British Embassy Vientiane

GGGI TECHNICAL REPORT

Pre-feasibility Study on a Battery Swapping System for Electric 2-wheelers in Vientiane Capital, Lao PDR

Preface

On behalf of the Ministry of Planning and Investment, as the Secretariat of the Green Growth National Steering Committee, it is my great pleasure to introduce this pre – feasibility study on a battery swapping system for electric two-wheelers in Vientiane Capital, Lao PDR. The ultimate purpose of this study is to translate the 9th National Socio-Economic Development Plan (NSEDP), the National Green Growth Strategy, Paris Agreement – COP 26 and the Global Agenda 2030 into plans, activities and actions.

As I look forward to seeing our country transition towards a green, climate-resilient and socially inclusive world, I would like to express my heartfelt thanks to the Government of and the people of the United Kingdom for their support extended to us in the development of this study.

One of the major growth drivers identified in the 9th NSEDP is our green energy sector which has been under-utilized and inadequately invested. With great power generation capacity, we are in good shape to promote higher local consumption of energy by transitioning towards electric vehicles of all kinds. This transition is in line with regional and global sustainable development trends. More importantly, it will also reduce the need for fossil fuel imports and hence foreign currency which undermine economic stabilization. With that goal in mind, this study extensively supports the targets identified in the National Agenda on Economic and Financial Difficulties particularly the priority on new and diversified revenue collection base and currency stabilization.

Transitioning toward electric mobility is a challenging task and we need to ensure wide stakeholder engagement from key sectors and relevant partners. As we maneuver, I strongly encourage the private sector to fully utilize the detailed information from the study to develop alternative solutions to internal combustion engines motorbikes. I am highly confident that, with the technical lead of our main government counterparts including the Ministry of Public Work and Transport (MPWT), Ministry of Natural Resources and the Environment (MONRE) and Ministry of Energy and Mines (MEM) in their respective fields together with the expertise of GGGI, who has been our partner since 2017, we will be able to advance this work in the most constructive manner. I am very keen to see the rising share of electric mobility in Lao PDR in the near future.

Phonevanh Outhavong

Vice Minister

Ministry of Planning and Investment of the Lao PDR

Foreword

At the 26th United Nations climate change Conference of Parties (COP), held in Glasgow, Scotland in 2021, almost 200 countries came together to forge the Glasgow Climate Pact. The UK will hold the COP Presidency until late 2022; and our objective is to work with governments and organizations to make sure they deliver on the Glasgow Climate Pact, which includes transitioning to clean vehicles as well as ensuring that international financing commitments are flowing to enhance climate action.

One of the top priorities of the British Embassy in Laos is to reinvigorate and enhance the relationship between the UK and Laos, by engaging with the government and other stakeholders to champion our values and promote sustainable development. We are thus glad to have supported this 'Pre-feasibility Study on a Battery Swapping System for Electric 2-wheelers in Vientiane Capital, Lao PDR' prepared by GGGI, under the guidance of the Lao PDR Ministry of Planning and Investments.

Gasoline motorcycles are the primary mode of transport in Lao PDR, accounting for 75% of total vehicle registrations, and 67% of total daily trips in the capital city of Vientiane. As the country is embarking on a development pathway towards 'net-zero' emissions, making the most of its largely untapped potential for carbon sequestration and renewable energy, electrification of the 2-wheelers segment must be set as a priority in the decarbonisation of the transport sector. Innovative business models such as battery swapping systems are part of the solutions that fit the Lao context and could address the concerns of local users about electric motorbikes: these include anxiety about the range of electric motorbikes, long battery charging times, high upfront costs, as well as battery degradation, recycling and disposal.

I sincerely hope that the findings of this pre-feasibility study will contribute to accelerate the phase-out of fossil fuel consumption in the Lao transport sector and to meet the country's GHG emission reduction targets. The Foreign, Commonwealth and Development Office stands ready to facilitate any discussion between the Lao government, financiers and the private sector so that a pilot project can promptly be implemented, to provide commuters with an economically, environmentally and socially sustainable alternative to internal combustion engine motorbikes.

John Pearson

British Ambassador to Lao PDR

Acknowledgements

The Pre-feasibility Study on a Battery Swapping System for Electric 2-wheelers in Vientiane Capital, Lao PDR" was conducted by Christophe Assicot and Angkhanhack Keomanivong from the Global Green Growth Institute Lao team, together with a consortium of Price Waterhouse Coopers India and Mekong Consultants Company Limited.

GGGI would like to extend our gratitude to the British Embassy in Laos and the Lao PDR Ministry of Planning and Investments for supporting this study and for their leadership in the country's green transition. As part of this study, the team conducted extensive consultations of stakeholders and is thankful for their inputs to Mr Saneu Chounramany (Managing Director, Honda Laos); Mr. Wayne Mcintosh (Managing Director, RMA Group); Mr. Biju Narayanan (General Manager, Lao Land Rover); Mr. Nouxay Vengsavanh (CEO, KOLAO); Mr. Bounleuth Luangpraseuth (CEO, EV Lao); Mr. Phongphiboun and Mr. Bounchaloun (PTL Petrol Trading Laos Holding); Mrs. Somneuk Phoumixay (CFO, Mini Big C); Mr. Kouthong Thongsavanh (CEO, FB Battery); Mr. Sysay Khoungkhakoune (Founder and Owner, Shopping D); Mrs.Thanhyalath Chalernsouk (Managing Director, Delivery Hero (Laos) Co., Ltd); Mr. Phengphouvanh Phommabouth (Operation Manager, Go Teddy); Mr. Vannapha Southivong (CEO, LAI LAO Lab).

Executive Summary

With large untapped and low-cost renewable energy resources from hydropower, Lao PDR must rapidly shift its transport sector to electric mobility practices. The Government is committed to lead the transition and has set an ambitious target of 30% Electric Vehicles penetration for 2-wheelers and passengers' cars in national vehicles mix by 2030. Electrification of the transport sector will bring significant benefits to the country's post-covid economic recovery as well as balance of payments by displacing the consumption of imported fossil fuels with domestically produced electricity.

GGGI with the support of the UK Embassy in Vientiane and the Ministry of Planning and Investment has prepared this Pre-feasibility Study on a Battery Swapping System for Electric 2-wheelers in Vientiane Capital, Lao PDR, to assess the potential applicability to the Lao context of the innovative 'battery swapping' business model which is proving successful in accelerating general adoption of e-motorbikes in a growing number of countries in Asia.

The study starts by reviewing the different possibilities in fee and operating models based on an analysis of multiple and brings forward a combination of three solutions for the users, namely Battery-as-a-Service (BaaS) where a customer owning an e-motorbike has access to 24h battery swapping service, Mobility-as-a-Service (MaaS) where e-motorbikes plus swapping service are offered as a leasing package, and Ride Sharing where electric motorbikes are made available across the city on a pay-per-use fee model.

Next, financial models are built for a pilot stage including 100 e-motorbikes and for a scale-up phase which will aim to contribute to 5% of the total Government EV target in the 2-wheelers segment. The results show that both phases would be profitable for investors, by calculating an equity internal rate of return significantly above the relevant benchmark recommended by the United Nations. After that, financing structures consisting of equity and grant for phase 1, with the addition of loan for phase 2, are proposed, considering the social and environmental co-benefits of the project, such as the reduction of air pollution and greenhouse gases emissions, as well the costs savings for the users, as demonstrated through an analysis of the total cost of ownership (TCO) of different 2-wheelers options, including those with internal combustion engines.

The study also undertakes the identification of local partners, including potential operators, corporate users, early adopters, and hosts of the swapping kiosks. Stakeholders consulted during quarter 1 2022 all express support for the introduction of a battery swapping solution in Vientiane Capital. Several have voiced interest in continuing discussions as the project moves to the next stages of design, financing and operationalization. Feedback from existing players in the automotive sector in Laos was particularly useful and will need to be considered, such as the importance of a robust regulatory framework and definition of clear strategy to avoid theft and damages.

The last chapter of the prefeasibility report focuses on battery waste management. In the long run, the project is expected to generate end-of-life battery waste which should not cause negative impacts on the environment. A review of the different methods for sound management of such a waste is conducted, costs associated are estimated then potential partners that would offset negative impacts are identified.

The Global Green Growth Institute is an inter-governmental organization dedicated to supporting strong, inclusive and sustainable economic growth in developing countries. We look forward to bringing this project forward as well as helping Lao PDR transition to sustainable transport practices, generate costs savings, reduce pollution, GHG emissions and increase resilience to climate change.

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ABBREVIATIONS

BaaS	Battery-as-a-Service
BSS	Battery Swapping System
CAGR	Compounded Annual Growth Rate
EV	Electric Vehicle
EVSE	Electric Vehicle Service Equipment
2W	Electric Two-Wheeler
GGGI	Global Green Growth Institute
GoL	Government of Lao PDR
ICE	Internal Combustion Engine
kWh	Kilowatt Hour
LAMEA	Latin America, Middle East, and Africa
Lao PDR	Lao People's Democratic Republic
LIB	Lithium-Ion Battery
MaaS	Mobility-as-a-Service
NDC	Nationally Determined Contribution
OEM	Original Equipment Manufacturer
PTL	Petrol Trading Laos Holdings
QIS	Quick Interchange Stations
TCO	Total Cost of Ownership
US	United States
2W	Two-Wheeler
3W	Three-Wheeler
4W	Four-Wheeler

1 INTRODUCTION

1.1 BACKGROUND

The Government of Lao PDR (GoL) has set the objective of transitioning to e-mobility in the transport sector as a priority in the National Green Growth Strategy, the 9th National Socio-Economic Development Plan (2021-2025) as well as in the 2020 Updated Nationally Determined Contribution (NDC). GoL's target is to achieve 30% Electric Vehicles (EV) penetration including 2-wheelers and passengers' cars in national vehicles mix by 2030. GGGI, with support from the British Embassy in Vientiane, is advising the GoL in accelerating the electrification and decarbonization of the transport sector in the country.

Considering that gasoline motorcycles are the primary mode of transport in the country, accounting for 67% of daily trip in Vientiane Capital, the transition to Electric Vehicles in Lao People's Democratic Republic (Lao PDR) will be achieved through adequate solutions for the users and sustainable business models for investors in the Electric Two-Wheelers (E2W) segment. Charging time and range anxiety are the key barriers to EV adoption identified globally. Among the various options available with regard to EV charging, Battery Swapping System (BSS) has arisen as a promising technology as it addresses both above-mentioned challenges to EV adoption. This technology allows users to locate nearby swapping station, replace discharged battery in as fast as 2 minutes, pay for the service and resume his/her journey.

1.1.1 PURPOSE AND SCOPE

This prefeasibility study aims to examine the financial viability and environmental sustainability of implementing a BSS model in Vientiane Capital and contribute to achieve the Vision 2030 by enabling adoption of E2W.

According to research conducted by GGGI on promoting electric mobility in Lao PDR, it is estimated that Laos would have registered around 2.4 million two-wheelers by 2030 and 3.9 million by 2050. With E2W sales penetration to be 30% by 2030 and 80% by 2050, the projected number of E2Ws would be as below. The figure illustrates the projections of 2W by the end of 2050.

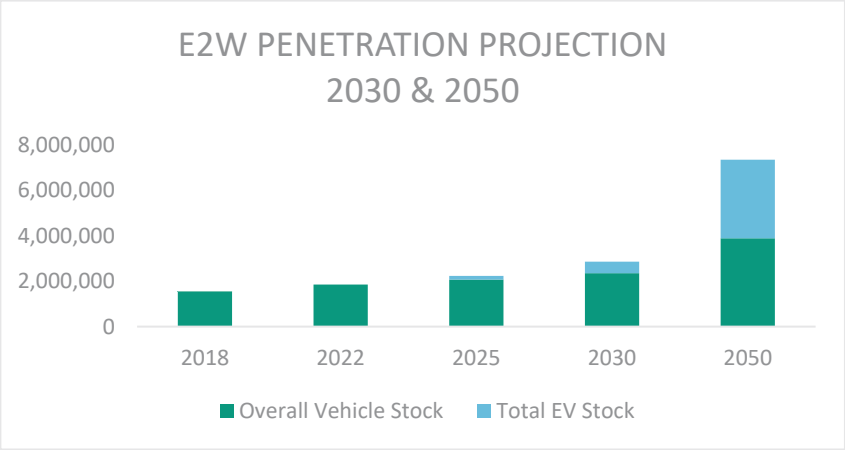

Figure 1. Graphical representation of E2W penetration for 2030 & 2050

This prefeasibility study of BSS in Lao PDR focuses on the following aspects:

- **Design an optimal operating model for a BSS project to be implemented in Vientiane Capital** – This section includes detailed explanation of the BSS through research and case study analyses to highlight several types of business models adopted across the world and propose a viable business model in the Lao PDR context, including a preliminary assessment of potential partners for project implementation.
- **Prepare a financial analysis for the proposed model**, including phases of implementation and their investment sizes - A dynamic excel based model is prepared to arrive at the project and equity IRRs for the operator. Phase 1 model details the costs, revenues, investments for the pilot project to be implemented while Phase 2 model details out the financial aspects for the BSS model to be implemented at commercial scale.
- **Propose a financing structure including share of equity, loan, concessional loans, guarantee** – This section of the report highlights the available financing options and suggests instruments among the different financing options based on the local circumstances and size of investment calculated for Phase 1 and Phase 2 model as per the financial model.
- **Study of battery recycling system, associated costs and identified potential** – It is a non-debatable fact that battery recycling is important for the sustainability and long-term success of the Battery Electric Vehicles (BEVs). This section covers the global review of the recycling systems adopted around the world by studying the techniques, costs and potential partners which can be consulted for battery recycling in Lao PDR.

1.1.2 METHODOLOGY

The report is compiled using a combination of both primary and secondary information to produce an overall framework of BSS implementation in the Lao PDR context.

The study is carried out in consultation and collaboration with key stakeholders, mainly the Ministry of Planning and Investment, Ministry of Public Works and Transport, Ministry of Energy and Mines, Electricity Authority, 2-wheelers and electric 2-wheelers retailers, technology providers and relevant business operators.

BSS is also studied in the global context by identifying key players and different operating models incorporated by those players in their respective geographies. Information from secondary sources is then combined with primary research insight from interviews towards EV penetration to estimate project sizing and design a financial model for project implementation. Drivers and restraints in the global, regional, and national markets and submarkets are also taken into consideration while preparing the projection models.

The entire framework of secondary and primary research is then combined to produce a unified research report which, due to its extent of sources, produces a thorough and logical overview of implementing BSS in Lao PDR and provides strategic recommendations.

1.2 RATIONALE FOR BATTERY SWAPPING

A Battery Swapping System, in simple terms, is replacing a discharged battery with a fully charged battery using a kiosk-based swapping structure which can house 6 to 10 batteries. BSS technology has multiple advantages such as:

- **Reduction in cost of E2W through purchasing the vehicle without battery** – Batteries make up for 50-60% of the E2W cost. BSS enables business models where E2W can be sold to consumers without them having to pay for the battery. This flexibility will help achieve cost parity between ICE vehicle and E2W, and hence boost electrification through faster adoption.
- **Reduction in infrastructure cost** – Battery swapping is by far the quickest (up to 2 minutes) means of re-powering an electric two-wheeler and does not require a large parking area for the vehicles. Unlike a conventional EV charging station, there is no requirement to develop an extensive infrastructure and only a limited space is required to install battery swapping kiosks.
- **Reduction in time-to-charge** - Conventional AC charging or even fast DC charging takes a long time to recharge when compared to an ICE vehicle. Battery swapping offers a quicker solution in terms of turnaround time, equivalent to refueling an ICE vehicle. Swapping kiosks can be accessed using a smartphone application to switch the charged battery with a discharged one.
- **Reduction in range anxiety** – One of the key barriers to adoption of electric vehicles is the fear of running out of energy. A well-knit and diverse network of BSS can offer an unlimited range to the electric vehicle, thus overcoming the anxiety of getting immobilized midway during a journey.

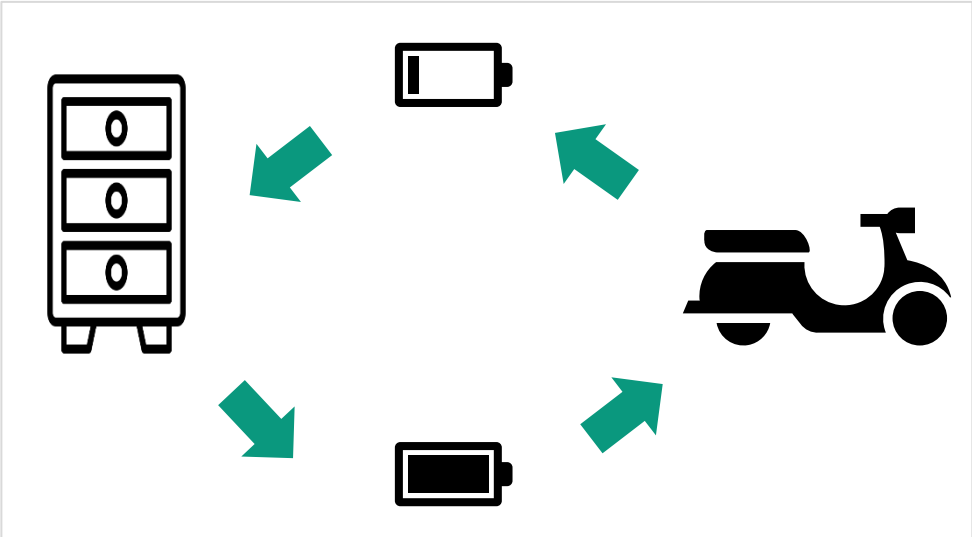

Figure 2. Sample illustration of a Battery Swapping System

Significant EVs uptake by 2030 will require supporting charging infrastructure in place. While home charging is the most viable option for the private 2W and 4W users, public charging is the most suitable option for commercial 2W/3W/4W, buses, and trucks. Public charging services can be provided through charging stations or battery swapping stations. Considering the time and speed of charging, the charging station model is not economical for 2W and 3W. However, for commercial 4Ws, buses, and trucks, fast-charging stations improve the economics of charging. Battery swapping is economical for 2Ws and 3Ws, as it is time effective to swap these batteries over station charging. Additionally, the time required for swapping is minimal compared to charging through Electric Vehicle Service Equipment (EVSE).

BSS stands out as a key element to electrification for Lao PDR given that Laos is a nation where 2W vehicles account for the majority of daily trips. As seen in Cambodia and Indonesia, a network of BSS can be set up by private companies with or without the support of subsidies or grants, making it a preferrable option over setting up charging to accelerate e-mobility transition. The table below displays the recommended charging mode/system as per type and segment of the respective EV.

Table 1. EV segment wise preferred charging system

Vehicle segment	Home Charging	Public Charging Station	Battery Swapping
Private E2W	√		
Commercial E2W			√
E3W			√
Private 4W	√	√	
Commercial 4W		√	
Buses/ Trucks		√	√

The concept of Battery swapping in contrast with conventional cable charging offers an efficient solution addressing key barriers to adoption of EVs around the globe. EVs can either be sold or leased under two models based on who owns the battery:

- **With Battery**: Customer pays for and owns the battery along with the EV.
- **Without Battery**: Customer pays only for the EV and battery is owned by the Original Equipment Manufacturer (OEM) or the BSS operator.

Key drivers and restraints of the Battery Swapping System are as follows:

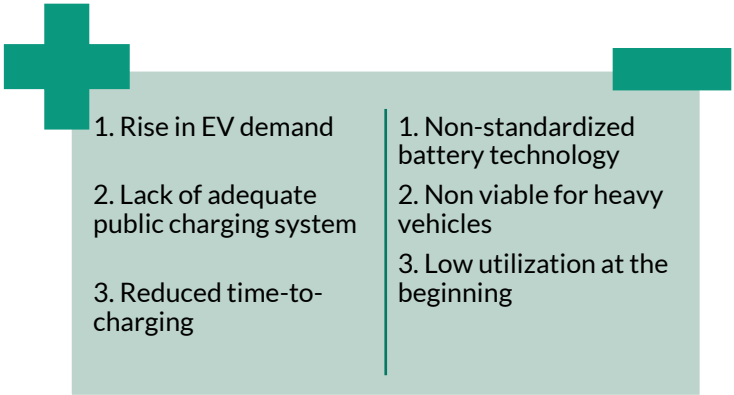

Figure 3. Drivers and restraints of battery swapping system

40% - 60% cost of an EV is for the battery. If an EV is sold without a battery, total cost of ownership (TCO) can come down drastically helping in faster adoption. Battery-as-a-Service (BaaS) comes into play when a vehicle is sold without a battery and offers a flexible & cost-effective way of vehicle ownership.

1.3 CHALLENGES IN THE LAO CONTEXT

While some of the key challenges towards e-mobility transition in the 2-wheelers segment, such as range anxiety and charging time, would be addressed through the battery swapping approach, other hurdles will need to be overcome in Laos to achieve substantial public adoption of E2W.

First, electric motorbikes and scooters available on the global market have so far been designed mostly for cities in developed countries or emerging countries where roads are paved and maintenance conditions are of good

standards. In Vientiane Capital, a significant share of back streets and alleyways are made of dirt and gravels, and as such more prone to potholes and damages especially during the rainy season. E2W to be made available in Laos in the long term should feature specifications that fully consider the state of local roads, including in terms of ground clearance and robustness of the components. Moreover, the variety of the models should be expanded to appeal to different types of customers. At present, only a few brands of electric 2-wheelers are on offer in the market. What's more, after sales service and EV maintenance skills are extremely limited in the whole country. Capacity building will be required alongside the development of innovative business models tailored to the local context. Finally, there is a sustained negative perception with regard to the reliability of E2W in the country, owing to the poor quality of vehicles currently available, including the short lifetime and driving range of lead-acid batteries. Communication and awareness raising should be a major component of the operationalization of a BSS project.

Second, Lao PDR's status as lower middle-income country will have to be reflected in the pricing of swapping solutions in order to convince the vast majority of users, potentially through international support. Current minimum wage in Laos is LAK 1,100,000 per month or approximately USD 85. Hence, the upfront capital expenses of shifting to an electric motorbike, which can cost the equivalent of a few months' salary, is significant and financial incentives should be made available to end-users and early adopters. Government ministries provide civil servants with monthly stipend to cover for fuel costs associated with daily commute. Such budget could be redirected to incentivize more sustainable transport practices in the public sector.

Third, the regulatory framework surrounding electric vehicles is limited and not easily accessible by the general public. Although the country's commitment to e-mobility transition has been expressed at the highest levels of government, including by the Prime Minister, the message will have to be continuously repeated and reflected in policies over the coming years. At present, climate change mitigation objectives, including in the transport sector, are insufficiently integrated in sectoral development objectives, due to the lack of technical capacity to mainstream EV into existing regulations. International public climate finance, such as the Green Climate Fund, should be leveraged to enhance the policy framework including through the design of incentives for promoting electric vehicles, such as tax exemption, subsidy, and/or for accelerating the phase-out of the most polluting old internal combustion engines vehicles.

Fourth, although vehicles and batteries in swapping systems are usually tagged with a GPS chip to be traced by the operator at any time, the risk of theft and damage cannot be underestimated. COVID outbreak and lockdown has exacerbated the difficult economic situation of the country, which in turn has had immediate impacts on poverty and employment. E2W under the ride sharing model as well as swapping kiosks will be publicly accessible and therefore at risk of thieving and vandalism. Although interviews with existing operators elsewhere in the region prove that related loss of assets has not been a major issue, a solution could be to have the kiosks located in areas with 24h security.


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2 OPERATING MODEL

Battery swapping stations or kiosks are considered infrastructure which can house and charge batteries made available to E2W riders running out of power. Customers may choose to pay for this service based on their usage and need. The swapping market may be segmented based on fee model and vehicle type. Fee models can be further categorized into Subscription and Pay-per-use model, while vehicle type can be categorized into two-wheeler, three-wheeler, passenger cars, and commercial vehicles.

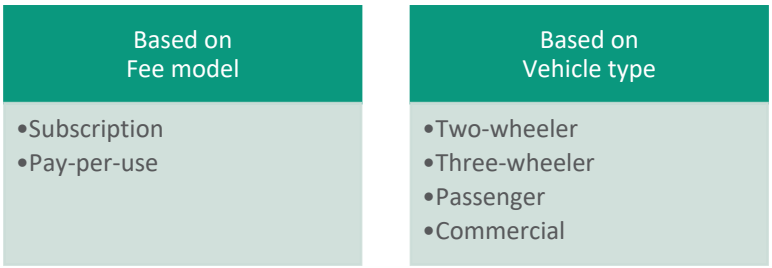


Figure 4 Key approaches to study the battery swapping market
Source: https://www.alliedmarketresearch.com/electric-vehicle-battery-swapping-market-A10601

The two approaches are detailed in the upcoming sections, showing market size of the battery swapping system in different regions across the globe over the horizon years. Setting up and operating a battery swapping station requires significant investment in a variety of functions which may be broadly categorized into capital expenditure (CAPEX) and operating expenditure (OPEX). CAPEX is a type of business expense incurred on acquiring assets like property, equipment, patents to create a benefit for the company in the future whereas OPEX is an expense incurred on day-to-day basis like employee salaries, maintenance, administration costs to ensure smooth operations for running a business. Table below lists down the various cost heads along with their classification in CAPEX and OPEX.

Table 2. Cost parameters for setting up a Battery swapping system

Cost item	CAPEX	OPEX
Additional batteries	√	
Electricity charges		√
Technology		√
Real estate rental		√
Swapping unit/Kiosk	√	
Manpower		√
Installation	√	
Annual maintenance charges		√

Batteries, kiosks, IT and installation costs are usually classified as capital expenditure, or CAPEX, while electricity consumption, land rental, staff cost, and maintenance cost are classified as operational costs. Based on a swap factor (generally between 1.5 – 3), which is defined as the number of battery swaps per vehicle per day, additional batteries must be kept in circulation to ensure smooth and efficient operations around the swapping system. Each swapping unit can house 6 to 10 batteries depending upon need and design. Purchasing swapping kiosks is a one-time cost dependent on total number of batteries and capacity of the kiosk structure. Installation costs involve expenses made towards commissioning swapping stations including civil, mechanical, or electrical work required for the said purpose.

Electricity consumed for charging purposes, technology (software development, updating, further development), site rent, staff cost, and swapping station maintenance cost are classified as operation expenditures, or OPEX, as these are recurring expenses which fluctuate depending on a variety of factors. Electricity consumption is measured in Kilowatt hour (kWh) where one kWh is equivalent to one unit consumption. Every electricity provider has a fixed tariff per unit of electricity consumed. Cost towards charging is variable and depends on the number of units consumed and tariff fixed by the electricity provider where the swapping station is located. Technology cost may be divided into information technology infrastructure (servers, platforms, services) and staff required to develop, update, maintain and upgrade the system from time to time. Similarly, operational manpower and annual maintenance cost are the recurring expenses made towards day-to-day activities and maintenance of the swapping station to ensure customer service and operational effectiveness at all times.

2.1 ANALYSIS OF THE GLOBAL BATTERY SWAPPING MARKET

As stated in the previous section, a battery-swapping market can be broadly analyzed based on service type and vehicle type. This section will analyze different types of battery swapping service models and their market size across different geographies. We will also review battery swapping market size projections over the years for different type of vehicle segments such as 2W, 3W, Passenger and Commercial vehicles.

2.1.1 FEE MODEL

Based on the business model, the Electric Vehicle battery swapping market across vehicle segments, can be categorized into a subscription model and a pay-per-use model. A subscription model is one where a fixed number of swaps (package) over a time period is defined and provided at a discounted cost to the consumer when compared to pay-per-use cost since the consumer is paying upfront for the package. Pay-per-use on the other hand, is a straightforward approach where customer pays each time for using the swap service at a defined cost.

2.1.1.1 SUBSCRIPTION MODEL

Subscription models are built for products or services that have a recurring use. In cases of electric mobility, subscription models are offered for both EV ownership and battery swapping. Customers pay a fixed monthly subscription fee, like Equated Monthly Instalments (EMI), for a fixed tenure. During the tenure, customers get to use the vehicle along with having access to the provider's swapping network. At the end of the tenure, vehicle ownership is transferred to the consumer or the subscriber. One example is Oyika, which is a Singapore based swapping infrastructure company which offers a monthly subscription plan at USD 79 per month for a period of 2 years. This monthly plan covers the cost of E2W and power cost (i.e., unlimited battery swapping). After the end of 2 years, the vehicle is transferred to the consumer. The consumer may then choose to subscribe to a package of USD 29 per month which comprises 30 swaps per month across Oyika's swapping network. Key benefits of this model lie in the fact that the customer is not responsible for secondary liabilities and expenses such as maintenance, breakdown, managing end-of-life and other activities. Oyika in Singapore, Cambodia and Indonesia, Nio in China, Gogoro in Taiwan, and Bounce in India are some of the key names offering subscription models in E2W space. As can be seen in the below table, Asia-Pacific and Europe contributed majority share (~75%) under the subscription model in 2019 followed by Latin America, the Middle East, Africa (LAMEA) and North America (~25%).

Table 3. Subscription model battery swapping market, by region, 2019-2027 ($ million)
Source: https://www.alliedmarketresearch.com/electric-vehicle-battery-swapping-market-A10601

REGION	2019	2020	2021	2022	2023	2024	2025	2026	2027	CAGR% 2020-2027
North	16.31	13.82	16.52	19.91	24.22	29.70	36.74	45.83	57.66	22.60%
Europe	20.69	17.50	20.84	25.04	30.35	37.11	45.76	56.90	71.26	22.20%
Asia-Pacific	48.31	40.18	47.07	55.62	66.30	79.71	96.64	118.17	145.55	20.20%
LAMEA	7.16	6.18	7.53	9.25	11.45	14.29	17.98	22.80	29.21	24.90%
Total	**92.49**	**77.69**	**91.97**	**109.84**	**132.33**	**160.82**	**197.13**	**243.71**	**303.69**	**21.50%**

China alone accounted for ~30% of the market share with $27 million in 2019 whereas US stood at ~15% with $14 million in 2019. Asia-Pacific is set to grow at a CAGR of ~20% with $145 million projected in 2027[3].

2.1.1.2 PAY-PER-USE MODEL

Unlike a subscription plan, under a pay-per-use model a customer pays each time when he uses a swapping service and does not pay any fixed monthly fee. It is similar to visiting a fuel station and paying for re-fuelling only in this case a customer pays for swapping a discharged battery for a fully charged battery. Sun Mobility India is a known name in establishing a network of quick swap station across major cities in India thus helping in faster adoption of EV by extending vote of confidence to the customers through its pay-per-use model.

Table 4. Pay-per-use model battery swapping market, by region, 2019-2027 ($ million)
Source: https://www.alliedmarketresearch.com/electric-vehicle-battery-swapping-market-A10601

REGION	2019	2020	2021	2022	2023	2024	2025	2026	2027	CAGR% 2020-2027
North	44.70	3.90	4.80	5.96	7.45	9.40	1.19	15.32	19.78	26.10%
Europe	59.67	5.16	6.33	7.88	9.74	12.24	15.50	19.79	25.57	25.70%
Asia-Pacific	13.58	11.58	13.96	16.98	20.81	25.71	32.04	40.23	51.07	23.60%
LAMEA	19.28	1.73	2.17	2.75	3.50	4.49	5.81	7.56	9.85	28.20%
Total	**25.94**	**22.39**	**27.28**	**33.51**	**41.51**	**51.85**	**65.30**	**82.92**	**106.29**	**24.90%**

Asia-Pacific led the pay-per-use market share with $13.5 million in 2019. At a projected growth rate of ~23.6% per annum, it is expected to reach $51 million in 2027 which is a significant ~48% market share of the global battery-swapping market. Asia-Pacific is followed by Europe, which is projected to reach $25.5 million, thus accounting for ~24% pay-per-use market share by 2027. In terms of country specific market share, as seen in case of subscription model, China and America led the way with $7.7 and $3.9 million respectively for the year 2019 and $2.6 million and $16.9 million respectively for the year 2027.

2.1.1.3 SUBSCRIPTION VS PAY-PER-USE MODEL

From a consumer standpoint, subscription model is preferred where daily EV usage is high (80-100 kms) as cost per swap for consumer is comparatively lower to pay-per-use model. Additionally, subscription models allow easy access to features such as custom alerts, battery leasing, and access to multiple swap stations. Businesses such as bike sharing, last mile delivery, and Mobility-as-a-Service would find a subscription model beneficial over a pay-per-use model given the possibility of multiple swaps per day. As cost per swap is lower, this leads to lesser expense and more profitability. On the other hand, pay-per-use is usually opted by owners who ride fewer average kilometers per day (30-50 kms) and generally use their E2W for personal use. This is because in such a scenario chances are high that a customer may not be able to avail and exhaust the entire monthly number of swaps offered to him in a subscription model.

Table 5. Battery swapping market share by service type, 2019-2027 ($ million)
Source: https://www.alliedmarketresearch.com/electric-vehicle-battery-swapping-market-A10601

SERVICE TYPE	2019	2020	2021	2022	2023	2024	2025	2026	2027	CAGR% 2020-2027
Subscription model	92.49	77.69	91.97	109.84	132.33	160.82	197.13	243.71	303.69	21.50%
Pay-per-use model	25.94	22.39	27.28	33.51	41.51	51.85	65.30	82.92	106.29	24.90%
Total	**118.44**	**100.08**	**119.25**	**143.35**	**173.85**	**212.68**	**262.44**	**326.63**	**409.99**	**22.30%**

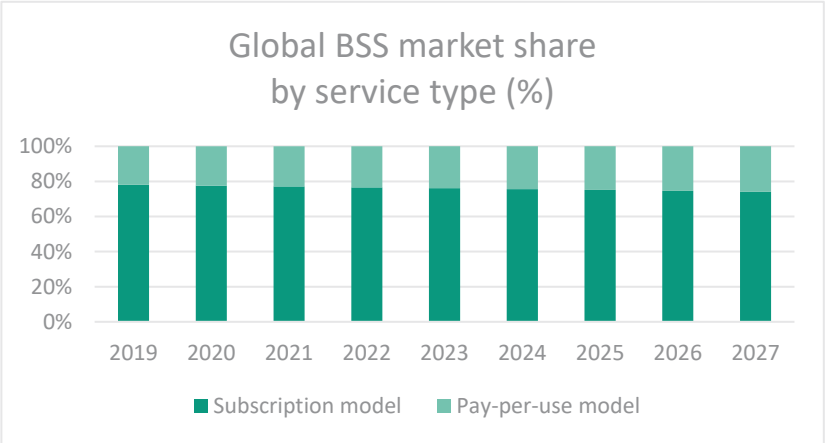


Figure 5. Battery swapping market share by service, 2019-2027 (%)

In 2019 the global EV battery swapping market inclusive of all vehicle segments was valued at USD 118 million and projected to be around USD 409 million by 2027 i.e. Compounded Annual Growth Rate (CAGR) of 22.3% per annum[1].

2.1.2 VEHICLE TYPES

Battery-swapping market based on vehicle type can be classified into two-wheeler, three-wheeler, passenger cars & commercial vehicle battery swapping.

We saw in previous table that global EV battery swapping market is set to reach $409 million by year 2027. Three-wheelers, followed by two-wheelers have been among the first and fastest adopted segments of electric wheelers, and so it is no surprise that three-wheelers topped the market values in 2019 with over $40 million followed by two-wheeler with $36.8 million.

Table 6. Battery swapping market by vehicle type, 2019-2027 ($ million)
Source: https://www.alliedmarketresearch.com/electric-vehicle-battery-swapping-market-A10601

VEHICLE TYPE	2019	2020	2021	2022	2023	2024	2025	2026	2027	CAGR% 2020-2027
Two-Wheeler	36.87	31.85	38.81	47.70	59.11	73.85	93.04	118.17	151.41	25.00%
Three-Wheeler	40.66	33.62	39.07	45.78	54.07	64.39	77.27	93.45	113.54	19.00%
Passenger Cars	24.53	20.74	24.69	29.64	35.90	43.86	54.05	67.19	84.03	22.10%
Commercial Vehicle	16.36	13.85	16.66	20.22	24.76	30.57	38.07	47.81	60.99	23.60%
Total	**118.44**	**100.08**	**119.25**	**143.35**	**173.85**	**212.68**	**262.44**	**326.63**	**409.99**	**22.30%**

[1] https://www.alliedmarketresearch.com/electric-vehicle-battery-swapping-market-A10601

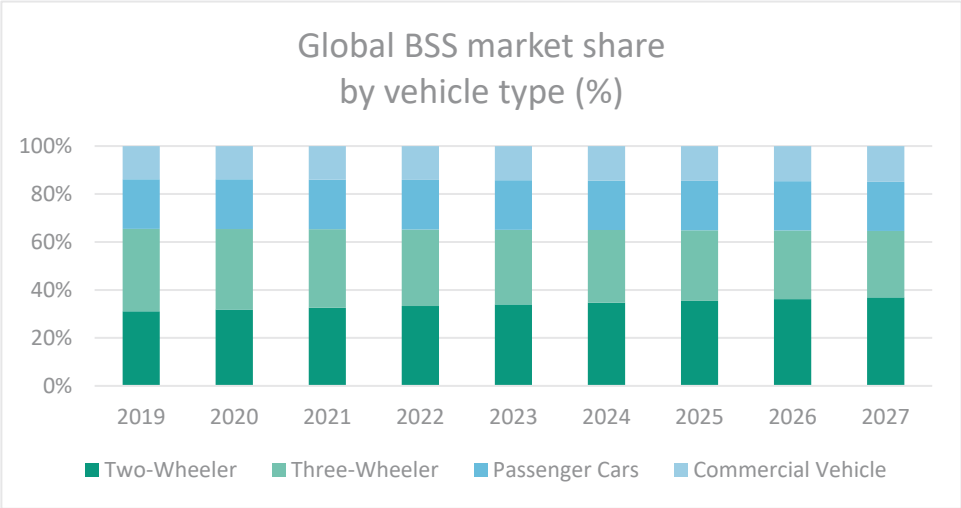


Figure 6. battery swapping market share by vehicle type, 2019-2027 (%)

It is projected that two-wheelers will surpass three-wheelers in swapping market share to lead with ~37% market share in 2027 where three-wheeler share is project to be at ~28%.

Demand for electric two-wheelers is expected to witness higher growth in line with the growth of low carbon services segment and vehicle ownership models such as scooter sharing and leasing across the globe. Battery swapping had emerged as the adequate solution for two-wheelers especially for businesses which use electric two-wheelers for last mile delivery (food, medicines, and daily needs) where minimum time to charge is instrumental to competitiveness. In 2018, Honda Motor collaborating with Panasonic Corporation to pilot out battery swapping. Hero MotoCorp and Gogoro, Bounce Infinity and Greaves Cotton[2] are some examples of similar collaborations witnessed for battery swapping projects.

Geographical and environmental factors make Asia-Pacific a great market for electric two-wheelers. This is evident from the below data, which illustrates the share of battery swapping for the two-wheeler market in this region. The Asia-Pacific emerges as a clear leader, followed by Europe and North America. Asia-Pacific is set to reach $72.894 million at a CAGR of 23.6% per annum by 2027, followed by Europe with $35.52 million at a CAGR of 25.7%.

Table 7. Global two-wheeler battery swapping market ($ million)
Source: https://www.alliedmarketresearch.com/electric-vehicle-battery-swapping-market-A10601

REGION	2019	2020	2021	2022	2023	2024	2025	2026	2027	CAGR% 2020-2027
North America	6.44	5.63	6.92	8.59	10.74	13.55	17.23	22.08	28.51	26.10%
Europe	8.22	7.17	8.80	10.88	13.57	17.06	21.63	27.64	35.52	25.70%
Asia-Pacific	19.53	16.53	19.94	24.24	29.72	36.74	45.78	57.50	72.89	23.60%
LAMEA	2.84	2.50	3.14	3.97	5.06	6.49	8.39	10.93	14.48	28.50%
Total	**36.87**	**31.85**	**38.81**	**47.70**	**59.11**	**73.85**	**93.04**	**118.17**	**151.41**	**25.00%**

[2] https://timesofindia.indiatimes.com/business/india-business/bounce-infinity-partners-with-greaves-retail-for-battery-swapping-stations/articleshow/90371250.cms

Among the vehicle types, two-wheelers lead the battery swapping market owing to high demand in the last mile transportation, delivery, ride-sharing services where minimum time-to-charge service is required for the success of the customer and the business.

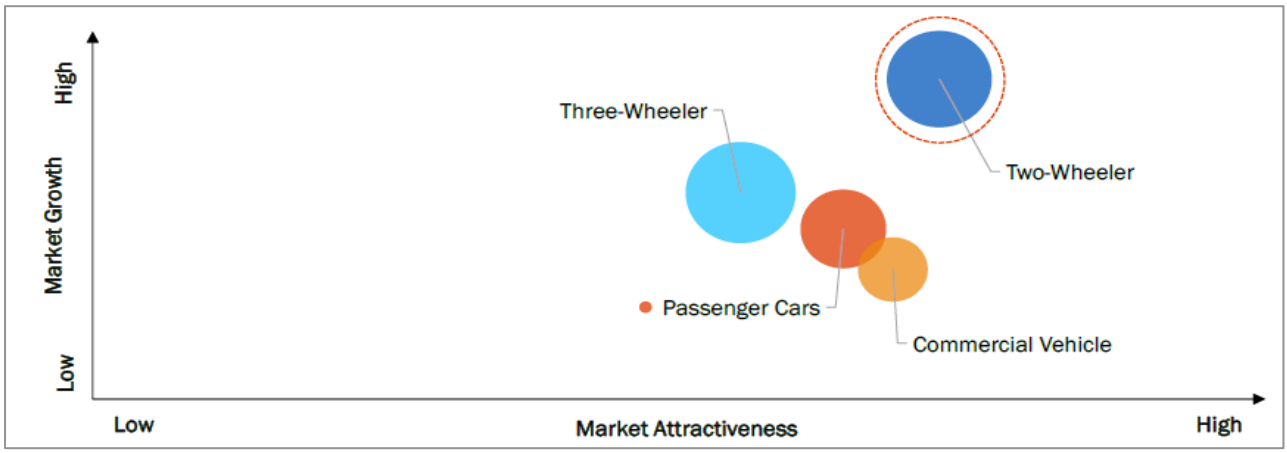


Figure 7. Top BSS investment pockets globally by vehicle type

2.2 GLOBAL CASE STUDIES

Transport electrification has been led by battery-powered vehicles globally. To overcome the challenges of range, time-to-charge, and infrastructure cost the industry developed the concept of battery swapping. The concept has been adopted by multiple entities across geographies. It was utilized by the German automotive giant Mercedes-Benz for its model back in the 1970's, Israel based Better Place in 2007, and US-based Tesla in 2013 which initially designed a modular car to enable battery swapping. Battery swapping has proven to be an effective technology for battery powered vehicles especially for two-wheelers which require less space and are used for short travel. In this section, we have identified some of the present-day companies which have adopted battery swapping or BaaS model for its customers thus helping in enabling EV adoption. We will briefly review these companies, their challenges and success factors one by one.

2.2.1 BOUNCE

Bounce is an India born startup which started with a ride-sharing business model initially under the name 'Bounce Share'. It offers last-mile commute to its customers at an average price of USD 0.07 per kilometer or USD 0.007 per minute. The Bounce share platform provides user access to keyless bikes. Customers can access 'Bounce' mobile app to find scooters that are available for booking at a nearby location. Only the scooters with battery charging of 60% and above are discoverable on the app. Once a scooter is located, customer can use a QR code scanner built within the app to unlock the scooter and take it for a ride. The app will count the time and length of the commute to calculate the final fare.

Bounce has teamed up with battery manufacturers and infrastructure companies to install a network of swapping stations across the cities in India. Customers have two options to choose from for using a Bounce scooter. One option is to book an on-demand ride in which once a nearby scooter is located, customer can use a QR code scanner built within the app to unlock the scooter and take it for a ride. When the batteries get discharged, they are swapped at the nearest swapping hub by the on-ground operations team which ensures that majority fleet is available for booking at any given point in time. These swapping stations or hubs are usually located at an easy to discover location such as convenience stores. Another option is to subscribe to a long-term rental plan in which

customers pay a pre-determined fixed amount for the chosen duration. Customers are provided a charger along with the E2W for the duration of the plan. Customers can charge their rented E2W at their home using the charger.

Table 8. Company snapshot, Bounce

Information	Description
Incorporation Year	2018
Country of Origin	India
Key Executive(s)	Vivekananda Hallekere - CEO Anil G - COO Varun Agni – CTO
Primary Business	Electric scooter manufacturing, electric bike sharing, Mobility & Battery-as-a-Service
Key Partnerships	Twenty-two motors, Cotton greaves, Park+, NoBroker

However, Bounce witnesses at least 2,000 cases of theft and vandalism every month. Additionally, EV being a relatively new technology, there have been cases of wiring failure and vehicle damage leading to consumer dissatisfaction. To overcome this Bounce has come up with a dealership model where an individual or entity is responsible for operating the bikes and maintaining the swap station to ensure a seamless customer experience.

2.2.2 SUN MOBILITY

Sun Mobility is an electric mobility infrastructure and solutions company, with 65 SWAP points in 15 cities in India for two-wheeler and three-wheeler fleet operators. This company provides Mobility-as-a-Service (MaaS), and Battery-as-a-Service offerings. Sun mobility's MaaS option provides customers a bundled offering of EVs on lease along with flexibility of unlimited swaps for the duration of the contract. The company's MaaS model is built on top of its Battery as a service model which offers smart batteries to its clients and customers through its innovative battery swapping technology. The company aims to support its customers in maintaining an asset lite model through various leasing options for commercial and retail consumers. The charging pricing ranges between USD 0.70 to USD 0.80 per battery swap. Sun Mobility has been implemented in Chandigarh, Mohali, Amritsar, Panchkula, Calicut, Vijayawada, Trivandrum, Bhubaneswar, Noida, Faridabad, Delhi, Ghaziabad, Bengaluru and Gurugram. The company recently raised USD 50 million from Vitol, which is a global independent energy trader and investor in zero-emission and renewable energy assets. The strategic investment by Vitol will enable Sun Mobility to expand its offering in India and select global markets where Vitol has a presence[3].

The swapping of batteries happens at Quick Interchange Stations (QIS) that support interoperable batteries for E2W and E3W. The model helps in standardizing the batteries through an ecosystem, reducing the upfront costs of EVs for its consumers. Fleet operators subscribe to the MaaS service on a lease basis, instead of buying vehicles from manufacturers. The fleet operator gets access to EVs, batteries, and Sun Mobility's battery-swap subscription. This model of Sun Mobility is building demand and scale for the OEMs in the ecosystem through a complete mobility service to its customers.

[3] https://www.vitol.com/vitol-invests-in-emerging-market-electric-mobility-business/

Table 9. Company snapshot, Sun mobility

Information	Description
Incorporation Year	2017
Country of Origin	India
Key Executive(s)	Chetan Maini – Co-Founder, Chairman Uday Khemka – Co-Founder, Vice Chairman Ajay Goel – Co-Founder, Executive Director
Primary Business	Battery-as-a-Service
Key Partnerships	Bosch, Piaggio, Kinetic Green, Exicom, Omega Seiki

Being a unique model, Sun Mobility faced challenges such as converging different vehicle and battery OEMs to its standardized specifications. There were multiple issues faced by OEMs to attain specifications, such as economically feasibility. Sun Mobility tackled this problem by committing to minimum-order quantity and the model's ability to scale. Sun Mobility's vision is to promote electric mobility by reducing upfront cost of purchase through its BaaS model, and by helping fleet companies and aggregators incorporate electric vehicles and build an asset light model using its MaaS models.

2.2.3 GOGORO

Gogoro is a smart-safety scooter and battery swapping network provider with Battery as a Service offering with subscription plans for individual and commercial users. The company creates synergy through scooters with cloud connectivity, as well as electric powertrain and swappable battery infrastructure for gathering, analyzing, and sharing riding data through a mobile application on the rider's smartphone. Gogoro operates in Taiwan and is expanding to China, Indonesia and globally, including a recent public listing on NASDAQ. The company also partnered with a new subsidiary of Germany's Bosch group called Coup to launch a smart e-scooter sharing service in Berlin.

Table 10. Company Snapshot, Gogoro

Information	Description
Incorporation Year	2011
Country of Origin	Taiwan
Key Executive(s)	Horace Luke – Founder, CEO Matt Taylor – Co-Founder
Primary Business	Electric scooter manufacturing & Battery-as-a-Service
Key Partnerships	Panasonic, Hero Moto Corp, Tier mobility, Maxxis, RideGoShare

Gogoro has been one of the first companies to conceptualize and implement a Battery as a Service model, which helps reduce upfront costs of vehicles, reduce the time of charge and increase EV adoption. Major challenges faced initially were technical issues such as battery network downtime, delay in Gogoro service and spare parts availability along with some countries pressing for local manufacturing. However, the company has been able to convince users and get buy-in from the global auto community for its swapping network as enabler of electric mobility for 2W.

2.2.4 OYIKA

Oyika plans to revolutionize the EV market in the ASEAN region with its battery swapping technology by lowering barriers to EV Adoption through battery-as-a-service model. The model includes a no-down payment, no deposit, and no-contract power subscription plan that comes bundled with an e-motorbike for a weekly fee of USD 18. Oyika currently operates 27+ swapping stations in Indonesia and Cambodia. It plans to expand to Vietnam in the near future due to the size of the market.

Table 11. Company Snapshot, Oyika

Information	Description
Incorporation Year	2019
Country of Origin	Cambodia
Key Executive(s)	Jinsi Lee - CEO Tai Ling Chun - COO Tay Chin Kwang - CFO
Primary Business	E-motorbikes EV Chargers, Ride sharing & Battery-as-a-Service
Key Partnerships	PLN (Indonesia Electricity Company), Foodpanda

Oyika's Go2 ride sharing rental bikes use the battery swapping mechanism for their energy use. In a ride-sharing model, electric scooters are made available for short-term rentals. Customers can rent the nearest available scooter using a Go2 mobile app, ride it, and leave it responsibly at a designated parking spot for the next customer. Through Go2 ride sharing model, the company has been able to increase demand for its battery-as-a-service system. Initially Oyika had low utilization of BaaS, but the increased demand and scale through Go2 ridesharing is helping the company penetrate urban regions and expand into rural locations in Cambodia. Recently, Oyika signed an MOU with Foodpanda for provision of electric motorbikes to their delivery riders. This is a step towards realising their vision of enabling EV adoption by demonstrating their products' capability when it comes to range, speed, and reliability[4].

2.2.5 KYMCO

Kymco is a Taiwanese 2-wheelers manufacturer which has developed Ionex Recharge[5] solutions – a door to destination on-demand battery swapping solution for electric scooters and motorcycles. The company aims to personalize the battery swapping at a convenient time and place without the need for user presence. The company is bundling this solution with its EV solutions across Asia, US, and Europe. The Ionex charging network is an inclusive, open-to-all, standardized energy platform that can provide charging solutions for all makes and manufacturers worldwide. The service is currently piloted in Taiwan, and the company has forged ties with several manufacturers in the US, Europe, and Asia, targeting the countries that have pledged net zero emission goals.

Table 12. Company Snapshot, KYMCO

Information	Description
Incorporation Year	1964
Country of Origin	Taiwan
Key Executive(s)	Allen Ko - Chairman
Primary Business	EV manufacturing & Battery-as-a-Service
Key Partnerships	Twenty-Two motors, Super SOCO and FELO Technology

Their model is reducing customers' inconvenience they experience by supporting them with swapping facilities at the location and time of their choice. This way, the customer can further reduce the anxiety of finding the nearby battery-swapping network and increasing the adoption of E2W. The challenges currently faced are mainly towards delivering timely services to the customers. Current manufacturer's network and partnerships have helped Kymco to get the stakeholders' buy-in for its idea to standardize batteries.

[4] https://www.oyika.com/news-and-events/oyika-signed-an-mou-with-foodpanda/

[5] https://www.kymco.com/news/kymco-launches-ionex-recharge-the-worlds-first-on-demand-battery-delivery-and-swapping-service

2.2.6 DABADIGO

Dabadigo is a 100% electric and app-based rental low-speed scooter that can be booked at USD 0.60 per hour and does not need a license to operate (over 18 years). The bikes are available for pick up and to be dropped at the nearest rental points, which are also the swapping outlets for batteries. Dabadigo is implemented in Kolkata, India currently with multiple rental points spread over the city.

Table 13. Company Snapshot, Dabadigo

Information	Description
Incorporation Year	2016
Country of Origin	India
Key Executive(s)	Reshmi Nath – Co-Founder Basabjit Nag – Co-Founder
Primary Business	Electric scooter rental
Key Partnerships	Hero Electric

Their model helps consumers to book a bike at an hourly rate from the nearest hub. The customers can swap batteries for free at the swapping location (also the hub) in case they want to extend their rental duration and run out of range. While they use a distributed battery swapping model, charging of discharged batteries happen at a centralized location while swapping can be done from a choice of hubs/ swapping outlets. Being an initial player using lithium-ion batteries, the company had to face multiple financial challenges in procuring and running operations sustainably but over the time they have been able to successfully introduce their bike-sharing scheme in Kolkata and implement battery swapping model from their hubs.

2.2.7 VOLTUP

VoltUp provides battery swapping and smart charging technology platform for EV owners, logistics players, and OEMs at pay-as-you-go model. It has strategic partnerships with Hindustan Petroleum Corporation Limited (HPCL) for opening swapping centers across India. VoltUp deployed swapping stations in Jaipur, Kolkata, Delhi NCR, Karnataka and plans to expand to other states in the country. VoltUp currently supports battery-swapping for electric three wheelers.

Table 14. Company Snapshot, Voltup

Information	Description
Incorporation Year	2019
Country of Origin	India
Key Executive(s)	Siddharth Kabra - CEO
Primary Business	Battery-as-a-Service
Key Partnerships	HPCL

The company currently provides swapping services to commercial customers through setting up swapping infrastructure at their fleet hub. It plans to expand to service retail consumers by setting up stations in petrol pumps in partnership with HPCL. Getting the right space for setting up swapping stations was a problem, however the partnership with HPCL gives access to its network of gas stations which are in the center of the urban spaces. Initially, their focus was on fleet providers who need dedicated swapping stations for their fleets. With support from Hindustan Petroleum Corporation Limited, VoltUp got access to a greater market, including consumer market, through their payment systems, real estate and highly penetrated network of petrol pumps.

2.2.8 LITHION POWER

Lithion Power is India's largest "Battery as a Service" operator, providing lithium-ion batteries for e-bikes and 3 wheelers. It supports an intelligent energy platform for battery swapping infrastructure, along with software assets that allow for asset tracking and monitoring energy utilization. It plans to invest $1 Billion into BSS. The company has implemented 200+ Lithion swap stations in Delhi - National Capital Region and the Haryana region. The expansion was helpful for low- to the medium-power commercial vehicles such as e-rickshaws and bikes where standardization can be introduced more comfortably.

Table 15. Company Snapshot, Lithion Power

Information	Description
Incorporation Year	2016
Country of Origin	India
Key Executive(s)	Piyush Gupta – Co-Founder, CEO Chandrashekhar Bhide - Co-Founder Prem Chand Gupta - Co-Founder
Primary Business	Battery-as-a-Service

The company currently provides swapping to ride-sharing service providers with its BaaS model. Social perception towards ownership of batteries and financial payment models were initial challenges for the company. Their unique battery-management design is compatible with different battery standards available in India and across Delhi. NCR gives them an edge over other players in the market.

2.3 PROPOSED OPERATING MODEL FOR LAO PDR

Based on the information as detailed in the previous section, three key business models emerge around the Battery swapping system. These are:

- Ride sharing
- Mobility-as-a-Service (MaaS)
- Battery-as-a-Service (BaaS)

From among the nine companies studied in the previous section, all but one offer Battery-as-a-Service via swapping stations to enable adoption of EVs. This seems correct, as a major cost of owning an EV is the cost of the battery. BaaS ensures that battery cost is shifted from a CAPEX to an OPEX, hence making upfront purchase cheaper and operation hassle free. Similarly, a ride-sharing model is effective where customers can experience EV without having to buy one. It is a solution for people who commute rarely using a personal vehicle while allowing swapping station operators to increase utilization rates. Companies offering MaaS, usually have two options: one, where a company sells an EV without battery and then offer BaaS (either by itself or through strategic partnerships) for day-to-day commute and two, lease an EV to the customer spreading the cost of ownership using Equated Monthly Instalments (EMI) and eventually transferring the EV to customer once all the EMIs are paid off.

Table 16. Types of business models for battery swapping

Business Model	Description	Pros	Cons
Bike Sharing Model	• Electric bikes with swappable batteries are provided to the retail users on easy to pick and drop model for an hourly fee of use • Battery swapping is done either at the pickup drop hub or at the bike parking location on demand	• High asset utilization and value creation due to large consumer-base • Provides the ability to scale operations as demand for batteries is created internally	• High upfront costs due to large capital investment • Return of investment depends on the penetration of network • Problem of theft and vandalism of assets by users
Mobility-as-a-Service	• Electric Fleet is provided generally to commercial users as a plug and play with a subscription per month or per year model • Provider is responsible for the battery swaps, vehicle maintenance and others	• High asset utilization and higher standardization of batteries as demand is created internally through fleet provided • High ability to scale	• High upfront costs due to large capital investment • High liability due to asset-heavy model
Energy/Battery-as-a-Service	• Only the battery is provided to the end-user (individual or commercial) with a pay as you go or subscription model • Provider is only responsible for the battery life and battery swapping as per contract	• Support adoption of electric vehicles due to lowered upfront costs for customers • Cost of swapping for consumers is lower compared to gasoline refill	• Low utilization due to lack of standardization of batteries • Lower ability to scale due to high cost of additional batteries

The above table illustrates the discussed business models by comparing their pros and cons. Ride sharing and MaaS models are more efficient when coupled with BaaS as it becomes easier to optimize utilization as demand for Batteries is created internally without having to depend on partnerships from OEMs or worrying about operational hassles that may arise due to non-standardization of battery technology.

Upon studying the market and various models around battery swapping system, it is suggested, in the Lao PDR context, that in the initial phases a single operator be selected to operate a fleet of 100 E2W under ride sharing and MaaS model supported by BaaS in order to bring down the cost of ownership for the customer and transfer battery charging, degradation, disposal or recycling responsibilities away from the customer.

3 PROJECT SIZING AND FINANCIAL MODELLING

The global case studies listed in the previous sections demonstrate the role of battery swapping in successful adoption of E2W across geographies. As we will see in the upcoming sections, to achieve Government of Lao's target of 30% electrification by 2030, battery swapping could help overcome many of the challenges identified in the Lao context. In this section, we will also be sharing findings of the comprehensive and dynamic financial models built around phased implementation of a battery swapping system in Vientiane Capital. The model considers assumptions derived from international experience of existing operators. This section shall cover financial analyses of the pilot and scale-up phases, potential implementation partners, and the proposed financing structure.

3.1 PHASE 1: PILOT PROJECT

The phase 1 model is built considering an operator will deploy 100 E2W as a pilot to test the market and the proposed approach, under a combination of the three key business models i.e. ride sharing, Mobility as a Service and Battery as a Service. The figure below shows a comparison of the three models with regard to pricing, revenue model and ownership.

	Battery as a Service	Mobility as a Service	Ride Sharing
Ownership	Investment on the batteries and charging stations E2W purchased and owned by users	Investment on E2W, batteries and charging stations E2W ownership transferred to user after 2 years	Investment on E2W, batteries and charging stations
Revenue Model	Users subscribe for batteries swapping service payable monthly	Users subscribe for E2W and swapping for 2 years, then only battery swapping after 2 years	Users pay as per usage
Pricing	29 USD per month for access to swapping kiosks	79 USD per month for 2 years, then 29USD if keeping the same E2W	2 USD per hour

Figure 8. Comparison among the business models

3.1.1 KEY INPUT VALUES

Input values are the foundation to the financial model. It is important to benchmark and choose values that best suit the case which need to be modelled. A good financial model is dynamic in nature to adjust output based on variations in input parameters. To better forecast the results, it is suggested to develop an exhaustive list of input parameters and assumptions that may or may not be co-related but have an impact on the final output. The table shown below illustrates key input parameters and assumptions considered to model the project.

Table 17. Input values considered for financial modelling in Phase 1

Parameter	Value	Unit
Business model split		
BaaS	30	%
MaaS	40	%
Ride Sharing	30	%
E2W		
Total no. of E2W to be deployed	100	E2W
Service life	15	Years
Cost per E2W	1,000	USD
Salvage value	5	%
No. of batteries per E2W	1	battery
Pricing model		
Monthly subscription charges – BaaS model	29	USD
Monthly subscription charges – MaaS model	79	USD
Duration of MaaS contract	2	Years
Hourly charges – Ride sharing model	2	USD
Funding structure		
Grant	50	%
Equity	50	%
Battery		
Charging lifecycle	2,000	lifecycles
Depth of discharge	85	%
Cost of battery pack	360	USD
Salvage value	5	%
Year-on-year cost reduction	10	%
Battery Swapping System		
Service life	15	Years
Cost per kiosk	2,700	USD
Batteries per kiosk	10	Batteries
Time to charge	2	Hours
Factor of safety	1.25	-
Salvage value	5	%
Conversions		
Operational calendar days	330	days
USD to LAK	11,515	LAK
Operational details		
Daily commute	50	KM
Swap factor	3	-
Charge per battery per day	1	Charge
Annual maintenance charges	1	%
Operations and maintenance staff per BSS	0.5	Staff
Total annual costs for manning the BSS	1980	USD

3.1.2 PROJECT COSTS

Project costs refer to the total cost that would be incurred by the operator to set up the infrastructure for deploying and operating 100 E2W. Based on the global case studies, it is assumed that 20 swapping stations

should be set up to support operations of 100 vehicles. Key capital costs include cost of electric motorbikes, batteries, swapping kiosks, and IT system.

A swap factor of 3 has been considered. This translates into a total of 300 batteries to support the project including 100 batteries that would be put in the scooters and remaining 200 batteries would be housed in planned 20 kiosks. Cost of each vehicle is estimated at USD 1,000 while a swapping kiosk costs USD 2,700 per unit. IT system (app) development is estimated at USD 10,000. Taking the cost of 100 E2Ws, 300 batteries and 20 kiosk stations into account, total cost of the project is estimated at **USD 272,400**.

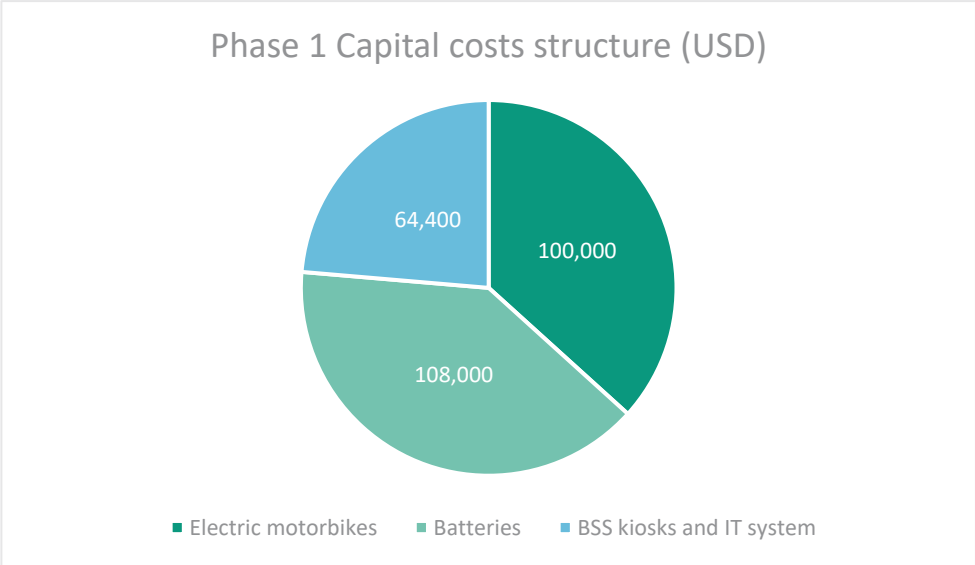


Figure 9. Capital costs' structure

3.1.3 ANALYSIS AND RESULTS

3.1.3.1 TOTAL COST OF OWNERSHIP

Globally electric vehicle adoption has been driven by lower cost of operations and lower total cost of ownership (TCO). TCO is the aggregate value of all the costs incurred by the owner (individual or corporate) during the EV's lifetime (we have assumed 15 years as end of life). Cost of ownership comparative analysis between an ICE 2W and E2W is an accurate measure of economic efficiencies and provides key insights to customers in making a viable decision for themselves. A TCO analysis between different type of EV ownership models such as with or without battery, BaaS or MaaS model also helps operators in tailoring their offerings to the customers thus helping in the overall agenda of accelerating EV adoption and utility.

In the model we have calculated TCO for ownership of Petrol 2W, E2W with on-board battery, E2W without on-board battery (BaaS) and for E2W leasing (MaaS model). The model considers an average commute of 16,500 km per annum on a 2W (50 kms per day for 330 calendar days), cost of petrol at USD/liter 1.55 and cost of electricity at USD/KWh 0.1. To obtain the cost of ownership over the lifetime, it is important to incorporate inflation (4%), share of debt financing (60%), loan tenure (3 years). The table below illustrates key input parameters for different TCO analysis.

Table 18. Inputs for TCO calculation

Parameter	Value	Unit
ICE 2W		
Purchase cost	1,000	USD
Fuel efficiency	60	km/liter
Year-on-year efficiency reduction	2	%
End of life	10	Years
Repair and Maintenance	7	%
E2W		
Purchase cost (with battery)	1,360	USD
Purchase cost (without battery)	1,000	USD
Energy consumption	0.01275	KWh/km
End of life	15	Years
Repair and Maintenance	1	%
Annual BaaS subscription	348	USD
Monthly MaaS subscription	79	USD

As per Table below, petrol motorbikes have the highest TCO per 100km mainly due to cost of fuel and maintenance over the lifetime. Electric bikes purchased outside of swapping scheme have the lowest cost of ownership but face additional constraints in terms of charging, maintenance, access to spare sparts and range anxiety, etc. compared to similar vehicles under a BaaS or MaaS subscription. The TCO demonstrates that in any case, shifting to e-mobility is financially attractive for the customer.

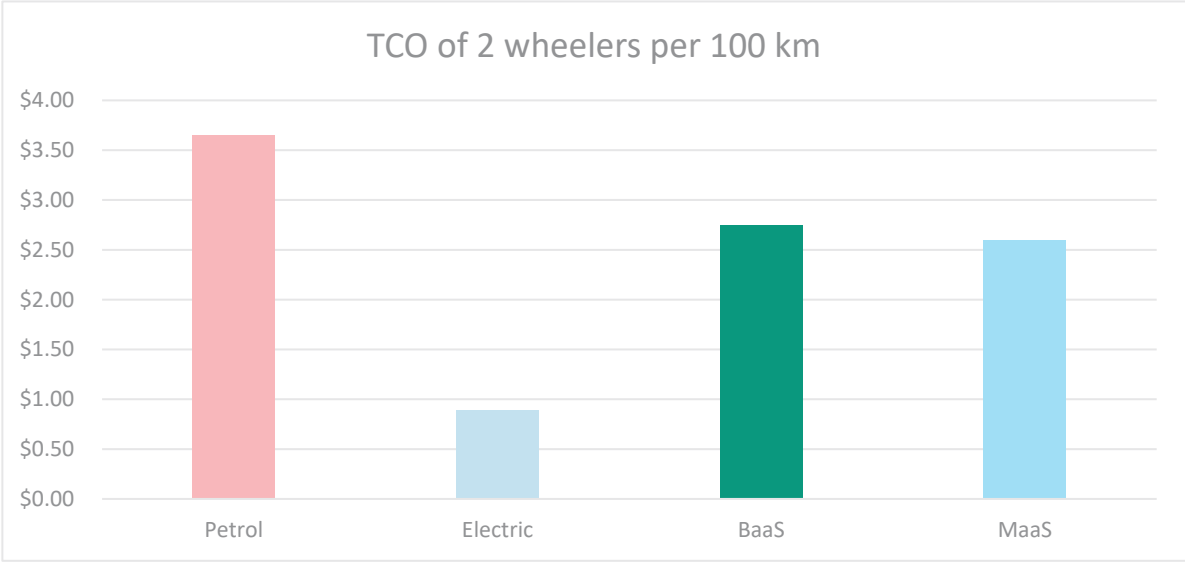


Figure 10. TCO comparison for different ownership models

3.1.3.2 REVENUE SPLIT

As discussed in earlier sections, the selected operator shall implement the pilot via three key business models i.e. Ride sharing, Battery as a Service (BaaS) and Mobility as a Service (MaaS). The project is sized for 100 E2W deployments with the following share of each of the three business models:

- Ride sharing – 30% or 30 E2W
- BaaS – 30 % or 30 E2W
- MaaS – 40% or 40 E2W

Revenue is calculated from the standpoint of the operator considering key inputs such as subscription cost, E2W resale value, and utilization rate over 12 years of operations.

Table 19. Input assumptions for revenue projection

Parameter	Value	Unit
E2W		
Monthly subscription cost - BaaS	29	USD
Monthly subscription cost - MaaS	79	USD
Resale value of E2W	10	%
Hourly cost – Ride sharing	2	USD
Daily utilization	2	Hours
Y-o-y improvement in utilization	2	%

Over the lifetime of the project, the ride sharing option is the highest revenue contributor among the three models, followed by MaaS and finally BaaS model. Revenues from the BaaS option are higher in year 1 due to the sales of the E2W. Revenues from the MaaS decrease after year 2 assuming that users choose to keep existing 2EW and switch to a MaaS option, which is conservative from a revenue projection perspective. The figure below displays a graph representation of yearly revenue comparison among the three models.

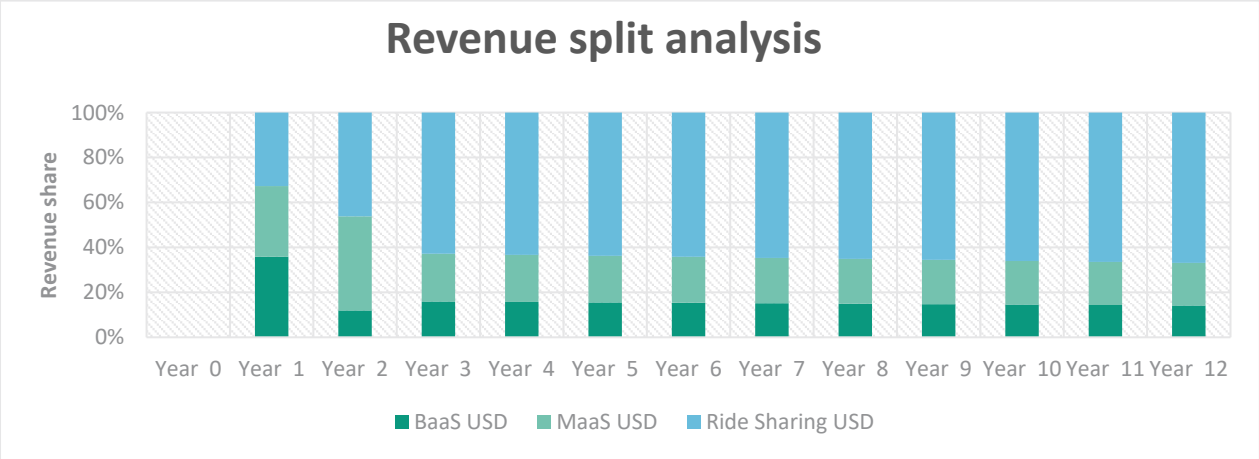


Figure 11. Revenue split analysis

3.1.3.3 IRR & SENSITIVITY ANALYSIS

Internal rate of return or IRR is the reference metric to estimate the return-on-investment potential of a project to help investors (operators and multilateral banks/institutions in this case) take informed financial decisions. It is a measure of the per annum growth an investment is estimated to make for the investor. In the model we assume depreciation of E2W, batteries, and BSS kiosks at respectively 6%, 15%, and 6% over the lifespan of 15 years, 6 years, and 15 years and a WACC (Weighted Average Cost of Capital) of 4%.

While a range of parameters influence the IRR, one of the most impactful is the swap factor. Swap factor is the number of batteries per E2W that an operator should keep in circulation for effective and efficient implementation of the project around the three key business models discussed in previous sections (ride sharing, BaaS, and MaaS). A sensitivity analysis was conducted to understand the impact of swap factor on IRR and the results of the activity are presented in the form of a graph below.

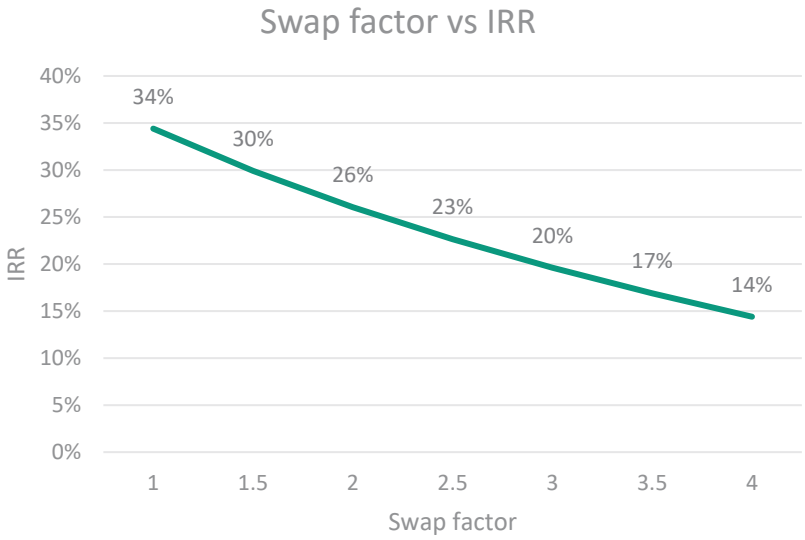


Figure 12. IRR Sensitivity analysis to swap factor

Based on information collected as part of the global case studies, a swap factor of 3 is selected. The analysis demonstrates that IRR improves with decrease in swap factor. Swap factor depends primarily on the type of battery (technology) used in the E2W and what range do they present. The higher the range & life of the battery, the lesser number of swaps per day would be required and so operator can run the operations effectively with lesser number of total batteries in circulation.

In phase 1, the project IRR reaches 18%, while the return on equity is calculated at 45%, assuming 50% grant funding for the pilot stage. The results demonstrate the profitability of the project in pilot phase as IRRs are above the default values for the approximate expected return on equity for transport project types in the Lao PDR, as recommended by the United Nations[6].

Project IRR

- 18%

Equity IRR

- 45%

Figure 13. IRR results

[6] Tool on Investment Analysis, version 10, UNFCCC

3.2 PROPOSED FINANCING STRUCTURE

The common practice to finance innovative e-mobility projects is through a combination financial instruments such as equity, debt, and grants. While there is an obligation to repay the amount funded through debt, there is no such liability on the funded entity to repay the amount received by means of equity or grant.

Equity financing means selling a share or stake of the firm to an individual or a group of investors, in return of cash, who believe in the business model and vision and are interested in infusing funds by acquiring certain number of shares of the limited company based on firm's valuation at the time of fund raising. Investors make money on dividends (share in profits) by eventually selling of their stake. Debt financing involves raising money in the form of a loan by pledging fixed income products such as bonds, notes etc. Money infused in the firm using debt financing can be used for business expansion by increasing production and sales as the money needs to be repaid to the lending entity. The illustration shown below lists the pros and cons of Equity and Debt financing.

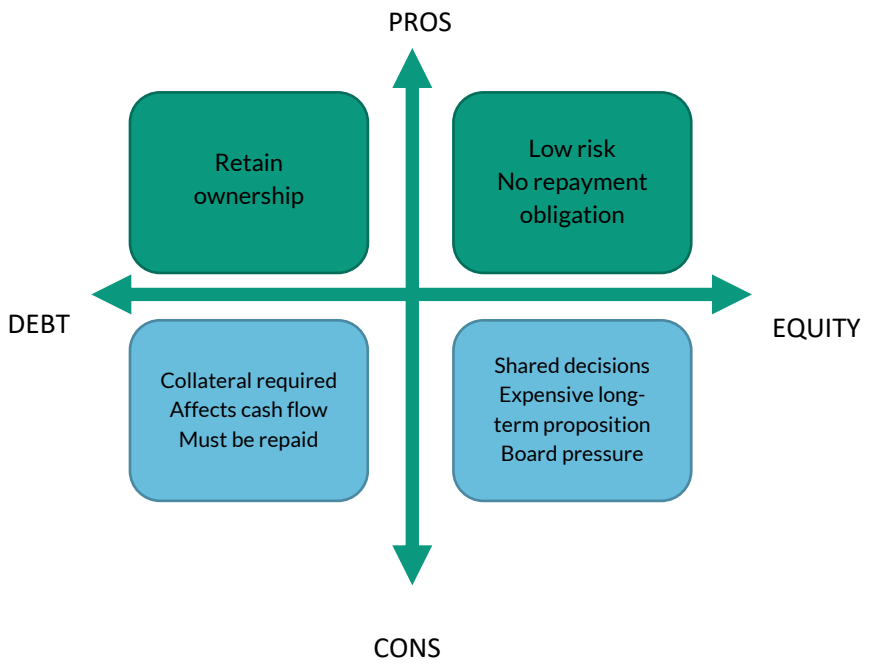


Figure 14. Equity financing vs Debt financing

Grant is a special type of financial instrument usually awarded to a firm, government, or an organization to accomplish a goal and support in the initial phases of the concept. Similar to equity and unlike debt, funds received through grant need not be paid back to the funding organization. Grants require a series of evaluations, checks, and are awarded on the basis of merit.

In light of the expected economic, environmental and social positive impacts of the project, it is proposed to fund the pilot with a capital infusion of an equal split between equity and grant financing. Through displacing demand for imported fossil fuels and creating demand for domestically produced electricity, the project will have positive impact on the balance payments. Moreover, displaced fossil fuel combustion will improve air quality and reduce greenhouse gases emissions. Finally, the project will contribute to financial savings for the users as highlighted in the TCO analysis.

Avoiding debt at this stage of the project will motivate the operator to take up the opportunity and implement without the pressure of repayment. Debt financing can be explored in later phases of the project once the

foundation is laid, and that money can be used for scaling the business and operations to accelerate adoption and penetration of E2W in the Lao PDR.

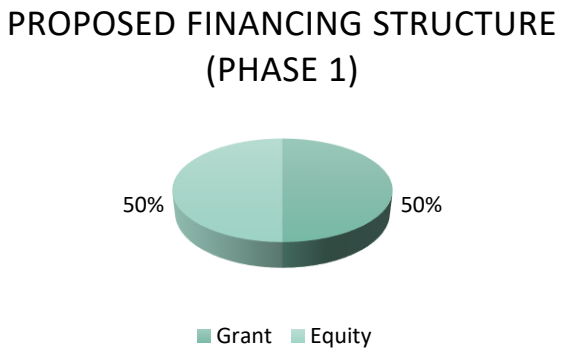


Figure 15. Proposed financing structure for Phase 1

3.3 PHASE 2: PROJECT AT SCALE

The Lao PDR Government has set the target to reach 30% electric vehicles penetration for 2-wheelers and passengers' cars in national vehicles mix in 2030. Phase 2 model is built with the aim of meeting 5% government target in the 2-wheelers segment. Depending on the actual results, learnings, and challenges from the pilot project, the battery swapping system will be scaled. While the basic assumptions as stated in Phase 1 remain the same, few inputs differ when sizing the model for a scaled-up version. Phase 2 model is preliminary and would need to be fine-tuned based on lessons learned from the operation of Phase 1. The table below highlights the key assumptions that differ from Phase 1.

Table 20. Key Phase 2 input assumptions different from Phase 1

Parameter	Phase 1 Value	Phase 2 Value	Unit
BaaS option	30	50	%
MaaS option	40	20	%
Ride Sharing option	30	30	%
E2W to be deployed	100	5500 (2030)	E2W
Grant	50	40	%
Equity	50	30	%
Debt	0	30	%
Cost of Debt	0	10	%

With the increase in the number of E2W supported under the project i.e. assumed 5% of the national target (30%), which means that the projected number of vehicles is set to increase from ~250 in 2022 to ~5500 in 2030. All associated costs such as cost of batteries, kiosks, operations will change. The envisioned capital expenditures which are illustrated in the graph below, are considering a swap factor of 2 for the project at scale. Projections have been carried out with inflation accounted for at a rate of 4%.

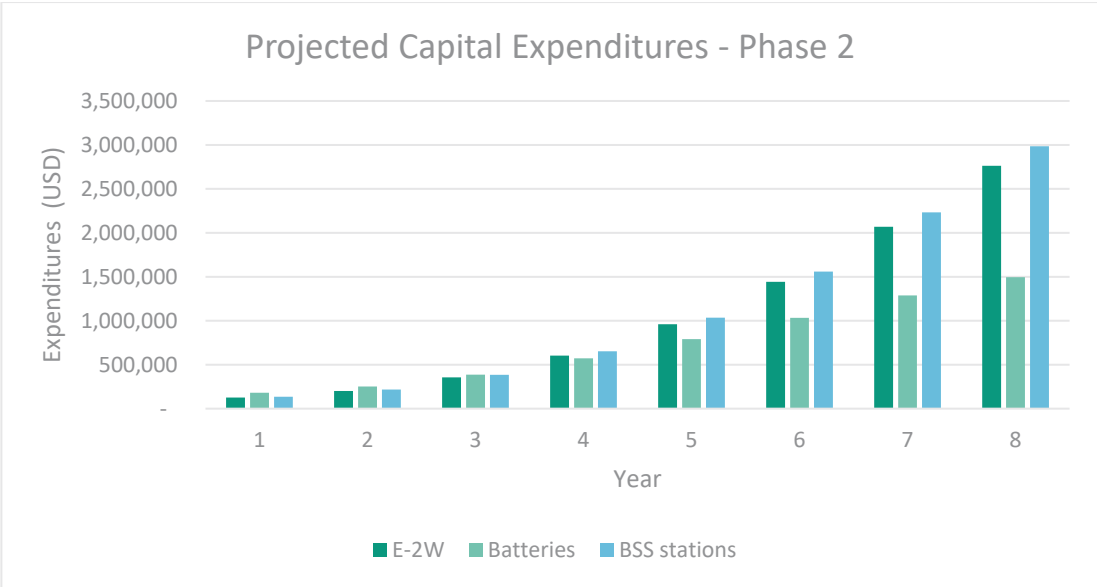


Figure 16. Capital Cost Structure for phase 2 implementation for the next 8 years

As per below figure, business model split in phase 2 is 50% BaaS, 30% ride sharing, 20% MaaS, to reflect the anticipated increased share of individual users adopting the system, provided that Phase 1 is successful.

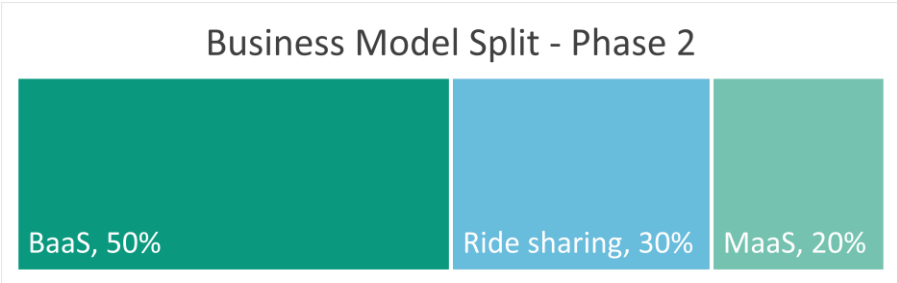


Figure 17. Business model split for Phase 2

The revenue split shown in the graph below is calculated based on the business allocated to BaaS, MaaS and ride sharing for the scaled-up model.

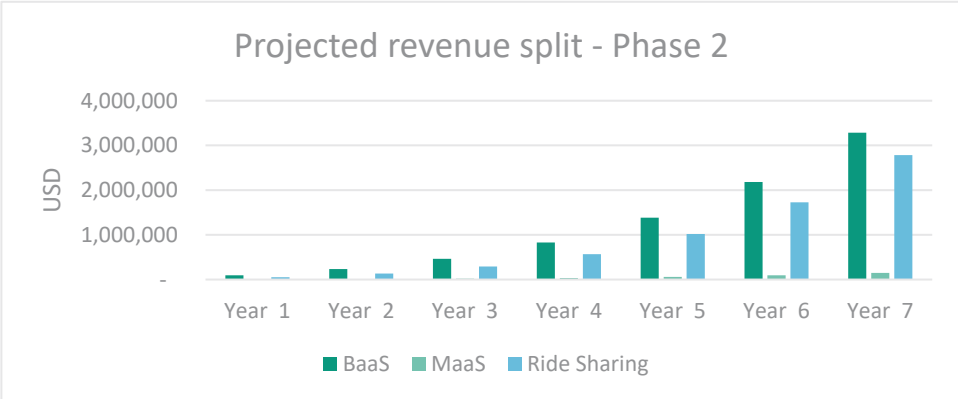


Figure 18. Revenue split from different business lines for phase 2 over the next 7 years

As we can observe, ride sharing and MaaS are anticipated to constitute the bulk of revenues in Phase 2. This is mainly due to the lowest share of business allocated to MaaS in the model. The rationale is that only a few number of organizations that manage corporate fleets of 2-wheelers have been identified in Lao PDR. Another potential profile of customers for MaaS would be expatriates on short-term contracts in Laos, where purchasing and reselling a motorbike might be perceived too cumbersome. Ride sharing is a successful business in many countries and acts as a great booster for E2W to be tried out by consumers for their regular use without any liability of ownership, maintenance or battery management. This may also give confidence to consumers to purchase E2W as their next personal vehicle.

3.4 IMPLEMENTATION PARTNERS

While conducting the prefeasibility study of battery swapping system for E2W, potential implementation partners were identified and series of consultation meetings were organized. A full list of stakeholders consulted and their feedback is provided in Annexure 1. This section highlights the outcomes of the consultation with entities which are supportive of the project and have expressed interest in further exploring cooperation opportunities in relation to setting up a battery swapping system for E2W in the city of Vientiane. To ensure successful implementation of the project, a step-by-step approach as listed below, is suggested:

3.4.1 IDENTIFICATION OF THE BSS OPERATOR

The successful operationalization of the project relies on the selection of an adequate operator. An ideal operator of the battery swapping system for the city of Vientiane would be an experienced player in the automotive or transport sector in Laos, or an existing BSS start-up active in the region. The operator would make final decision on the procurement of E2W, batteries, kiosks, and technology from suppliers within or outside Lao PDR. The onus of setting up and operating the 20 Battery Swapping Stations along with 100 E2W and 300 batteries in circulation for executing the project around the three business models i.e., ride sharing, Mobility as a Service and Battery as a Service will lie with the operator. The following organizations identified as potential operator were consulted as part the study process:

Table 21. Potential operators identified

Name	Current Business
Honda Laos	ICE 2W assembler/distributor
RMA Group	Automotive
Kolao group	Automotive
Loca	Mobility service provider
FB Battery	Battery importer
Yamaha (KP)	EV importer and Exporter
OYIKA	BSS Operator in Cambodia

All entities expressed support to the project as a solution to accelerate the transition to e-mobility in the 2-wheelers segment while addressing some of the key challenges in the Lao context. Kolao, RMA and FB battery have shown interest in getting associated with the project. Kolao has operating experience in repair and maintenance domain with a network of workshops across Vientiane and Lao PDR. Kolao believes that subscription is the way forward and has offered to cooperate and collaborate on battery recycling technology .

Honda is the market leader for ICE 2-wheelers in the country, with over a million vehicles in circulation. Loca is a dynamic start-up providing mobility services through their signature phone application and expanding to the development of charging stations for 4-wheelers. RMA Group has a rich experience in the automotive sector and is taking the lead in the electrification of the 4-wheelers segment through importing the Jaguar E-pace model. RMA Group is keen on taking part of the dialogue with the government and would call for a clearer policy framework around the EV ecosystem including but not limited to strategic priorities, standardisation, technology, charging system, and financial support. RMA already setup a battery disposal plan which consists of exporting used batteries to Korea for recycling. FB battery, as the third largest importer of auxiliary car batteries in Lao PDR has gained considerable experience in the sector. Oyika's immediate priorities for regional development are larger markets such as Vietnam and Indonesia but franchising in Laos is of interest.

Discussion with potential operators must continue beyond this prefeasibility study in order to address the different challenges towards investing in such a system. Those involve the design of a solution that best fit the Lao context, in terms of vehicle specifications, pricing, risk of theft, etc.

3.4.2 POTENTIAL LOCATIONS FOR THE SWAPPING STATIONS

Another key factor in the success of a BSS project is the easy of access to battery swapping stations. Several organizations were identified as potential hosts of the kiosks. Two entities, namely Mini Big C and Petrol Trading Laos Holdings (PTL) expressed interest in participating in the project through offering their real estate for setting up battery swapping stations. Mini Big C has a vast and growing network of retail outlets in Vientiane and 10 store locations have been envisaged for the purpose of this study, with the objective of covering the main transport routes in Vientiane. These are preliminary suggestions, and no commitment has been made by either Mini Big C or PTL for the project.

Table 22. Latitude and Longitude of 10 locations identified with Mini big C

#	Station name	Latitude	Longitude
1	Mini Big C Phonthan	17.95756	102.636427
2	Mini Big C Souanmone	17.91363	102.620287
3	Mini Big C Lanexang Avenue	17.96707	102.615094
4	Mini Big C Dongnaxok	17.98245	102.586253
5	Mini Big C Dondeng	17.99087	102.608074
6	Mini Big C Samsenthai Road 1	17.96585	102.60926
7	Mini Big C Samsenthai Road 2	17.96944	102.585608
8	Mini Big C Thatluang	17.97442	102.634425
9	Mini Big C Phonpapao	17.94913	102.640361
10	Mini Big C Thongkhankham	17.97261	102.606361

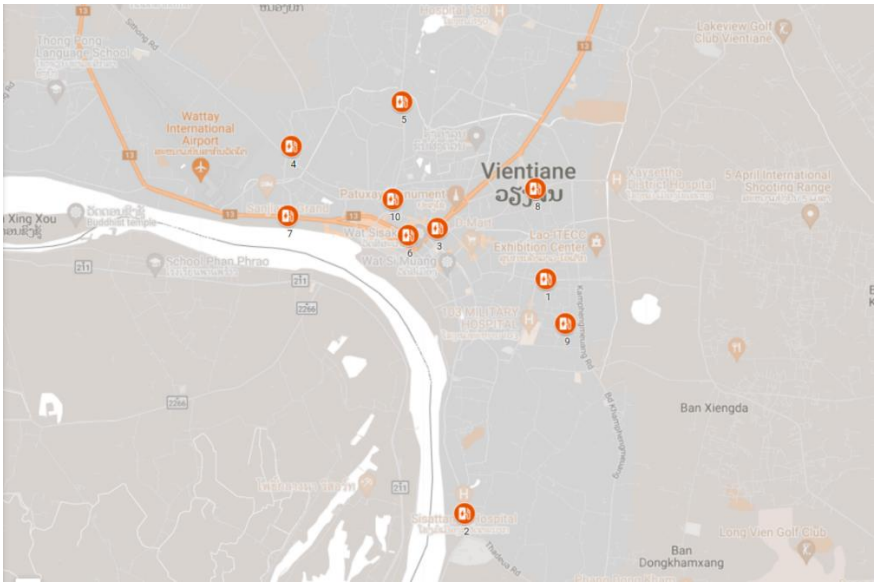


Figure 19. Map view of Mini Big C locations

Similarly, PTL operates a solid network of petrol stations across Vientiane and setting up battery swapping stations at key locations would ensure convenient and all year-round access to users. The remaining 10 locations out of the 20 needed are identified to be PTL gas station locations as per Table and Figure below.

Table 23. Latitude and Longitude of 10 PTL stations

#	Station name	Latitude	Longitute
1	Plus Gas Station, ASEAN Road	17.9726	102.598656
2	Plus Gas Station, Phongsavanh Bank KM7	18.01698	102.650586
3	Plus Gas Station, Phonpanao	17.98906	102.636063
4	Plus Gas Station, Simeung	17.95685	102.617316
5	Plus Gas Station, Petro Trade Building	17.96493	102.642529
6	Plus Gas Station, Khamphengmeung Road	17.93724	102.64737
7	Plus Gas Station, Xiengda	17.93588	102.675243
8	Plus Gas Station, 450 year road	18.02637	102.675098
9	Plus Gas Station, Nongduang	17.97379	102.603901
10	Rimping Supermarket	18.01636	102.648007

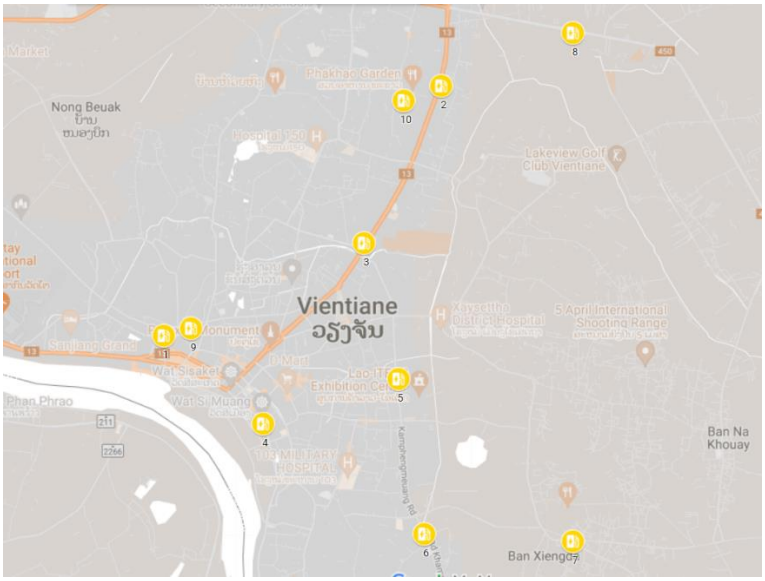


Figure 20. Map view of PTL locations

Ground assessment of these 20 locations should be carried out to establish a layout plan for setting up the battery swapping stations accounting for basic parameters such as parking space, circulation space, visibility, accessibility, grid connection etc.

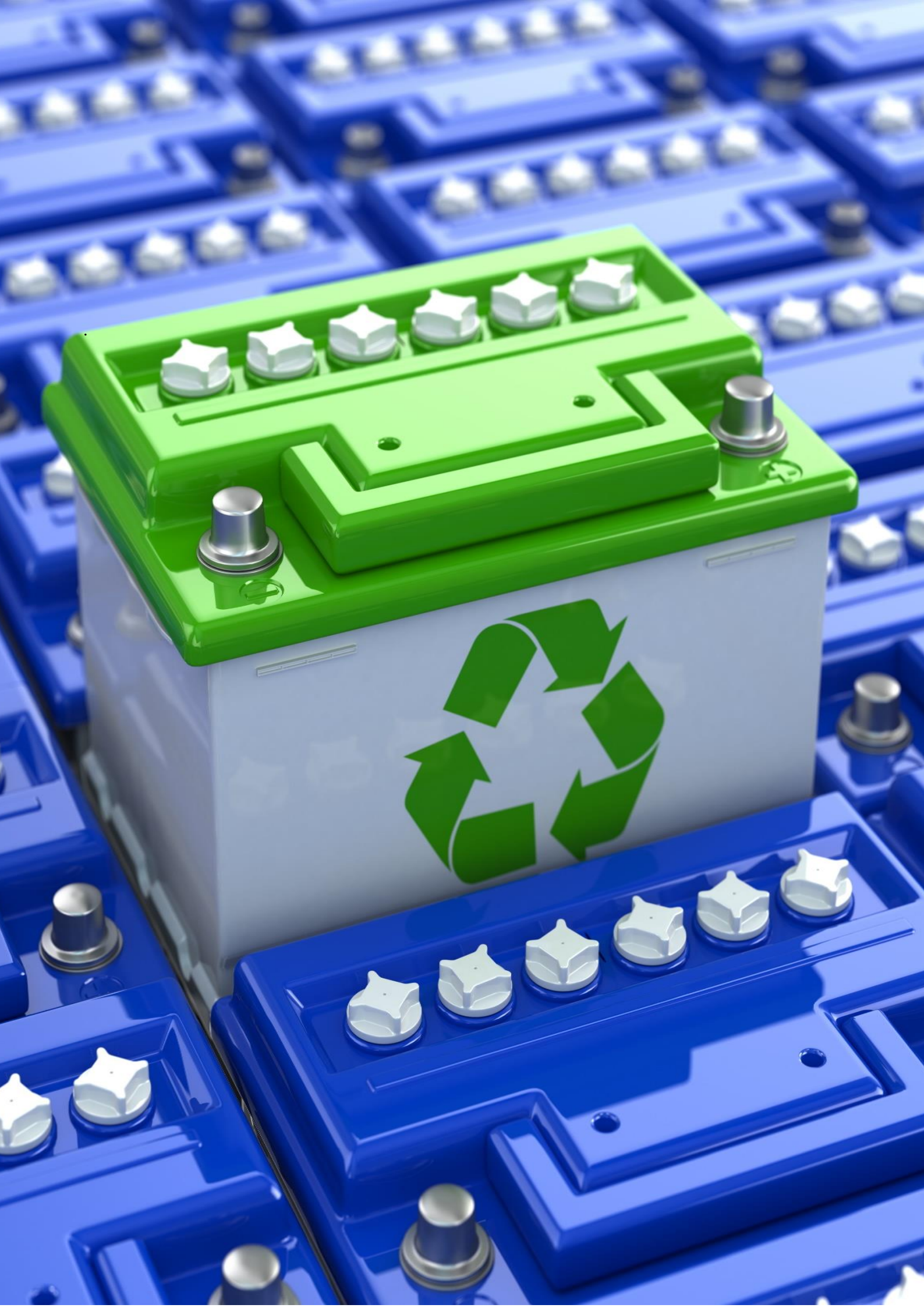
Another option to be considered in the Lao context, especially in view of the risks of theft and vandalism highlighted in the introduction, would be to locate the kiosks within the premises of selected government ministries, and limit the participants of the pilot project to selected civil servants.

3.4.3 IDENTIFICATION OF EARLY ADOPTERS

In order to ensure successful implementation, it is equally important to identify the entities willing to adopt E2W in their day-to-day operations, such as organizations operating large fleets of vehicles. Food delivery companies such as Food Panda, Go Teddy and Shopping D are among those which could benefit from incorporating E2W in their fleet for their businesses. These companies' business model is to cooperate with freelancers who own a bike and earn a commission for delivering orders to customers. With thousands of deliveries happening each day and every rider travelling 50-100 kms each day make E2W a lucrative proposition. Ride sharing and Mobility as a Service can make up a good model for these companies and their riders as the cost of ownership is less as compared to gasoline vehicle translating to cheaper cost per order and hence more profit per order.

Large fleet operators expressed strong interest for the project including the associated carbon emissions reductions, as some companies such as Food Panda have the ambition of reaching carbon neutrality in the near future. However, these companies do not own the bikes therefore innovative financing solutions must be provided to the riders. Food Panda is already testing such as scheme in Singapore where riders are incentivized to shift to E2W[7].

[7] https://sg.news.yahoo.com/foodpanda-offering-ebikes-to-its-escooter-riders-who-qualify-under-new-scheme-110925251.html



4 SUSTAINABLE BATTERY WASTE MANAGEMENT

4.1 GLOBAL REVIEW

4.1.1 EV SALES

The stage is set for the global automotive industry to experience an electric revolution driven by the central theme of decarbonizing transportation, both personal & commercial, in order to meet global targets of reduction in GHG emissions, carbon neutrality and to improve air quality.

Market growth is imperative for countries to achieve their 2030 targets. The GoL has set a target to achieve 30% penetration of EVs in the national mix by end of this decade. However, a growing number of EVs pose a major challenge for waste management at end-of-life.

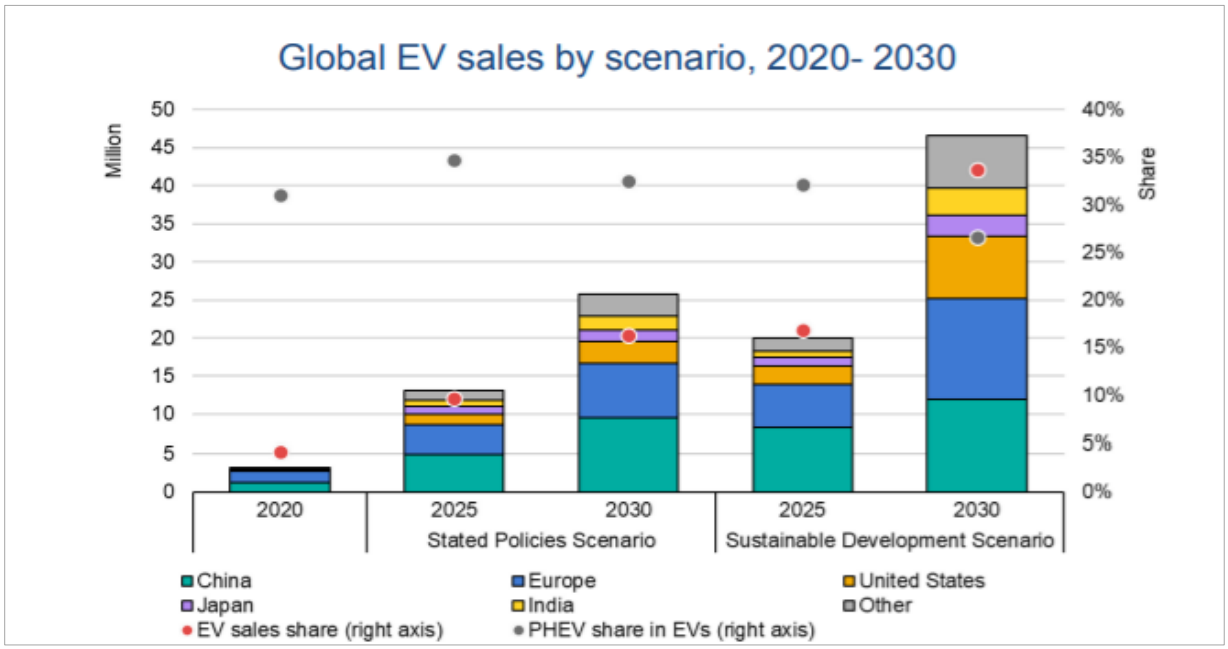


Figure 21. Projected country wise Global EV Sales

As per a report published by IEA, in a sustainable development scenario, there would be almost 70 million EVs on road globally by 2025 and 230 million by 2030. Annual EV sales would reach ~20 million by 2025 and ~45 million by 2030[8].

[8] https://www.iea.org/reports/global-ev-outlook-2021

Table 24. Projected annual EV sales by region breakdown (in millions)

Year	China	Europe	USA	Japan	India	Other	Total
2020	1.28	1.41	0.3	0.03	0	0.14	3.16
2025	8.27	5.68	2.34	1.2	0.84	1.65	19.98
2030	11.95	13.27	8.08	2.76	3.67	6.91	46.64

4.1.1 WASTE MANAGEMENT

An estimated 45 million EVs sold in 2030 could potentially lead to 11,250,000 tons of retired batteries by 2040, considering average battery weight of 250 kgs and average battery life of 10 years. Disposal of end-of-life batteries into landfills can cause fires due to defective or damaged cells resulting in leakage of toxic compounds into the environment. Instead, recycling can help take this load off the landfills and contribute to recover high value minerals such as Lithium, Cobalt & Nickel, thereby reducing the overall raw material demand, ensuring an alternative sustainable, stable supply chain, and reducing the carbon emissions resulting from extraction of such raw material for production of Lithium-Ion Battery (LIB).[4]

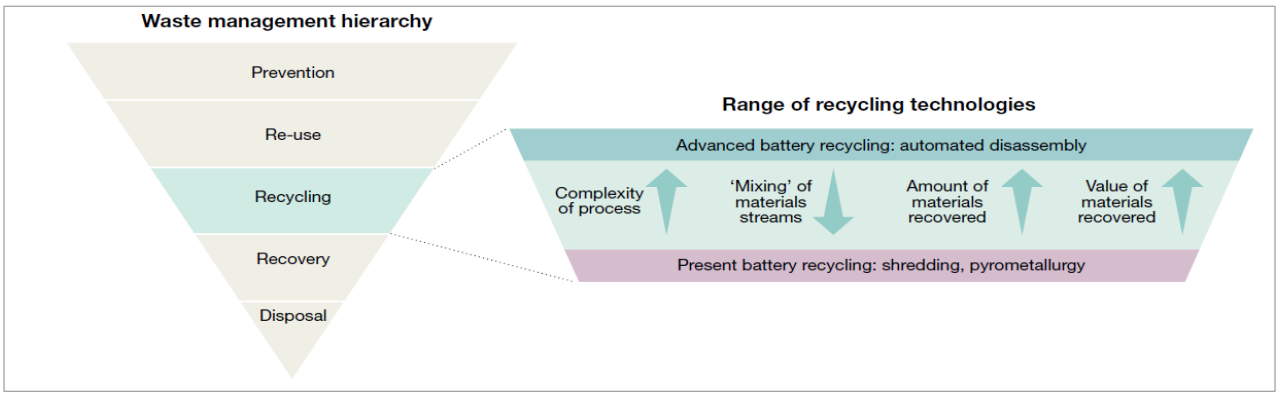


Figure 22. The waste management hierarchy

'Re-use' is preferred over recycling given a considerable value is embedded in the LIB. In order to optimize material, use and lifecycle impacts, a secondary or second use to these batteries should be arranged, such as for stationary energy storage applications. 'Recycling' means that batteries should be recycled, recovering as much material as possible and preserving any structural value and quality (for example, preventing contamination). 'Recovery' means using some battery materials as energy for processes such as fuel for pyrometallurgy (one of the recovery processes). Finally, 'disposal' means that no value is recovered, and the waste goes to landfill[9].

Recycling is the cornerstone of the overall sustainability of the EV ecosystem and it is essential for achieving the greater 'Net-zero' vision. A variety of minerals such as Aluminum, Cobalt, Copper, Graphite, Iron, Lithium, Manganese & Nickel is used in different types of LIB.

[9] https://www.nature.com/articles/s41586-019-1682-5.pdf?origin=ppub

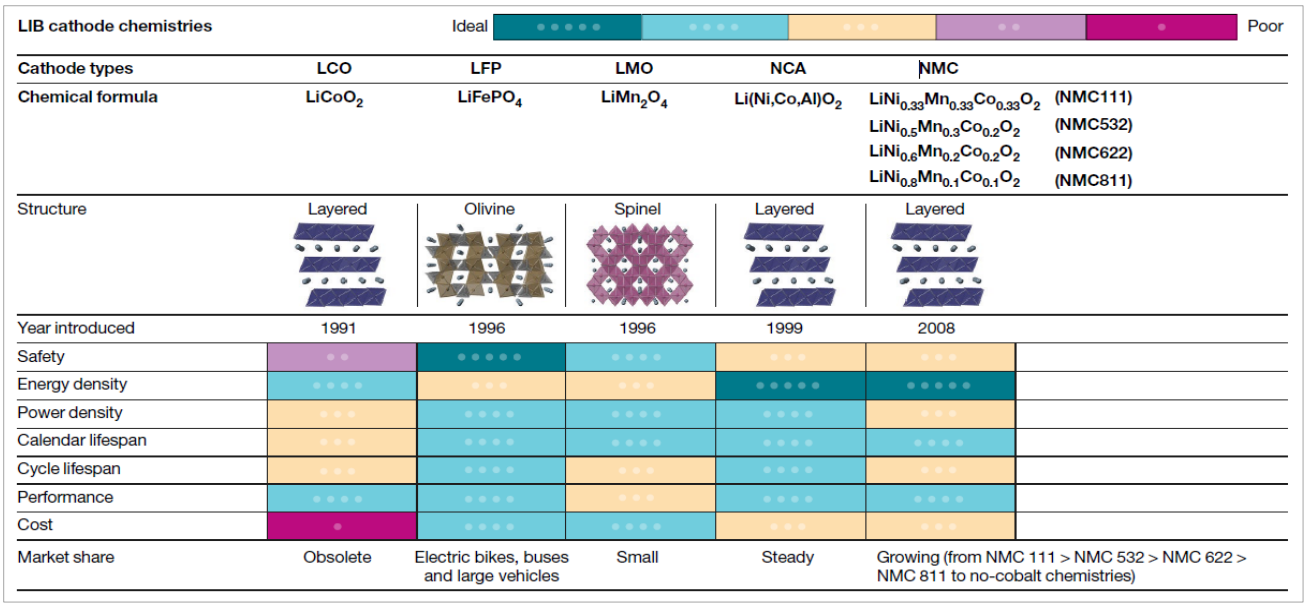


Figure 23. Types of LIB based on cathode chemistry

As per CNBC figures, owing to increasing demand for Li, Ni, Co and Cu, global Lithium-ion battery recycle market is projected to be a US$18.1B industry by end of this decade with countries such as China, US, Germany, UK currently at the forefront. Below figure illustrates the mine production for raw materials contained in LIBs worldwide and locations of a selection of LIB recycling facilities.

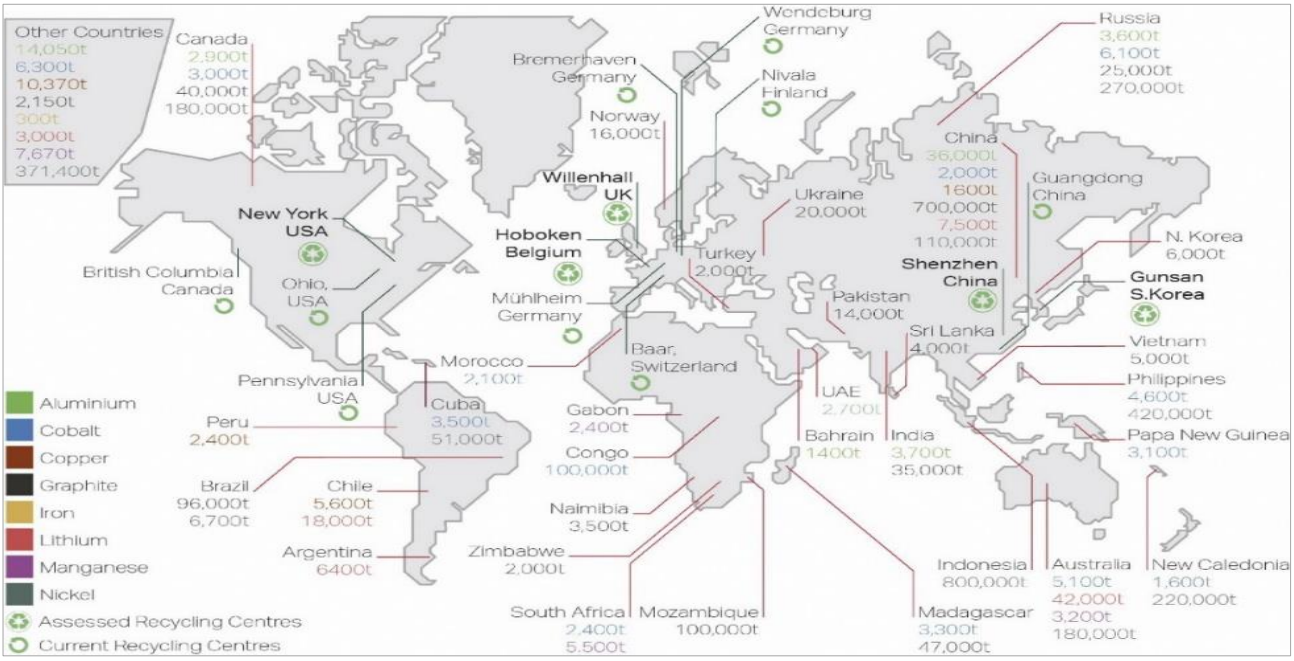


Figure 24. Glance at Lithium-Ion Battery recycling centers worldwide
Source: https://www.sciencedirect.com/science/article/pii/S2589004221007550

4.2 DRIVERS – BATTERY RECYCLING SYSTEM

4.2.1 VALUE CHAIN

Once any LIB reaches end-of-life it is transported to a recycling facility which may or may not be located in the city/country where the EV is sold. Once the drained batteries are collected at the recycling center they go through a variety of checks. It is at this stage where second use batteries are separated from the ones to be recycled.

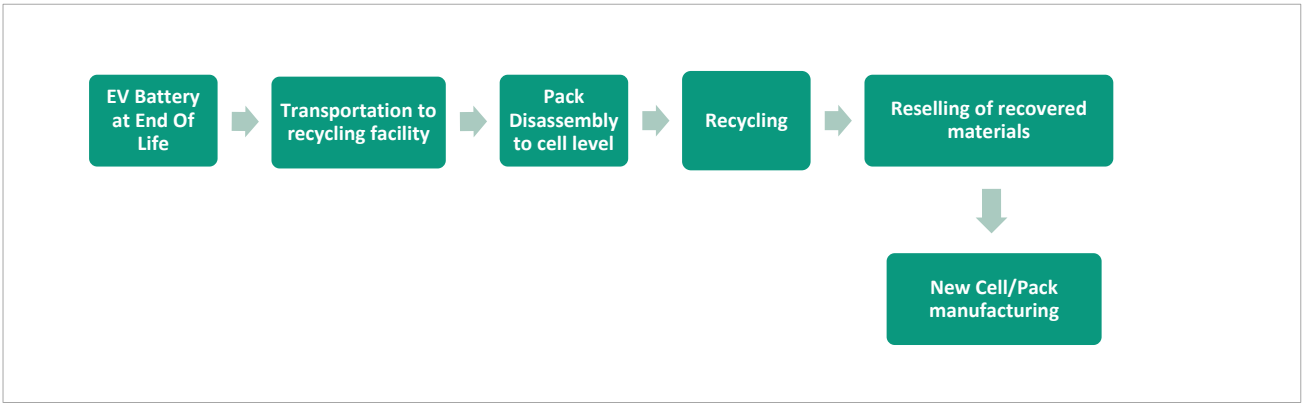


Figure 25. Steps involved in LIB recycling

It is at this stage where second use batteries are separated from the ones to be recycled. The recycled ones are pushed back into the ecosystem either by supplying the recovered minerals as raw materials to battery manufacturers or by re-packing the unused modules into new battery packs.

4.2.2 LIB RECYCLING PROCESS

a) **Stabilization**: This is achieved using either of the two – Brine or Ohmic discharge. This is an additional and an important step when it comes to recycling Lithium batteries from EV as compared to Lithium batteries from other sources such as electronics. Discharging of batteries before dismantling is required to avoid shock, probable short circuiting, and thermal runaway in cases.

b) **Opening**: This includes dismantling or disassembling of battery packs to at least module level in order to process further for either recycling or re-manufacturing. In order to minimize cost, in most cases stabilization and opening and are carried away together. This requires high-voltage training and insulated tools to prevent electrocution and short circuiting.

c) **Separation**: While minerals are recovered using chemical separation techniques such as Pyrometallurgy, Hydrometallurgy and bio metallurgy, other material such as steel, plastic and the likes are recovered through mechanical separation techniques (e.g., magnetic separation) after shredding or crushing of stabilized batterie

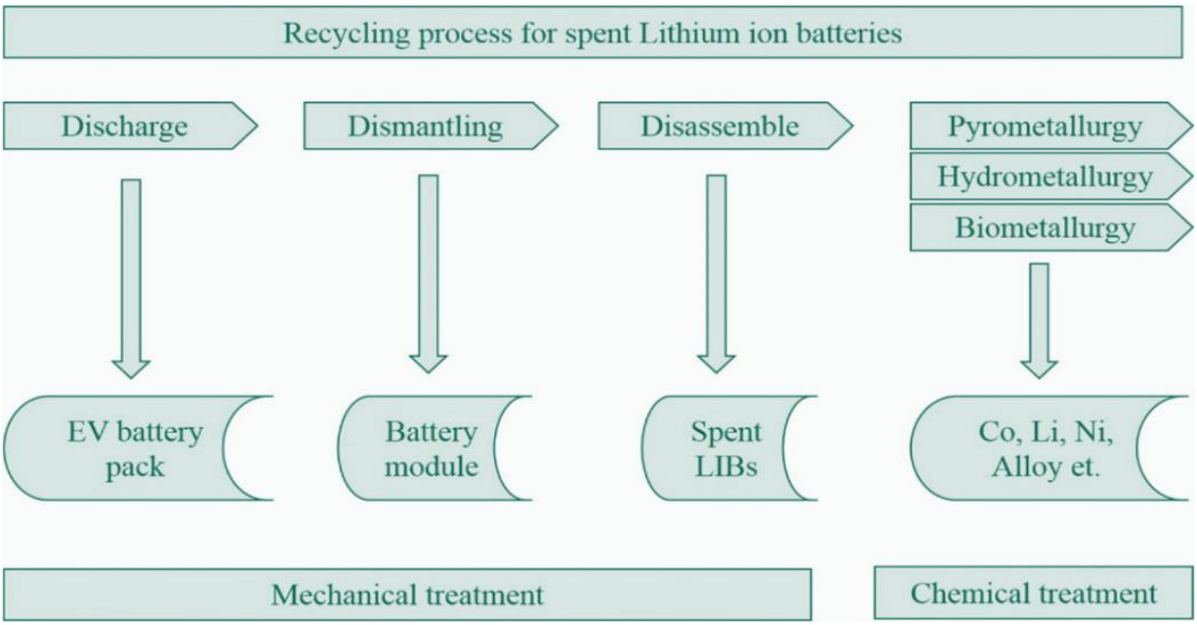


Figure 26. Comprehensive recycling process of Lithium-ion batteries

The above representation distinguishes mechanical treatment from chemical treatment during a recycling process. Mechanical treatment broadly entails dismantling the batteries and prepare them to undergo actual recycling or metal recovery process during the chemical treatment process which may vary as per the metal to be recovered or as per the suitability of the set up in place[10].

4.2.3 COST PARAMETERS

As per a report published by Roland Berger, taking assumptions based on volume OEM pack using NCM622, average recycling cost can fall anywhere between $1.09 - $1.59 per kg of battery pack. Estimated breakdown of the total recycling cost by stage is stated below:

Table 25. Estimated cost of LIB recycling

Cost Head	Cost (USD/Kg)	Percentage
Logistics & transportation	0.38	28%
Diagnostics & removal	0.31	23%
Mechanical separation	0.1 – 0.3	15%
Chemical separation	0.3 – 0.6	34%

In the current scheme of things, number of tasks are accomplished manually ranging from battery discharging to opening to separation making the entire process labor intensive. Hence, it can be deduced that countries with relatively lower labor rates (e.g. China - $3/hr) will incur a lesser recycling cost when compared to other countries (e.g. US - $20/hr). Also, as logistics & transportation constitute 28% of the total recycling cost which tells that companies exporting batteries to other nations for recycling will incur a higher total recycling cost when compared to companies manufacturing and recycling batteries within the country[11]. In order to set up a Battery recycling plant, following expense heads might be considered:

[10] https://www.sciencedirect.com/science/article/abs/pii/S0921344918301599

[11] https://www.rolandberger.com/en/Insights/Publications/Battery-recycling-is-a-key-market-of-the-future-Is-it-also-an-opportunity-for.html

Table 26. Cost heads for setting up a LIB recycling plant

Capex	Opex
Land or premise cost	Logistics or drop-off cost
Equipment & technology	Labour cost
License or permission fee	Utilities cost

4.2.4 POTENTIAL PARTNERS – BATTERY RECYCLING

China tops the ranking in terms of LIB recycling capacity globally catering to ~68% of the total demand followed by Europe catering to <5% demand. The major players of the LIB recycling industry are spread among three geographies namely North America, Europe, and Asia Pacific. Below is the list of 29 players along with their country names:

Table 27. List of major LIB recycling companies

No.	Company name	Country
	EUROPE	
1	Umicore	Belgium
2	Glencore International AG	Switzerland
3	Batrec Industrie AG	Switzerland
4	Duesenfeld GmbH	Germany
5	Accurec-Recycling GmbH	Germany
6	Euro Dieuze Industrie	France
7	NAWA Technologies	France
8	uRecycle Group Oy	Finland
9	Fortum	Finland
10	AkkuSer Oy	Finland
11	Ecobat	UK
	ASIA / PACIFIC	
12	TES	Singapore
13	GEM co Ltd	China
14	Contemporary Amperex Technology	China
15	Tata Chemicals Limited	India
16	Envirostream Australia Pty Ltd	Australia
17	Neometals Ltd	Australia
	AMERICAS	
18	Retriev Technologies Inc.	United States
19	American Zinc Recycling	United States
20	Battery Recycling Made Easy	United States
21	Metal Conversion Technologies	United States
22	OnTo Technology LLC	United States
23	SMC Recycling	United States
24	Redwood Materials, Inc.	United States
25	Li-Cycle Corporation	Canada
26	Lithion Recycling Inc.	Canada
27	Raw Materials C ompany Inc.	Canada
28	American Manganese Inc.	Canada
29	SITRASA	Mexico

A research conducted by 'Startup Insights' identified the top 5 players in the sector. Below comparison illustrates their unique capabilities.

Table 28. Top 5 LIB recycling companies

Name	Methodology	UVP
Li-Cycle Corporation, Canada	Hydro-Metallurgical Recycling	Best metal recovery method, Low cost
Lithion Recycling Corp., Canada	Direct Recycling of Cathodes	95% recovery of all LIB components
AkkuSer Oy, Finland	Curing Treatment Recycling	Easily scalable, High recycling efficiency
NAWA Technologies, France	Biological Recycling Technology	Reduced Pollution, Carbon sourced from Biomass
Duesenfeld GmbH, Germany	Electrolyte Recovery Method	Energy savings, Greater amount of raw material recovered

Different companies use different methodologies and sometimes different operational techniques in terms of either amount of material recovered through the recycling process or reduced emissions and energy consumption during the recycling process.

5 CONCLUSION

Battery swapping is a substitute to EV charging that involves switching depleted or discharged batteries for charged ones. Battery swapping helps in faster adoption of EVs as it reduces upfront cost of purchase for the end consumer by separating the vehicle and the battery. Battery in this scenario is usually owned either by the OEM or the operator. Battery swapping solution is particularly suited for smaller vehicles, such as E2W and E3W, which have lighter batteries when compared to E4W and heavy-duty transport vehicles. While there are a lot of benefits of battery swapping system over traditional EV charging, there are four major advantages: quick turnaround time, cost effective infrastructure, space-efficient and reduced upfront purchase cost.

This report outlines the results of the financial analyses (Phase-1 and Phase-2) developed around three key business models, i.e. ride sharing, Mobility as-a-Service and Battery-as-a-Service, identified with regard to battery swapping operations for E2W. Phase-1 financial model is developed considering a pilot project to be operated in the Vientiane City with 100 E2W, 20 swapping stations, and 300 batteries. Phase-2 model is developed considering the larger picture of supporting the GoL in achieving 5% of the overall 30% target of Electric Vehicles penetration including 2-wheelers and passengers' cars in national vehicles mix by 2030.

Phase-1 model is built considering a business percentage split of 30%, 40% and 30% among the three identified models i.e. BaaS, MaaS, and Ride sharing respectively. The model goes on to calculate the TCO (Total Cost of Ownership) of an EV in three scenarios i.e. one, when owned with a fixed battery, two, when owned without an onboard battery and third, when owned under MaaS model (vehicle leasing with BaaS). TCO is the lowest for EV with fixed onboard battery followed by EV without onboard battery and MaaS model respectively. Out of the three key business models, ride sharing model turns out to be the most profitable model followed by MaaS and finally by BaaS model respectively. Phase-1 model is proposed to be financed by means of Grant and Equity with a split of 50% each between the two instruments. Phase 1 model yields an equity IRR significantly above the recommended minimum benchmark as published by the United Nations. Project's performance may be monitored by collecting real time data around the operations such as the number of trips, number of swaps, utilization rate, maintenance turnaround time and similar data points. Analysis of such data points would help in establishing the success of the pilot and preparing roadmap with detailed list of challenges, lessons learned for scaled up implementation in upcoming phases across the city of Vientiane.

Phase-2 model is built considering a business percentage split of 50%, 20% and 30% among BaaS, MaaS and Ride sharing respectively. While BaaS model contributes to maximum revenue over first 8 years of operations followed by ride sharing and MaaS respectively, ride sharing leads the three in terms of revenue contribution when the entire duration (20 years) of the project is accounted for. Phase-2 model is built considering operations at scale. The project is proposed to be financed by a mix of Grant, Equity and Debt with a tentative split of 40%, 30% and 30% respectively.

For the purpose of project design close to 12 consultations of stakeholder were conducted, among a mix of manufacturers, operators, and entities which could be potential contributors or participants in the project. Several entities garnered their interest to get associated with the project. Detailed discussions should continue with these entities in line with the findings of the financial models and key challenges faced by these entities in coming forward and participating in the project.

Finally, the report highlights the key steps involved in the Li-ion battery recycling value chain, the techniques, and related costs. It is found that the major cost recycling a Li-ion battery is incurred at the chemical separation stage followed by cost of logistics and transportation.

ANNEXURE 1: STAKEHOLDER CONSULTATION

Name	Current Business	Potential role in the project	Advantages	Stakeholder concerns
Mini Big C	Supermarket/ Retail stores	Real estate infrastructure for setting up Battery swapping stations	High footfall Revenue sharing	Clarity on connection type Electricity charges Meter type Space requirement BSS specification
EV Lao	EV Chargers supplier	BSS equipment BSS Operator [Technology & Operations]	Experience in EVCI No challenge on investment front Network with Lao PDR government agencies	Approval from govt agencies (Ministry of energy and mines) Clarity from government on policy for investing into EV Charger/Battery standardization rules not yet approved from govt
Food Panda	Food delivery	Large fleet operator MaaS	Presence in 18 cities with 4000 freelancers in Lao PDR Aims to become carbon neutral by 2025	Absence of economical EV option for its riders

Go Teddy	Food and Parcel delivery	Ride sharing MaaS	Existing network of delivery partners in 4 cities Real estate opportunity with Go teddy partner restaurants for setting up BSS	EV cost of ownership for delivery partners Useful life (years) of EV in comparison to Gasoline bikes Availability of charging stations
Honda Laos	Honda Two-Wheeler assembler and distributor	E2W import BSS operator Ride sharing/Mobility-as-a-Service	Established brand for two-wheelers International presence	Support from government on legal aspects Policy on EV from Government No clarity on EV registration process Risk of theft
RMA group	Automotive	Battery OEM/importer BSS owner and operator Battery disposal and recycling	Experience in automotive domain Network with neighboring countries	No scrappage policy by Government yet Clarity on policy and framework Need bigger scale of business to be involved
Kolao group	Automotive after sales service	BSS operator Repair and Maintenance of EV and BSS Discharge battery disposal/ recycling Real estate for setting up BSS Staff for operating BSS	Existing experience in maintenance and repair Existing network of workshops Interested in pilot project	Clarity from Government on EV policy for manufacturers

Lai Lao Lab	Technology provider	Software development Digital marketing	Experienced in technology development Interested in the project Developed Lao's AI	Ready to develop technology if it gets required resources
FB Battery	Battery importer	Battery importer BSS operator	Experience in importing automotive batteries	Illegal activities across border to import batteries High import tax and VAT
Petrol Trading Laos Holding	Gas stations	Real estate infrastructure for setting up BSS	Existing network of gas stations High footfall Interested in the project	Standardization of EV charging adaptor
Shopping D	Ecommerce - Grocery delivery	Mobility-as-a-Service	Existing EV user Interested in pilot project	Battery durability After sales service
Yamaha (KP)	EV importer and Exporter	E2W for the project	80+ years of experience in automotive field	Awaiting instructions from mother company in Japan

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