to the deployment of infrastructure, the private sector will also hold associated roles in structuring the EVCS market, such as:

- **Developing cooperation and synergies.** The private sector expressed its willingness to open channels of cooperation between different initiatives to facilitate the economy-wide adoption of EVs. Potential topics of cooperation include: the creation of technical standards, the development of a battery processing value chain, and the establishment of an association of EV companies that would bring key players under one umbrella.
- **Leading the innovation on EV-related products.** The private sector will help promote and develop services and products related to the EV and EVCS markets, such as insurance, financial products, or other e-mobility based businesses.
- **Participating in raising public awareness.** It is expected that the private sector will have a role in improving the visibility of electric vehicles in Cambodia, particularly with regard to the economic and environmental benefits of EVs, and working to address misconceptions by providing accurate technical information on the operation of vehicles and charging stations.

Mobilising Financial Resources

As detailed in the **Future Scenarios Modelling** section, the development of the charging infrastructure on a national scale will require substantial capital investments in the coming years, most of them coming from the private sector.

It was indeed highlighted during interviews and discussions with private sector representatives that the private sector is readily prepared to start investing in charging infrastructure as soon as a clear regulatory framework is put in place, and ensures a well-defined playing field. Financial resources are widely available, notably through the mobilisation of foreign Environmental, Social, and Governance (ESG) and impact funds.

The private sector is convinced that investing in charging stations is largely worthwhile. Private actors have many reasons to push in this direction: (i) leveraging Corporate Social Responsibility (CSR) projects, (ii) enhancing their corporate branding, (iii) issuing carbon credits, (iv) promoting an ecosystem of EV-related businesses (utilising user data, etc.), or (v) getting involved in the implementation of cutting-edge innovations such as demand management, Vehicle-to-Grid battery storage (V2G), or smart-grids[3].

2. Gap Analysis

The following list describes the most relevant roadblocks and concerns related to the development of Cambodia's EVCS network, as identified throughout consultations with key stakeholders:

1. Required grid infrastructure upgrades.
(Technical and regulatory gap)
The quality and capacity of grid infrastructure available in most potential locations in Cambodia is not sufficient to allow the installation of high-power charging infrastructure: most of these locations will need an upgrade. This is true for both potential charging station site hosts (gas stations, malls, parking spaces, etc.), and residences which seldom have connections above 20 Amps, making it impossible to accommodate charging equipment above Level #2 which needs a minimum of 60 Amps. Upgrading the installation at a given location, by installing a new connection point or a higher-capacity transformer, can be a difficult endeavour in terms of process and cost.

2. Multiplicity of charging connector standards.
(Standardisation gap)
The co-existence of a multitude of non-compatible standards in terms of EVCS connectors is counter-productive, creates doubt amongst potential investors, and risks damaging the confidence of potential EV users. In Thailand, Malaysia, Indonesia, and Singapore, government agencies have enforced the use of the European CCS2 standard for public chargers, which integrates both AC and DC charging in one connector (see **Table 24.**). However, other charger standards, such as CHAdeMO for DC chargers, are still occasionally found in these countries. Cambodia does not have a national standard at present; the charging infrastructure, and imported EVs utilise Chinese and/or European standards.

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[3] See Annex 5 for further information

3. **Not-standardised registration for EVs.**
(Standardisation, knowledge, and data gap)
The registration of electric vehicles with MPWT, especially in the two-wheeler segment, is neither widespread nor systematic. This makes it difficult to obtain quality data on the development of the market, and negatively impacts the development of charging infrastructure whilst facilitating the sales of lower-quality imports.

4. **Existing legal void regarding authorisation to operate a charging station.**
(Regulatory gap)
The process for a location to be authorised to operate charging equipment is not currently defined. Some stations have been put off-line by EDC because they lacked a proper licence to sell energy as per the provisions of the Law on Electricity (EAC, 2015). The private sector sees the preparation of a clear regulation regarding the licensing of charging equipment as a pre-requisite to any large-scale investment.

5. **Lack of safety and equipment quality standards.**
(Standardisation gap)
There is a need to develop and enforce technology standards to promote the adoption of high-quality components, thereby preventing low-quality and potentially hazardous products from entering the Cambodian market. Specifically, these should encompass vehicle battery packs, charging equipment, and home chargers. Regulations may also request mandatory sourcing of spare parts as well as the provision of aftersales services to further protect potential EV-users.

6. **Lack of national uptake targets for EVs and EVCS.**
(Policy gap)
The only existing targets regarding EVs or EVCS are those defined by the Long-term Strategy for Carbon Neutrality, calling EVs to represent 70% of motorcycles and 40% of cars and urban buses on the road by 2050 (MoE, 2021). There are currently no detailed uptake targets or governmental action plans illustrating the national commitment to promote these new technologies.

7. **Limited incentivisation of EVs and EVCS.**
(Incentive gap)
Further reduction or most importantly streamlining and clarification of import taxes on vehicles and associated equipment could help EVs become more cost competitive with ICEVs which is still not the case despite the tax reduction that were already put in place. In addition, the private sector advocates for the implementation of a wide array of measures designed to promote the adoption of electric vehicles and the installation of charging stations, such as capital support or tax incentives.

8. **Lack of a structured and unified approach from public bodies to date.**
(Regulatory and policy gap)
The development of Cambodia's EV market will require synergy across multiple government institutions such as MME, MISTI, EDC, EAC, MLMUPC, MEF, MPWT, MoE, or MRD. There currently is no single window system that could facilitate investments and accelerate market development. Avoiding interaction with multiple government contact points for users,

operators, manufacturers, or investors and limiting unnecessary bureaucracy in the regulations will be critical in ensuring an orderly deployment of charging infrastructure.

9. Limited awareness of EVs and EVCS in Cambodia.

(Awareness gap)

Misconceptions and misunderstandings regarding EVs and EVCS remain common amongst the Cambodian public. Their confidence in these new technologies is low, and runs the risk of being permanently damaged should poor quality and untested components be put on the market.

10. Limited technical capacity.

(Skillset gap)

Policy measures will need to be put in place to help build the new technical skillsets, especially in terms of safety and maintenance, that will become increasingly necessary with the widespread use of EVs and the country-wide deployment of EVCS.

Action Plan

1. Guiding Principles

This section outlines the recommended development approaches for each type of charging infrastructure:

1. Home charging

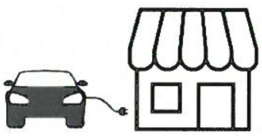
Home charging encompasses slow charging, both for electric cars and electric motorcycles, taking place either at an owner's residence or at their workplace. Home charging is carried out with standard mains electrical outlets at low-power levels (less than 7 kW in on phase, and up to 22 kW in three phase). It does not require any significant infrastructure deployment. It is expected that home charging will represent the vast majority of charging by EV users across all vehicle segments. The recommended approach is:

i. To avoid enforcing regulations (such as authorisation or permits) below a defined power threshold, thus allowing all EV users to charge their vehicles freely at home.
ii. To promote and facilitate the installation of charging stations in existing shared residences and offices (condominiums, *boreys*), and to encourage "EV-ready" construction.
iii. To ensure the safety of users, by setting standards for component quality, and by proposing guidelines on their installation and use.
iv. To plan the exploration of demand management and Vehicle-to-Grid (V2G) measures.

Key implementation model:

- Single houses: self-investment from vehicle owners.
- Shared residences and offices: third-party owner-operator.

2. Away-from-home AC charging



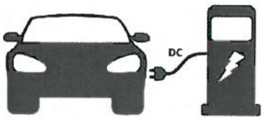
Away-from-home-charging encompasses the short top-up charges done whilst an EV-user runs errands in a public location within urban areas (e.g., coffee shop, mall, hotel, touristic site, etc.), carried at a low power level – below 22 kW in AC mode. These are expected to be largely limited to electric car users, but they will play a key role in the integration of electric vehicles in the urban landscape. The recommended approach is:

i. To avoid enforcing regulations (such as authorisation, permits, or electricity tariffs) below a defined power threshold or number of outlets, thus allowing any private location to freely install low-power charging equipment for their visitors – whether as an amenity or on a fee-basis.
ii. To implement a transparent and market-based approach, openly recording and sharing statistics about the number and usage of these stations.
iii. To adopt national and provincial targets for the number of these stations to build the confidence of potential investors.

iv. To ensure the safety of users by setting standards for component quality and safety of installation, and by proposing guidelines on charging station use.
v. To incentivise locations to install such charging equipment within their grounds by providing soft incentives in the form of tax support.
vi. To promote and facilitate the installation of these charging equipment, and to encourage "EV-ready" construction.

Key implementation model: Private investment from smaller location; third-party owner-operator for larger locations.

3. DC fast charging

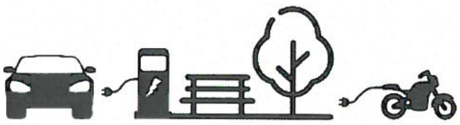


Fast charging encompasses high-power charging used during long journeys – above 40 kW DC charging. Fast chargers will be most needed directly on national roads, between urban areas. DC fast chargers will represent the heavy-lifting part of the charging infrastructure development – both technically and financially. These will be critical to facilitate country-wide travel with electric cars and to address range anxiety from potential EV owners. The recommended approach is:

i. To develop a clear regulatory framework regarding the installation of such equipment, including an authorisation process, technical requirements, as well as associated rules regarding electricity tariffs – both for electricity purchase and resell.
ii. To implement a transparent and market-based approach that facilitates openly recording and sharing information about the numbers and usage of these stations.
iii. To adopt national and provincial targets for the number of these stations to build the confidence of potential investors.
iv. To develop a limited Early Incentive Programme to subsidise and efficiently kick-start the installation of the first set of fast chargers and to promote their implementation in under-served areas by Viability Gap Funding (VGF) provided under competitive bidding. This programme is further discussed in the **Milestones and Recommended Actions** section.
v. To streamline procedures and provide transparent costs for the upgrade of electrical installations necessary to provide fast charging.
vi. To incentivise locations to install such charging equipment within their grounds by providing soft incentives in the form of tax support.
vii. To ensure the safety of users by setting standards for component quality and safety of installation, and by proposing guidelines on charging stations use.

Key implementation model: facility to act as owner-operator.

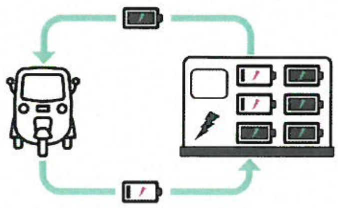
4. Public space charging



Although the majority of the charging infrastructure will be installed within private premises, a number of locations situated on public space (street side, city car parks, touristic sites, public buildings, universities, schools, etc.) may benefit from the installation of charging stations within their grounds. To facilitate these, it is recommended to build a transparent framework for open call-for-tenders. These will allow opportunities for concessional lease agreements to private operators, who will then take care of the investment, installation, and operation of the charging equipment under a set of defined conditions.

Key implementation model: Public private partnerships.

5. Battery swapping



Battery swapping is expected to constitute a partial solution used mostly by logistics companies, company fleets, delivery services, or shared mobility services, in the two- and three-wheeler segments. Existing battery swapping models are carried out by a variety of private actors, each with different approaches, and each making use of their own proprietary battery technology. Although an alignment of these initiatives is desirable, and whilst a number of manufacturers have been taking steps in this direction, forcing interoperability between different initiatives – effectively prohibiting any proprietary approach, and imposing alignment between technologies – is highly unlikely and would be counter-productive.

Battery swapping models are short-term effective solutions to start the economy-wide adoption of electric vehicles by providing a rapid response to range anxiety and by compensating for the short-comings of charging infrastructure in specific transport applications. However, these are unlikely to constitute a universal large-scale or long-term solution. Full reliance on these business models would require an unfeasible number of swapping locations to meet the needs of EV-users in the long-term. Instead, battery swapping will coexist with approaches that enable EV owners to charge their batteries at home or at dedicated charging stations.

Therefore, the recommended approach is:

i. To avoid enforcing regulations (authorisation, permits, electricity tariffs) below a defined power threshold or number of battery packs, thus allowing private locations to freely install battery swapping cabinets within their grounds.
ii. To ensure the safety of users, by setting standards for component quality and safety of installation, and by proposing guidelines on battery swapping use.
iii. To implement a transparent and market-based approach wherein information on the number and usage of charging stations is standardised and openly shared between market participants.
iv. To regulate and support the development of channels of reprocess and recycling of battery packs.

Key implementation model: Private investment from EV supplier.

6. Heavy vehicle charging

The electrification of heavy vehicles (e.g., trucks, vans, or buses) is currently at very early stage in the Kingdom and raises issues that go beyond the scope of this roadmap.

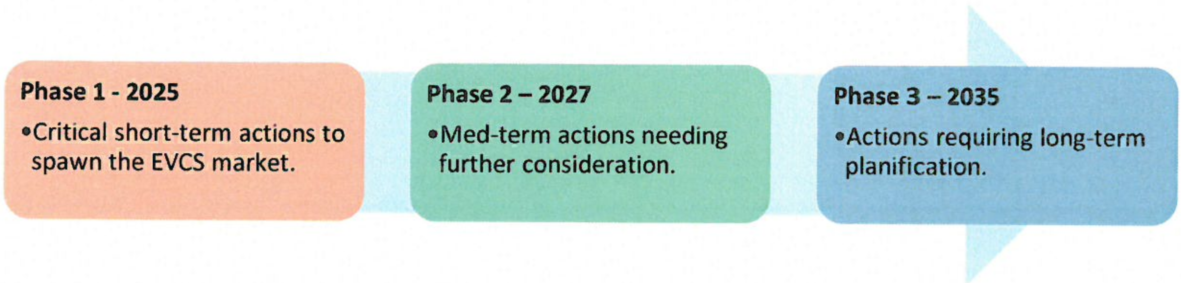
- **For trucks**, freight transport, cross-border trade, and the Kingdom's logistical circuits must be considered.
- **For buses**, muti-modal passenger transport in urban areas and on a national scale must be considered.

For these vehicle segments, approaches and implementation models will significantly differ from smaller vehicles, and will need to be adapted to their specific context. As described in the **Future Scenarios Modelling** section, the electrification of the heavy vehicle stock will raise particularly complex challenges in terms of grid integration and vehicle stock renewal. It is therefore recommended that these be the subject of further standalone studies.

2. Milestones and Recommended Actions

The action plan described below has been built to guide the action of the Government and other public bodies in developing a robust institutional framework, which will enable and support the emergence of a successful charging infrastructure[4].

Actions have been divided into four categories: #1 Coordination and Support, #2 Regulatory and Policy Framework Development, #3 Grid Integration, and #4 Capacity Building and Awareness Raising. The timeline proposed spans from 2022 to 2035; actions are defined by their priority level:



[4] The actions described here are specifically targeting the development of the charging infrastructure, not the adoption of electric vehicles more broadly. It will be important to ensure synchronisation between these proposed activities and other initiatives that are more directly related to EVs.

Table 14: Roadmap timeline for recommended actions.

Recommended actions	Lead and cooperating ministries	2022	Phase 1 2025	Phase 2 2027	Phase 3 2035
Topic #1 - Coordination and Support					
1.1 Establishment of an inter-ministerial Technical Working Group (TWG)	*(TWG)*				
1.2 Set-up of national uptake targets and issuance of a development strategy	*(TWG)*				
1.3 Developing an Early Incentive Programme for fast chargers	*(TWG)*				
1.4 Supporting the establishment of business associations pertaining to EV and EVCS	*(TWG)*				
1.5 Developing a vehicle battery disposal action plan	*(TWG)*				
1.6 Building a monitoring and reporting framework for EVCS	*(TWG)*				
Topic #2 – Regulatory and Policy Framework Development					
2.1 Development of an authorisation process for high-power charging infrastructure	*(TWG)*				
2.2 Developing of a procurement framework for public locations	*(MPWT)*				
2.3 Assessment of safety risks and requirements for AC charging	*(TWG)*				
2.4 Issuing quality and safety standards for charging equipment	*(MPWT / MISTI / TC8)*				
2.5 Definition of regulatory approach for low-power charging infrastructure	*(TWG)*				
2.6 Issuing technical standards for charging connectors (plugs)	*(MPWT / MISTI / TC8)*				
2.7 Incentivising EVCS installation and the emergence of EVCS-related businesses	*(MEF)*				
2.8 Setting requirements to the installation of EVCS in new constructions	*(TWG)*				
Topic #3 – Grid Integration					
3.1 Facilitating infrastructure upgrades for site hosts	*(MME)*				
3.2 Country-wide assessment of EVCS installation risks and necessary upgrades	*(MME)*				
3.3 Including charging infrastructure in long-term power development plans	*(MME)*				
3.4 Planning for cutting-edge approaches	*(MME)*				
Topic #4 – Capacity Building and Awareness Raising					
4.1 Campaign for leading by example	*(RGC)*				
4.2 Developing best-practices guidelines	*(MPWT)*				
4.3 Building the new technical skillsets	*(RGC)*				

Topic #1 - Coordination and Support

These actions aim to enable MPWT to adopt a regulator and coordinator role in the development of the charging infrastructure market.

1.1 Establishment of an inter-ministerial Technical Working Group (TWG)

Responsibility: TWG   Phase 1 – Short-term

The development of the EV market will require coordination across multiple government institutions such as MME, MISTI, EDC, EAC, MLMUPC, MEF, MPWT, MoE, or MRD, which are all included in the inter-ministerial technical working group.

The TWG will be established in order to address all inter-ministerial issues. It will be composed of ministerial technical staff that will ensure coordination and provide support for (i) the development and implementation of legal, policy, standards, and regulatory frameworks, (ii) research, education, and training, and (iii) technology and information exchange, innovation, and the dissemination of best practices.

In particular, the TWG shall create a single window system to avoid interaction with multiple government contact points for users, operators, manufacturers, and investors, whilst ensuring alignment of all Government initiatives.

1.2 Set-up of national uptake targets and issuance of a development strategy

Responsibility: TWG   Phase 1 – Short-term

Setting clear and ambitious short-, medium- and long-term targets, as well as detailing the Government's approach for EV adoption and EVCS deployment will show a strong and holistic commitment to support these new technologies. These targets are paramount to build market confidence, thereby boosting the adoption of EVs and the associated investment in infrastructure, manufacturing, and product deployment.

1.3 Developing an Early Incentive Programme for fast chargers

Responsibility: TWG   Phase 1 – Short-term

It is recommended to set up an Early Incentive Programme in order to kick-start the development of a network of fast charging stations, by bringing the necessary conditions for the early development of the market.

The proposed mechanism to do so is for development partners to provide Viability Gap Funding (VGF) to the first infrastructure investments through rounds of competitive bidding. VGF is widely used to incentivise private investment in infrastructure projects that are economically and socially beneficial but are not financially viable in the short-term. In effect, this would amount to offering non-refundable grants for a defined number of key locations - both private and public - in prioritised areas.

Fast chargers shall be the priority target of this programme in order to circumvent the typical EV-EVCS chicken-and-egg situation: at an early stage of the market, deployment of fast chargers is financially non-viable whilst the stock of electric cars is insufficient to ensure high utilisation of the infrastructure, and in return EV sales are hampered by a lack of infrastructure and range anxiety.

Key aspects of the programme design shall include (i) selecting priority locations - such as national roads or specific provinces, (ii) ensuring a transparent and inclusive selection process, based on proposed costs and quality of service, and (iii) putting in place output-based agreements with the winning companies.

The objectives behind this programme are (i) to fast-track the implementation of fast chargers, (ii) to collect feedback on the implementation of these pilot projects and provide proof-of-concepts, (iii) to send a signal of long-term commitment to the private sector and help build its capacity, (iv) to ensure that a minimal network exists to ensure country-wide travel with electric vehicles, even in provinces or locations that would otherwise be under-served - thus helping to reduce range anxiety of potential EV owners, thereby promoting the adoption of EVs.

Whilst the exact conditions of such programme require further consideration and could be refined as the programme develops, a quick estimation of necessary funds can be proposed as such:

- *Round #1: by 2025, $25,000 grant for 25 fast chargers*
- *Round #2: by 2027, $15,000 grant for 25 fast chargers*
- *Round #3: by 2030, $10,000 grant for 25 fast chargers*

Total cost: $1.25 million, or $156,000 per year, to fast track the installation of 75 DC chargers.

1.4 Supporting the establishment of business associations pertaining to EV and EVCS

Responsibility: TWG | Phase 1 – Short-term

Assisting in the establishment of business associations to bring all key players together under one roof, and setting up regular discussion channels to foster initiatives and facilitate infrastructure development.

1.5 Developing a battery disposal action plan

Responsibility: TWG | Phase 2 - Medium-term

In order to facilitate the adoption of electric vehicles, coordination at national level will be necessary on the management of battery packs. In addition to the consideration of their potential environmental impact, the establishment of a robust battery disposal value chain is a key economic opportunity, which will both facilitate the installation of new manufacturers and meet the new demand for batteries. According to the results of the **Future Scenario Modelling** section, the demand for batteries will reach between 137 and 620 MWh per year by 2030. As EV adoption accelerates between 2030 and 2040, battery demand is expected to exceed a GWh per year during this period, reaching 2.6 to 8.9 GWh per year by 2050. These batteries will need to be efficiently channelled into second use and recycling. Long-term planning through a dedicated action plan which will integrate recent regulatory development and private initiatives will be key to ensuring this.

1.6 Building a monitoring and reporting framework

Responsibility: TWG | Phase 2 - Medium-term

To build an efficient market-based approach, provide potential investors with accurate data, and to guide future decision-making. It will be important to establish a monitoring and reporting framework for the charging infrastructure. Such framework would require collecting and publishing EV adoption and EVCS deployment statistics, and monitoring site performance and usage.

Topic #2 – Regulatory and Policy Framework Development

These actions aim to enable the development of market-enabling measures, such as supporting private investment and facilitating procedures.

2.1 Development of an authorisation process for high-power charging infrastructure

Responsibility: TWG | Phase 1 – Short-term

As detailed in the **Guiding Principles** section, it is not recommended to set up a specific authorisation/permitting process for low-power charging infrastructure whether as an amenity or on a fee-basis (i.e., home charging, AC charging, or battery swapping cabinets). Such infrastructure will little impact on the power infrastructure, and the private sector is much more likely to take ownership of EVCS development if small-scale private actors are allowed to proceed freely.

On the other hand, it will be important to clarify the regulatory framework in which installations above a certain power capacity, or a certain number of charging outlets, must be implemented and operated. This will primarily concern DC fast charging stations, but also large battery charging centres, and charging stations for heavy vehicles.

Such a regulation will clarify the situation with regard to the Law on Electricity, which regulates the sale and purchase of energy (EAC, 2015), whilst facilitating procedures and avoiding excessive bureaucracy. As it stands today, the Law on Electricity prohibits the sale of electricity by unlicensed entities – effectively, this means that it does not allow site operators to make clients pay for vehicle charging, even for low-capacity installations. This is a major obstacle for the development of the infrastructure and should be addressed as early as possible.

Furthermore, it will be necessary to ensure that such regulation is compatible with the regulatory framework put in place by MLMUPC in the Land Development Prakas (MLMUPC, 2018). In particular, the establishment of an electric vehicle charging service activity shall be facilitated regardless the type of land it shall be installed in.

In particular, this regulation will need to encompass (i) a well-defined and single-window authorisation process, (ii) description of roles, responsibilities, and conditions of operations of the equipment, (iii) technical and safety requirements, as well as (iv) associated rules regarding electricity tariffs – both for electricity purchase and resell, if any.

2.2 Developing a procurement framework for public locations

Responsibility: MPWT — Phase 2 - Medium-term

As detailed in the Guiding Principles section, it is recommended to build a transparent framework for open call-for-tenders in order to install charging infrastructure at public locations.

2.3 Assessment of safety risks and requirements for AC charging

Responsibility: TWG — Phase 2 - Medium-term

It is recommended that an extensive donor-funded study, in direct coordination with EDC, be undertaken to understand the risks of future mass installation of AC chargers in residential areas. This study, which could be conducted through household sampling, will help to understand the risks and the need for upgrades to the electricity infrastructure to ensure safe and efficient installation of EVCS.

2.4 Issuing quality and safety standards for charging equipment

Responsibility: MPWT / MISTI /TC8 Phase 1 – Short-term

As detailed in the Gap Analysis section, adopting component quality standards, and issuing safety standards for installations will ensure safety for users, and prevent the import of hazardous low-quality components.

2.5 Definition of regulatory approach for low-power charging infrastructure

Responsibility: TWG Phase 2 - Medium-term

As described in the Guiding Principles, it is recommended that a light-handed regulatory approach be taken with regard to low power installations such as AC chargers installed in residential or commercial areas, effectively allowing for their installation and for the sale of vehicle charging as a service with limited regulatory requirements below a certain power threshold.

Indeed, these low-power chargers are important to ensure the integration of electric vehicles into Cambodia's transport landscape, and contrary to DC charger, they will have a limited impact on the national grid. It is recommended to identify the regulatory requirements that should be set for these low power stations: depending on the type of station, identifying how to ensure the efficient application of safety and technical standards without hindering on the deployment of these stations.

2.6 Issuing technical standards for charging connectors (plugs)

Responsibility: MPWT / MISTI Phase 1 – Short-term

The adoption and enforcement of a defined standard for charging connectors (see Table 24.), will limit the counterproductive co-existence of several standards.

2.7 Incentivising EVCS installation and the emergence of EVCS-related businesses

Responsibility: MEF Phase 2 - Medium-term

This action aims to establish a fiscal framework that incentivises the installation of charging equipment and the development of service providers, through corporate income tax exemptions, reductions in import duty for machinery, exemptions of import duty on raw or essential materials used in manufacturing, or soft loans.

2.8 Setting requirements for the installation of EVCS in new constructions/real estate sector

Responsibility: TWG Phase 2 - Medium-term

In addition to the effort to facilitate the deployment of charging stations, it is recommended that new buildings (*boreys*, condominiums, residences, commercial facilities, etc.) incorporate charging facilities from the outset, and are therefore built EV-ready. For this purpose, the introduction of obligations by installation size is recommended.

Topic #3 – Grid Integration

These actions aim to tackle the energy shift, and ensure that the charging infrastructure will integrate flawlessly into the national grid.

3.1 Facilitating infrastructure upgrades for site hosts

Responsibility: MME   Phase 2 - Medium-term

As detailed in the **Gap Analysis** section, many locations will need to upgrade their electrical installation to accommodate high-power charging equipment. At present, changing a transformer or adding a new connection point can be time-consuming and expensive. It will be necessary to establish clear processes for doing so, with a set of defined prices.

3.2 Country-wide assessment of EVCS risks and necessary upgrades

Responsibility: MME   Phase 2 - Medium-term

The widespread installation of charging stations, such as DC chargers installed in areas of low electrical demand, will create great pressure on the national grid and generate increased risks of equipment damage or even fire. Such accidents would not only be detrimental to users, but could also impact on the adoption of electric vehicles by the general public. It is recommended that a national study be carried out to assess the risks involved and to identify the necessary infrastructure upgrades.

3.3 Including charging infrastructure in long-term power development plans

Responsibility: MME   Phase 2 - Medium-term

It will be necessary to build the technical capacity of the power sector actors regarding charging infrastructure, in order to (i) ensure that such infrastructure is taken into account in the long-term planning and development of the sector, and (ii) that stations can be installed, where they are needed, and with minimal impact on other network users.

3.4 Planning for cutting-edge approaches

Responsibility: MME   Phase 3 - Long-term

This action aims to prepare and plan for the development of initiatives regarding smart EV charging systems, such as Vehicle-to-Grid, demand management, or time-dependant electricity tariffs, in order to optimise electricity demand and supply in the future.

Topic #4 – Capacity Building and Awareness Raising

These actions aim to build the new skillsets that will become increasingly necessary with the widespread use of EVs and the country-wide deployment of EVCS, whilst promoting safe operations of the equipment and providing potential EV-users with accurate information - avoiding misconceptions, providing guidelines, ensuring safe operations, etc.

4.1 Campaign for leading by example

Responsibility: RGC Phase 3 - Long-term

A campaign to promote the installation of charging equipment in public institution buildings would set an example for the public and showcase the importance given by the RGC to the topic.

4.2 Developing best-practice guidelines

Responsibility: MPWT Phase 2 - Medium-term

A number of guidelines and information campaigns shall be put in place to promote best practices for the installation and use of charging equipment, targeted in particular at EPC companies, users, or potential site hosts. Additionally, raising awareness around the environmental impact of electric vehicles, and how they can become effective tools of decarbonation should be a key priority.

4.3 Building new technical skillsets

Responsibility: RGC Phase 3 - Long-term

Actions will be required to build educational and vocational training courses to acquire new technical skillsets associated with charging equipment, especially in terms of safety and maintenance.

Annex 1 - Basics of EV and Charging Stations

1. Basics of Electric Vehicles

Types of Electric Vehicles

An electric vehicle (EV) is a vehicle which is propelled by one or more electric motors, powered by a storage battery. Road vehicles are commonly classified according to their powertrain as follows:

Table 15. Classification of vehicle powertrains.

Type	Acronym	Energy	Definition
Battery Electric Vehicle *(Main focus of this document)*	**BEV**	**Electricity**	**Fully electric vehicle without a combustion engine.**
Hybrid Electric Vehicle	HEV	Fossil	Vehicle with an internal combustion engine and an electric powertrain that can be run in pure electric mode for a limited range and benefits from regenerative braking.
Plug-in Hybrid Electric Vehicle	PHEV	Fossil + Electricity	HEV that has a larger battery and can be plugged in and charged.
Fuel Cell Electric Vehicle	FCEV	Hydrogen	Hydrogen-fuelled vehicle which includes a fuel cell and a battery-powered electric motor.
Internal Combustion Engine Vehicle	ICEV	Fossil	Conventional fossil powered vehicle which uses diesel, gasoline, or gaseous fluids.

EVs are present in all transport modes and vehicle categories. EVs used in road transport range from two-wheelers all the way to heavy-duty trucks. A standard classification of BEVs segments is given as follows:

Table 16. Main BEV segments and associated battery characteristics[5]

Category	Type	Technology maturity	kWh per km	Battery size	Battery voltage
Two-wheelers	Bicycle	**High**	~ 0.03	0.25 – 1 kWh	36 - 48 V
	Scooter	**High**		~ 1 kWh	36 - 48 V
	Motorcycle	**High**		3 – 20 kWh	48 - 300 V
Three-wheelers	Tuk-tuk	**High**	~ 0.06	3.6 – 8 kWh	48 – 72 V
Cars	1st gen. BEV	**High**	0.1 – 0.3	~ 20 kWh	72 V
	2nd gen. BEV	**High**		30 – 150 kWh	350 – 500 V
Heavy duty vehicles	Urban bus	Medium	0.5 – 1.2	80 – 300 kWh	350 – 500 V
	Urban truck	Medium		80 – 300 kWh	350 – 500 V
	Inter-urban bus	**Low**		> 300 kWh	350 – 500 V
	Long-haul truck	**Low**		> 300 kWh	350 – 500 V

The average driving range of new BEVs has been steadily increasing: the weighted average range for a new battery electric car went from 200 km in 2015 to over 350 km in 2022 (IEA, 2022).

[5] Compiled from market data of available EV models.

Main Components of Electric Vehicles

The internals of BEVs are fundamentally different from ICE vehicles: BEVs do not have a fuel tank but rechargeable batteries, their engines are electrically powered, significantly less voluminous than combustion engines and have far fewer parts.

The main battery pack stores energy in direct form and at high voltage (see **Table 7.**), whilst the energy consumption of the vehicle is either in three-phase AC (for the traction motor) or in DC at low voltage (for the on-board electronics). Furthermore, the charging process can happen both in AC and in DC depending on the location. Overall, the main complexity of BEVs stems from the intricate power electronics used to operate them.

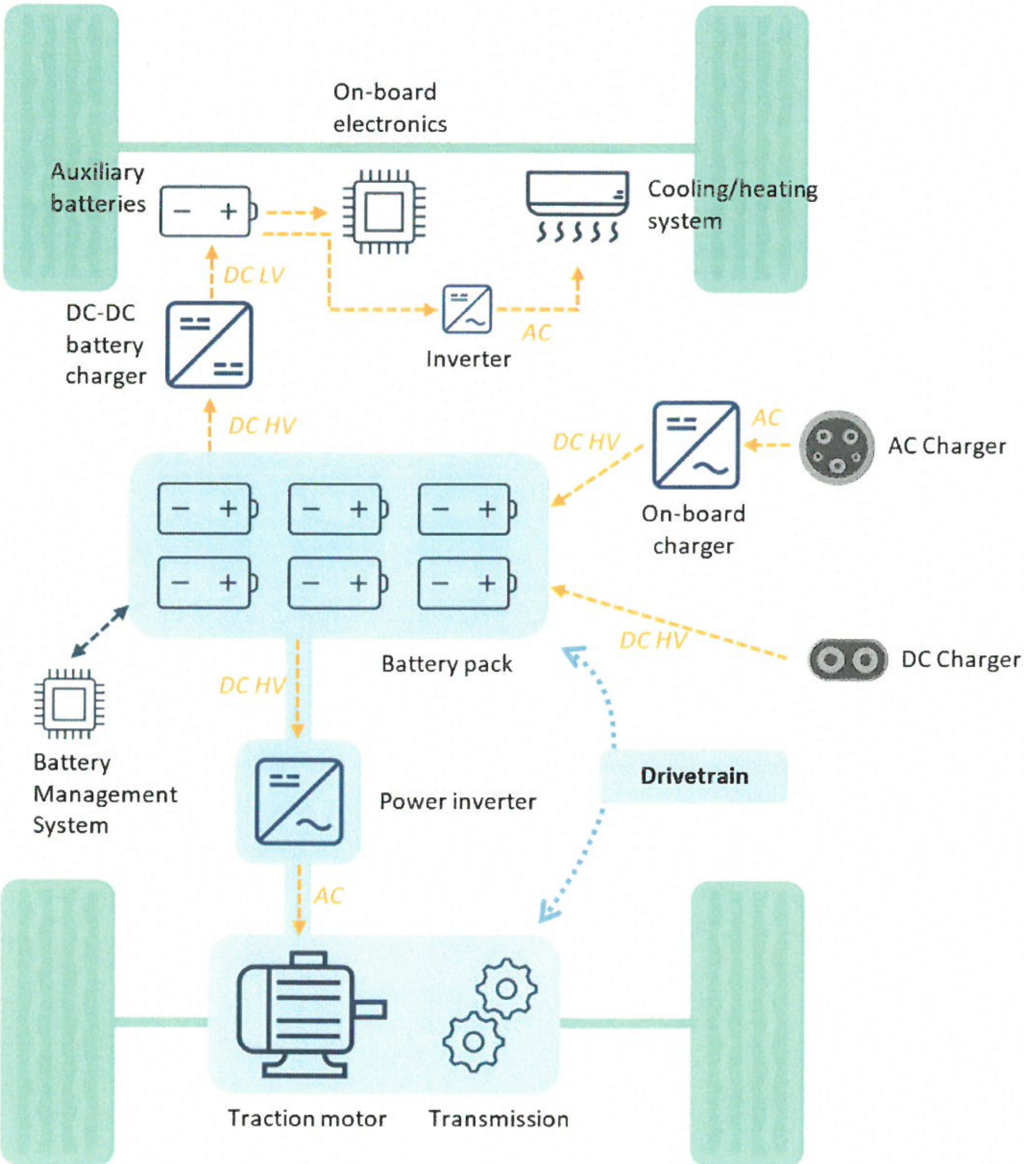


Figure 26. Main components of a BEV and power distribution.

- **Battery pack.** BEVs almost exclusively use lithium-ion or lithium polymer batteries. The battery pack is designed to be capable of receiving high electric discharges. Since their size and weight have a direct impact on the vehicle's operation, the batteries must allow for an optimised ratio of power per volume and per mass. A detailed note on battery packs is provided in Annex 2.
- **Battery management system.** A BMS is an essential component of all battery packs. It monitors the status of the battery elements, such as the voltage of the cells and the current flowing in and out of them, their temperature, their State of Charge (SOC), and their State Of Health (SOH).
- **Power inverter.** The power inverter is an integral component in the drivetrain of BEVs. Its function is to convert high-voltage DC power from the battery pack to three-phase AC current that drives the traction motor. The inverter chops the DC signal and sends pulse signals that simulates an AC waveform at a controlled frequency. By controlling the frequency and the amplitude of the AC signal, the inverter commands the speed and torque of the traction motor. In the process of converting the electrical energy from DC to AC, heat losses occur in the inverter, careful consideration is therefore required to remove excess heat and prevent equipment damage. Quite uniquely, inverters in BEVs are designed to handle reverse power so the vehicle can convert the kinetic energy into re-charging the battery pack whilst braking.
- **Traction motor.** Traction motors are three-phase AC motors used to propel the BEVs. Some high-end vehicles may have two, three, or even four motors. The transmission is usually much simpler than that of an ICE vehicle, containing few or no gears at all. Traction motors fall into two categories:
    - *Synchronous* – making use of permanent magnets or externally excited rotors – mostly used for lower power BEVs.
    - *Asynchronous, or "inductive"* – making use of wound or squirrel cage type rotors – mostly used for higher power vehicles.
- **Charging ports.** Charging ports, or vehicle inlets, are the electrical outlets that allow the vehicle's batteries to be recharged. Most BEV models can accept both AC and DC power. If charging is done with an AC charger, such as when charging at home in a mains socket, the on-board battery charger converts the AC current into DC current. In AC charging, the power is therefore curtailed by the maximum power that the vehicle's on-board charger can receive. Even for high-end BEVs, this value rarely exceeds 11 kW, which means that AC chargers of more than 11 kW are seldom used at their maximum power.
- **Auxiliary batteries.** BEVs usually have a secondary battery at 12 or 24 V that is used to power the internal electronics in the vehicle (lamps, fans, headlights, on-board computer, etc.), similarly to an ICE vehicle. This battery is charged through a DC-to-DC converter that steps down the high-voltage from the main battery pack.
- **Cooling/heating system.** BEVs do not produce heat by combustion, unlike ICE vehicles. In cold climates, heating a BEV can be a challenge due to the additional high-power consumption required. Most high end BEVs are therefore equipped with high efficiency heat pumps, which also contribute to the temperature control of the battery pack. These cooling/heating systems are powered by the DC low-voltage auxiliary battery and therefore have their own DC-to-AC inverters.

2. Basics of Electric Vehicle Charging Stations

Basics of Battery Charging

Electric vehicle supply equipment, also called Electric Vehicle Charging Stations (EVCS), is the equipment used to recharge the battery pack of an electrical vehicle. As explained in E.1.2, the battery pack of a BEV stores energy in chemical form, whilst charge and discharge occur through electrical high-voltage direct current.

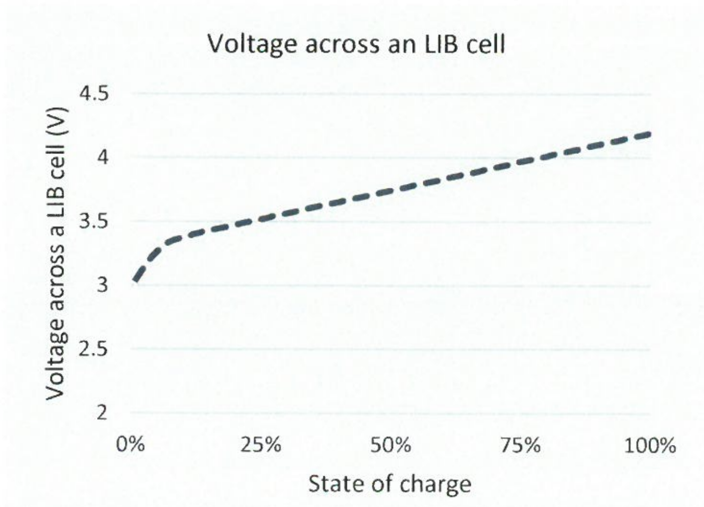


Figure 27. Example voltage across an LIB cell per state of charge.

Most BEV models on the market accept both AC (one and three phase) and DC power for charge. If charging is done with an AC charger, an on-board battery charger converts the AC current into DC current.

Designing EVCS requires providing special attention to the charging circuitry to ensure fast, safe, and complete charging of the batteries.

Throughout the charging process, the LIB cells should be provided with a fixed current level. The voltage across the cells increases with the state of charge, until it reaches its fully-charged nominal value at 100% state of charge (typically 4.2 V). At this point, the EVCS circuitry switches to constant voltage mode, in order to maintain the battery at full charge.

The DC voltage applied by the EVCS has to be sufficiently high to provide a useful level of current through the internal resistance embedded in the battery pack and thus ensure a quick charge, whilst not being too high, which could overheat and damage the battery.

Charge time can vary from fifteen minutes to multiple hours depending on the battery size and EVCS characteristics. The amount of time necessary to go from a 0% to a 100% state of charge can be estimated as follows:

$$Charging\ time\ [hours] = \frac{Battery\ capacy\ [kWh]}{Charging\ power\ [kW]}$$

The C-rate is used to compare the level of charge and discharge between batteries of different capacity. Charging at 0.5 C is often considered optimal to ensure battery lifespan; on the contrary, fast-charging at high C-rates (over 1 C) should be used on an exceptional basis.

$$C\ rate\ [C] = \frac{Current\ [A]}{Battery\ capacity\ [Wh]} * Battery\ voltage\ [V] = \frac{Current\ [A]}{Battery\ capacity\ [Ah]}$$

Classification of Charging Modes

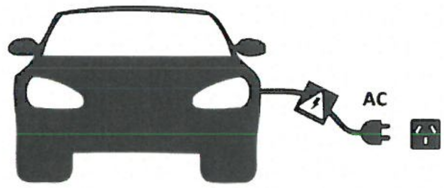
Charging stations are commonly classified into **four levels** based on their nominal charging power, and **four modes** based on the charging method:

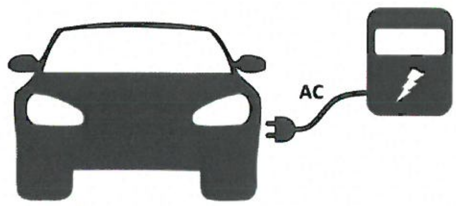
Table 17. Power range definition of charging levels of EVCS.

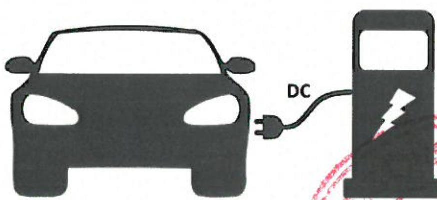
EVCS power level	Charging power	Range delivery	Type
Level #1	< 3.7 kW	< 20 km per hour	Slow charger
Level #2	3.7 to 22kW	< 150 km per hour	
Level #3	22 to 120 kW	150 to 600 km per hour	Fast charger
Level #4	> 120 kW	> 600 km per hour	

Table 18. EVCS charging modes typology.

Mode #1 – None-dedicated home charging	
Description	Connection of the BEV to the main AC grid via standard residential socket outlets, without any specific safety features.
Application	Overnight home charging, usually for two wheelers.
Grid access	Mono-phase
Power	3 kW (1-ph)
EVCS power level	#1
Current	Up to 16 A (230V per phase)
Mode #2 – Dedicated home charging	
Description	Similar to Mode #1, with the addition of a built-in safety control box in the charging cable.
Application	Overnight home charging.
Grid access	Mono or Three-phase
Power	7 kW (1-ph) - 22 kW (3-ph)
EVCS power level	#1 - #2
Current	Up to 32 A (230V per phase)
Mode #3 – Wall charging	
Description	The BEV is plugged in to a power supply system permanently which is itself connected to the electrical network. The control box is integrated directly into the dedicated charging point.
Application	Public space charging (wall boxes, commercial charging points).
Grid access	Three-phase
Power	Up to 40 kW AC
EVCS power level	#2 - #3
Current	32 – 64 A (230V per phase)
Mode #4 – DC fast charging	
Description	The BEV is plugged in to a power supply system which is itself permanently connected to the electrical network that provides **direct current**.
Application	Public space charging, gas stations and expressways.
Grid access	Three-phase
Power	Up to 400 kW DC
EVCS power level	#3 - #4
Current	Up to 200 A DC







Typology of Charging Points

In general, not all charging levels are accepted by all vehicles. For instance, light electric vehicles, since they have small battery packs, need a low-power supply, whereas heavy-duty vehicles need a high-power supply to be charged in a reasonable amount of time and without incurring damage to the battery.

Alternatively, instead of charging the battery directly, some manufacturers favour a Battery as a Service (BaaS) or battery swapping approach. In these models, a depleted battery is physically removed from the vehicle and swapped with a fully-charged battery. Annex 3 - describes battery swapping models in more detail.

The table below summarises charging levels that are commonly used for different electric vehicle segments.

Table 19. Main BEV segments and associated appropriate charging levels.

EV segment	Type	Level #1 < 3.7 kW	Level #2 3.7 – 22 kW	Level #3 - #4 > 22 kW	(Battery swapping)
Two-wheelers	Bicycle	•			•
	Scooter	•			•
	Motorcycle	•	*Rarely*		•
Three-wheelers	Tuk-tuk	•	•		•
Cars	1st gen. BEV	•	•	•	*Rarely*
	2nd gen. BEV	•	•	•	
Heavy duty vehicles	Urban bus			•	
	Urban truck			•	
	Inter-urban bus			•	
	Long-haul truck			•	

Typology of EVCS Connectors

The connector is the interface between the BEV and the EVCS. The function of connectors is to ensure safe charging by using two-way communication between the EVCS and the car.

Although standards have been slowly converging, an eclectic range of mutually incompatible connector designs has been developed over the years, and their use now depends on the regions, the EVCS mode, and the vehicle manufacturers. Despite their similarities, connectors of different standards are not interoperable. Public EVCS are commonly equipped with multiple connectors to be able to supply a wide variety of BEVs. Connectors contain all or part of the following ports:

- Neutral and each phase of the alternative current (N, L1, L2, L3).
- Protective earth or ground (PE, FG).
- Control and proximity pilot pinouts that enable the charge and disable the drive train (CP, PP, PLC).
- Sequence signal pinouts that start and stop the charging process (SS).
- Direct current pinouts (DC+, DC-).

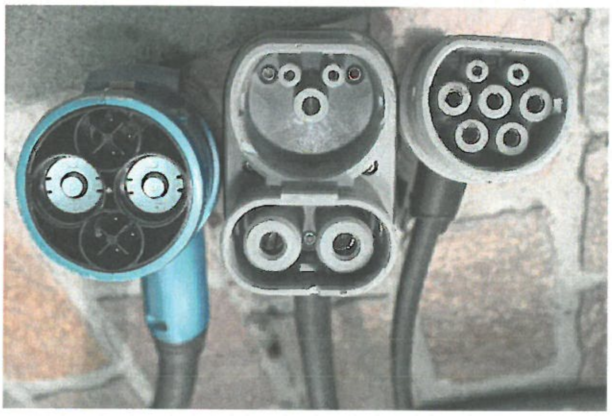


Figure 28. Example of three common connector types.

The main standards currently in use worldwide are given below:

Table 20. Profiles and standard codes of the main EVCS connectors on the market.

	North America	Japan	Europe	China	(Tesla)
AC charger (One-phase)	Type 1 (SAE J1772)				
AC charger (Three-phase)	Type 2 (SAE J3068)	N/A	Type 2 (IEC 62196-2)	(GB/T 20234.2)	Tesla
DC charger	CCS Combo 1	CHAdeMO	CCS Combo 2 (IEC 62196-3)	(GB/T 20234.3)	

In Thailand, Malaysia, Indonesia, and Singapore, government agencies have enforced the use of the European CCS2 standard for public chargers, which integrates both AC and DC charging in one connector. However, other charger standards, such as CHAdeMO for DC chargers, are still occasionally found in these countries. Cambodia does not have a national standard at present; the charging stations installed in the country therefore follow Chinese and/or European standards.

EVCS Unit Costs

The cost of a given charging point is dependent on the specific requirements and constraints of the station and its users. Therefore, the costs associated with installing and operating EVCS can vary extensively, depending on the power rating of the station, the desired charging point features, the site location, the existing electrical infrastructure, and the necessary civil work. The main costs can be broken down as follows:

v. **Hardware costs**
- EVCS unit
- Equipment to connect the station to the electrical service (cables, electrical panels, trenching, boring, repaving, metering, etc.)
- Optional EVCS equipment (payment system, advertising platform, energy monitoring, connectors, etc.)

vi. **Installation costs**
- Design and engineering review
- Contractor labour and materials
- Licensing and inspection

vii. **Additional capital costs**
- Potential electrical infrastructure upgrades (breakers, transformer, cabling, etc.)
- Civil work (lighting, signage, painting, parking space, etc.)
- Hardware and installation warranty
- Land/parking space purchase or lease

viii. **Operation and maintenance costs**
- Electricity consumption and demand charges
- Subscription to EVCS online monitoring system
- Management time
- Billing transaction costs
- Preventative and corrective maintenance

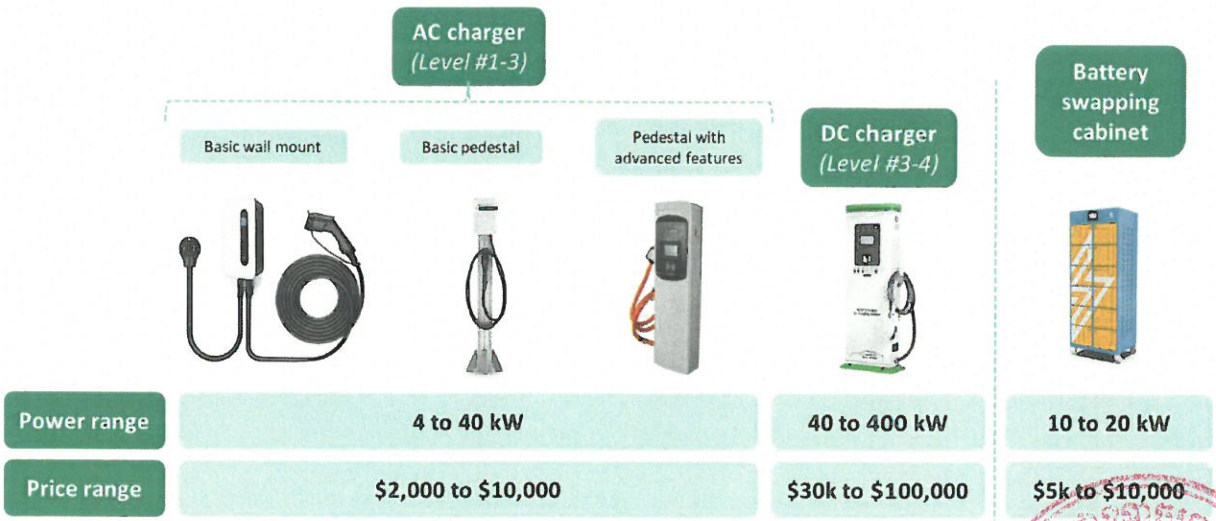


Figure 29. Benchmark price of different types of EVCS in 2022.
Compiled from market data of available EVCS models; costs are given as an indication and may vary significantly between components, locations, and project specifics. Battery swapping cabinet costs do not include batteries.

Annex 2 - EV Battery Packs

Batteries are a component capable of storing electrical energy in chemical form for later release. Battery capacity is measured either in kWh (kilowatt-hour) or in Ah (Ampere hour).

Each type of battery provides varying characteristics in terms of durability, price, size, dangerousness, maintenance, resistance to heat, and deterioration. Lithium-Ion Batteries (LIBs) are common in devices such as laptops, smartphones, flashlights, and cordless tools, and are used in the vast majority of BEVs.

LIBs have dominated the BEV market due to (i) their high energy densities, (ii) the large current they can deliver, (iii) their absence of memory effect, a detrimental process whereby repeated partial discharge/charge cycles can cause partial capacity loss.

Table 21. Average values of main characterics of LIBs.

Main characteristics of LIBs		
Specific energy	Amount of energy that can be stored per kilogram of battery	200 Wh per kg
Energy density	Amount of energy that can be stored per unit volume of battery	400 Wh per litre
Specific power	Maximum power that can be delivered by the battery per unit mass	300 W per kg
Charge/Discharge efficiency	Share of the energy that can be recovered after a charge-discharge cycle	90%
Cycle durability	Number of complete charge-discharge cycles that can be performed before the performance of the battery is significantly affected.	1,000 – 1,500
Retail price	Prices have dropped by 85% since 2010 and depend heavily on the quality of the components.	\$100 – \$200 per kWh

There is a wide and rapidly-evolving variety of LIB technologies available, with different materials for the electrodes and electrolytes. Despite their name, LIBs contain less than 10% of lithium, meaning that a BEV may only hold a few kilograms of lithium. The main types of LIBs are:

- Lithium Nickel Manganese Cobalt (LI-NMC)
- Lithium Iron Phosphate (LFP)
- Lithium Cobalt Oxide (LCO)
- Lithium Titanate Oxide (LTO)
- Lithium Manganese Oxide (LMO)
- Lithium Nickel Cobalt Aluminium Oxide (NCA)

The majority of BEV producers make use of Li-NMC batteries, with the notable exception of Tesla which favours NCA batteries.

LIB cells produce current by having lithium ions move from the anode to the cathode during discharge and the other way around during charge:

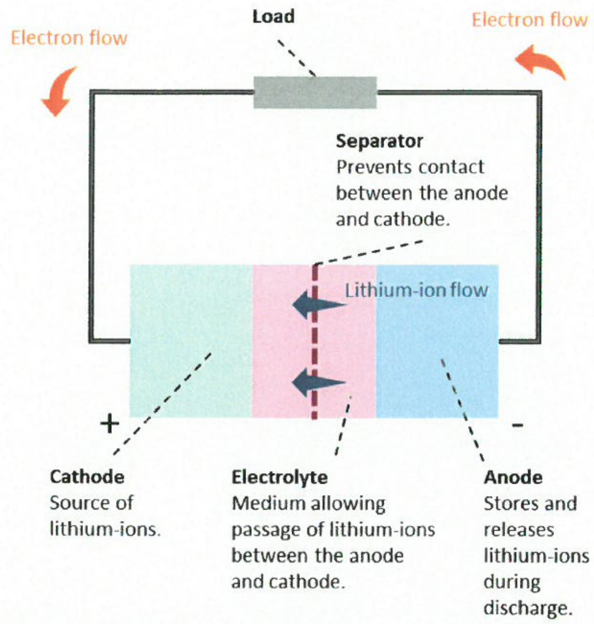


Figure 30. Schematics of the inside of a LIB cell in discharge.
In charge, the flows of electrons and lithium-ions are reversed.

A standard 18650 LIB cell is 18 mm around by 65 mm long and produces a nominal voltage of 3.6 V. Capacity per cell can vary from 2,000 to 4,000 mAh (7 to 15 Wh). The battery pack of a BEV can contain hundreds to thousands of LIB cells, arranged in battery modules:

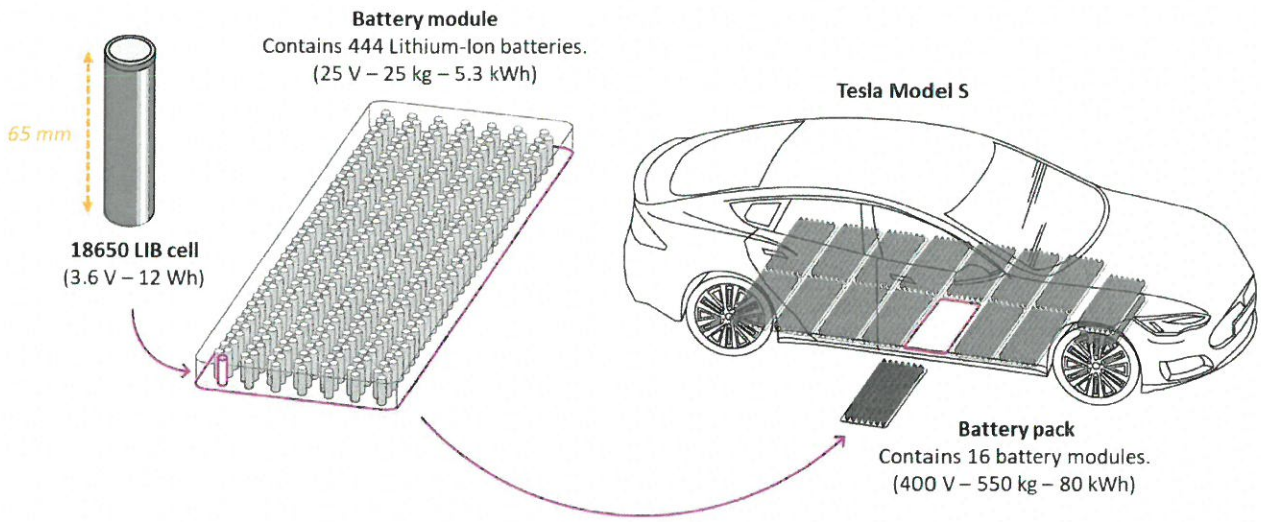


Figure 31. Breakdown of the battery pack of a Tesla Model S.

Rechargeable batteries in general and LIBs in particular experience a natural decrease in energy storage performance upon extended cycling. Performance decay originates from degradation of electrode and electrolyte materials upon aging. This drop in performance manifests itself in (i) decreased discharge capacity and average discharge potential, (ii) decreased power output, and (iii) increased internal resistance and heating.

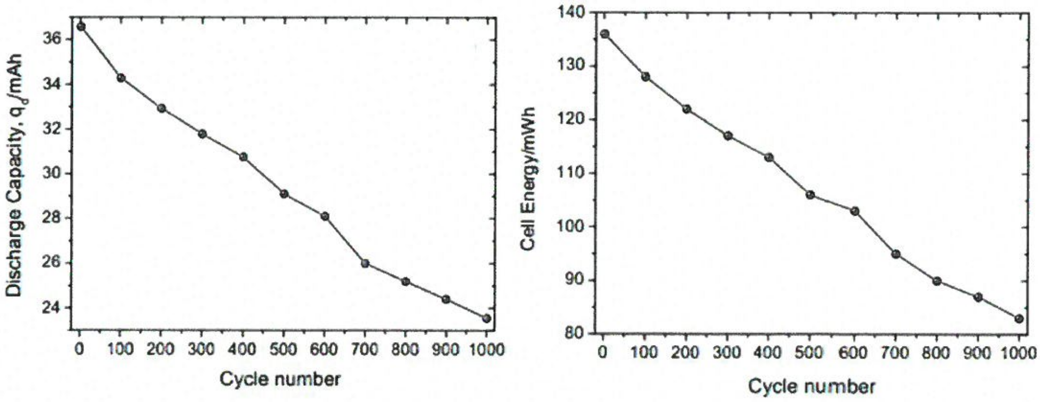


Figure 32. Example of the performance decay of an LIB cell over the course of 1,000 cycles at C/2.
Left: discharge capacity. Right: energy stored in the cell.
(Maher & Yazami, 2014)

Although battery degradation is one of the main concerns with potential new BEV buyers, it is commonly accepted that under normal conditions of use, a BEV equipped with quality LIBs will only lose 10 to 20% of its energy storage capacity after 1 to 2 thousand charge-discharge cycles. Depending on the type of vehicle, this can represent a mileage of 100 to 200 thousand kilometres before any battery replacement is necessary.

With an estimated less than 5% of LIBs undergoing a recycling process worldwide (IEA, 2018), proper LIB reuse, recycling, and disposal is not yet a universally well-established practice, due to raw material low prices, small volumes of spent BEV batteries, and a lack of regulatory measures. Because the LIB industry lacks a clear path towards economic viability for economy-wide reuse and recycling, it has instead historically focused on lowering costs and increasing battery performance and lifespan.

A fundamental approach to proper battery disposal is to set up battery reuse channels that allow to extend lifetime beyond automotive applications. Indeed, the reduced energy storage capacity in a battery that would impact the range and performance of an electric vehicle does not prevent the battery from being used in stationary applications. For example, used batteries can be utilised in battery storage facilities to assist variable renewable energy integration into national grids.

Increasing the lifetime of batteries reduces the need to produce new ones and the associated considerable environmental impacts, and helps to reduce the cost of storage facilities.

Once battery performance has decayed too significantly for secondary applications, they cannot be disposed of as ordinary waste: cobalt, nickel, manganese, titanium, and other metals found in batteries can readily leak from their casing and severely contaminate soil and groundwater, thereby harming ecosystems and human health.

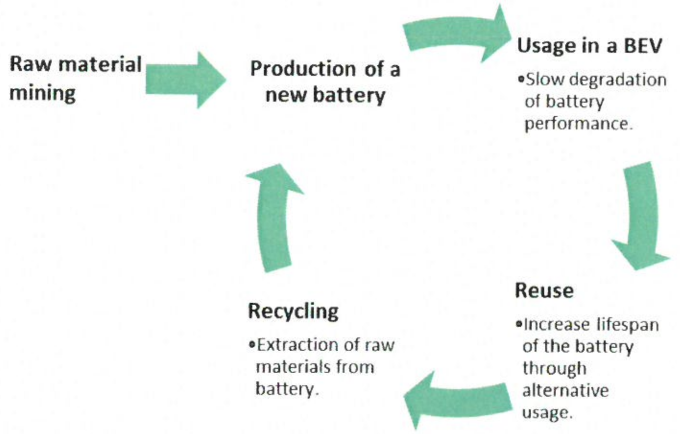


Figure 33. Stages of the ideal lifecycle of an LIB.

Significant technical challenges arise when establishing LIB recycling channels. Indeed, LIBs are compact, intricate, heavy, hazardous, flammable, and sealed-shut devices. They are not designed in a way to be disassembled easily. There is a wide variety of battery types, each with their own chemical composition. Battery packs from BEVs can contain thousands of cells, as well as sensors, safety devices, and other circuitry that control battery operation, all of which further complexify their treatment.

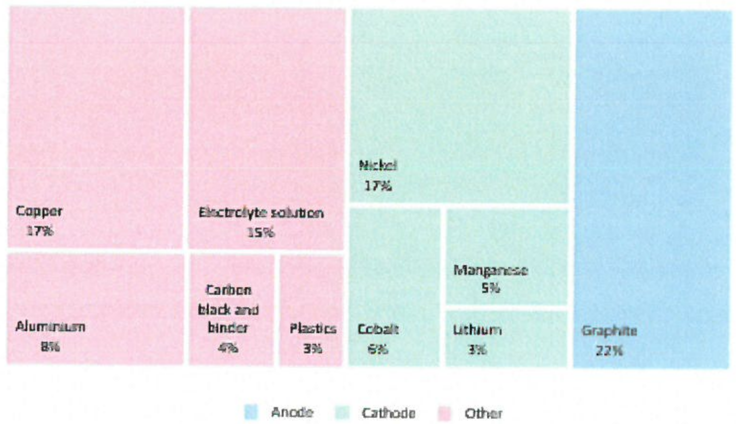


Figure 34. LIB chemical component distribution by weight, example of an NMC LIB cell (IEA, 2018).

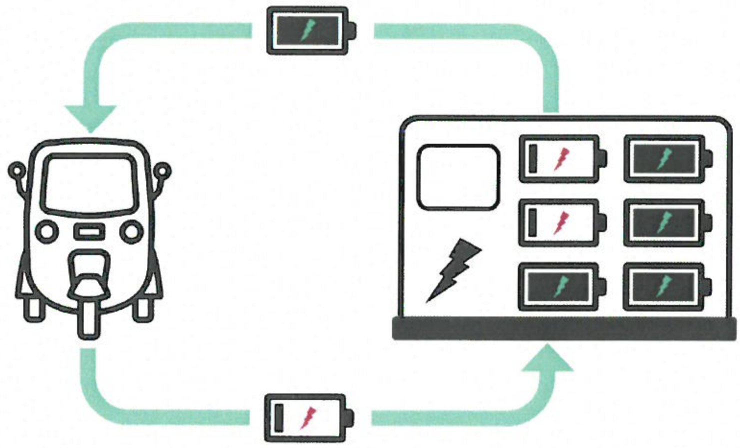
There are currently two mainstream approaches to recovering raw materials from batteries:

- **Smelting**: facilities use high-temperature processes (pyrometallurgy) to recover copper, nickel, and cobalt. This process is heavily energy-intensive, and does not allow for organic compounds, plastics, as well as lithium and aluminium to be recovered.

- **Leaching**: facilities use hydrometallurgical methods to chemically isolate each compound of the batteries. This method is capable of recovering the lithium and is less energy-intensive. However, it relies on large volumes of environmentally harmful chemicals in the process.

Both approaches induce an additional environmental impact both in terms of CO_2 emissions and of generated ecotoxicity. Methods relying on automation and robotic procedures for sorting, disassembling, and recovering valuable materials from LIBs will increase the efficiency of the process but they are still in research stage.

Annex 3 - Battery Swapping



Battery swapping is an alternative approach to BEV battery recharging in which depleted batteries are replaced by fully-charged ones by a third-party operator.

Figure.35 Schematic of a battery swapping station.

The swapping takes place at a battery swapping facility, where depleted batteries are then recharged, later to be picked up by another BEV. The exchange is usually carried out manually by an operator, although automated approaches have been considered. As the exchange can be as fast as a few minutes, battery swapping can significantly offset charging time.

Battery swapping is commonly considered a feasible solution for commercial BEV fleets, especially in the two and three-wheeler segments. However, these approaches have mostly been abandoned in the car and heavy-duty segments due to practicality concerns, lack of compatibility, high infrastructure costs, and the availability of high-powered chargers at a relatively lower cost.

Manufacturers pursuing a battery swap approach follow a Battery-as-a-Service (BaaS) model: EV owners do not have ownership of the battery and cannot charge it by themselves, and instead pay either a monthly fee, or a per-swap fee.

Table 22. Benefits and constraints of battery swapping approaches.

Benefits and constraints of battery swapping models	
Benefits	- Reduction of charging time for BEV users. - Lower upfront cost for BEV ownership as the battery is leased. - Increased battery lifespan thanks to fully controlled and regular charging conditions. - Facilitation of the establishment of battery recycling and reuse channels. - By centralising charging points: possibility to use swapping stations as energy storage facilities, to implement demand control, or vehicle to grid approaches.
Constraints	- Strong technical and practical challenges in establishing well-distributed and efficient swapping stations. - High capital cost and difficult set-up of battery swapping stations. - Lack of standardisation amongst BEV manufacturers. - Greater amount of battery needed to power the same number of BEVs.

There are two main approaches to battery swap models:

Decentralised charging points

In a decentralised model, swapping stations also act as charging points. At each swapping location, cabinets capable of storing 6 to 12 battery packs are installed. The batteries are charged at a slow rate to maximise their lifespan, thereby optimising the quantity of power needed to run the cabinets. An online app lets users know where they can find fully-charged batteries and drop their depleted ones. The establishment of each new swapping point requires an investment in charging equipment.

Centralised charging points

In a centralised approach, no charging takes place at the swapping stations—instead they only act as depleted battery collection and charged battery distribution centres. Depleted batteries are carried to a dedicated charging centre with high charging capacity and sent back to swapping cabinets after being recharged. The centralised approach is generally the easiest for the operation of self-service EV fleets. This model enables economies of scale by mutualising the charging equipment and facilitating the establishment of new swapping locations. However, this approach does create significant logistic challenges when the number of users and swapping locations increases.

- Potential end-user targets of battery swapping systems include urban dwellers living nearby swapping stations and commuting over short distances.
- Private companies utilising a fleet of vehicles with a limited range of action but a high driving time per day, such as food delivery services, city taxis, tuk-tuks, last mile delivery services, public technical services, and hotel rental fleets.
- Shared self-service EV fleets.

Annex 4 - Business Models for EVCS

1. Typology of EVCS Site Hosts

A site host is the entity that owns the property where a charging site is located. Site hosts can be classified according to the type of access to the EVCS they provide:

- **Private charging.**
    - Example: homes and individual workspaces.
    - Mode #1, #2, and occasionally #3, with limited charging power.
    - Slow-charge overnight or during working hours.
    - Energy paid for via the electricity bill of the facility.

- **Semi-public charging.**
    - Private location with charging equipment specifically dedicated to its users, but not fully open to the public.
    - Example: shared office spaces, shared residential areas, organisations which have an EV fleet, etc.
    - Usually occurs in Mode #3, with a dedicated and secure installation, but with limited charging power.
    - Either each EV user directly pays for their charging fees, or the location integrates the charges into its electricity bills.

- **Public charging.**
    - Charging stations open for use by any EV user.
    - Example: hotels, leisure sites, shared residential areas, parking garages, retail sites, transit sites, gas stations, workspaces, on-street parking spaces, etc.
    - Charging occurs in Mode #3 or #4, with high power capacity if needed.
    - Each user directly pays for their charging fees.

2. EVCS Governance and Implementation Models

Owner-operator Model

In an owner-operator implementation model, the site host purchases the equipment from an EVCS provider which handles the installation of the system as part of an Engineering, Procurement, Construction (EPC) contract. Although the EVCS provider may offer warranties and assistance with common issues encountered, the operation of the charging station, including the coordination with the relevant authorities, is the sole responsibility of the site host, who may subcontract part of it to an Operation & Maintenance (O&M) provider.

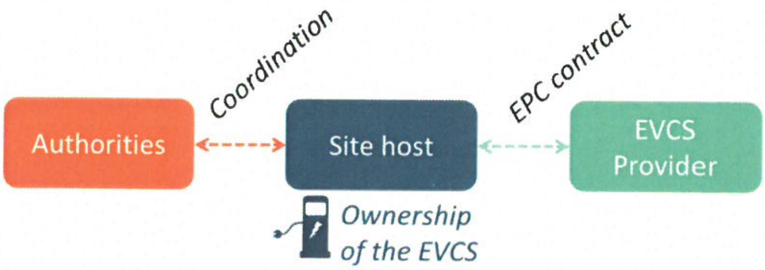


Figure 36. Owner-operator model.

Owner-operators will usually pay for a subscription from the EVCS manufacturers to have access to their station management software. This software allows owner-operators to easily track station usage, make their station locatable via mobile app-based software, and manage pricing and customer payments.

Table 23. Roles and responsibilities - Owner-operator model.

Roles and responsibilities	
Investment and ownership of the EVCS	**Site host**
Construction	**EVCS provider**
Day-to-day operation and maintenance	**Site host** (with O&M provider)
Coordination with relevant authorities	**Site host**
Set up of pricing strategy and collection of payments	**Site host**

This model allows the site host to have total control over the EVCS, at the cost of bearing the full financial and technical risks.

Table 24. Site host perspective - Benefits and constraints of owner-operator model.

Benefits	- Full control over pricing strategy. - Full control over user experience so as to smoothly integrate it within the site. - Internalisation of the revenue generation from charging fees.
Constraints	- Balancing the optimal pricing structure can be highly challenging. - Detailed knowledge of the applicable regulations is required to ensure compliance and safety of operations. - Regular and time-consuming monitoring is required to ensure that operating costs do not exceed the benefits received. - The financial burden rests entirely on the site host.

Third-party owner-operator

In a third-party owner-operator model, the site host relies on an EVCS provider to install, own, and operate the infrastructure. In doing so, the site host reaps the indirect benefits from the EVCS in the form of additional revenue and branding. Depending on the agreement, the site host may receive a consistent stream of rental income from the EVCS provider.

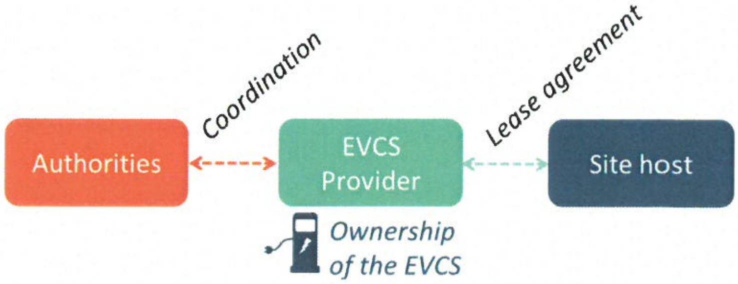


Figure 37. Third-party owner-operator model.

This model allows the site host to delegate the investment, and limits its exposure to operational cost overruns, unexpected maintenance, or complicated coordination with authorities.

Table 25. Roles and responsibilities - Owner-operator model.

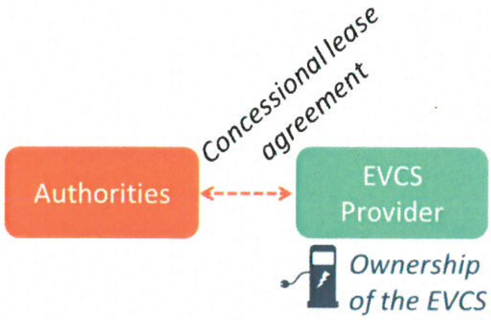
Roles and responsibilities	
Investment and ownership of the EVCS	EVCS provider
Construction	EVCS provider
Day-to-day operation and maintenance	EVCS provider
Coordination with relevant authorities	EVCS provider
Set up of pricing strategy and collection of payments	EVCS provider, in accordance with Site host

In return, the site host relinquishes control of the EVCS, especially in terms of customisation, user-experience, and pricing strategy.

Table 26. Site host perspective - Benefits and constraints of owner-operator model.

Benefits	- No investment needed for the operator. - Simplified and all-inclusive process. - Limited risk exposure.
Constraints	- Lack of control over user-experience, potentially damaging the consistency of the site. - Limited direct revenue stream. - Limited control over pricing strategy that may have otherwise encouraged high turnover or extended customer dwell time. - The EVCS provider will only invest in such a model if it is confident that it will turn a profit and that the constraints laid out in the lease agreement are acceptable.

Government-driven Approach



In a government-driven approach, a government agency provides financial subsidies, concessional land lease agreements, and potential electricity incentives to encourage private actors to install a network of public charging stations.

Figure 38. Government-driven model.

In general, this approach involves the authorities issuing a **call for tender** for a number of identified locations. The tender is then awarded to the companies providing the best compromise between fees and quality of service. The concessionaire is then responsible for the supply, installation, maintenance, and operations of the charging equipment at its own cost and for the agreed lease period.

Roles and responsibilities	
Investment	EVCS provider - Authorities
Construction	EVCS provider
Day-to-day operation and maintenance	EVCS provider
Coordination with relevant authorities	EVCS provider
Pricing strategy	Authorities

In particular, the government-driven model enables to spur a network of public charging points when market conditions are still unfavourable without incentives due to a lack of potential users. This model is **usually dominant in the early years of the development of an EV ecosystem**. It helps set up a basic network of public charging facilities that then kick-starts the private-driven deployment of a wider network. This approach has also been widely used for the implementation of networks of **on-street charging stations in urban areas**.

Figure 39. Example: Autolib's charging points in the streets of Paris, France.

For instance, the Singaporean Land Transport Authority issued in 2022 a large-scale call for tender for the installation of 12,000 electric vehicle charging points at public housing carparks by 2025. The concessional lease agreements will be provided with a 10-year tenure, and will allow for a certain level of flexibility in the installation of additional charging points.

Annex 5 - Financial Modelling of EVCS

Financial Benefits

Ensuring the profitability of charging equipment is of primary concern to potential investors. Proper financial forecasting can be challenging, as it needs to account for factors such as EV user on-site dwell time, charging fee structure, charging station utilisation rate, and indirect benefits for the site host. Generally speaking, charging services are a low-margin investment which require substantial utilisation of the equipment to ensure profit. Even with significant subsidies, EV charging stations are rarely short-term profitable ventures on their own.

By installing open-to-the-public EVCS within their ground, sites hosts can attract or retain BEV-driving visitors, employees, and customers. Benefits induced by the equipment include:

- **Revenue generation.**
    - **Direct**: fees paid by EV users to use the charging equipment.
    - **Indirect**: (i) sales revenue from customers either coming to a site for the purpose of using the charging station or spending longer time at the location whilst waiting for their vehicle to charge (ii) revenue from on-site advertising boards.
- **Corporate branding and increased attractivity.** Hosting EV charging stations can signal commitment of the host site to advancing sustainability goals.

Private actors entering the EVCS market at an early stage (i.e., when EV uptake in a specific region is still low) usually do not pursue direct profits from this activity. Investment rationale is based on other objectives:

- Investing first to lead the market in the future, betting on the economy-wide uptake of EVs (example: energy producers or providers).
- Diversifying their offer, adapting to the market transformation, and attracting more clients (example: gas station operators, highway operators, shopping centres).
- Contributing to the growth of the charging network to drive EV sales (example: EV manufacturers, EV suppliers).

Charging Structure

Depending on the desired objective, pricing strategies can be divided into three categories:

- **Free of charge approach:** charging is offered for free to users, as an amenity. Value is derived from indirect alternative sources such as increased sales or corporate branding.
- **Cost recovery approach**: Fees are set high enough to compensate for CAPEX and OPEX costs and break even. The resulting per kWh fees are typically higher than electricity tariffs. A safety margin can be added on top to further de-risk the investment for the owner-operator.
- **Profit-driven approach**: the fee for charging is designed to turn a profit primarily from the sale of charging services.

In cost recovery and profit-driven approaches, operators of public chargers are free to set their own fee tariffication structure based on their business strategy. The faster the charger, the higher the cost of the equipment, an additional cost that the operator passes on in charging fees. The rule of thumb is that a fast charge is approximately 2 to 3 times more expensive than a home charge, for the same amount of energy supplied.

Adjusting charging fees is one of the most effective ways to influence the usage rate of a charging station. Operators are not limited to "per kWh" price structures, and have developed a wide variety of tariffication models: per minute of connected time, fixed fees, charging network membership subscription, hybrid approaches, time-of-day tariffs, overnight fees, parking fees, etc. Most large-scale charging operators have developed membership cards that provide preferential prices and benefits to their subscribers. Such schemes improve the attractivity of an operator's charging stations and strengthen customer fidelity, whilst simplifying the charging operations of customers.

Capacity Utilisation Factor

The Capacity Utilisation Factor (CUF) of a charging points is defined as the ratio of the time that the equipment is in use over its availability:

$$Capacity\ Utilisation\ Factor\ [\%] = \frac{Average\ daily\ time\ of\ use\ [min]}{Daily\ equipment\ availability\ time\ [min]}$$

Table 27. Correspondence between CUF and daily time of use of an EVCS open 24h per day.

Capacity utilisation factor	0%	1%	5%	10%	50%	70%
Approx. corresponding daily time of use	-	15 min	1h	2h30	12h	17h

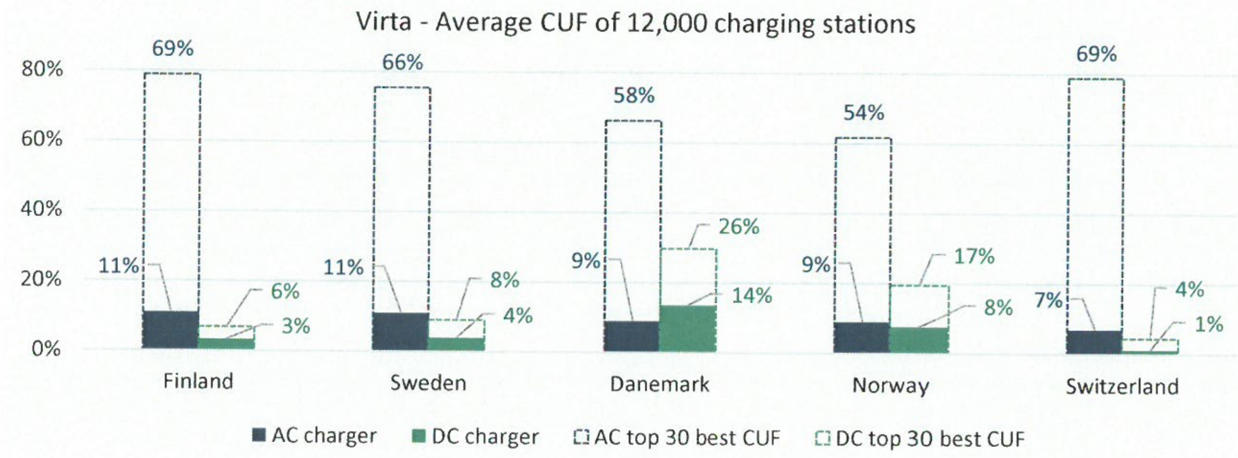


Figure 40. Example: 2021 CUF of 12,000 charging stations from Virta.
Stations are divided between AC and DC chargers. Some AC chargers are private. The average CUFs from the top 30 best performing DC and AC chargers of each country are added for reference ***(Virta, 2022).***

Choosing a charger that fits both the location and the needs of potential customers is an essential step in designing a charging station. Knowledge about the local market and customers' desired type of use of the chargers are required when making decisions about the prospect of a charging points. Overall, the CUF of a given station can range from a few percent (e.g., being used for a few minutes a day) for unsuccessful sites, to over 70% (17 hours a day) for sites used almost continuously.

Charging Point Profitability

If both the CUF and the charging fee of a given charging point are high enough (i.e., the station is sufficiently used and the fee is set sufficiently high), the equipment can generate net income.

A useful way to represent the business case of a given charging station is to draw a diagram with the CUF on the x-axis (which indicates how much the station is used, and therefore indirectly how much energy is delivered), and the charging fee in dollars per kWh on the y-axis.

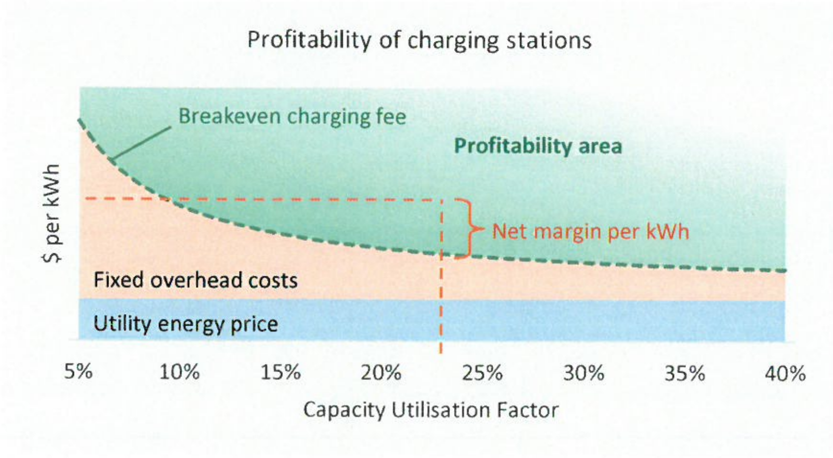


Figure 41. Relationship between capacity utilisation rate and breakeven charging fee.

As the fixed overhead costs of the charging equipment are spread amongst all users, a charging station with a high CUF can provide more attractive tariffs to users whilst being more profitable for the operator.

Generally, when a charging station installs several charging points at the same location, it benefits from both greater visibility and attractiveness, but also a lower price per installed kW due to economies of scale on infrastructure and monitoring costs. Through this double effect, these can generally offer more competitive prices. Additionally, despite their high installation cost, DC fast charge stations tend to have a lower price per installed kW than low power stations. However, they also often have a lower CUF than low power AC stations, as users spend less time charging their vehicles.

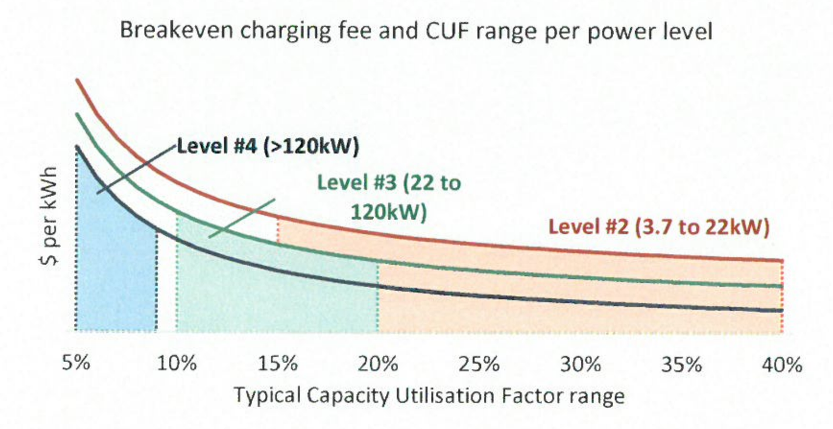


Figure 42. Relationship between breakeven charging fee and charging level.

Charging points with higher power levels tend to have lower "per kW" installation costs – which is why the Level #4 breakeven curve is the lowest on the graph. However, in general, the higher the power of a station, the lower its CUF, which is why fast chargers tend to be more expensive than slow chargers at equivalent kWh supplied.

Appendix 1 - Landscape of EVCS in ASEAN

Table 28. Targets and incentive mechanisms for EV and EVCS uptake in ASEAN.
(Source: Interviews and desk research from consultant).

	Battery electric car stock	Public EVCS stock	Targets				Support mechanisms				Regulation on EVCS	
			Carbon neutrality target	ICEV phase out target	EV target	EVCS target	EV demand-linked support	EV import tax support	EVCS tax support	Support on electricity tariffs for EVCS	Connector standards	Building regulations
Cambodia	200	7			Under dev.	Under dev.					Under dev.	
Malaysia	500	420	2050		2030 15% of new vehicles	2025 9,000 AC, 1,000 DC		Under dev.	Under dev.		Type 2 CSS2	
Thailand	4,100	2,200	2050		2030 LEV: 40% new sales, 30% of production Car: 50% new sales, 30% of production	2025 4,400 fast chargers 2030 12,000 fast chargers					Type 2 CSS2	
Philippines	300	140	Under dev.		2030 21% of stock 2040 50% of stock	2026 5,000 EVCS	Under dev.	Under dev.	Under dev.		Type 2 CSS2	
Lao PDR	N/A	N/A			2025 1% of vehicle stock 2030 30% of vehicle stock							
Myanmar	200	N/A										
Vietnam	N/A	N/A	Under dev.									
Singapore	3,700	1,900	2060	2040	2040 100% stock (includes BEV, HEV, PHEV, FCEV)	2030 60,000 EVCS (20,000 private, 40,000 public)					Type 2 CSS2 CHAdeMO	

Appendix 2 - Modelling Methodology

Vehicle Stock Projections

The growth of the motorised vehicle stock, given below, is assumed to be the same in all scenarios.

Table 29. Modelling of the stock of motorised vehicles in Cambodia.

Size of the vehicle stock and ratio of vehicles per person						
	Motorcycles		Cars		Heavy-vehicles	
2021 *(actual)*	5.1m	*0.28*	0.6m	*0.03*	0.23m	*0.01*
2025	6.5m	*0.38*	0.8m	*0.05*	0.27m	*0.01*
2030	7.9m	*0.44*	1.0m	*0.07*	0.31m	*0.02*
2040	9.6m	*0.50*	1.6m	*0.08*	0.39m	*0.02*
2050	10.4m	*0.50*	2.7m	*0.13*	0.50m	*0.02*

These vehicle stock projections were built and cross-checked with (i) historical vehicle registration data from MPWT, (ii) benchmarks from neighbouring countries, (iii) UN population projections, (iv) market trends identified by the consultant, and (v) Cambodian economic development projections[6].

In particular, this model emphasises the expected slowdown of the growth of the motorcycle stock, which is postulated to converge and get saturated at around 10 million vehicles by 2050 – equivalent to one motorcycle per two inhabitants, coherent with the motorcycle stocks of Vietnam, Thailand, or Malaysia. Conversely, the stocks of cars and heavy-vehicles are likely to increase sharply, following Cambodia's economic development; the car stock will multiply more than fivefold by 2050 as Cambodia moves deeper into the car market phase.

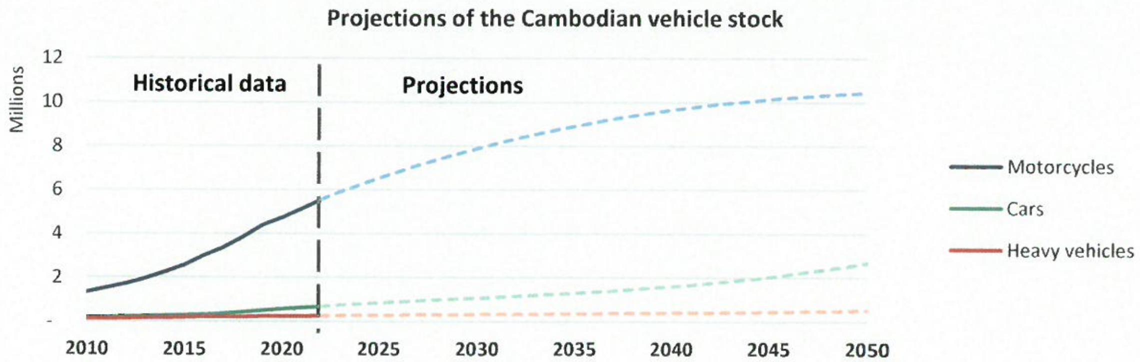


Figure 43. Modelling of the stock of motorised vehicles in Cambodia.

[6] Whilst a more complex model could also incorporate finer assumptions - such as the rate of urbanisation, household access to credit, road infrastructure development, regulatory developments, public transport improvement, or vehicle taxation rate - this exercise was based on the best available data, and is believed to accurately highlight key market trends.

Adoption of Electric Vehicle

As presented in **Table 8.** the growth of the share of EVs in new vehicle sales, given below, constitutes the basic assumption of the three scenarios.

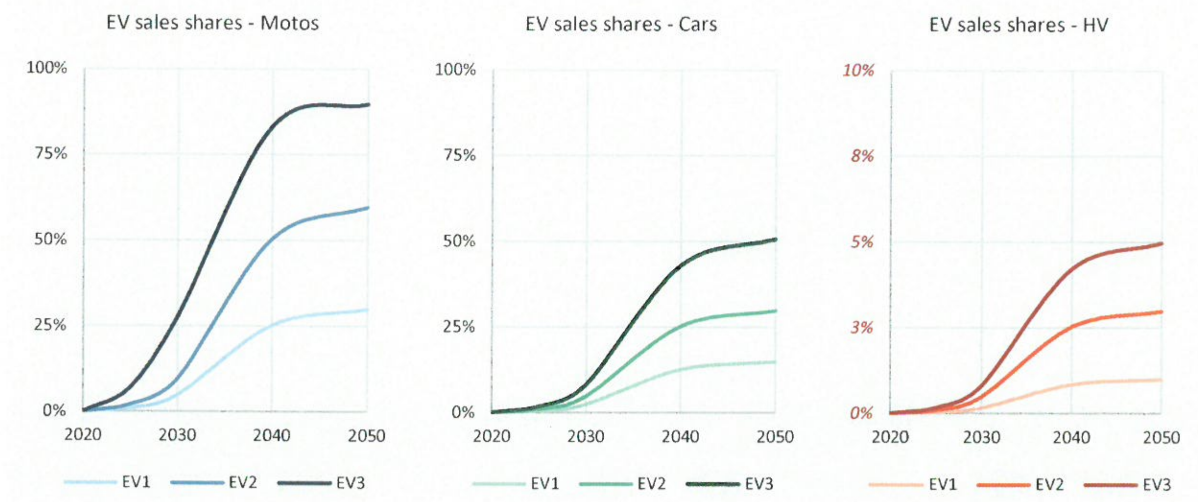


Figure 44. Assumptions of EV market share of new vehicle sales per segment and per scenario[7].

Starting from a market share set to 0% in 2020, the market growth is modelled with logistic S-curves until 2050. Importantly, **Figure 20. represents the percentage of EVs amongst the new vehicles put on the road at any given year**. Because of the inertia of the existing ICEV stock which takes decades to renew, these relatively high market shares translate into lower percentage of overall stock electrification.

To best model the penetration of EVs in the country's vehicle fleet, it is assumed that new ICEVs are retired after a period of 20 years - this reflects the fact that EVs will be economically more attractive than ICEVs for consumers, that their adoption will be supported by policies, and that ICEVs will be eventually phased out.

Electricity Demand

The introduction of EVs will create a shift in final energy consumption from refined petroleum products (diesel, gasoline, and LPG) towards electricity. The assumptions taken to estimate the yearly energy consumption of a given EV, provided below, was estimated from:

(i) **The average distance travelled per vehicle segment in Cambodia** (data obtained from energy consumption surveys conducted in the development of Cambodia's Petroleum Master Plan 2022-2040 (ERIA, 2021)).

[7] The sales share of each scenario has been chosen in order to represent a broad spectrum of scenario, whilst being in line with historical market data and with similar modelling exercises that have been developed either:

- for the world (see (IEA, 2021) (IEA, 2022) (BNEF, 2022) (ICCT, 2022)),
- for the ASEAN region (see (BNEF, 2022) (IRENA & ACE, 2016) (ICCT, 2022) (AIDIC, 2021)),
- or for neighbouring countries (see (UNEP, 2014) (Schröder, M. and F. Iwasaki, 2021) (Dhar & P.R., 2015) (ADB, 2018) (WB, 2016)).

(ii) **The average consumption of EVs on the market** (data compiled from (MoE, 2019), (EV-Database, 2022), and (Prakobkaew & Sirisumrannukul, 2022)).

Table 30. Assumptions used for the electricity consumption per EV.

Assumptions used for the electricity consumption induced by EVs			
	Motorcycles	**Cars**	**Heavy-vehicles**
Distance travelled per year	5,000 km	10,000 km	90,000 km
Electricity consumption of EVs	0.025 kWh per km	0.2 kWh per km	1.0 kWh per km
Yearly electricity consumption	125 kWh per EV	2,000 kWh per EV	90,000 kWh per EV

The modelling of energy consumption for residential charging is based on usual models of EV user behaviour. The load curve used is given below:

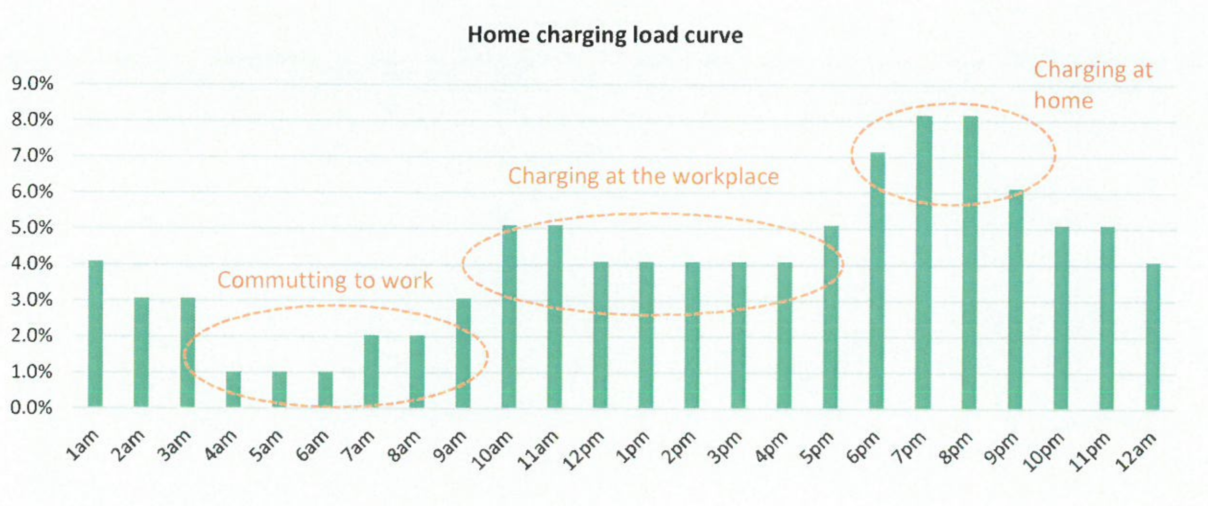


Figure 45. Home charging load curve.
Based on ***(BNEF, 2022)***

Battery Demand and Disposal

In line with current benchmarks, batteries are supposed to have a lifespan of 10 years for motorcycles, and 15 and 5 years for cars and heavy vehicles respectively. Beyond this period, it is assumed that batteries are used for 5 years in secondary stationary use, before they need to be recycled.

Table 31. Assumptions for battery demand and disposal.
Based on a benchmark of current electric vehicle models.

Assumptions used for the battery demand and disposal			
	Motorcycles	**Cars**	**Heavy-vehicles**
Lifespan of batteries	10 years	15 years	5 years
Battery size	2.8 kWh	55 kWh	300 kWh
Distance travelled per battery pack	50,000 km	150,000 km	450,000 km

Greenhouse Gas Emissions

Table 32. Assumptions for GHG calculations.
Based on a benchmark of current electric vehicle models, and on ***(IEA, 2022), (ICCT, 2021)*** *and* ***(UNFCCC, 2019)***.

Assumptions used for greenhouse gas emissions of electric vehicles		
	Motorcycles	**Cars**
Weight	100 kg	1,500 kg
Battery size	2.8 kWh	55 kWh
GHG emissions from vehicle manufacturing		4 kg CO_2e per kg
GHG emissions from battery manufacturing		68 kg CO_2e per kWh
Grid factor		0.58 kg CO_2e per kWh
Emissions from fossil fuel		
Diesel		2.33 kg CO_2e per litre
Gasoline		2.75 kg CO_2e per litre
LPG		1.75 kg CO_2e per litre

Charging Infrastructure

The modelling distinguishes between four types of EV charging methods:

(i) **Home charging:** *(both for cars and motorcycles)* Slow charging at night or during the working day, taking place either at home or at workplaces; does not require any significant infrastructure deployment.

(ii) **Away-from-home charging:** *(only for cars)* Slow top-up charge done whilst the EV-user runs errands in a public location within urban areas (e.g., coffee shop, mall, hotels, touristic sites, etc.).

(iii) **Fast charging:** *(only for cars)* DC fast charging used during long journeys; the station is located directly on a national road connecting urban areas (e.g., gas stations).

(iv) **Battery swapping:** *(only for motorcycles)* Public charging is relatively uncommon for two- and three-wheelers. Battery swapping is assumed to be a partial solution, used in particular by logistics companies, delivery services, or shared mobility services. In terms of infrastructure, battery swapping is modelled by the installation of decentralised battery charging cabinets solely within urban areas (e.g., at convenience stores).

To model the need for each of these infrastructures, a number of assumptions (provided in the tables below) have been made regarding the behaviour of electric vehicle users, as well as the costs and characteristics of these charging points.

Table 33. Assumptions used for the characteristics of the EV charging infrastructure[8].

Assumptions used for the characteristics of the EV charging infrastructure			
Electric cars	**Home charging**	**Away-from-home charging**	**Fast-charging**
Location	Residential	Urban	National roads
Percentage of charges	85%	9%	6%
Power level	Level #1 or #2	Level #2	Level #3 or #4
Charging point power rating	*Not considered*	10 kW	50 kW
Capacity utilisation rate		10%	5%
Investment per charging point		$7,500	$50,000
Equipment		*($6,000)*	*($40,000)*
Upgrade of grid-connection		*($1,500)*	*($10,000)*

Electric motorcycles	**Home charging**	**Battery swapping**
Percentage of charges	85%	15%
Location	Residential	Urban
Power level	Level #1 or #2	-
Cabinet power rating	*Not considered*	20 kW (one cabinet)
Battery charging rate		0.2 C
Cabinet size		6 battery packs of 2.8 kWh
Capacity utilisation rate		40%
Investment per cabinet		$10,000

In order to characterise how the charging infrastructure will need to be distributed geographically within the country, a three-tier model (given below) was utilised. Effectively, provinces and key national roads are divided into three tiers that were based on (i) market prospects for EVs, (ii) estimated size of the vehicle fleets, (iii) available traffic data, (iv) demographics and urbanisation data. These three tiers do not represent development priorities, but are instead used to weight the distribution of the charging infrastructure within the country.

Table 34. Assumptions of the three-tier system used to distribute the charging infrastructure geographically.

For battery swapping and away-from-home charging		For fast charging	
Province	Tier	National road	Tier
Banteay Meanchey	3	NR1	2
Battambang	2	NR11	3
Kampong Cham	3	NR2	2
Kampong Chhnang	3	NR3	2
Kampong Speu	3	NR31	3
Kampong Thom	3	NR4	1
Kampot	3	NR48	3
Kandal	1	NR5	1
Kep	3	NR56	3
Koh Kong	3	NR57	3
Kratie	3	NR6	1
Mondulkiri	3	NR62	3
Oddar Meanchey	3	NR64	3

[8] These assumptions were based on global market trends, on interviews with the private sector, and on a benchmark of user behaviour in other countries, adapted to the Cambodian context.

Pailin	3	NR66	3
Phnom Penh	1	NR68	3
Preah Sihanouk	2	NR7	2
Preah Vihear	3	NR71	3
Prey Veng	3	NR78	3
Pursat	3	NR76	3
Ratanakiri	3	NR8	3
Siem Reap	2		
Stung Treng	3		
Svay Rieng	3		
Takeo	3		
Tboung Khmum	3		

Limitations of the Modelling

The modelling presented here does not constitute a detailed market analysis, but rather a first step in understanding the need for charging infrastructure to best support the uptake of electric vehicles in Cambodia. This is a first-of-its-kind exercise, and a number of limitations, related to the quality of the available data and the level of detail of the model, can be highlighted:

- The model is particularly sensitive to assumptions about the behaviour of electric vehicle users, particularly in terms of making use of their personal chargers or publicly available infrastructure.
- The modelling is static and therefore does not take into account possible improvements in the performance or price of EVs and EVCS, nor possible changes in user behaviour or in transport infrastructure development.
- The ability for EV users to source and finance the electric vehicle stocks is not discussed.
- Three-wheelers, heavy vehicle charging infrastructure, and more generally commercial uses of road transport (delivery, logistics, public transport), are not directly studied in this analysis.
- The various environmental benefits and impacts (GHG emissions, generated ecotoxicity, air quality, waste management, etc.) of the development of the EV stock, of the deployment of the charging infrastructure, of the electricity generation and distribution, and of the retirement of ICEVs are not included within the scope of this analysis.
- This study is largely focused on battery electric vehicles, whilst a non-negligible share of plug-in hybrid vehicles could lead to a number of subtleties concerning the charging infrastructure.

Appendix 3 - Electricity Tariffs in Cambodia

Table 35. Electricity tariffs in Cambodia[9]

Tariff structure	(i) General tariff	(ii) Time-of-use tariff			(iii) Solar PV tariff	
Description	Flat kWh tariff throughout the day. Still applies to a large majority of consumers.	The ToU tariff is divided into two parts: - Capacity charge ($/kW): a fixed cost calculated based on the contracted capacity. By default, the contracted capacity is equal to the total capacity of the transformer(s) on the facility. - Electricity charge ($/kWh): a variable cost based on the amount of energy consumed each month. This energy charge is time dependant, introducing a peak-hour tariff (7am-9pm) and a night-time tariff in order to promote off-peak electricity consumption.			The solar PV tariff is compulsory for all PV system owners. It is identical to the ToU, except that it does not entitle the holder to the preferential off-peak tariff.	
		Monthly capacity charge	**Peak-hour tariff (7am-9pm)**	**Off-peak-hour tariff (9pm- 7am)**	**Monthly capacity charge**	**Electricity charge**
Connected directly to a sub-station						
- High voltage	$0.1170 /kWh	$2.90 /kW	$0.1140 /kWh	$0.0940 /kWh	$2.90 /kW	$0.1140 /kWh
- Medium voltage						
o Phnom Penh and Ta Khmao	$0.1320 /kWh	$3.10 /kW	$0.1180 /kWh	$0.0960 /kWh	$3.10 /kW	$0.1180 /kWh
o Provinces	$0.1210 /kWh	$4.00 /kW	$0.1290 /kWh	$0.0960 /kWh	$4.00 /kW	$0.1290 /kWh
Connected to an HV or MV line[10]						
- Industry & Agriculture consumers	$0.1370 /kWh	$5.00 /kW	$0.1300 /kWh	$0.1100 /kWh	$5.00 /kW	$0.1300 /kWh
- Commercial & Administration consumers	$0.1580 /kWh	$5.80 /kW	$0.1500 /kWh	$0.1240 /kWh	$5.80 /kW	$0.1500 /kWh
Connected to an LV distribution line[11]						
- Residents (>200 kWh/month)	730 KHR /kWh	(approx. $0.1825 /kWh)				
- Residents (51 to 200 kWh/month)	610 KHR /kWh	(approx. $0.1525 /kWh)				
- Residents (11 to 51 kWh/month)	480 KHR /kWh	(approx. $0.12 /kWh)				
- Residents (<10 kWh/month)	380 KHR /kWh	(approx. $0.095 /kWh)				

[9] Tariffs are set in USD, and are paid in KHR based on the current exchange rate set by the Central Bank of Cambodia on the day of the invoicing.
[10] "Industry and Agriculture" and "Commercial and Administration" facilities can be subjected to additional charges based on (i) whether the metering is set on the LV or MV/HV side, (ii) whether the transformer was supplied by the utility or installed by the facility itself.
[11] There are also special tariffs for water pumping stations, schools, hospitals, and health care centres.

Appendix 4 - Import Taxes on Vehicles

Table 36. Main import tax per type of vehicles
(Source: General Department of Customs and Excise).

Vehicle type	Drivetrain type	Ignition type	Import		
			Customs Duty	Special Tax	VAT
Passenger cars	ICE	Spark	35%	20% (< 1,000 cc) 50% (>1,000 cc) 55% (>3,000 cc)	10%
		Compression	35%	50% (<3,000cc) 55% (>3,000 cc)	10%
	HEV	Spark	35%	20% (< 1,000 cc) 50% (>1,000 cc)	10%
		Compression	35%	20% (<1,000 cc) 50% (>1,000 cc)	10%
	PHEV	Spark	35%	20% (<1,000 cc) 50% (>1,000 cc)	10%
		Compression	35%	20% (<1,000 cc) 50% (>1,000 cc)	10%
	BEV	-	35%	10%	10%
Three-wheelers (for logistic purposes)	ICE	Spark	15%	20%	10%
		Compression	15%	20%	10%
	HEV	-	15%	20%	10%
	PHEV	-	15%	20%	10%
	BEV	-	15%	10%	10%
Three- wheelers (for people transportation)	ICE	Spark	35%	20%	10%
		Compression	35%	20%	10%
	HEV	-	-	-	-
	PHEV	-	-	-	-
	BEV	-	35%	10%	10%
Two-wheelers	ICE	-	15%	5% (<50cc) 15% (<250cc) 20% (<800cc) 25% (>800cc)	10%
	BEV	-	15%	0% (bicycles) 5% (motorcycles)	10%
Heavy-duty (for logistic purposes)	ICE	Spark	15%	40% (< 5t) 30% (>5t)	10%
		Compression	15%	40% (< 5t) 30% (>5t)	10%
	HEV	Spark	15%	40% (< 5t) 30% (>5t)	10%
		Compression	15%	40% (< 5t) 30% (>5t)	10%
	PHEV	Spark	15%	40% (< 5t) 30% (>5t)	10%
		Compression	15%	40% (< 5t) 30% (>5t)	10%
	BEV	-	15%	10% (pick-up trucks) 40% (< 5t) 30% (>5t)	10%
Heavy-duty (for people transportation)	ICE	Spark	15%	40%	10%
		Compression	15%	40%	10%
	HEV	Spark	15%	40%	10%
		Compression	15%	40%	10%
	PHEV	Spark	15%	40%	10%
		Compression	15%	40%	10%
	BEV	-	15%	10%	10%

Appendix 5 - Maps of Cambodian Infrastructure

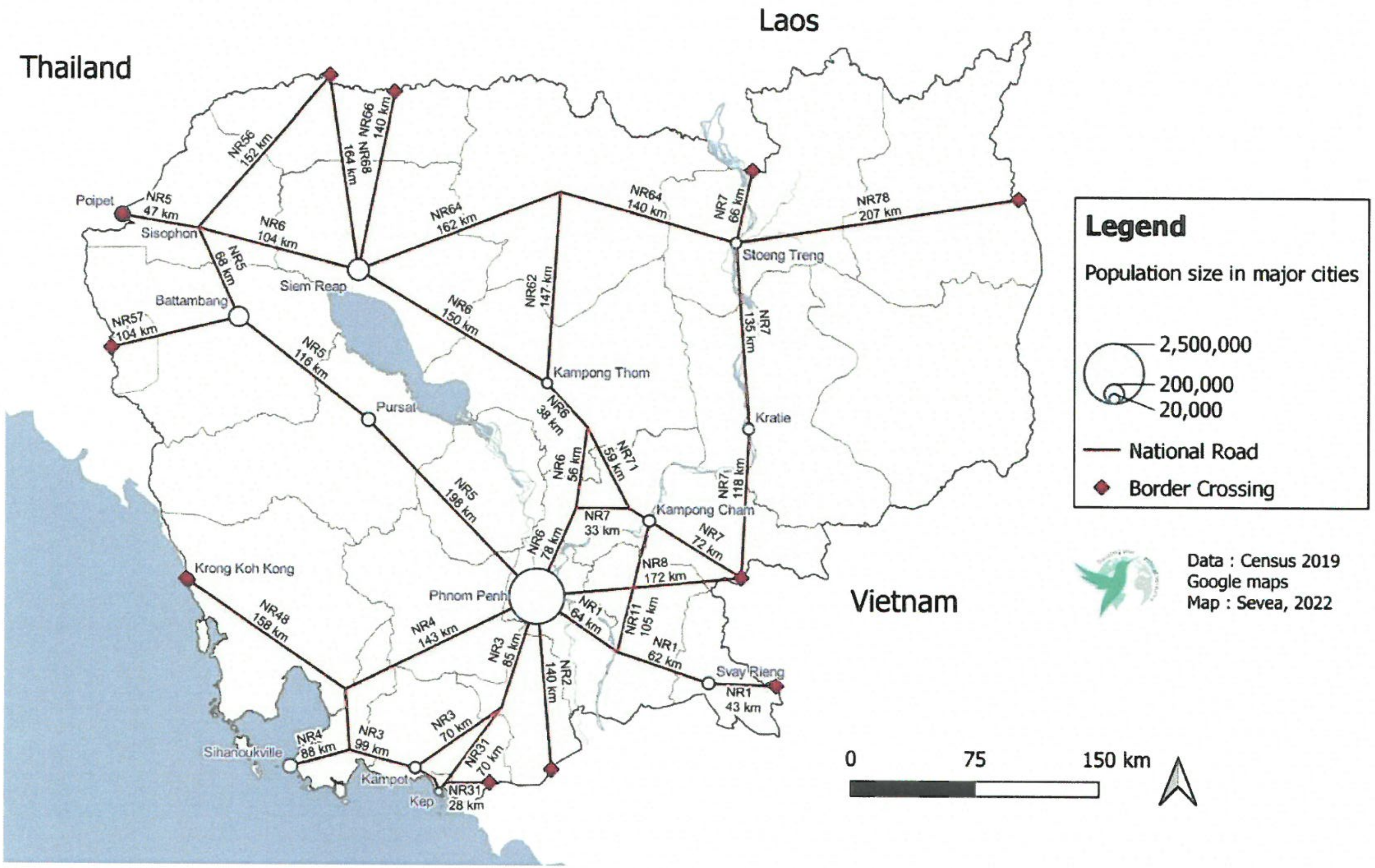


Figure 46. National road network and population centres.

(Credits: Sevea Consulting)

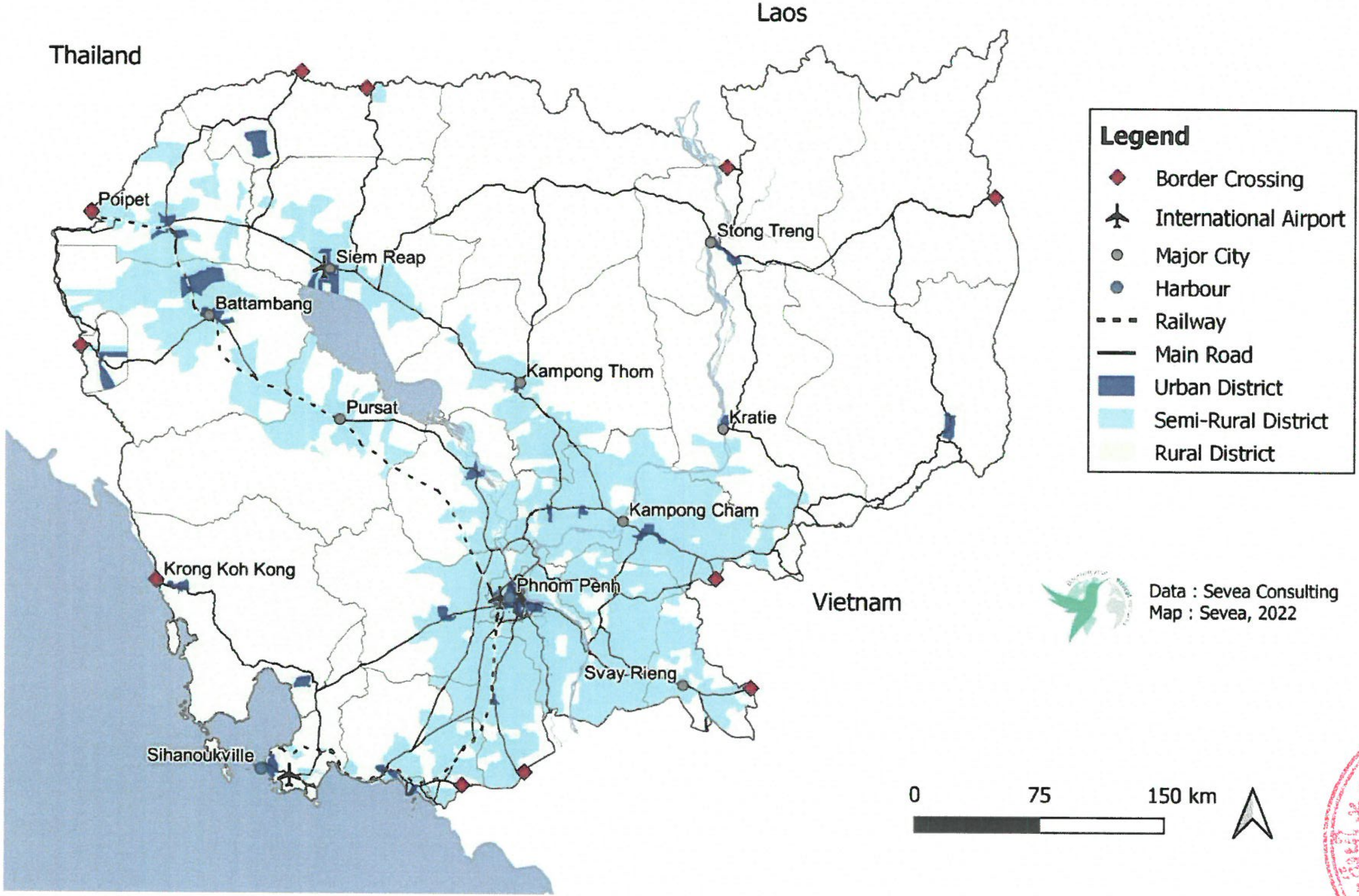


Figure 47. Main transport infrastructure of Cambodia, and urbanisation.

(Credits: Sevea Consulting)

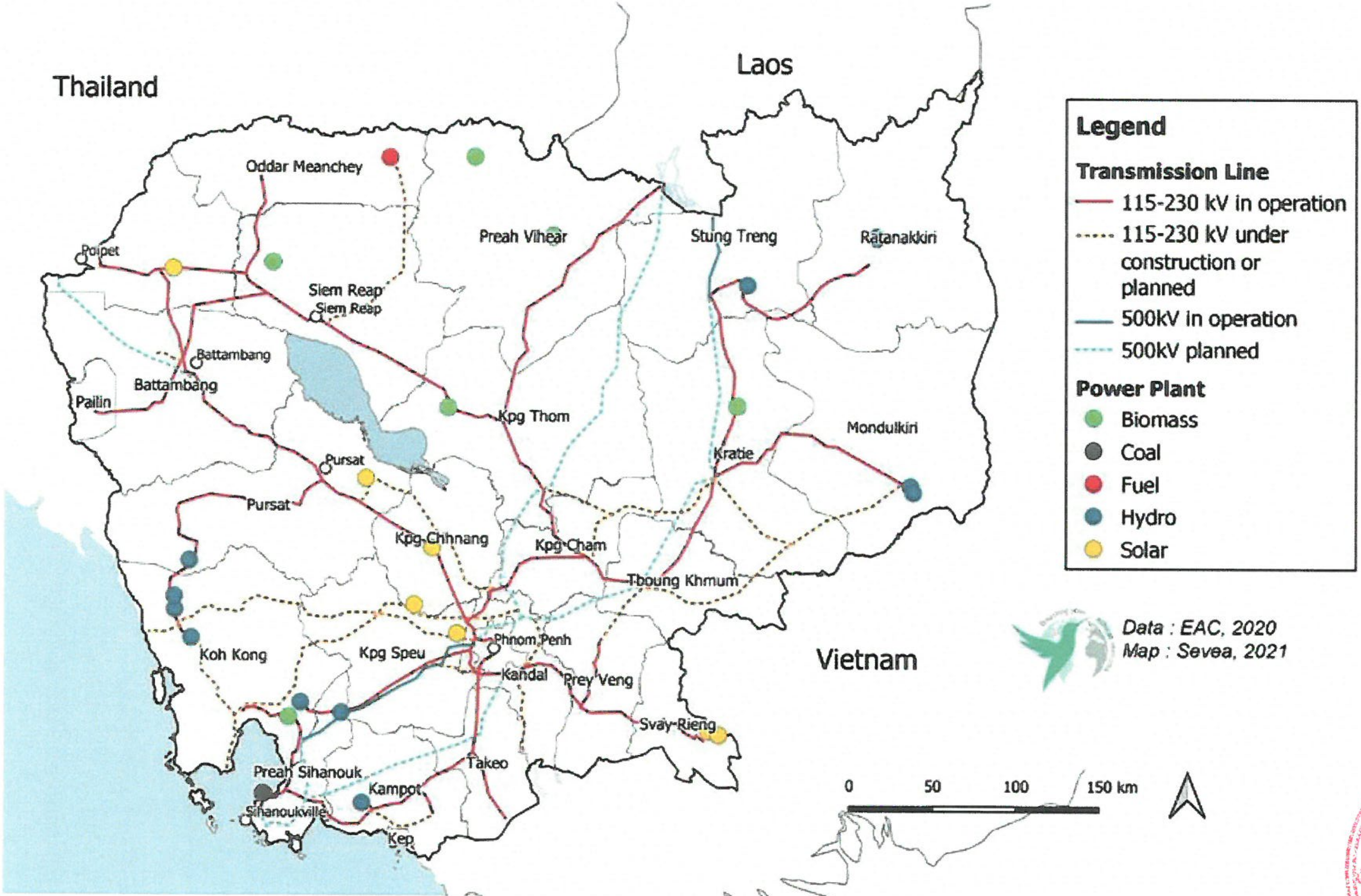


Figure 48. Map of the Cambodian national electricity grid.

(Credits: Sevea Consulting)

Appendix 6 - Detailed Modelling Results

1. Scenario EV1

Sales share	Electric motorcycles	Electric cars	Electric heavy-vehicles
2020	0%	0%	0%
2025	1%	1%	0%
2030	5%	2%	0%
2035	15%	8%	1%
2040	25%	13%	1%
2045	29%	14%	1%
2050	30%	15%	1%
Sales per year	**Electric motorcycles**	**Electric cars**	**Electric heavy-vehicles**
2020	744	71	1
2025	3,961	328	5
2030	20,748	1,336	22
2035	75,501	6,001	129
2040	119,200	16,951	166
2045	114,120	22,000	196
2050	85,430	28,368	228
Stock of EVs	**Electric motorcycles**	**Electric cars**	**Electric heavy-vehicles**
2020	744	71	1
2025	12,285	1,003	15
2030	78,084	5,374	96
2035	318,108	23,250	476
2040	943,380	89,193	1,123
2045	1,582,011	187,807	2,037
2050	2,067,042	315,683	3,105
Electrification of stock	**Electric motorcycles**	**Electric cars**	**Electric heavy-vehicles**
2020	*0%*	*0%*	0%
2025	*0%*	*0%*	0%
2030	*1%*	*1%*	0%
2035	*4%*	*2%*	0%
2040	*10%*	*6%*	0%
2045	*16%*	*9%*	0%
2050	*20%*	*12%*	1%
GWh per year	**Electric motorcycles**	**Electric cars**	**Electric heavy-vehicles**
2020	0	0	0
2025	2	2	1
2030	10	11	9
2035	40	47	43
2040	118	178	101
2045	198	376	183
2050	258	631	279
Charging infrastructure	**Battery swapping cabinets**	**AC chargers**	**DC fast chargers**
2020	-	-	-
2025	20	0	0
2030	124	1	1
2035	507	5	6
2040	1,502	18	24
2045	2,519	39	51
2050	3,292	65	86
Cumulated Investment	**Battery swapping cabinets**	**AC chargers**	**DC fast chargers**
2020	$ -	$ -	$ -
2025	$ 195,651	$ 154,537	$ 274,732
2030	$ 1,243,535	$ 828,250	$ 1,472,444
2035	$ 5,066,078	$ 3,583,119	$ 6,369,989

2040	$ 15,023,959	$ 13,745,434	$ 24,436,326
2045	$ 25,194,599	$ 28,942,904	$ 51,454,051
2050	$ 32,919,048	$ 48,649,791	$ 86,488,517

Battery swapping cabinets					
	PP + Kandal	**Siem Reap**	**Sihanoukville**	**Battambang**	**Other Provinces**
2020	-	-	-	-	-
2025	6	1	1	1	1
2030	40	5	5	5	6
2035	163	22	20	22	26
2040	475	68	55	68	85
2045	776	121	83	121	158
2050	989	166	100	166	224

AC chargers					
	PP + Kandal	**Siem Reap**	**Sihanoukville**	**Battambang**	**Other Provinces**
2020	-	-	-	-	-
2025	13	2	2	2	2
2030	72	9	9	9	11
2035	311	40	38	40	48
2040	1,197	155	133	156	192
2045	2,525	331	248	335	421
2050	4,244	561	374	572	735

DC fast chargers	2020	2025	2030	2035	2040	2045	2050
NR1	-	0	2	7	27	57	95
NR11	-	0	0	1	2	5	8
NR2	-	0	1	6	22	47	79
NR3	-	0	2	11	40	85	143
NR31	-	0	0	1	2	5	8
NR4	-	1	4	18	69	145	244
NR48	-	0	0	1	4	8	13
NR5	-	1	7	28	109	230	386
NR56	-	0	0	1	3	7	12
NR57	-	0	0	1	2	5	8
NR6	-	1	7	28	108	228	383
NR62	-	0	0	1	3	7	12
NR64	-	0	0	2	7	14	24
NR66	-	0	0	1	3	7	11
NR68	-	0	0	1	4	8	13
NR7	-	1	4	18	67	142	238
NR71	-	0	0	0	1	3	5
NR78	-	0	0	1	5	10	17
NR76	-	0	0	1	5	10	17
NR8	-	0	0	1	4	8	14

2. Scenario EV2

Sales share	Electric motorcycles	Electric cars	Electric heavy-vehicles
2020	0%	0%	0%
2025	2%	1%	0%
2030	10%	5%	0%
2035	30%	15%	2%
2040	50%	25%	3%
2045	58%	29%	3%
2050	60%	30%	3%
Sales per year	**Electric motorcycles**	**Electric cars**	**Electric heavy-vehicles**
2020	1,488	142	3
2025	7,922	656	15
2030	41,495	2,672	66
2035	151,003	12,001	388
2040	238,401	33,901	498
2045	228,241	43,999	587
2050	170,860	56,736	685
Stock of EVs	**Electric motorcycles**	**Electric cars**	**Electric heavy-vehicles**

2020	1,488	142	3
2025	24,571	2,006	46
2030	156,167	10,749	288
2035	636,215	46,501	1,429
2040	1,886,759	178,385	3,368
2045	3,164,022	375,615	6,111
2050	4,134,085	631,366	9,314
Electrification of stock	**Electric motorcycles**	**Electric cars**	**Electric heavy-vehicles**
2020	*0%*	*0%*	0%
2025	*0%*	*0%*	0%
2030	*2%*	*1%*	0%
2035	*7%*	*4%*	0%
2040	*20%*	*11%*	1%
2045	*31%*	*18%*	1%
2050	*40%*	*24%*	2%
GWh per year	**Electric motorcycles**	**Electric cars**	**Electric heavy-vehicles**
2020	0	0	0
2025	3	4	4
2030	20	21	26
2035	80	93	129
2040	236	357	303
2045	396	751	550
2050	517	1,263	838
Charging infrastructure	**Battery swapping cabinets**	**AC chargers**	**DC fast chargers**
2020	-	-	-
2025	39	41	11
2030	249	221	59
2035	1,013	955	255
2040	3,005	3,665	977
2045	5,039	7,718	2,058
2050	6,584	12,973	3,460
Cumulated Investment	**Battery swapping cabinets**	**AC chargers**	**DC fast chargers**
2020	$ -	$ -	$ -
2025	$ 391,303	$ 309,073	$ 549,464
2030	$ 2,487,069	$ 1,656,499	$ 2,944,888
2035	$ 10,132,157	$ 7,166,238	$ 12,739,978
2040	$ 30,047,918	$ 27,490,867	$ 48,872,653
2045	$ 50,389,198	$ 57,885,807	$ 102,908,102
2050	$ 65,838,096	$ 97,299,581	$ 172,977,034

Battery swapping cabinets					
	PP + Kandal	**Siem Reap**	**Sihanoukville**	**Battambang**	**Other Provinces**
2020	-	-	-	-	-
2025	13	2	2	2	2
2030	80	11	10	11	13
2035	323	45	39	45	55
2040	911	150	93	149	199
2045	1,379	291	119	289	441
2050	1,583	418	126	414	751

AC chargers					
	PP + Kandal	**Siem Reap**	**Sihanoukville**	**Battambang**	**Other Provinces**
2020	-	-	-	-	-
2025	27	3	3	3	4
2030	144	18	18	18	22
2035	623	80	73	81	98
2040	2,399	315	229	319	403
2045	5,041	677	377	697	926
2050	8,398	1,153	526	1,204	1,692

DC fast chargers	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
NR1	-	1	3	14	54	113	190
NR11	-	0	0	1	5	10	17
NR2	-	0	3	12	44	94	157
NR3	-	1	5	21	81	170	286
NR31	-	0	0	1	4	9	16

NR4	-	2	8	36	138	290	487
NR48	-	0	0	2	7	15	26
NR5	-	2	13	57	218	459	772
NR56	-	0	0	2	7	15	25
NR57	-	0	0	1	5	10	17
NR6	-	2	13	56	216	456	766
NR62	-	0	0	2	7	14	24
NR64	-	0	1	4	14	29	49
NR66	-	0	0	2	6	13	23
NR68	-	0	0	2	7	16	26
NR7	-	2	8	35	135	284	477
NR71	-	0	0	1	3	6	10
NR78	-	0	1	2	9	20	33
NR76	-	0	1	2	9	20	33
NR8	-	0	0	2	8	17	28

3. Scenario EV3

Sales share	Electric motorcycles	Electric cars	Electric heavy-vehicles
2020	1%	0%	0%
2025	7%	2%	0%
2030	28%	8%	1%
2035	63%	26%	3%
2040	83%	43%	4%
2045	89%	49%	5%
2050	90%	51%	5%
Sales per year	**Electric motorcycles**	**Electric cars**	**Electric heavy-vehicles**
2020	5,176	241	5
2025	26,575	1,116	25
2030	120,071	4,542	109
2035	317,363	20,402	647
2040	393,386	57,632	830
2045	349,249	74,798	978
2050	257,276	96,452	1,142
Stock of EVs	**Electric motorcycles**	**Electric cars**	**Electric heavy-vehicles**
2020	5,176	241	5
2025	83,718	3,409	77
2030	485,622	18,273	480
2035	1,605,855	79,052	2,381
2040	3,833,274	303,255	5,613
2045	5,833,393	638,545	10,185
2050	7,301,040	1,073,322	15,523
Electrification of stock	**Electric motorcycles**	**Electric cars**	**Electric heavy-vehicles**
2020	*0%*	*0%*	0%
2025	*1%*	*0%*	0%
2030	*6%*	*2%*	0%
2035	*18%*	*6%*	1%
2040	*40%*	*19%*	1%
2045	*58%*	*31%*	2%
2050	*70%*	*40%*	3%
GWh per year	**Electric motorcycles**	**Electric cars**	**Electric heavy-vehicles**
2020	1	0	0
2025	10	7	7
2030	61	37	43
2035	201	158	214
2040	479	607	505
2045	729	1,277	917
2050	913	2,147	1,397
Charging infrastructure	**Battery swapping cabinets**	**AC chargers**	**DC fast chargers**
2020	-	-	-
2025	133	70	19
2030	773	375	100

2035	2,557	1,624	433
2040	6,105	6,231	1,662
2045	9,290	13,121	3,499
2050	11,627	22,055	5,881
Cumulated Investment	**Battery swapping cabinets**	**AC chargers**	**DC fast chargers**
2020	$ -	$ -	$ -
2025	$ 1,333,265	$ 525,425	$ 934,088
2030	$ 7,733,857	$ 2,816,049	$ 5,006,309
2035	$ 25,574,331	$ 12,182,604	$ 21,657,963
2040	$ 61,047,476	$ 46,734,474	$ 83,083,510
2045	$ 92,900,735	$ 98,405,872	$ 174,943,773
2050	$ 116,274,009	$ 165,409,288	$ 294,060,957

Battery swapping cabinets					
	PP + Kandal	**Siem Reap**	**Sihanoukville**	**Battambang**	**Other Provinces**
2020	-	-	-	-	-
2025	43	6	5	6	7
2030	248	34	30	34	42
2035	782	125	82	125	165
2040	1,481	390	117	386	679
2045	1,590	550	125	539	1,841
2050	1,641	571	127	560	2,915

AC chargers					
	PP + Kandal	**Siem Reap**	**Sihanoukville**	**Battambang**	**Other Provinces**
2020	-	-	-	-	-
2025	46	6	6	6	7
2030	244	31	30	31	38
2035	1,061	138	117	139	170
2040	4,077	545	314	560	736
2045	8,412	1,178	448	1,246	1,837
2050	13,603	1,989	601	2,170	3,691

DC fast chargers	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
NR1	-	1	5	24	91	192	323
NR11	-	0	0	2	8	17	29
NR2	-	1	5	20	76	159	268
NR3	-	2	8	36	137	289	485
NR31	-	0	0	2	8	16	27
NR4	-	3	14	61	234	493	829
NR48	-	0	1	3	12	26	43
NR5	-	4	22	97	371	780	1,312
NR56	-	0	1	3	12	25	42
NR57	-	0	0	2	8	17	29
NR6	-	4	22	96	368	775	1,302
NR62	-	0	1	3	11	24	40
NR64	-	0	1	6	23	49	83
NR66	-	0	1	3	11	23	38
NR68	-	0	1	3	13	27	45
NR7	-	3	14	60	229	482	810
NR71	-	0	0	1	5	10	16
NR78	-	0	1	4	16	34	57
NR76	-	0	1	4	16	34	57
NR8	-	0	1	3	13	28	47

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