POLITECNO DI TORINO

MASTER's Degree in AUTOMOTIVE ENGINEERING

MASTER's Degree Thesis

SMART BATTERY MANAGEMENT THROUGH POOLING AND SWAPPING: A BUSINESS CASE ANALYSIS FOR THE ITALIAN EV MARKET

Supervisors

Prof. FRANCO LOMBARDI

Dott. ALBERTO FAVETO

Dott. EMILIANO TRAINI

Candidate

PIETRO COZZI

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Abstract

Battery-swap technology has been on the market for years, but its potential has not yet been fully developed. The impact of this technology could be a turning point in the forthcoming environmental and sustainability problems in our cities.

The rapid growth of the electric car market is laying the foundations for a smart city, providing short-term solutions to reduce emissions, but what will happen in the long term? The following thesis aims at analysing the state-of-the-art technology and its possible applications in different contexts. The main body of the thesis will focus on the development of an innovative business model capable of making a long-term positive impact on the environment and the energy management of our cities.

In a plausible scenario in which electric vehicles are the major players in mobility, battery swap stations can create the basis for effective energy sharing. The mobility of the future will certainly have batteries as a major player, and the aim of this thesis is to show that it is possible to reduce their number and increase their efficiency, if they are controlled through an intelligent platform based on real-time data.

Summary

The market for electric vehicles (EV) is finally growing up to its promises. While sales and adoption increases, also the necessary infrastructure is built alongside. Conventional charging approaches are time-consuming and potentially damaging to the batteries used in EV.

Battery-swapping offers a technological alternative. However, the implementation in the market at scale is still not happening. The reasons may be related to the supply side (upfront cost, profitability) and to the demand side (adoption by customers, lack of knowledge).

This Master's thesis takes the initiative to study battery swapping from a venture perspective. After the analysis of the market realities, some innovative approaches are presented to improve the market success. The objective is paired with the use of proven academic methods to assess a potential venture's profitability.

For the analysis of the business model, the Business Model Canvas method was applied. This is a well-known technique formalised by Alexander Osterwalder and Yves Pigneur in 2010. It helps to visualise business models along nine main elements: Value Propositions, Customer Segments, Customer Relationships, Channels, Key Activities, Key Resources, Key Partners as well as Revenue Streams and Cost Structure.

The Canvas method allows defining the core parts of any business and connects the nine elements in a story-telling way. It is the basis for a more elaborate business plan writing or a deeper financial analysis.

In the business case analyses, multiple tools and methods have been used. Those include the queueing model to evaluate waiting times and capacity planning for the battery swap stations, the break-even method to calculate the point of profitability and simulation studies using MATLAB to estimate the efficiency of the battery swapping compared to regular charging.

After the presentation of the business model, three key customer segments are discussed. Those cover a wide spectrum of potential applications with different vehicle types and different customer accounts.

In the passenger EV segment, the most sold EV in Italy are considered. It can be shown that a single battery swap station can serve a high number of vehicles. When multiple brands are considered, a queueing model allows estimating whether a mixture of brands is not only possible but also profitable because it diversifies the utilisation and reduces the cost of the battery pool.

In the case of a public bus lane in Turin, battery swapping allows serving a given schedule with fewer buses. This is because it significantly reduces waiting times for the charge. With the heavy commercial vehicles, i.e. electric cargo trucks, modular batteries are examined. This leads to the observation that unused battery packs can be taken out to increase the vehicle's efficiency. Alternatively, a replaced battery pack extends the range of the cargo truck.

The main innovation is inviting customers to join a commonly managed battery pool. This reduces upfront investment cost and allows an optimised management of the battery life cycle.

The total investment for the studied venture adds up to approx. 1.2 million Euro and promises two-digit million revenues after five years of operation. The break-even point should be achieved in the third year of full operation.

This thesis provides insights into the potential and attractiveness of battery swapping as a generally future-oriented technology. The practical relevance is shown and connections to academic and venture investigations are presented.

The work also lays the foundation for the creation of a spin-off of the Polytechnic university in the field of smart battery swapping. It provides a solid foundation to engage in a proper business plan writing and initiate a capital raise round.

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Infine, dedico questa tesi a me stesso, con la speranza che il bambino che vive in me non smetta mai di sognare.

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Acronyms

BaaS
: Battery as a Service

BEV
: Battery Electric Vehicle

BMC
: Business Model Canvas

BMS
: Battery Management System

BMU
: Battery Monitoring Unit

BNEF
: Bloomberg New Energy Finance

BSS
: Battery Swap Station

CEO
: Chief Executive Officer

CTO
: Chief Technology Officer

EV
: Electric Vehicle

GDP

Gross Domestic Product

HEV

Hybrid Electric Vehicle

kWh

KiloWatt-Hour

KPI

Key Performance Indicators

LAMEA

Latin America, Middle East, and Africa

MaaS

Mobility as a Service

OEM

Orginal Equipment Manufacturer

PHEV

Plug-In Hybrid Electric Vehicle

SLI

STarting, Lighting, and Ignition

SWOT

Strengths Weaknesses Opportunities Threads

USP

Unique Sales Proposition

Chapter 1

Introduction

1.1 Motivation: The Future of Mobility is Electric

When we look at our cities today, emissions, congestion, and safety are among the major issues. If the status quo persists, mobility challenges will escalate as population and GDP growth result in increased car ownership and mileage. In response, the mobility industry is unleashing a dazzling array of innovations designed for urban roads, such as Mobility as a Service (MaaS) and advanced traffic management as well as parking systems, sharing solutions and new two- and three-wheeled transport concepts (known as micromobility).

The current possibility of transforming the way we travel is fundamentally the result of changes in three main areas: regulation, consumer behavior, and technology.

Regulation: Governments and cities have introduced regulations and incentives to accelerate the shift to sustainable mobility. Further, regulators around the globe are setting stricter emission targets.

Consumer behavior: Consumer behavior and awareness is shifting as more people accept alternative and sustainable modes of mobility. Downtown travel with bicycles and electric scooters increased by 60 per cent year-over-year . In addition, consumers are becoming more open to shared mobility options.

Technology: Industry actors are accelerating automotive technological innovation by developing new concepts for connected, autonomous, shared and electric (CASE) mobility. The industry has attracted more than $400 billion in investment over the last decade, including approximately $100 billion since early 2020. All this money will cut electric vehicle costs and make shared electric mobility a true alternative to owning a car.

The tipping point in the adoption of passenger electric vehicles (EV) occurred in the second half of 2020, when EV sales and penetration accelerated in major markets; a development observed despite the economic crisis caused by the CoViD-19 pandemic. In Europe, adoption of EV has reached 8% as a result of policy mandates such as stricter emissions targets for Original Equipment Manufacturers (OEM) and generous subsidies for consumers. Consumer mindsets have also shifted toward sustainable mobility, with more than 45 percent of car customers considering buying an EV.

The one thing that will tip the balance in this new scenario is the evolution of the EV battery. The problems of 'range anxiety' and 'long recharging times' will soon be seen as a relic of the past as batteries evolve technologically. The demand for better and cheaper EV batteries is creating a new gold rush as university research teams, start-up companies and car manufacturers investigate exciting new technologies and rush to meet demand. The goal is to develop improved EV batteries that charge faster and last longer while switching to less expensive and more environmentally-friendly materials.

Let's now have a look at the current e-mobility numbers in the global and Europe market putting some attention on the Italian perspective. More and more vehicles with electric drive trains are coming onto the market worldwide (compare Tab. 1.1. According to [1], the total number of EV worldwide can be estimated at approx. 10 million vehicles. In absolute numbers, the most electric cars are in China (4.2 million), followed by Europe (3.2 million) and the US (1.7 million).

Country/ Region	**Total EV**	**per 1,000** Inhabitants	**BEV proportion of new EV Registrations**
World	9,880,526	1.4	68%
China	4,190,273	3.0	80%
Europe*	3,201,644	6.1	54%
USA	1,700,825	5.2	79%
Germany	702,981	8.5	49%
UK	447,486	6.7	61%
Norway	433,609	81.0	73%
France	413,212	6.4	60%
Sweden	212,477	20.6	30%
South Korea	152,652	2.9	66%
Italy	100,680	1.7	54%
Greece	3,410	0,3	31%

Table 1.1: Electric Vehicle Statistics in 2020. Source: [1]. *Note: EU+EFTA, incl. UK

The differences in market development between continents became especially clear in 2020. In absolute numbers, Europe registered the most new EV then, with a total of 1,368,167 vehicles. As a result, it overtook China (1,246,289 cars) for the first time. In retrospect, European sales more than quadrupled during the five years to 2020. With a total of 302,929 new vehicles registered over the past year (2019: 321,702), the US took third place.

If we count the number of EV per 1,000 inhabitants, Europe also leads the way. Statistically, there are 6.1 EV per 1,000 European inhabitants, compared to the global average of 1.4. The figures for international leaders Norway (81.0) or Sweden (20.6) are significantly higher VDA, 2021). These examples illustrate how the European market is now setting the pace internationally for the development of e-mobility.

Europe is leading the way, and Italy is on track to achieve double-digit market share for plug-in vehicles, after steady monthly growth and record registrations at the end of the quarter. The latest UNRAE data from June 2021 provide a new boost to electric cars.[1] While the effects of the pandemic are slowly fading and government incentives are bridging the price gap between technologies, electric mobility is booming in the previously inactive Italian EV market. Electric cars registered 30,384 cars in the first half of 2021 alone. During the same period, sales were more than three times higher.

Looking in detail at sales on the Italian market, the *Fiat 500e* proves the need to be the annual best-seller with more than five thousand registrations in the first half of the year and forecasts of reaching ten thousand units by the end of the year. The second place in sales goes to the compact Smart ForTwo, which has sold 3,500 units. It is followed on the podium by the *Renault Twingo ZE*, which could prove to be the surprise of the Italian market, following the performance of the *Renault Zoe*; this model had dominated the market in recent years. It emerges from these figures that the race for electromobility is currently won by the cars of the A-segment.

So the trend for car companies and the market is clear: EV are the solution. In a market that wants to recover from the stagnation caused by the pandemic crisis and delays in logistics and materials for production, it will be essential to rely on the choice of new business models that capture the new dynamics of the market and its new needs. The state of technology allows us to be ready for major socio-economic changes.

Considering successful trends, the most disruptive business models are often those that are customer centred. New technologies have changed customer behaviour,

[1] UNRAE is the National Union of Foreign Motor Vehicle Representatives. This is an association of foreign car manufacturers operating in Italy in the distribution and marketing of vehicles and their parts.

and so this change also enables models that meet these needs. Subscription models, platforms, digital ecosystems and much more are worth noting. Disruptive business models are a form of disruptive innovation that brings a new idea or technology to an existing market. Disruptive market entrants usually capture unmet demand in the existing market. This can be either low-end or high-end pent-up demand, where they target the most price-sensitive or important customers.

The focus of this thesis lies at the intersection of the ongoing EV trend and a customer-oriented business innovation. It addresses a potential, specifically for the Italian market, to make electric mobility sustainable and profitable by implementing a battery-swap business model. By the end of the thesis, the reader shall be informed about the feasibility of this approach with a balanced discussion of promises and potential limitations.

1.2 Structure of the Thesis

The thesis follows the typical line of a coherent, academically oriented presentation. It is not designed to serve as a business plan or alike. Rather its goal is to provide a profound basis for a more elaborated business plan in the future. The core of the present thesis is addressing the following two research questions:

i *How does a battery-swap approach to e-mobility compare to (fast-)charging in terms of efficiency and cost?*

ii *What is a feasible business model including a road to implementation for such a battery-swap venture?*

To answer those questions, Chapter 2 discusses the state of the art of the technologies relevant to battery electric vehicles. This includes a summary of the charging of EV and a description of the battery swap approach. A discussion of examples will facilitate understanding the current market situation. Afterwards, Chapter 3 completes the theoretical background of the thesis with a comprehensive presentation of the Business Model Canvas. This provides the necessary background to discuss the feasibility of a battery-swap venture.

The actual discussion of the business model for the new venture follows in Chapter 4. This includes the systematic analysis of all nine components of the business model canvas and a general evaluation of the business model. To evaluate the profitability and investment needed, the business cases are subsequently analysed in Chapter 5. This also includes the calculation of the break-even cases to bring the venture into a situation of sustainable profitability.

The thesis closes with a discussion in Chapter 6. The focus is put on the implementation of the business model with the investment demand and a strategy. A brief financial analysis provides the framework to finally evaluate the venture's feasibility. Then, the outcome is discussed with respect to the general and current expectations towards the sustainability of the business. The conclusion in Chapter 7 summarises the main results and sheds light on the limitations of the studies. Last, an outlook for continuing academic work and practical implementation is given.

Chapter 2

State-of-the-Art Technologies

2.1 Electric Vehicles Batteries

To power the engine of EV, we need to get in touch with batteries for electric vehicles. They can also be used to power a hybrid (plug-in) vehicle. EV batteries are rechargeable and usually those batteries that use lithium ions. They are specifically designed for a high kilowatt-hour (kWh) capacity. Unlike conventional, they are used to supply energy over longer periods of time and are therefore so-called deep-cycle batteries (Arora et al., 2021).

A battery is characterised by its specific energy, energy density and power-to-weight ratio. Looking at these characteristics, batteries with a high energy density and a very high power-to-weight ratio are preferred for EV. This allows us to say that small, lightweight batteries are preferable as they reduce the weight of the vehicle and improve its performance.

In view of the normal arrangement of battery packs in cars currently on the market, it can be seen that they greatly influence the distribution of weight on the vehicle, affecting the vehicle's dynamics and safety.

If we compare today's batteries to normal fossil fuels, they have a much lower specific energy as petrol, the most commonly used fossil fuel in internal combustion engines. Petrol contains 46.7 MJ/kg (13 kW/kg), which is 35 times the energy of the best lithium battery (Hore-Lacy, 2007). Compared to liquid fuels, most current battery technologies have a much lower specific energy, and this often has an impact on the maximum all-electric range of vehicles.

The most common battery types in modern EV are lithium-ion and lithium-polymer, due to their high energy density relative to their weight.

The use of lithium batteries was initially developed for the market of laptops and consumer electronics. Given the high density and long cycle life, they were then adopted for the use of batteries in electric vehicles. There, the ability to be charged and discharged on a daily basis and at each state of remaining charge has become a major reason for adoption.

There is no shortage of issues with this technology as traditional lithium batteries present a high risk if punctured or improperly charged. Also, they come with substantial performance issues in some environments, such as low temperatures. Newer batteries used in EV feature new lithium-ion variants that make the battery more fire resistant and more sustainable, but with lower specific energy. However, they allow for longer battery lives and very fast recharging. An overview about the current state of lithium-ion batteries can be found in [4].

The pressing demands of the market have produced an advancement not only in lithium-battery technology but also in promising alternatives such as Structural Component Batteries.[1] These batteries have the ultimate goal of making the overall vehicle lighter as the battery becomes a structural component of the car. This is made possible by the use of carbon fibre as the negative electrode and lithium iron phosphate as the positive electrode.

Another alternative are the Carbon nanotube electrodes batteries. This is one of the most promising technologies in the near future, with the use of ultrafast carbon electrode. Vertically aligned carbon nanotubes could lead to a substantial increase in the power and energy stored in these batteries. The technology was patented by [5] and could be in use from 2023 with extremely short charging times compared to the rest of the available technologies.

Of the total final price of an electric vehicle or a hybrid vehicle, the battery pack constitutes the largest share. Although since 2010 the cost of the battery pack per kW has decreased by more than 80% (see Fig.2.1), it remains the single cost component that influences the choice of consumers at the time of purchase the most.

Internal components

On the market, battery pack designs vary depending on the manufacturer and the specifications of the segment, in which they are used. Hereby, complexity is the main factor reflecting a lack of standardisation. However, each battery pack consists of simple elements essential to the battery's function. Battery chemistry, physical shape and size may vary, but each battery pack is normally composed of

[1] `https://www.greencars.com/guides/the-future-of-ev-batteries`.

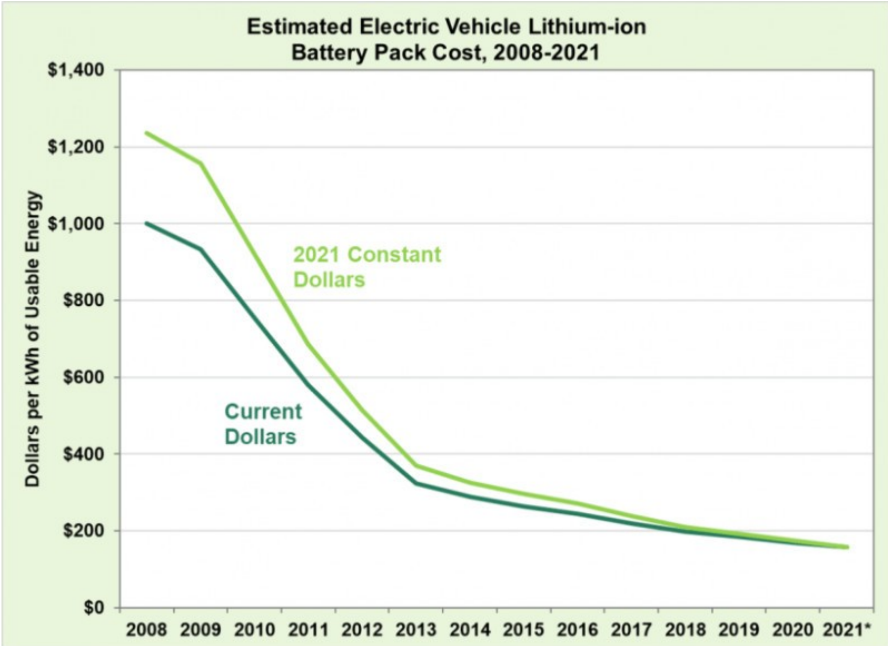

Figure 2.1: Development of battery cost. Source: `https://www.hdmotori.it/auto/articoli/n545179/riduzione-prezzi-batterie-auto-elettriche/`.

a combination of multiple cells.[2] Those are connected in parallel or in series to achieve the voltage and current required by the battery pack.

According to [6], there can be several hundred cells in a pack with each cell having a nominal voltage of 3-4 V depending on its chemical composition. In order to facilitate manufacturing and assembly, the cells are grouped into stacks and these are then assembled into modules. Each module is then assembled with other modules to form a single pack. The cells of each module are soldered together to allow current flow.

The modules also in most cases incorporate cooling and temperature monitoring systems, as the temperature must remain within a certain range for each cell type in order to achieve maximum performance. The most advanced systems also allow the voltage produced by each individual cell to be monitored. This allows precise identification of possible performance losses in the pack.

Further important elements of the pack are the fuses that limit the current circulating in the pack in the event of a short circuit. However, there are also relays

[2]`https://www.dmcinfo.com/latest-thinking/blog/id/9969/everything-you-need-to-know-about-ev-battery-and-bms-testing-in-validation-and-production-scenarios`.

in order to control the distribution of electrical power to the output terminals of the pack.

Finally, in the battery packs we find temperature, current and voltage sensors, all monitored by the Battery Management System and its battery control unit, which is responsible for initiating information with the vehicle.[3]

Battery cost

In 2010, the cost per kW of battery supply was around $400. At the same time, only two of the 15 manufacturers on the market were able to issue the necessary technical documents for fire safety and quality (Bredsdorff, 2010). The cost reduction we see on the market today is due to technological advances that go hand in hand with the current spread of the technology. However, the subject of the real cost of battery packs remains a delicate topic as manufacturers refuse to release much information on the subject.

Compared to conventional car, EV cars are usually more expensive to purchase in the beginning, but cheaper to operate and maintain. Following [8] the total cost of ownership can be lower than the one of internal combustion vehicles, depending on the utilisation of the car.

According to estimates published by [9] in 2017, EV had become truly competitive in terms of purchase price in 2017, when the cost of the battery pack became $100 per kW. In any case, the battery remains the most significant cost component in EV. Managing its life cycle well is definitely in the interest of every EV owner.

2.2 Battery Swap

Reducing charging times, making up for inadequate infrastructure, and decreasing charging costs are the main goals. of battery swapping in general. Its original mission was thought to revolutionise the use of EV.

Following the exemplary description of [2], a battery swap station is a place, where an EV can be driven to and where an automated, robotic system can open the bottom of the car, where the battery is housed, remove it, and replace it with a new one. This replaced battery is fully charged and, hence, ready for use.

This station for exchanging the battery is referred to as a battery swap station (BSS). It can be described as a mechanical robot capable of implementing a full charge on an electric vehicle in less time than normal charging times. For an illustration of such technology, see Fig. 2.2.

[3] `https://www.dmcinfo.com/latest-thinking/blog/id/9969/everything-you-need-to-know-about-ev-battery-and-bms-testing-in-validation-and-production-scenarios`.

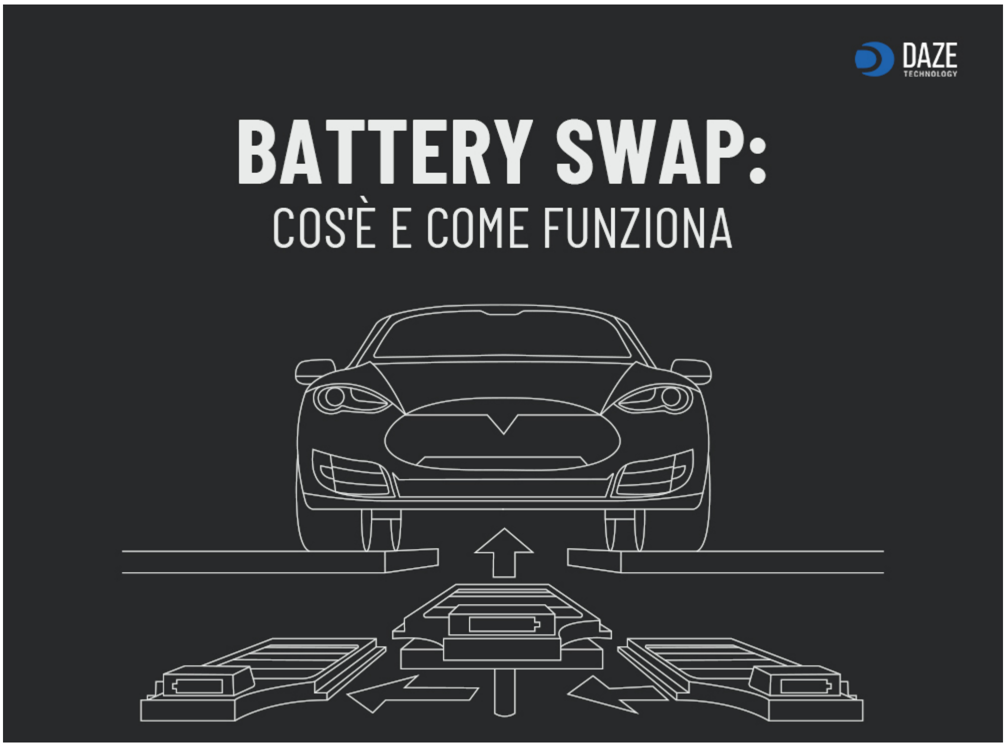

Figure 2.2: Illustration of a Battery Swap System for Electric Vehicles.

This technology is the only current solution whereby an electric vehicle can be charged super fast and compete with the refuelling times of internal combustion cars. In order to use this technology, the vehicle must be designed in such a way that it can be opened from the bottom quickly using bolts and also be closed again. This requirement explains that the lack of standardisation of vehicles and their components, such as the battery pack, is one of the biggest delays in adopting this technology.

The time to perform a battery exchange in a BSS is estimated to be less than 10 minutes from the moment the vehicle enters the station to the moment it leaves the station again (Arora et al., 2021). In addition, the floor space occupied by this station is smaller than that occupied by a normal charging station.

In order to implement this technology, the battery swap company normally offers battery-as-a-service (BaaS). This reduces the high initial price given to EV, thus separating the cost of the vehicle from the cost of battery ownership. In doing so, the customer does not only reduce the downtime of normal charging, but also pays only for the energy they use.

Three factors are expected to foster the growth of the battery swap market. First, it will be driven by the growing market for EV in general. Even more, it benefits from the still underdeveloped public charging network. Third, its most convincing argument is the effective reduction of charging times. However, there are obstacles such as the lack of standardisation and the operational cost of developing this technology (Arora et al., 2021).

The market of BSS can be split based on region, vehicle type and service offered. It is segmented in North America, Europe, Asia-Pacific and LAMEA (Latin America, Middle East, and Africa). The split by vehicle type yields the categories of Two-Wheeler, Three-Wheeler Passenger vehicle, Three-Wheeler Light commercial vehicle, Four Wheeler Light commercial vehicle, Buses, and Others. In the end, the service type offered distinguishes pay-per-use and a subscription model.

The companies that are operating in the electric vehicle battery swapping market include Ample, Amara Raja, Amplify Mobility, ChargeMYGaadi, EChargeUp solutions pvt Ltd, Esmito Solutions Pvt Ltd, Gogoro, Inc., Lithion Power Pvt Ltd, NIO, Inc., Numocity and Oyika Pte Ltd.

Rising carbon dioxide emissions and the resulting climate problem have prompted major governments to use strict regulations that are driving the adoption of EV especially in developed regions such as North America and Europe (Arora et al., 2021). However, the time factor becomes a significant element in the adoption of EV, where most EV employ a slow charging system to recharge the battery. Batteries are then charged up to 8 hours by on-board chargers that recharge the vehicle at the rate of 2.5-3 kW per hour.

Battery swapping technology plays a vital role in eliminating these (perceived) charging problems and through this may even help alleviating the "range anxiety" phenomenon. Therefore, the implementation of battery swapping reduces the charging time for EV, which in turn drives their market growth.

Table 2.1 below summarises strengths and weaknesses of the battery swap technology.

2.3 Companies and Approaches

2.3.1 Better Place

Better Place was born in Israel from an idea of its founder Shai Agassi.[4] It was created as a solution to the electrification of cars, as the company's goal was to offer electricity and battery recharging as a service to customers. At the same time,

[4] `https://www.inc.com/kathleen-kim/better-place-ceo-steps-down.html`.

Pros	**Cons**
+ Reduction of the recharging time up to 80% with respect to fast charge and up to 95% for slow charge + Reduction of the placing space for the recharging infrastructures + Possibility to use renewable energy from the power grid + Safe management of the battery recharging cycle + Cutting cost of the electricity	- Fragmentation in battery technology and design - High initial set-up and operating cost of battery swapping

Table 2.1: A Summary regarding Battery Swap Technology. Source: Own elaboration.

they were targeting retaining ownership of the batteries. In other words, they were riding the wave of BaaS and significantly lowering the purchase price of EV Budde Christensen et al., 2012).

Thanks to the skill of its founder, Better Place was able to acquire a huge amount of funds, about 900 million dollars from investors, needed to develop the technology. The main assumption made by Better Place was that a customer, who does not own his own battery, does not care if it is exchanged several times by mechanical robots. This assumption, given the premature of their venture start, turned out to be wrong. The obstacles to taking on the service, however, just came later.

The company's main problem in the first place was convincing car manufacturers to design cars that could take advantage of the technology. This led to Better Place having a limited market offering in Israel, with only Renault willing to cooperate. In 2011, the collaboration with Renault led to the Fluence Z.E. model, an electric sedan with an 80-mile range. There, the boot was reduced by the vertical battery pack.

Performance in terms of capacity was still remarkable, with the ability to add 80 miles to an electric car in just 10 minutes compared to hours of charging. Better Place then expanded to Denmark, believing that the green mentality of potential Danish customers would increase the uptake of the technology. This assumption also failed to materialise later. Finally, this led to Better Place's implosion.

In total, Better Place sold less than 1,500 electric Renault cars before being liquidated.

From today's perspective, Better Place had significant strengths but failed in a variety of aspects. Table 2.2 summarises their situation regarding the company

Figure 2.3: A Better Place battery swap station. Source: `https://www.inc.com/kathleen-kim/better-place-ceo-steps-down.html`.

itself but also their customers.

	Strengths	**Misconception**
Company	-Electricity and battery service Manage the state of the battery -Owned battery -Cut electricity cost -Renewable resource	Poor timing and environmental choice -Convince auto maker to enable battery swap -Cost of the station
New Customers	-Offering battery as a Service (cutting upfront price for operating EV) -10 minutes recharge -Cost of energy per kilometres/miles -Renewable resource	-Dealing with two different entities, one for the car and one for the battery -Cost of station

Table 2.2: Evaluation of Better Place's performance. Source: Own elaboration.

2.3.2 Ample

Ample is an American company that offers a new way to recharge EV.[5] Their proposal is the ability to quickly replace modular battery packs through their swap station.

Ample's system is less expensive, has more flexibility and is basically aimed at commercial fleets and taxis. It does not target average owners or drivers. The company currently claims a partnership with 5 OEM with a total of 9 different EV, on which to adapt its modular battery packs. The other claimed strength is its low-cost, low ground occupancy and quick-to-mount stations.

Ample solves the problem of range anxiety with "recharges" that take as long as a full tank of fuel. Effectively, Ample solves this perceived problem by focusing on vehicle fleets. The driving of the fleets is planned and therefore allows the swapping service to be customised according to the operational needs of the fleet itself. Even greater advantages are given by the local area, in which they operate.

Ample's stations are installed on a space equivalent to two parking spaces in a normal car parking slot. The machines are then lifted into the station and the various standardised 2.5 kwh modules are installed. The stated time is 10 minutes to replace 20 modules.

The cost claimed by Ample for its stations is about 1/10 to 1/3 of the price of a high-power DC fast-charging station. The modularity of the station also offers the possibility of slow charging for the modules, ensuring a lower price and greater attention to performance and module life.

Let us now have a closer look on how Ample actually works.

- It is faster thanks to the possibility of a modular exchange. Complete recharge in less than 10 minutes is possible.
- It is potentially suitable for every vehicle. Car manufacturers do not need to redesign their cars to work with the Ample technology
- An Ample station is cheaper than a fast-charging station. It is cheaper to build and cheaper to install. Therefore, Ample can provide energy at a cost that is 10-20% cheaper than gas.
- They achieve a high speed of network assembly. Ample stations are lightweight and no specialised construction is required.
- The stations use renewable energy such as wind and solar when available

[5] www.ample.com.

- They pursue a continuous implementation of the best battery technologies available in the market.

2.3.3 NIO

NIO is a Chinese multinational company founded in 2014 by William Li.[6] The first model produced by Nio was the NIO EP9 sports car, which actually made its market debut on the same day the brand was established. In 2018, NIO entered the battery swap market by opening its first "Power Swap Station" in Guangdong, China. Two years later in 2020, NIO launched Battery as a Service (BaaS), which lowered the purchase price of its vehicles by 25%.

In 2021, NIO announced plans to expand into the Norwegian market. This was an escalation in terms of numbers and sales for the future Chinese giant in which several companies have invested such as Tencent, Temasek, Sequoia, Lenovo and TPG. The growth of the Chinese market and the integration of vehicles and BSS made NIO one of the leading companies in the market segment. However, it will have to contend with the lack of standardisation on the part of European and American customers, unlike the domestic market.

Although highly automated, NIO's stations require a physical operator to monitor operations. Each battery removed goes through a thorough performance inspection before it can be passed on to the next step for recharging, before eventually being swapped again. The stated swap time is 3 minutes.

NIO offers a free swap service for life for its customers. 135 states are installed in China as of June 2020. 500,000 swaps have been reported to date, far more than the 10,000 reported by Better Place.

After having reviewed the technology and discussed relevant market examples of battery swapping, we are now ready to look at the business model foundations.

[6] www.nio.com.

Chapter 3

Business Model Canvas

The theoretical basis for the development of the service innovation is a well-known to from the innovation management literature. Its foundations and its meaning will be discussed along that chapter. At the end, the reader is prepared for the subsequent application of the battery swap case at hand.

3.1 Origin and Concept

The Business Model Canvas (BMC) as it is known today goes back to the work of Alexander Osterwalder. Alex Osterwalder is a Swiss business theorist and entrepreneur who invented the canvas as part of his Ph.D. research. The Business Model Canvas is a strategic management template that helps businesses to describe, design and analyse their business models. It was developed in the book entitled "Business Model Generation", co-written with his graduate supervisor Yves Pigneur (Osterwalder and Pigneur, 2010).

The BMC is applicable not only to whole businesses but also to business units, projects, and even new ventures. It combines simplicity in design and power in impact and is therefore the tool to be chosen within this thesis.

The template is presented in the form of a visual chart describing an organisation's value proposition, infrastructure, clients, market and finances. The Model is made up of nine so-called building blocks: customer segments, value propositions, channels, customer relations, revenue streams, key resources, key activities, key partnerships and cost structure. The best-known visual representation of the BMC is presented in Fig. 3.1.

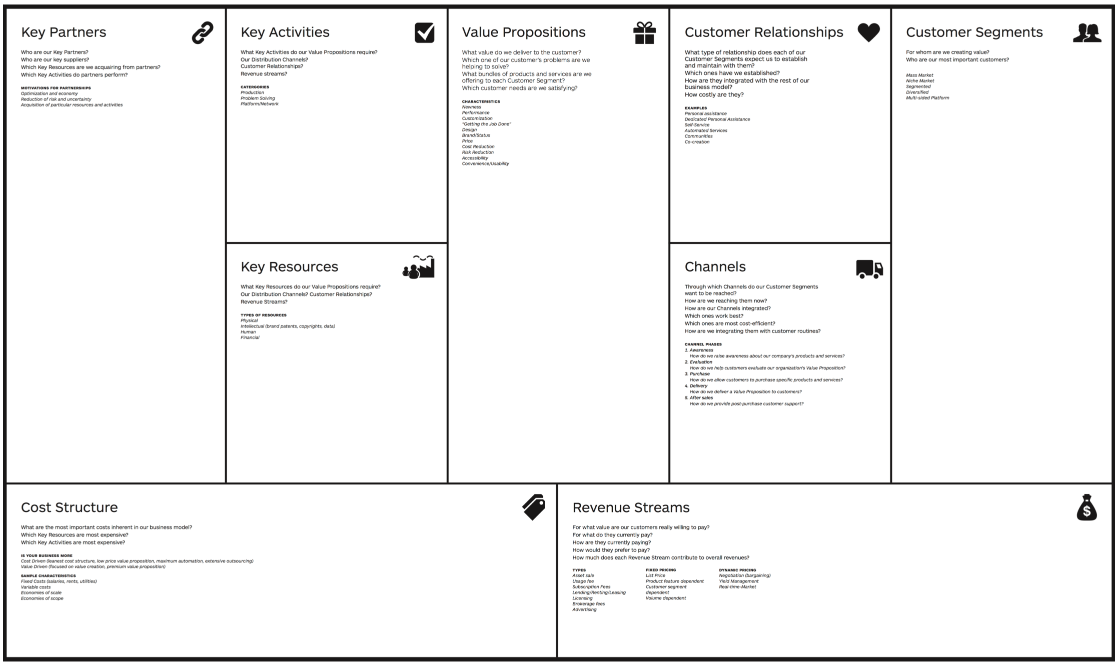

Figure 3.1: The Business Model Canvas as proposed by [11].

3.2 Description of Main Elements

The BMC is built along the four important areas of each business or business-related project:

1. Offering: What does the business promise?
2. Customers: To whom and how it wants to deliver?
3. Infrastructure: What does the business have and need?
4. Finances: What money goes in and out?

Let's look at each of these aspects systematically by going through the proposed elements of the BMC one by one.

3.2.1 Offering

At the core of every business stands its Unique Sales Proposition (USP) or "Value Propositions". This is the collection of products and services a business offers to meet the needs of its customers. According to [12], a company's value proposition is what distinguishes it from its competitors. The value proposition provides value through various elements such as newness, performance, customisation, "getting the job done", design, brand/status, price, cost reduction, risk reduction, accessibility, and convenience/usability.

The value propositions particular to the business activities may be:

1. Quantitative or
2. Qualitative.

Quantitative value propositions refer to aspects like a lower price or an increased efficiency in technical processes. On the other hand, *qualitative* ones refer to aspects like overall customer experience or the quality of the outcomes. Those are typically harder to measure and, hence, to quantify.

Once the value proposition is clear to the business itself, it is important to clarify the market side. Who and how will be buying the proposed goods and services?

3.2.2 Customers

This part covers the blocks related to the sales side. Three elements are included in here: customer segments, the sales channels, and the type of customer relationship.

Customer Segments: To build an effective business model, a company must identify which customers it tries to serve. Various sets of customers can be segmented based on their different needs and attributes to ensure appropriate implementation of corporate strategy. It will be important to specifically meet the characteristics of such selected groups of clients. The different potential types of customer segments take the following forms.

1. Mass Market: There is no specific segmentation for a company that follows the mass market element as the organisation displays a wide view of potential clients: e.g. passenger cars.
2. Niche Market: Customer segmentation based on specialised needs and characteristics of its clients, e.g. Rolex watches.
3. Segmented: A company applies additional segmentation within existing customer segment. In the segmented situation, the business may further distinguish its clients based on gender, age, and/or income, e.g. students discounts.
4. Diversified: A business serves multiple customer segments with different needs and characteristics, e.g. apparel industry.
5. Multi-sided Platform/Market: For a smooth day-to-day business operation, some companies will serve mutually dependent customer segments. For example, a credit card company will provide services to credit card holders while simultaneously assisting merchants who accept those credit cards.

Channels: A company can deliver its value proposition to its targeted customers through different channels. Effective channels will distribute a company's value proposition in ways that are fast, efficient and cost-effective. An organisation can reach its clients through its own channels (store front), partner channels (major distributors), or a combination of both. The selection of channels or its evaluation should always include the questions about the absolute (How much do we sell through this channel?) and the relative performance (How much does it cost us to serve that channel and how does it compare to the alternative ones?) of each channel.

Customer Relationships: To ensure the survival and success of any businesses, companies must identify the type of relationship they want to create with their customer segments. That element should address three critical steps on a customers relationship: i) how the business will get new customers, ii) how the business will keep customers purchasing or using its services, and iii) how the business will grow its revenue from its current customers. Various forms of customer relationships exist, often distinguished regarding the intensity of the relation.

1. Personal Assistance: Assistance in a form of employee-customer interaction. Such assistance is performed during sales and/or after sales, e.g. Apple Store.

2. Dedicated personal assistance: The most intimate and hands-on personal assistance, in which a sales representative is assigned to handle all the needs and questions of a special set of clients. A prime example is wealth management.

3. Self Service: The type of relationship that translates from the indirect interaction between the company and the clients. Here, an organisation provides the tools needed for the customers to serve themselves easily and effectively, e.g. public transport ticket sales.

4. Automated Services: A system similar to self-service but more personalised as it has the ability to identify individual customers and their preferences. An example of this would be Amazon.com making book suggestions based on the characteristics of previous book purchases.

5. Communities: Creating a community allows for direct interactions among different clients and the company. The community platform produces a scenario where knowledge can be shared and problems are solved between different clients. Examples include forums of Software companies or digital service providers.

6. Co-Creation: A personal relationship is created through the customer's direct input to the final outcome of the company's products/services, e.g. McDonald's Burger Creation Competition.

When looking at the customers, it is also important to identify who uses the products/services of a business and who decides about the purchase. In business-to-business (B2B) interactions this considers power hierarchies, while in business-to-customer (B2C) interactions it often considers household shopping organisation or kids-parents relationships.

Independently of the finally targeted customers, the value proposition can only be delivered with the right business setup in place.

3.2.3 Infrastructure

This part looks into the blocks that define the business creation side. It consists of three elements: activities, resources, and partner network.

Key Activities: These are the most important activities that need to be undertaken to achieve the value proposition of the business. Typical examples include customer acquisition, technology development or lobbying. The key activities can be undertaken internally (using the business' key resources) or externally (through partners).

Key Resources: This refers to the resources that are necessary to create value for the customer. They are considered assets for a business that are needed to sustain and support the business. These resources could be human (special talents), financial (strategic shareholdings), physical (machines) and intellectual (patents).

Partner Network: In order to optimise operations and reduce the risks associated with a business model, organisations typically maintain buyer-supplier relationships in order to be able to focus on their core business. Complementary business alliances also can be considered through joint ventures or strategic alliances between competitors or non-competitors. Typical partners can thus be suppliers, universities or public authorities.

While the former seven elements refer to the organisational aspects of the business, the financial side is covered by the last component of the BMC.

3.2.4 Finances

The financial side of the business model tries to capture the incoming (revenues) and outgoing money (cost). It is the basis for a subsequent more detailed analysis of the viability of the business.

Revenue Streams: This describes the way a company makes income from each customer segment. There are several ways to generate a revenue stream.

1. Asset Sales: This is the most common type of revenue. Technically, it refers to selling ownership rights to a physical good, e.g. retail corporations.

2. Usage Fee: Here, the money is generated from the use of a particular service, e.g. UPS.

3. Subscription Fees: Those are the revenues generated by selling access to a continuous service, e.g. Netflix.

4. Lending/Leasing/Renting: This means giving exclusive right to an asset for a particular period of time, e.g. leasing a car.

5. Licensing: With this stream, revenue is generated from charging for the use of a protected intellectual property. A restaurant chain franchise is a good example.

6. Brokerage Fees: Here, revenue is generated from an intermediate service between two parties. A typical example includes a broker selling a house for commission.

7. Advertising: This is revenue generated from charging fees for product advertising.

Cost Structure: In this block, the most important monetary consequences are considered when operating under different business models.

1. Classes of Business Structures: Business models can typically be classified according to their general strategic approach. We distinguish between *cost-driven* and *value-driven* business models. The former one focuses on minimizing all costs and having no frills, e.g. low-cost airlines. The latter one is less concerned with cost. This business model focuses on creating value for products and services: e.g. premium brand like Louis Vuitton.

2. Characteristics of Cost Structures: Independently of the strategic positioning, the cost can be split into fixed ones, i.e. cost that remain unchanged across different applications, e.g. salary or rent, and variable costs, i.e. cost that vary depending on the amount of production of goods or services. An example for the latter one are gastronomy sales at music festivals.

3. Economies of Scale: With this phenomenon, cost go down as the amount of goods are ordered or produced. This is typically the case when an existing machine is utilized more.

4. Economies of Scope: In this case, cost go down due to incorporating other businesses that have a direct relation to the original business core. This happens, for example, when knowledge can be shared or existing customer bases can be exploited, as in the case of Tesla's energy business

3.3 Resulting Canvas for Battery Swap Model

Considering all of the aforementioned parts and blocks of a generic BMC, Fig. 3.2 presents a filled version related to the battery swap business approach. The details are discussed in the next chapter.

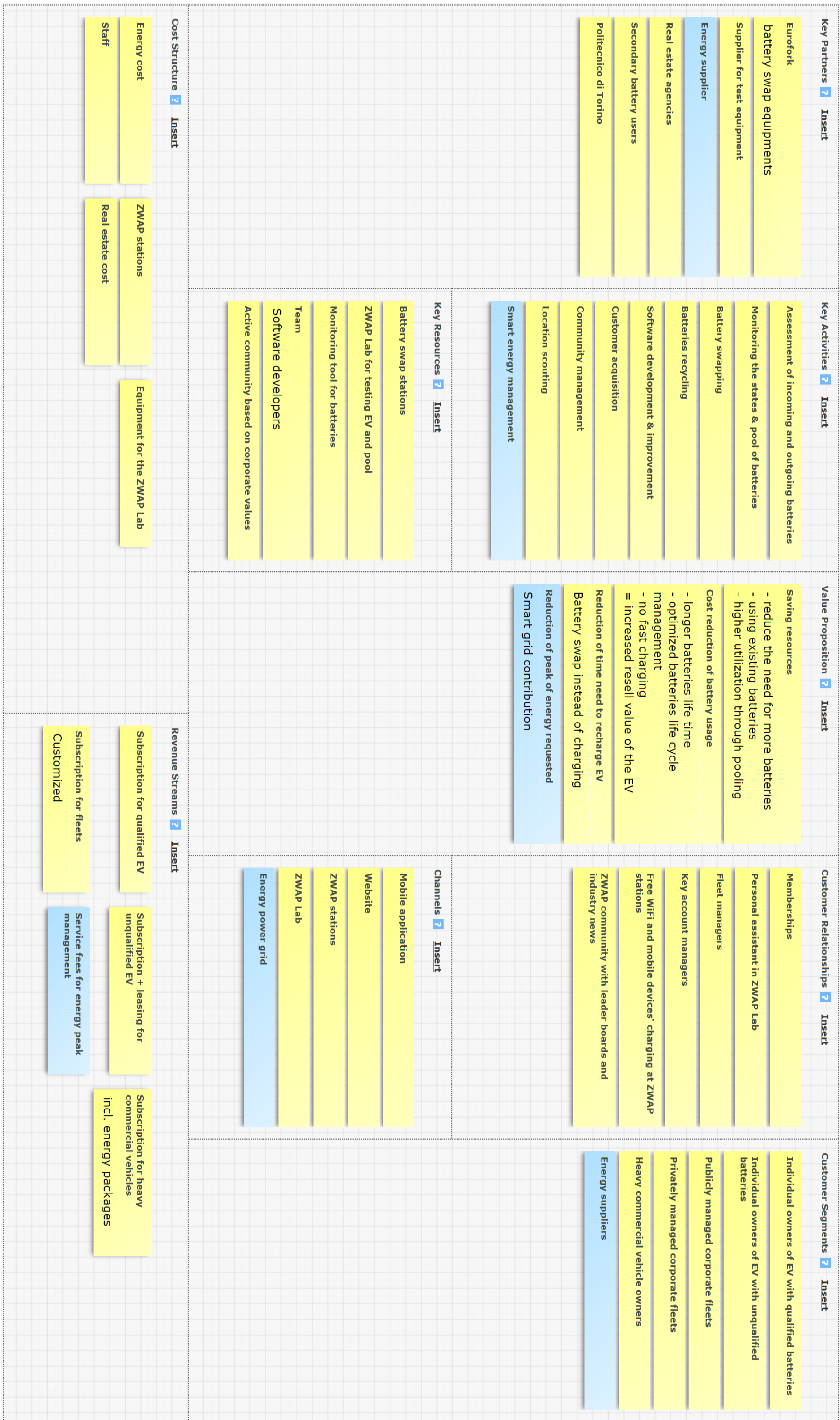

Figure 3.2: Illustration of the designed BMC. Source: Own elaboration using `canvanizer.com`.

Chapter 4

Business Model for ZWAP-IT: Smart Italian Battery Swap

In this chapter we will analyse *ZWAP-IT*. ZWAP-IT is Italy's first smart battery swap that aims to create an ecosystem capable of interacting intelligently with the customer and the environment. ZWAP-IT reduces downtime for the customer and optimises energy usage at each step of the service process. Using current technologies on the market, ZWAP-IT connects the ever-increasing needs of customers in a sustainable way, creating value for the entire ecosystem through every operation.

ZWAP-IT is totally customer-focused, like any company that wants to thrive in the future. At the same time, it does not want to create a new market with new customers but to serve an expanding market that already exists and is largely dissatisfied with the lack of standardisation and connectivity. In the following pages, we will therefore explain in detail the business model adopted by highlighting each part in the various sections of the BMC. The order of the explanation follows the rationale of the business model and is thought to support the storytelling.

The business model presented in this chapter will form the basis for the subsequent analysis of the financial model and its actual implementation.

[*Disclaimer: Because of its character, the description of the business model and its related information is subsequently written from the perspective of the venture to be created. Hence, the form "we" is used whenever the description is made as if speaking on behalf of the venture.*]

4.1 Value Proposition

This section refers to Value Proposition. It clearly states the values that the company can bring to each customer segment. This is done through focusing on the problem that it can solve for each customer segment as well as what needs it can satisfy. In other words, in this section we will explain the reasons why customer segments buy from us but not from others.

The business model of ZWAP-IT comes along with four main value propositions.

Saving resources ZWAP-IT was born on the idea of resource sharing as a unique way of conserving resources. In a world that continues to demand new technological development and consequently new raw materials day after day, we believe that sharing is the answer.

We see climate change as humanity's greatest challenge and ZWAP-IT is the embodiment of this challenge. Since the transportation sector contributes with 14% to the total global CO2 emissions, operating in the transportation industry is seen as a major goal. EV were seen as a big step in the challenge against climate change and they have a good chance to meet the expectations. However, with the use of batteries in massive number it seems that EV are basically postponing the real solution in the transportation sector. The doubt against batteries are due to poorly developed recycling methods and the oscillatory life span constrained to the operating environment of the batteries.

With the ZWAP-IT service we are able to significantly reduce the number of the batteries in the market thanks to our way of monitoring and sharing the existing one in the market. ZWAP-IT is capable of serving up to 140 vehicles with only 10 batteries in the stock of the ZWAP Station, thereby decreasing the number of new batteries in the market by more than 90%. Further, we are saving batteries for the 140 vehicles using batteries that are already present in the ecosystem.
This is possible due to the utilisation of the existing batteries because ZWAP-IT is a service centred on existing vehicle with shared characteristics. Existing batteries from our costumers become the pool of our service, increasing the utilisation of each battery trough pooling. The value of each unit of energy (KW) stored in the batteries can serve more customers and decrease the amount of money needed to actually supply the battery.

Reduce the cost of batteries usage: Sharing will be the most spread word speaking of the value proposition because the idea fully shapes every aspect of the company on a micro and macro level. Since our service is focused on the customer, one of the main goal for ZWAP-IT is the permanence of the value that our customers are investing in us. This relates to the permanence of the performance of the batteries that our costumer share in our fleets.

With our service, the life span of the batteries is longer due to the controlled environment of charging. That means no fast charging or similar way that can damage the battery. Moreover, we are able to smartly monitor the state of each battery. This way, we also control the charging in the pool of registered batteries and can give the advantage to individual customers of having a documented history of the characteristics of the batteries they are using.

This documented history is translated in an increase of value for the EV as a whole and in particularly in the resell value of the EV. This is the special case with EV since the state of the batteries is one of the major concern in buying a used vehicle.

Recall 2, where it was discussed that the battery pack usually is responsible of the more then 60% of the price of the passenger EV.

Reduce the time needed for recharge: ZWAP-IT is a battery swap service that follow the advantage of reducing the time of charging needed for EV through decoupling basically the charge phase and the full charge phase of the battery. Thanks to this decoupling, in order to have a full charged battery the time needed is based only on the operational mechanical manoeuvres of the Station. It does not depend on the technology of the battery. Therefore the only constrain remains the design of the car.

The average time needed in this way is reduced by 80% in most of the cases and can reach up to 95%. Still, the seven minutes average for swapping declared from the main actors in the market seems an eternity compared to the nostalgic idea fuel an internal combustion engine. However, the cost of fuelling and the sustainability are arguably all in favour of the battery swapping technology.

Reduce peak of energy requested: ZWAP-IT uses a smart management of the fleet that can be used as a container and machine learning for the peak of energy that nowadays our city try to fight.The main idea is using our station as a funnel for the peak of energy. Using a double mode, we are able to absorb energy that exceed from our power grid and vice verse, i.e. providing energy to the grid when it is needed. All this is thanks to the live data that we have on our fleet integrated with an active monitoring of the grid. Having a smart grid contribution is seen as one of the main reason in reducing the final cost of the energy for the end customer.

4.2 Customer Segments

ZWAP-IT is a service that aims to serve a market segment that is already present and that is not satisfied with the current situation. ZWAP-IT basically splits the EV costumers segment in two half: i) the first is represented by individual owners of EV and heavy commercial vehicle and ii) the second is associated with cooperate fleets.

In each of the two segments, ZWAP-IT identifies customers with qualified batteries and unqualified batteries. Customers with qualified batteries become part of the core business of ZWAP-IT since only qualified batteries go in the pool of our stock in the Swap station, i.e. batteries that successfully pass the technical test in the ZWAP Lab.

Concerning the customers with unqualified batteries (maximum remaining battery capacity smaller than 80% of its original capacity), they have the possibility to buy a share of a new batteries in our stock and sell the unqualified batteries to us leaving the recycling process obligation with us. It is important to notice that for the owner, an unqualified battery represents first a potential risk for the vehicle and second means a loss of money in the energy invested to recharge it.

As we discuss about the goal of reducing the peak of energy in the grid of our cities, the other important customer segment that ZWAP-IT wants to reach are the energy suppliers. We aim to create a synergy capable of smart managing the energy needed in our cities coupled with the focus on reducing loss in the energy management process. This together will help to reduce the overall price of electricity for the end customer.

Overall, ZWAP-IT has four main customer segments:

1. Individual EV owner
2. Corporate fleets
   - Publicly managed
   - Privately managed
3. Heavy commercial vehicles
4. Energy suppliers

For the customer segments of fleets, we mainly assume buses to be relevant. This is because their operation is regular, their number is greater than one, and they are expected to pay premium for a reliable service that supports their operation.

In the case of heavy commercial vehicles, we assume that in the future trucks can be targeted. With an improved battery technology and a dense network of logistics between international shipping nodes and places of consumption, those trucks seem to be a promising segment.

In the description of the segments the distinction between qualified and unqualified batteries is not specified. This is because the service remain with the same main features independently of the segment.

4.3 Customer Relationship

ZWAP-IT is a customer-centred company and the relationship with customers is one of the main asset, on which a solid business will be built. At ZWAP-IT, the customer is basically a brick in the creation of a solid structure, capable of sustaining an entire ecosystem. To achieve this, the transparency of all operation is given to every customer with all the live data and current states of our whole battery stock.

The first level of interaction with our customers is based on a membership that gives the customers access to our service and our data. Becoming a member of the ZWAP-IT community through the membership allows customers to receive assistance from a personal assistant during the time in the ZWAP Lab. The customers will visit the ZWAP-Lab at least two times in the membership period. One time, when the customer will test his battery in order to understand if they have a unqualified or qualified battery. At the same time, the customers will receive a course on our core values and on the technical operations to be carried out each time the service is used. This will be independent of the assessment of their battery status. In this way, the customers themselves can assess the level of service and possible errors so as to allow direct and active prevention.

We believe that transparency of operations and the awareness of our customers to be active participants can continuously improve the service we offer. As our service is also offered to vehicle fleets, each fleet will have a dedicated Fleet Manager, who will organise the terms and conditions of the service offered. Each membership will be linked to a highly encrypted account that will contain all of our customer's personal information. For all account management issues, our customers can interface with our 24-hour available key account managers.

We know that time is money and we don't want to waste it when we offer our services, but time is a resource not only for us but also for our customers. That's why our stations feature free WiFi and charging for mobile devices. This completes the experience to our customers.

The aim is to create awareness and transparency, and another means of achieving this is the ZWAP Community. Here, we will present all the news related to our universe and news from the industry. There will also be special rankings for our active members in order to push awareness through the gamification of the service.

4.4 Channels

The achievement of ZWAP-IT's goals is linked, as is the case with any customer-based company, to the achievement of its customers. The main channels through which ZWAP-IT wants to reach its customers are analysed below.

ZWAP Station: It is the BSS through which we offer our swapping service. The station is capable of serving two vehicles simultaneously. There are areas in the station where you can have free WiFi and charge your electronic devices. There is no physical operator inside the station, but a virtual assistant guides the customer through the operations. In case of need, customers can connect from the station with one of our experts, who is available 24 hours a day to help them.

Mobile application: Through the application, our member will be able to access all the information about their current battery, with accurate predictions about the kilometres that can be travelled with the current state. This is thanks to information from the smart flow-meter installed on each battery. The customer will be able to ask the application whether the battery status is sufficient or not based on future actions the customer wants to take. This is facilitated by the machine learning of our algorithms.

Our members will be alerted by the application whenever the need for a swap arises. The application can also advise our customers of the status and availability of stations in the city. In addition, customers will be notified when a power peak is present in the city in order to use the excess energy at a better price and condition.

ZWAP Lab: The ZWAP-Lab is our laboratory for the analysis and testing of batteries in our stock. Batteries that are not suitable for our service will then be disassembled in our laboratory in order to start the recycling and reuse process.

Website: We will use our website to promote our community initiatives. It will be a meeting place for our members and a place to enter in contact with ZWAP-IT, since every offer of collaboration will be posted on it. Moreover the website will contain all the frequent Q&A and every procedure that can help our community.

Energy power grid: The power grid is our main channel when we speak about our service towards the energy suppliers. With ZWAP-IT, it will be possible to provide any service that can be consistent in time. We will use the power grid for both buying energy and selling it, based on our current status and the one of the grid. We will make the grid smart through the various stations and other hubs thanks to our integrated system.

4.5 Key Activities

ZWAP-IT wants to advance its value propositions through customer care and through strategic use of existing technologies. This is why we are convinced, and the studies on the batteries themselves confirm this (Zheng et al., 2012; Wu et al., 2017), that a control on the recharge cycles and on the modalities can extend the life of the batteries, the efficiency and the safety.

Controlling a single battery may not make a difference in terms of numbers, but compounding the interest across the entire stock can bring previously unexpected benefits. That said, it is the acquisition of new customers that makes it possible for our stock to grow and increase the total benefits. The acquisition of new customers will therefore be spurred by a policy of immediate economic benefits for the customer that will translate into future benefits for the company when we reach the tipping point in our stock.

In order to protect and safeguard our customers, it is of fundamental importance that we assess the batteries that enter and leave our stock. By certifying each operation, the value of the batteries in stock will be devalued less than a normal battery on the market.

If we widen the lens of observation in order to obtain the above-mentioned advantages, developing smart energy management will not only extend the life of the batteries but also reduce the total cost of the energy we supply to the end customer. The application of green policies on the power grid of our cities will also be fundamental, with the objective for ZWAP-IT of using only energy supplied from renewable sources (Liu et al., 2015).

We are aware that the whole project is based on the power of our software to integrate different data from the ecosystem, and developing our algorithms in such a way as to avoid any waste of time and energy. Hence, those are among our main objectives. Thanks to the data coming from our batteries, we will have a mobile source of information and data that will allow us over time and time to have a clear picture of our cities.

ZWAP-IT does not stop at the life of the batteries in use on the market, but pays attention to those batteries that do not qualify for our service. The reuse of these batteries and the subsequent recycling is a key issue in terms of environmental pollution, and we through our workers will create new life for these batteries by using them in minor applications.

The bigger the flow of batteries, the more our ecosystem will grow and improve, and that's why we take great care when looking for places to install our ZWAP stations. Reshaping the flow of goods, people and ideas remains our goal, but we are aware that our stations have to fit into the current dynamics of the city and its peoples' expectations. That is why we believe that integration is possible with the current service gas stations that incorporate more than any other place attention to the needs of the customer.

It is essential to reiterate that ZWAP-IT is completely centred on the customers' needs and that is why the company pays the maximum attention to the management of our community, seen as a focal point in the evolution of our ecosystem.

4.6 Key Resources

Battery swap station: We firmly believe that we can extend battery lifetime through our BSS. We will do this by enabling controlled charging with low currents and minimising the use of fast charging. BSS are permanent structures with a high level of equipment. In the past, they were normally produced specifically for one type of vehicle, which meant that they could not be adapted to different solutions.

Moreover, the battery swap solution allowed the price of electric vehicles to be reduced by decoupling the cost of the battery (from contracts with battery swap companies) and the cost of the vehicle itself. This solution was used to facilitate the popularisation of EV in developing countries.

Our approach to swapping is reflected in our ZWAP stations, which are designed so that the features of our business can be achieved through it. Given the smaller number of batteries in stock, in order to have an optimal service our solution is developed vertically without any intrusion of the station in the ground. This allows a fast installation and mobility that could bring huge advantages in the early stages of the service provision.

The station will occupy the size of three parking lots, with the vertical space completely designed for battery storage. It will have two swap positions (left and right) in order to serve two customers at the same time, hence guaranteeing the possibility of having two completely separate spaces.

Once having entered the spot, the EV will be identified by the scanner on the ground that will inform the station about all the information of the car, including the model and the customer data. This information will be used by the station in order to position the robotic arms that will replace the battery in the correct positions. Once the arms are positioned, the car will be lifted and the swapping operations will start. When finished, the scanner will re-identify the machine and update the information on the system.

The station for the swapping of heavy vehicles, e.g. for buses and trucks, exploits the same technologies, but the design is developed horizontally. This guarantees the possibility to operate the swapping in a modular way to serve the longer vehicles. Of course, the surface of the latter is greater than that of the stations that will have to operate with EV.

ZWAP LAB: The ZWAP LAB is our company's research and development centre and the laboratory, where every single battery in our pool is tested. The lab is divided into two main areas.

The first is completely dedicated to testing and with an outdoor area that can simulate the operational condition of our stations. Moreover, this part of the lab is equipped with a thermal room, in which our team can test also the behaviour of our battery stocks at different temperature and conditions. The outdoor area is also used for the first contact with our costumers in the initial assessment phase.

The second main area is dedicated to our software and engineering teams that will develop the algorithm and structure that create our ecosystem.

ZWAPmeter: The ZWAPmeter is a small embedded system, that enables us to transform EV that use our service in literally smart devices. That way, they will be capable of integrating data and be interconnected in our ecosystem.

The ZWAPmeter is installed on every battery that enters in our stock. It is used to monitor the state of the charges of the battery itself. To turn the EV into a smart device, the ZWAPmeter contains a sophisticated GPS and an Internet connection. Both allow our software to track and show the live data of the battery and the EV.

Moreover a gyroscope is installed on it to assess the driving behaviour. Other sensors like temperature are also placed in the ZWAPmeter.

Software developers: The technological advantages that our company brings to the market are limited, if not linked to a powerful algorithm and software capable of handling a lot of data simultaneously. We therefore believe that our software developers will be one of our most important resources as they ensure constant and flexible improvement for our business.

ZWAP community: In order to put the customer at the centre of our project, we need to have a preferred channel from which to draw information about them. This channel is our community, which will be the means through which we will interact on a constant basis. It helps us to understand the strengths and weaknesses of our company and much more.

We will be able to use the community as a builder and shaper of the values that our company wants to propose. The community will also be used as a research network for partners or possible collaborations.

Team: The team currently consists of the following members, all bringing different aspects relevant to the success of the venture.

Founder and Chief Executive Officer (CEO) is Pietro Cozzi. He is an Italian Automotive Engineer from the Politecnico di Torino with hands-on experience with cars. Since being an adolescent, he supports the family car workshop. From this, he owns deep knowledge about cars and their internal technical components. In the past, he was involved in the Juno project both as an engineer and a driver in the Shell eco-marathon.[1]

[1] `https://areeweb.polito.it/didattica/h2polito/veicoli/juno.html`.

Moreover, he knows the numbers behind the car businesses by heart. This is why he originally came up with the ZWAP-IT business model.

His co-founder is Florian Sylvester, student of International Management (B.Sc.) at HAW Hamburg. Both have met in an Erasmus exchange semester abroad and since then spent numerous hours discussing and bonding. Florian bring in his previous experience from the transport logistics sector. Hence, he will be mainly responsible for the operations, including logistics and trade at ZWAP-IT.

Both together build the core founding team. They are currently looking for a chief engineer to supervise the software development team.

The venture is actively supported by two international entrepreneurs, who join the team as strategic advisors and sparring partners.

Dr. Daniel Cracau, is an entrepreneur and Kindness Advocate. He declares his vision is enabling sustainable technologies through hard work, creativity, and win-win networking. With his background in Management and Economics, he works with passionate teams in the mobility sector and beyond. He is a former UN staffer and has strong ties in academia.

Currently, he is CEO of Berlin-based AlphaLink Engineering GmbH, a company that provides embedded systems for mobility applications. He is also co-founder of Brilhon Tech., a São Paulo-based company that is building fast-charging stations across Brazil to enable electromobility.

Leon Sebastian Diab is also Co-founder of Brilhon Tech. and its acting CEO. He holds degrees in Urban Design and Architecture from European Universities and is a Stanford Business School graduate. He describes his international career as being stretched over seven countries and always related to his passion for science and technology.

4.7 Key Partners

Eurofork: Eurofork is an Italian company specialising in the production of automatic handling systems for warehouses.[2] The company is recognised worldwide in the field of automation and intralogistics. In its long tradition, it has always aimed to become a leader in innovation, investing in people and new businesses with a focus on sustainability.

With the technology currently in Eurofork's hands, our BSS could reduce swap times to less than 5 minutes and significantly improve our market offering. Eurofork

[2] `www.eurofork.com`.

is also already active in the battery swap market in China, where the natural success has led the company to seek new opportunities and challenges.

Politecnico di Torino: For years now, the Polytechnic Turin has been one of the best technical universities in Italy and Europe. It has always been at the side of Italy's biggest automotive companies, and we believe that this university can create a direct link with our company. This connection does not only allow research to find practical outlets but also directly trains the talent it produces.

Energy supplier: Energy suppliers are not only essential in order to offer an advantageous price to our customers, but they also become essential in the management of the offer we put on the market. This is because they are our suppliers on the one hand when looking at the energy provision towards the vehicles. However, they are also our customers in the long run, when it comes to managing power peaks in power grids.

With this partnership, our proposal is not only profitable but also sustainable. It is, hence, crucial for ZWAP-IT.

Real estate agency: They are essential when choosing where to install our stations. A profitable relationship with these agencies will bring enormous advantages in terms of the flow of customers we want to reach.

Supplier for test tools: The equipment that will allow us to test our battery stocks is the first asset that our company needs to acquire and develop. A fruitful collaboration with suppliers of this equipment allows us to customise the various tools in the long run. Also it gives us the possibility to take possession or lease them through partnerships.

Secondary battery users: Our company not only aims to speed up the electricity transition through a service that puts our customers at the heart of it, but also to take a step forward in the resolution of battery pack sustainability. Secondary battery users will become key to creating the parallel market that helps the sustainable transition. Reducing the immediate need to recycle, the use of battery packs will go beyond that of their high performance solutions such as vehicles and open new business fields like small-scale battery storage for mobile device charging.

4.8 Revenue Streams

Subscription for qualified EV: The primary source of income from the segment of individual EV owners is a flat subscription per month. This will include the initial assessment of the battery, all swapping throughout the membership, and the final assessment in case the customers wanted to leave our service.

This pricing scheme is most attractive to end customers because of its simplicity. Because of the flat payment, the profitability for ZWAP-IT is typically higher, because customers do not fully exploit their potential maximum capacity of electricity.

Subscription + leasing for unqualified EV: This is similar to the previously described revenue stream, with the difference of the battery leasing. Recall that only batteries with a remaining charging capacity of ≥80% are qualified for our pool. Hence, the remaining individual EV owners will be offered a kind of buy-in, where they pay extra for participating in our battery pool.

The higher cost for entering with an older, unqualified battery also have the positive side effect that it renders joining the ZWAP-IT community earlier. At least in the long run, it seems thus more likely to marginalise the size of this customer segment.

Subscription for heavy vehicles + customised energy packages: In the case of heavy vehicles, the energy consumption per vehicle is significantly higher compared to individual (passenger) EV owners. Moreover, the average consumption per month can much more precisely be forecasted. This is related to the typically regular schedule of their operation. Because of the two aspects, we offer this customer segment a pre-defined energy package related to their subscription.

While the base subscription price is similar for all heavy vehicles, customers select from a menu of energy packages. Within those packages, prices increase degressively, i.e. with higher packages, the per kW price goes down.

The energy packages are introduced for these customers for two reasons. On the hand, the reliance on the availability from the customers' perspective as the swapping takes presumably place along the highways. On the other hand, the utilisation rate from the perspective of ZWAP-IT needs to be sufficiently high.

Customised subscription for fleets: Looking at public fleets like operating buses, the subscription scheme is similar. What will be different is that the price of the actual subscription will be not the same for all customers within this segment. Because their operation is known and hence can be planned appropriately, a fair price can be offered depending on their expected consumption.

To prevent negative criticism from the different fleet customers, the pricing differentiation shall be reasonable and as transparent as possible. Depending on the signing of early customers or the potential of a fleet expansion, discounts may be offered. The exact calculation of the prices and their communication will be perfected subsequently.

Service fees for managing the peak of energy in the grid: A completely different revenue stream is created through intelligently managing the total energy storage in the battery stock. This is possible because an owner of a significant battery pool can use this total capacity to negotiate with the power grid supplier (Kempton and Tomić, 2005).

Once the total stock of battery is sufficiently large to help managing peaks in the power grid, we can offer to buy and sell electricity independently of the actual swapping business. The pricing of this will be dynamic and is up to further investigation along the growth of the venture.

4.9 Cost structure

Energy cost: The cost of energy is one of ZWAP-IT's key responsibilities. We believe that in adopting our business model, our customers must first have an economic advantage over other services. This is achieved primarily through the cost of the raw material of our service: electricity.

The cost of energy per kWh in Italy from the domestic grid is 0.2 Euro. We will consider the domestic cost because this is the first natural substitute for our company. In any case, the reference price will be the lowest direct cost per kWh on the market. Of course, the domestic network does not allow for fast recharges, which the other services do.

The competing providers in the market are *Enel x*, *Duferco*, *NextCharge*, and *EvWay*. They typically offer three solutions with regard to charging speed. Those are

- QUICK AC (22kW),
- FAST DC (50KW),
- HPC (350kW).

The prices for the charging per kWh offered vary from 0.4 Euro 0.61 Euro.[3] All of them apply an additional service fee for occupying the charging station, in addition

[3] `https://www.newsauto.it/notizie/costo-ricarica-auto-elettrica-alla-colonnina-prezzi-energia-enel-x-duferco-nextcharge-evway-2021-309286/`.

to the cost of the actual energy supplied. This fee varies from 0.09 Euro per minute up to 10 Euro per hour depending on the company and the type of charging.

These companies also offer monthly packages ranging from 21 Euro for 50 kWh to 61 Euro for 300 kWh.

The cost that prime suppliers charge from Italian companies can vary from a minimum of 0.04 Euro to a maximum of 0.08 Euro per kWh based on the volume of the commission contract. Our company therefore wants to position itself on the market with a cost that varies between 0.15 Euro and 0.25 Euro for our final customers. This can be achieved by purchasing energy at a price of 0.05 Euro per kWh implying a use of more than 50% of energy from renewable sources.

ZWAP station: As already mentioned in the section on energy costs, our customers will in the first instance obtain a direct economic advantage on the service offered. The cost of our stations therefore tips the scales for the final cost, as this represents the largest investment in economic terms. The cost will be determined by the cooperation with our supplier Eurofork and the number of stations for our cities. Initial forecasts estimate an investment of between €250,000 and €500,000 per station.

The modularity we want to achieve with the stations could further lower the initial investment. According to first estimations, it may be reduced to a level right below the costs needed to build a super fast-charging station. The ease of deployment of the station and its quick assembly to take it to another location, can lead to an increase in initial investment. However, in the long term we will pursue the possibility of serving an entire city network in a short time. This is all thanks to the characteristic of our station that does not depend on a large stock of batteries to offer the service.

Team: The cost of our team represents the most significant variable part of our costs. In the initial stages, the cost of acquiring new talent could be prohibitive. This will be stimulated by long-term contracts allowing not only professional continuity but also the possibility of owning assets in society. Offering shares and non-monetary benefits to core team members is another way of reducing this block of cost.

Equipment for ZWAP-Lab: The equipment of the ZWAP Lab is the investment we make in our future and in improving the service we offer. We need to acquire the best technology and equipment to test our batteries. To achieve this, all equipment will be purchased on a leasing basis, allowing for a lower initial investment and the possibility of continuous change.

This equipment will become an asset when the lease is redeemed if it has produced real value for the company. The equipment required is very expensive and our company will always move towards the idea of sharing it with other companies, including startups. Our main motivation here will be the reduction of costs and the increase of the productivity of each piece of equipment.

Real estate cost: This cost will greatly affect the flow and numbers of our service. That is why our stations will be located in areas, where other services are already present such as petrol stations. In this way, the cost for real estate is shared with other companies and therefore reduced.

Chapter 5

Business Case

We are going to build a case study in which we analyse the feasibility of our newly developed business model for ZWAP-IT and the possibility in the market for a new BSS.

5.1 Background and Assumptions

As a first step, we want to describe the assumptions taken into consideration in order to define the customer profile that we would to serve.

We work under six main assumptions:

1. The bigger the vehicle is that a customer needs to be moved, the farther they want to drive it without recharging. This reflects the fact that bigger vehicles typically come with larger batteries. From a certain size on, this means that the battery can or will be integrated in a modular way.

2. City buses are generally lightweight enough so that electricity powering is a viable option. This reflects the expectation that the electric bus market is a growing segment and therefore those vehicles are a reasonable target segment.

3. The EV market is sufficiently big and established to built economically feasible business models on that. In particular, this means that serving existing EV models is possible, as we want to serve an already existing market and not create a new one.

4. The technology for a BSS that serves the needs of ZWAP-IT already exists in the market, at least to start with. This means that with a budget of approx. 500.000 Euro, the station can be bought and directly implemented in the market. Potential development cost to improve the BSS are ignored within this case.

5. We analyse as our environment the city of Turin, since it is the hub of our company and also for the automotive industries that it represents. The underlying assumption here is that the EV models we will select as passenger EV to be served and the bus line case are representative for further market expansion in Italy.

6. EV owners/operators are willing to share their battery as along as they have transparent information about the performance and when leaving the service, they are given a battery with non-inferior status compared to the battery they initially had. This is based on the observation that used batteries, e.g. in refurbished mobile phones, are accepted by customers, if the performance information is clear and reliable.

With those assumptions in mind, we can now specify the demand side of our business.

Our idea is based on the development of a platform of battery swap capable of serving three main kind of costumers.Publicly managed fleets,e.g. bus lines organised by municipalities, individual owners of EV, and trucks as heavy commercial vehicles.

Within the framework of this business case, we will look at those three segments on e after another. At the same time, we ill apply different methodologies to assess those segments and their fit with our general business model.

5.2 Individual EV Owners

Let us briefly review why those are most attractive customers to our business model. For this particular segment, we identified four main reasons to address them.

- They are already endowed with a EV with a swappable battery.
- We don't need to sell vehicle or battery in order to provide our service.
- The target market can grow exponentially as it is driven by the EV market.
- We can sell only the service of providing charged battery whenever our costumers need one.

The special thing with the two described segments is that we want to provide a service capable of supplying an existing market without the limit of creating a new one and without selling cars or batteries.

Below follows a brief description of the service and the step that our costumers will take in the process of becoming our member and usage of our service.

Our customers own an EV and its corresponding battery pack and they are not bound to any contract for the supply of the energy. They also want to find a good option for the supply of energy for their EV. So the customers will come to our ZWAP-Lab in search of a viable solution.

To exactly understand the customer's perspective, let us look in detail at the future relation between them and our service. To do so, a description of the step that the customers is going to take with our service follows. We identified four main steps.

1. First, they come to our ZWAP-LAB. This is typically down driving in their own EV or the one that they are given by their manager.

2. For every new client, our operator tests the state of the battery pack of our customers. Two possible outcomes may occur:

   i The battery passes our test (battery state ≥80% of its maximum capacity). → The customer has the possibility to proceed to the next step.

   ii The battery does not pass our test (battery state <80% of its maximum capacity). → The customer has the opportunity to take a qualified battery from our pool via leasing or we can't serve this costumer. (Note: strictly speaking the battery pack of E have an average life of 8-10 years, so the second option is related to a small case, at least in the beginning.)

3. If the battery pack is qualified, our company proposes a contract to the owner, in which the battery of their vehicle became a battery of our fleet, and the customers receives the service for the supply of energy and the swap of the battery in our station whenever he wants. Basically, this means we offer a subscription as explained in Ch.4.

4. The customer may want to cancel the subscription to our service, so they come to our ZWAP LAB. After the re-assessment of the battery (the same that took in the first place), again two cases may occur. If the battery has passed our test, the owner stays with the same that they already had or, in case of a negative test, we will provide another battery that is qualified according to our standard. In both cases, the customers leaves our service with a qualified battery.

It is very important that we understand the reason of the last step. It is easy to assume that no one who owns an asset wants to share it unless they are sure that at the end of the sharing they or stay with an object with the same features – if not the very same object they initially had. We believe that costumers that own an EV are really concerned about having a battery pack with always strong performance even at the expense of not having a personalised one.

5.2.1 Serving different EV models

The market of the passenger EV is growing year by year; this can be taken as truth. When looking at this market segment, we are not interested in the specific type of vehicle that will lead our mobility but only in the technology itself.

It is presumable true that a capitalistic market is not necessarily based on standardisation. However, if we look close at the story of every object good at a certain point, we find that a particular characteristic, initially developed in different ways by different designers in order to diversify it and sell it on the market, eventually became standardised for one of two reasons: i) The designer builds upon the standard of one feature in order to develop a better solution in another aspect that is then more engaging for the market; or ii) The standard is already the best possible viable option.

The big obstacle for the BSS today is the (missing) standardisation of the battery. This obstacle can be expected to be cut out thanks to the two reasons above. Unfortunately, this option is not viable right now since the batteries market and the new EV market are in the early stage. No company has yet reached the best possible product.

We therefore have to start with the selected group of vehicles that will be able to be swapped at our station. Looking at the actual market, we can find the top 5 best selling EV in Italy . Those are:

1. Renault Zoe,
2. Smart EQ forfour,
3. Tesla Model 3,
4. Volkswagen e-Up!,
5. Fiat 500e.

Appendix A contains an overview about those five EV models and their specifications.

It is easy to see that during this case study we will not take into consideration the Tesla Model 3, because of their closed system (actually the opposite of standardisation) and their own contract to supply energy to their customers. Let us rather assume that our BSS can handle four different type of EV and thus needs to have four different kind of batteries in the stock.

The next step is taking into consideration the proposed business model and evaluating whether we can offer a reliable service. Moreover, we have to check, if our offer is influenced positively or negatively by the kind of cars that we want to serve.

The first case that we will to analyse is the case in which our BSS can provide the service to the Renault Zoe and the Fiat 500e. We chose the two models because of their current and future attractiveness in the Italian market.

Let us refer to the battery of the Renault Zoe as *Battery Type A*. It needs 70 minutes to recharge from 0-80%. Let us refer to the battery of the Fiat 500e as *Battery Type B*. It needs 35 minutes to recharge from 0-80%. Note that the difference in charging time originates from the smaller battery size of the Fiat 500e.

Let us assume that our system is capable of handling the service for 24 h and make a swap every 10 minutes. That way, we can change a maximum of 144 batteries per day per station.

Now let us look at the relation between swapping and charging. For charging an A battery, we need 70 minutes. Hence, in this time we can swap 7 batteries. For charging a B battery, we need 35 minutes. Hence, in this time we can swap 3.5 batteries, statistically speaking

Now we will picture the operational process at one of our BSS. To better understand the routine, the timeline is illustrated with the following description.

Let us suppose that at 8.00 a.m. the first customer (EV 1) arrives. After ten minutes the EV leaves the BSS. Now, we have 6 batteries completely charged in our stock plus one uncharged one that starts the charging cycle at 8.10 a.m.

In the simple case we are currently analysing, the queue is composed only by Zoe cars, i.e. EV with Battery type A. If our service works without interruption, the situation of our stock at 9.10 a.m. is depicted in Fig. 5.1.

So we are able to swap the car that arrives at 9.10 a.m. In the meantime, we complete the charge of the battery in the stock that was nearly fully charged, This routine guarantees the reliability of the system.

Generalising this observation, we understand that the number of batteries in our stock needed to give a reliable service is

$$N_{stock} = \lceil t_c/t_s \rceil + 1 \tag{5.1}$$

where t_c is the time needed for charging a battery unit and t_s is the time needed for swapping a battery unit.

This means that with eight batteries in stock, we can serve as many EV with Battery type A as possible, considering our swapping limit of 144 per day.

Let us now consider a feasible scenario with our service working for at least 12 hours a day. This would yield 72 daily swaps.

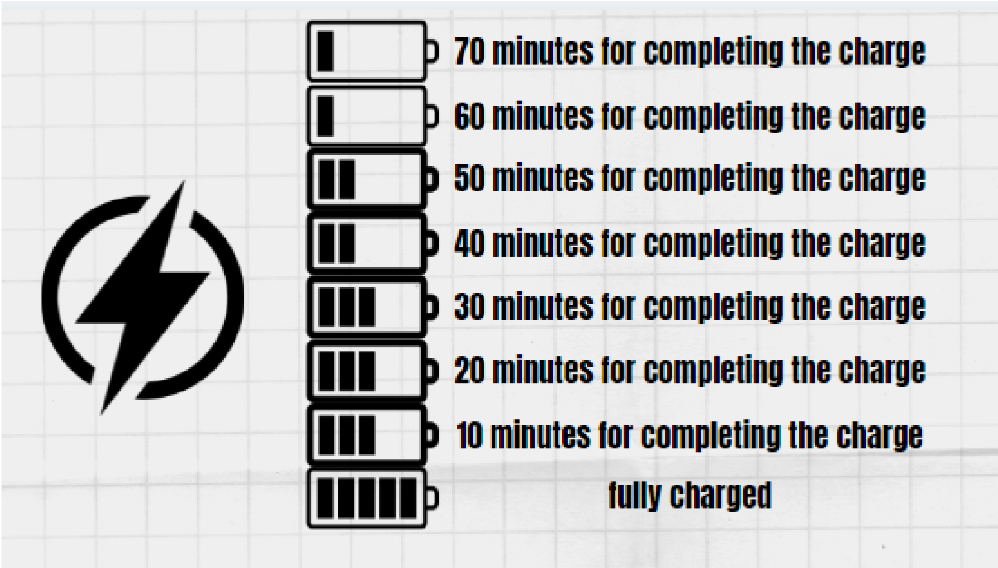

Figure 5.1: Status of the simplified battery stock. Source: Own elaboration.

Following the same logic like the one presented above for the generic scenario, the initial investment for the stock to serve Renault Zoe (battery type A) is

$$8 * 52\,kWh * €100/kWh = €41{,}600\,.$$

Suppose that we can make a margin of 0,10 Euro with every kWh that we trade, i.e. give to our customers after purchasing them from the energy provider. This means that the profit per day is $72 * 52\,kWh * €0.1/kWh = €374.4$.

To break even the initial investment of our battery stock, we hence need

$$€41{,}600/€374.4/day = 112days\,.$$

Now we consider a similar simplified situation, but with only Fiat 500e (battery tape B) in the queue. Following Eq. 5.1, now the initially needed stock is only five batteries (because of the smaller total size of the battery and, hence, the smaller ratio between a full charge and a swap).

The initial investment for the stock in this case is only

$$5 * 42\,.kWh * €100/kWh = €21.000\,.$$

Under the same assumptions like in the other case, the profit per day is $72 * 42\,.kWh * €0.1/kWh = €302.4$.

Similarly, to break even the initial investment of our stock, we need

$$€21{,}000/€302.4/day = 70 days\,.$$

In the real world, however it is unlikely that a queue will be composed only of one type of car. Therefore, we will simulate a real-world situation and see how many batteries and of what type we need in our stock to sustain a reliable service with a certain probability. We have to run a MATLAB random simulation in order to get to a precise number related to the current number of cars in the market.

If the queue is assumed to appear randomly, a pattern may look like this:

$$A - A - B - B - B - A - B - A - B - A - B - A \text{ (in the time frame of 2 hours)}\,.$$

It can be noticed that this further reduces the number of the battery units in our stocks. Specifically, the required stock drops by 3 units for type A battery and by 2 units for a type B battery.

We can conclude that increasing the different models of cars that we serve, is a beneficial way of reducing the initial investment in our battery stock. Because we need lees of each battery type in the beginning, the initial investment drops.

In order to verify that our multi-spot station does help in reducing the expected queue and thereby increases customer satisfaction, we showcase an application of a queuing model for our exact case.

5.2.2 Excursus: Queuing Model

A basic queuing system is a service system where so-called customers arrive to a bank of "servers" and require some service from one of them. It's important to understand that a *customer* is whatever entity is waiting for service and does not have to be a person.

The rule that governs the order in which the customers are served is called queue discipline. Ours will be First Come → First Served (FCFS).

We consider our system to be a steady state to focus our analysis on the most important elements. Those are:

- Utilisation
- Probability of delay
- Service time
- Average total capacity

- Average demand

The greater the variability in the service time, the longer is the potential delay at any given utilisation method.

We can consider our situation to be modelled as a Poisson process, since

1. Customers arrive one at a time.
2. The probability that a customer arrives at any time is independent of when other customers arrived.
3. The probability that a customer arrives at a given time is independent of the time.

The M/M/s Model According to [17], the most commonly used queuing model is the M/M/s or Erlang delay model. This model assumes a single queue with unlimited waiting room that feeds into s identical servers. Customers arrive according to a Poisson process with a constant rate, and the service duration has an exponential distribution. These two assumptions are often called Markovian, hence the use of the two M in the notation used for the model.

One advantage of using the M/M/s model is that it requires only three parameters and so it can be used to obtain performance estimates with very little data. Given an average arrival rate, λ, an average service duration, $1/\mu$, and the number of servers, s, easy-to-compute formulae are available to obtain performance measures such as the probability that an arrival will experience a positive delay, p_D, or the average delay W_q:

$$p_D = 1 - \sum_{n=0}^{s-1} p_n \tag{5.2}$$

$$W_q = p_D / [(1-\rho)s\mu] \tag{5.3}$$

for $\rho = \lambda / s\mu$ and

$$p_n = \begin{cases} \frac{\lambda^n}{n!\mu^n} p_0 & (1 \le n \le s) \\ \frac{\lambda^n}{s^{n-s} s! \mu^n} p_0 & (n \ge s) \end{cases}$$

where

$$p_0 = \left[\sum_{n=0}^{s-1} \frac{(\rho s)^n}{n!} + \frac{\rho^s s^{s+1}}{s!(s - \rho s)} \right]^{-1} \qquad \rho < 1\,.$$

Note that ρ is the average utilisation for this queuing system and the equation is only valid when the utilisation is strictly less than one. Also note that average delay increases as utilisation approaches one.

One common performance constraint is often referred to as the service level – a requirement that $x\%$ of customers start service within y time units. It's important to note that the model's delay predictions pertain only to waiting times due to the unavailability of the server.

```
clear all
close all
clc

%%parameter
delta_arrival_rate=4;
u=5; %1/average service time = 12 min
s=1%number of station service


p=delta_arrival_rate/(u*s); %average_utilization

p_00=[(p*s)+(((p^s)*4)/((s)*(s-1)*(s-(p*s)))))]^-1
p_01=[(p*s)+(((p^s)*4)/((s)*(s-1)*(s-(p*s)))))]^-1
p_tot=p_00+p_01;

p_n0=[1*p_tot];
p_n1=((delta_arrival_rate^1)/u)*p_tot

pd=1-(p_n0+p_n1);

Average_delay=pd/[(1-p)*s*u]
```

As a result, we get:

```
u =5 | s =1 |p_00 = 0.0| p_01 =0.|p_n1 = 0.0| Average_delay = 1 | pd
    =0.350 |p=0.8 [AVERAGE UTILIZATION]
```

```
clear all
close all
clc

%%parameter
delta_arrival_rate=8;
u=5.5; %1/average service time = 11 min
s=2%number of station service


p=delta_arrival_rate/(u*s); %average_utilization

p_00=[(p*s)+(((p^s)*8)/((s)*(s-1)*(s-(p*s)))))]^-1
p_01=[(p*s)+(((p^s)*8)/((s)*(s-1)*(s-(p*s)))))]^-1
p_tot=p_00+p_01;

p_n0=[1*p_tot];
p_n1=((delta_arrival_rate^1)/u)*p_tot

pd=1-(p_n0+p_n1);

Average_delay=pd/[(1-p)*s*u]
```

As a result, we get:

```
u =5.5 | s =2 |p_00 = 0.1875| p_01 =0.1875|p_n1 = 0.54555|
    Average_delay = 0.0265 | pd=0.0795 | p=0.7273 [AVERAGE
    UTILIZATION]
```

The results show us that an additional spot decreases the utilisation of the station but reduces the queue waiting time.

5.3 Public Fleets - Buses

Now, let us take a closer look on serving our second main customer group. Five main arguments speak in favour of considering buses in our case.

- They are suitable to use EV.
- Usually, the vehicles in the fleet are very similar so we can skip the problem of standardisation.
- The working time of the fleet is scheduled.

- Every small difference in time and maintenance can have a big impact on the cost.
- They are controlled by only one entity so the service can be tailored based on the priorities of the entity.

Taking into consideration that our environment is Turin, we can make a case study about the possibility of implementing our business for the new 100 e-bus that will arrive in Turin in the next years.[1] Some of them are already operating in Turin since the middle of May, 2021. They cover the line 58.

For this bus line, we collected the following information:[2]

- Average Distance = 9.4 km,
- Average buses per hour = 4,
- Hours of service = 16 h.

For the following calculations, we furthermore will assume:

1. Average distance = 10 km (from A to B and vice verse);
2. Average trip time = 30 min;
3. Service starts at 8.00 a.m.;
4. Buses arrive every 15 minutes for all the hours of service;
5. A bus waits 15 minutes before starting the next trip;
6. We have 6 stops in our single trip.

Figures 5.2 and 5.3 illustrate the schedule of the six assumed electric buses on their daily routine, including their return operation.

As we can notice from the two figures, to cover two hours of service, we need 6 e-buses working together. This means that each e-bus can cover three times the distance from A to B. Looking at our assumptions, this means 30 km every two hours of service. Hence, to cover the entire working day, the e-bus has to cover 240 km.

[1] urlhttps://www.gtt.to.it/cms/avvisi-e-informazioni-di-servizio/torino-e-cintura/8972-a-torino-un-nuovo-concetto-di-bus-in-servizio-i-primi-4-nuovi-bus-elettrici-byd-sulla-linea-58-da-lunedi-24-maggio

[2] Those information were provided by the Politecnico di Torino and were obtained in previous studies.

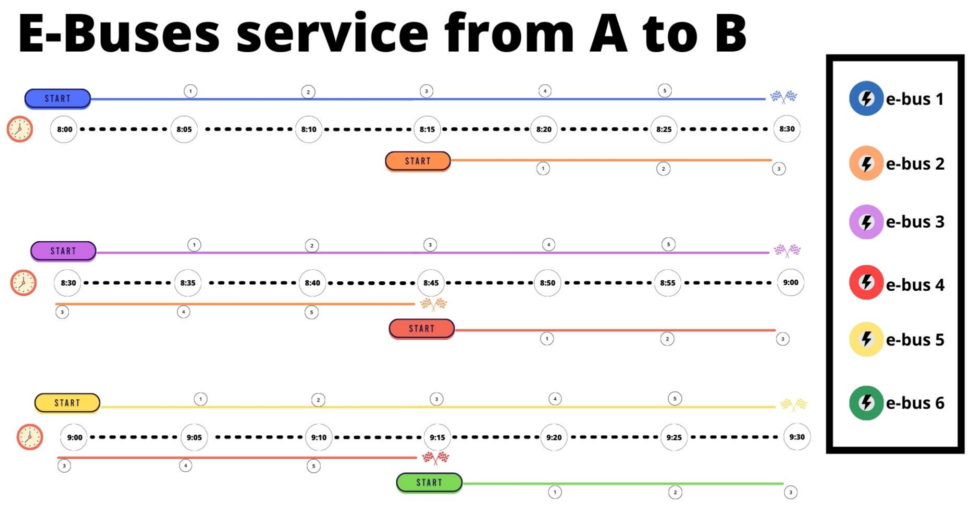

Figure 5.2: Assumed operation of buses. Source: Own elaboration.

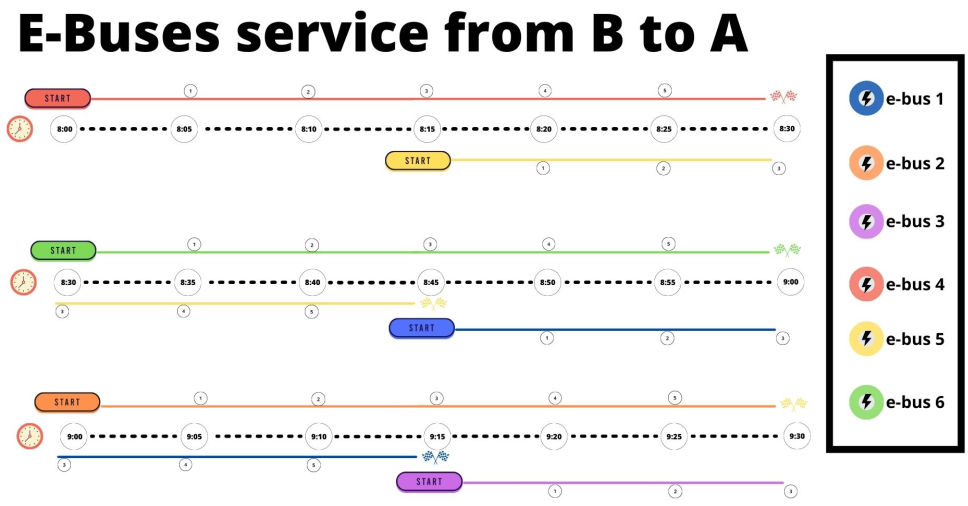

Figure 5.3: Assumed operation of buses, return. Source: Own elaboration.

Now let us look at the real data from the buses already operating in Turin serving on the 58 line. The bus model is a 12-metre BYD eBus. It has the following characteristics:

- Battery of 348 kWh (35 l of gasoline),

- Autonomy = 300 km,

- Recharge time = 3-5 hours.

Looking at the data, this means that a completely charged a e-bus can theoretically work for 20 hours straight. However, we are applying a safety margin of 20 %, i.e. we are considering here that the battery itself is safe if the charge does not overcome 80% of the battery's maximum capacity. We can therefore conclude that one single e-bus can work without recharging for the 16 hours of the scheduled service.

In summary, to cover the public line 58 for one day of service, we need 6 e-buses and 1 charge of the battery. This leads to the conclusion that we can recharge this battery in the 8 hours of non-service. This can even be done using fast-charging infrastructure.

Our relevant business case is now developed considering 100 e-buses. As average trip length, we are again taking 10 km. With this, our fleet is potentially capable of covering 20 lines. Because we are dealing with a significantly larger fleet now, we are going to take a 20% safety margin into account regarding the operational availability (not regarding the battery capacity). This considers regular maintenance of the e-bus as well as irregular spare time like accidents.

This means that we are able to deploy on average every day 80 e-buses working in Turin. The newly described scenario renders it clear that we can't recharge this whole fleet of e-buses using fast-charging stations. This is because first we would need at least 80 fast-charging sockets; and second we would need those to be always available at our convenience for a specific time to charge after service hours. Since a fast charger is usually shared by different customers, it is very unlikely that we can find these 80 charging sockets always available in the time we needed them.

Based on our previous example, let us take a look at the possible offer of a ZWAP-IT BSS and at the number of batteries that we needed have to have in the stock in order to offer a reliable service.

We specify the following two assumptions to look at our case:

1. We have only one BSS;

2. For every battery swap we need 15 minutes.

According to the above-mentioned assumption 2, in 24 hours of service the BSS is capable of changing 96 batteries. The time needed for a full recharge of a battery of BYD buses is 5 hours. This, in turn, means that during the time needed for one regular recharging period, we can swap 20 batteries.

To have a reliable service, we have to built a stock for supplying the BSS. This results in buying at least 21 batteries (see Eq.5.1). The start of the business in the usual way of BSS, therefore requires the purchase of 21 batteries for our stock plus acquisition of the 100 batteries needed for the e-buses that are circulating during the service.

Under the assumption of our case, the acquisition of 21 batteries can facilitate the operation of the whole Line 58. The upside of the battery swapping is that the operational time of each bus can be increased as there is no long standing time for the recharging process. In case the driving time of the bus shall not be increased (as serving the line follows a fixed schedule), the additional time can be used for higher-quality and more flexible maintenance and repair activities.

If we follow the usual business for BSS we need to have 21 in our stock that means 13,920 kWh of total storage capacity. The aspect of the total storage capacity can be later analysed in order to understand if there is the possibility to use the BSS as a energy balance and reservoir for the city grid.

Now we look at the cost side of the business. According to [18], the average cost for a battery of 1 kWh is 100 Euro. The cost of energy per 1 kWh is 0.5 Euro (Enel).

This adds up to an initial investment of

$$(100 + 21)x(348\, kWH) * €100/kWh = €4{,}210{,}800\,.$$

To recharge all the operating e-bus per day we need on average

$$348\, kWh * 80 = 27{,}840 kWh\,.$$

This leads to an energy cost per day equivalent to

$$27{,}840\, kWh * €0.5/kWh = €13{,}920\,.$$

We can buy energy at a price less than normal customers. For reasons of simplicity let us assume that we buy the energy for 0.3 Euro per kWh. In this case, we'd save 0.2 Euro per kWh. Hence, short-cutting the buying and the selling process, we can potentially make 0.2 Euro of margin per sold kWh. This resulted in a daily profit of 5,568 Euros.

Our initial investment is 4,210,800 Euros for the total battery storage plus the cost of the BSS itself. For now, we declare this to be 500,000 Euro. This gives us our total investment of 4,710,800 Euro.

If we want to break even this initial investment with our daily profits from the energy trading, we need

$$€4{,}710{,}800/\,(€5.568/\text{day}) = 846 \text{ days}\,.$$

An alternative to the purchase of all the total battery capacity upfront is using the existing batteries as part of the battery pool. The mayor difference for the analytic comparison in this case is the fact that with this alternative business model, we do not need to buy the 100 battery for the e-buses but only the 21 batteries needed for our stock. Let us take a look at how this changes the relevant figures.

The average battery cost and the cost of energy remain the same. The initial investment for the batteries, however, is significantly reduced to

$$21x348\,kWH * €100/kwH = €730{,}800\,.$$

The daily energy needed for recharging and the corresponding energy cost also remain the same as in the previous case. Assuming the same acquisition cost for the BSS, the total investment would 1,230,800 Euro.

The new break-even calculation regarding the amortisation time of the investment results in

$$1{,}230{,}800/€5{,}568/\text{ day} = 221 \text{ days}\,.$$

It becomes clear from this number that this strategy reduces our initial investment and, hence, becomes profitable in significantly less time.

Note that it is not extremely important to focus the attention on the exact number of days that we need to break even the initial investment. Nevertheless, it is important to notice the relation between the number in the two cases. Reducing 846 days to 221 means that there is the possibility to work on this strategic business model since it cuts the number to nearly 1/4.

In this stage of the business case analysis, we did not adequately represent the market numbers for the sake of the simplicity of the calculation. What can be noticed is that a strategy that involves a customer participation has a positive impact on the break-even time. In turn, it also reveals the potential to reduce the price of the service in order to increase the relationship with the customers, or give them corresponding incentives to participate in the proposed sharing model. The latter observation is well known from the sharing economy, see [19] for pricing or [20] for price fairness.

5.4 Trucks

For a long time, electric cargo trucks seemed to be a fantasy. According to a 2017 study by two mechanical engineer at Carnegie Mellow University, such a vehicle that would be capable of going 600 miles in a single charge, would need so many batteries that it would carry 25% less cargo (Gates, 2021). This in turn would render it economically not feasible under the reality of that time.

Fortunately, recent research and market news have confirmed that there are indeed models for electric trucks that are becoming technologically feasible and economically viable at the same time.

For the truck case, we consider two models. The Volta Zero model of Volta Trucks is illustrated in Fig. 5.4. The Volvo FMX is shown in Fig. 5.5.

Figure 5.4: Volta Zero. Source: `www.voltatrucks.com`.

A quantitative comparison of the two models is given in Tab. 5.1.

Truck Model	Volta Trucks "Volta Zero"	Volvo "FMX"
Powertrain	Electric energy	
Autonomy	200 km	300 km
Battery Capacity	200 kWh (standard)	540 kWh (utilisable)
Number of Batteries	3	6
Maximum Speed	90 km/h	120 km/h
Cargo	16 tons	44 tons

Table 5.1: Comparison of selected truck models. Source: Own elaboration.

For reasons of comparison, let's assume that both trucks have the same battery technology. Table 5.2 below then shows the charging time for both vehicles.

We can now take $170Wh/kg$ as density of the battery pack, This means that the Volta Zero truck has a battery weight of 1,177kg (392,15kg per pack) while the Volvo FMX has a total battery weight of 3,176.5kg (529,41kg per pack).

Furthermore, we assume the following constraints for the driver of both trucks:

Figure 5.5: Volvo FMX. Source: `www.volvotrucks.com`.

Truck model	Fast-Charging Time (0-100%)	Slow-Charging Time (0-100%)
Volta Zero	0.93 h	3.52 h
Volvo FMX	2.5 h	9.5 h

Table 5.2: Charging times for selected truck models. Source: own elaboration.

- Every driver can't work more than 6 consecutive hours
- If they work from 6-9 hours, they need 30 minutes of rest
- If they work for more than 9 hours, they need 45 minutes of rest.
- If they drive for more than 4.5 hours, 45 minutes of single rest are mandatory, and the rest can be split in 30 + 15 minutes.

In the following analysis, we will not take into consideration the weekly rest schedule or corresponding driving limitations of the drivers.

Now we introduce the possibility of a modular battery. This is possible because both trucks have separate packs. The analysis will, hence, focus on the reduction of the weight of the trucks. This will be correlated with the possibility of driving without packs and taking the battery pack only at the end of the supposed journey. For reasons of readability, let us analyse each case separately.

Volta Zero: The following MATLAB code was applied to obtain the results of the analysis for our first truck.

```
clear all
clc
close all
%% Fix parameter
% Drag coefficent
cw = 0.38;
% Reference area
S = 8.6229;
% Drag coefficent
mu = 0.01;
% Mass of Battery pack
mpack = 392.15;
% Empty mass of the car
mcar = 16000 - 3 * mpack;
% Density
rho = 1.225;
% Gravity
g = 9.81;
% All velocities
vall = linspace(2,100,500)/3.6;
%total resistence
Rtot=800;
% Loop over all packs
for j=1:3

    % Available energy
    Emax = 170 * 3600 * j * mpack;

     for i=1:length(vall)

         %% Extract velocity
         v = vall(i);

         %% Calculation
         stotal(j,i) = Emax / (rho/2*S*cw*v^2 + (mu * g * (mcar + j *
    mpack))+Rtot);
         ttotal(j,i) = stotal(j,i)/v;
     end
end
%% Diagram distance over speed
figure(1)
plot(vall*3.6,stotal(1,:)/1000,'k','LineWidth',2)
hold on
plot(vall*3.6,stotal(2,:)/1000,'b','LineWidth',2)
plot(vall*3.6,stotal(3,:)/1000,'m','LineWidth',2)
```

```
legend('n=1','n=2','n=3')
xlabel('Speed [1 km h^{-1}]','FontSize',16)
ylabel('Distance [1 km]','FontSize',16)
grid on
set(gca, 'FontSize',16)
%% Diagram time over speed
figure(2)
plot(vall*3.6,ttotal(1,:)/3600,'k','LineWidth',2)
hold on
plot(vall*3.6,ttotal(2,:)/3600,'b','LineWidth',2)
plot(vall*3.6,ttotal(3,:)/3600,'m','LineWidth',2)
legend('n=1','n=2','n=3')
xlabel('Speed [1 km h^{-1}]','FontSize',16)
ylabel('Time [1 h]','FontSize',16)
grid on
set(gca, 'FontSize',16)
%% Second calculation
% Fixed distance
s = 200 * 1000;
% All velocities
vall = linspace(2,100,500)/3.6;
% Loop over all packs
for j=1:3
    % Avialable energy
    Emax = 170 * 3600 * j * mpack;
    for i=1:length(vall)

        %% Extract velocity
        v = vall(i);

        %% Calculation
        E(j,i) = (rho/2*S*cw*v^2 + (mu * g * (mcar + j * mpack))) * s;
        Esave(j,i) = Emax - E(j,i);
        ttotal(j,i) = stotal(j,i)/v;
    end
end
%% Diagram saved energy over speed
figure(3)
plot(vall*3.6,Esave(1,:)/1000/1000,'k','LineWidth',2)
hold on
plot(vall*3.6,Esave(2,:)/1000/1000,'b','LineWidth',2)
plot(vall*3.6,Esave(3,:)/1000/1000,'m','LineWidth',2)
legend('n=1','n=2','n=3')
xlabel('Speed [1 km h^{-1}]','FontSize',16)
ylabel('Saved Energy [1 MW]','FontSize',16)
grid on
set(gca, 'FontSize',16)
```

The results of the simulation for the Volta Zero truck are displayed in Fig. 5.6 to 5.8. In each of the graphs, the three coloured lines represent the consideration of one, two, or three of the existing battery packs.

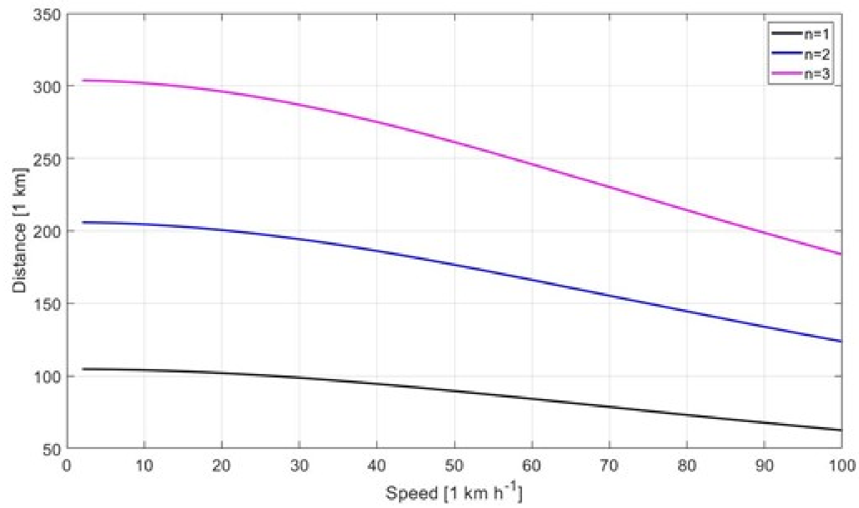

Figure 5.6: Volta Zero, autonomy achieved. Source: Own elaboration.

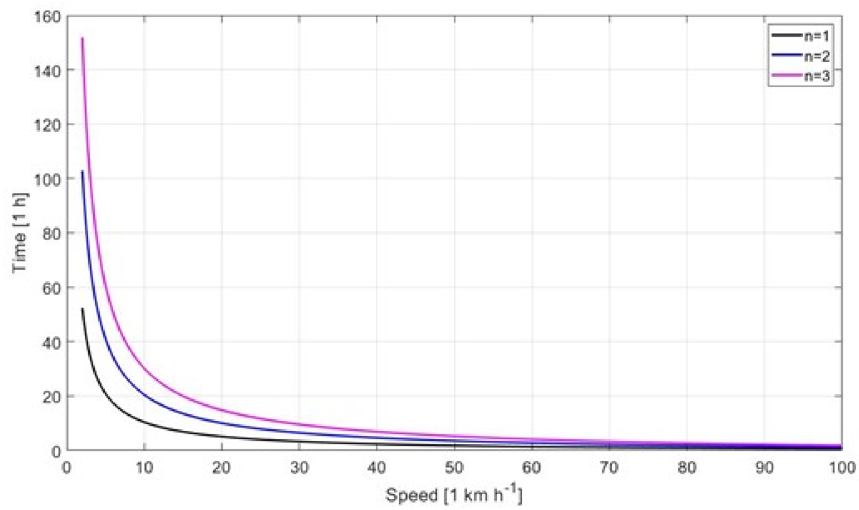

Figure 5.7: Volta Zero, swapping time. Source: Own elaboration.

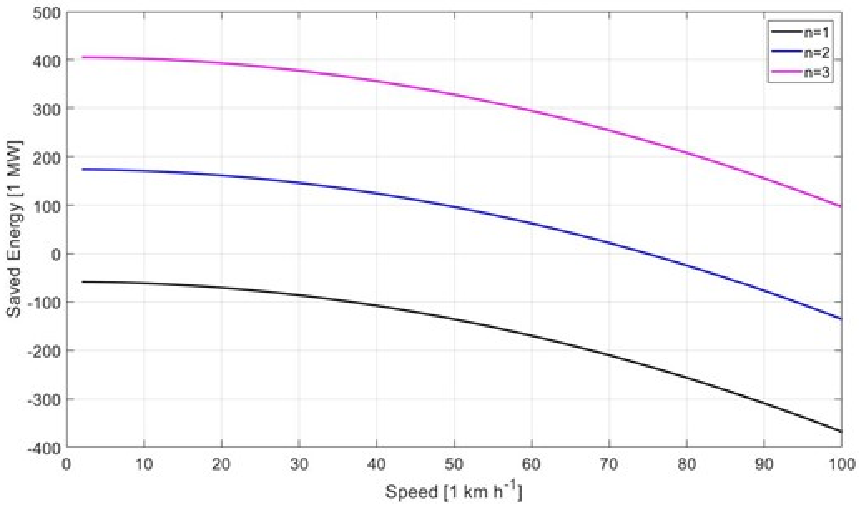

Figure 5.8: Volta Zero, saved energy. Source: Own elaboration.

Volvo FMX: For the simulation of our second truck, only the parameters had to be adapted. The rest of the code remains the same.

```
%% Fix parameter
% Drag coefficent
cw = 0.38;
% Reference area
S = 9.200;
% Drag coefficent
mu = 0.01;
% Mass of Battery pack
mpack = 529.41;
% Empty mass of the car
mcar = 44000 - 6 * mpack;
% Density
rho = 1.225;
% Gravity
g = 9.81;
% All velocities
vall = linspace(2,100,500)/3.6;
%total resistence
Rtot=800;

%% Second calculation
% Fixed distance
s = 300 * 1000;
```

The results of the simulation for the Volvo FMX truck are displayed in Fig. 5.9 to 5.11. In each of the graphs, the six coloured lines represent the consideration of one, to six of the existing battery packs.

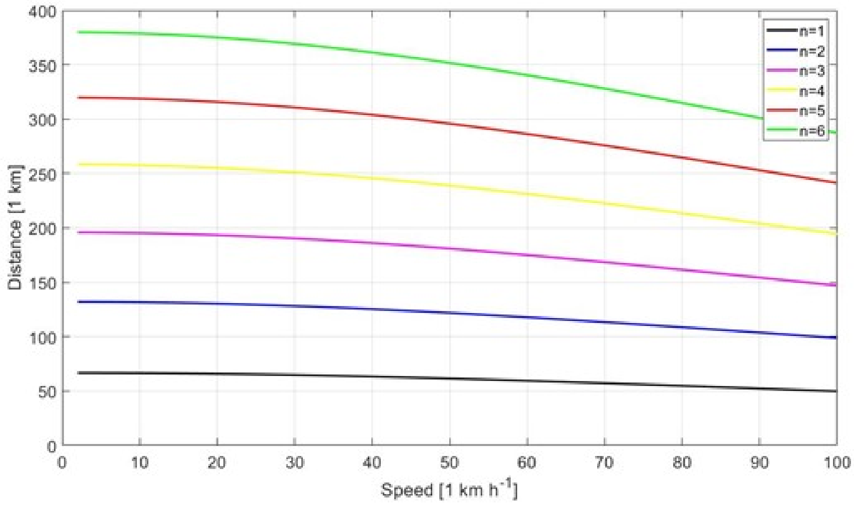

Figure 5.9: Volvo FMX, autonomy achieved. Source: Own elaboration.

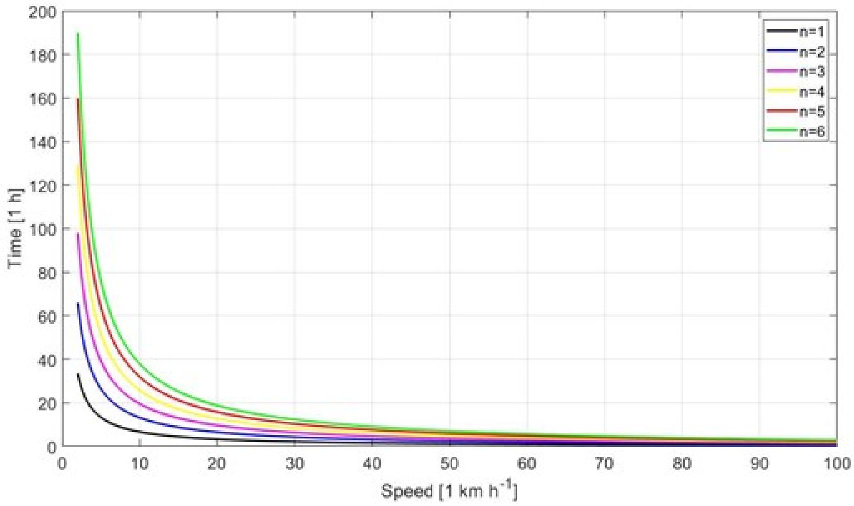

Figure 5.10: Volvo FMX, swapping time. Source: Own elaboration.

Now, let us have a final look at the charging times. Recall that the total fast-charging time for the Volta Zero truck was 0.93 h = 57 minutes and for the

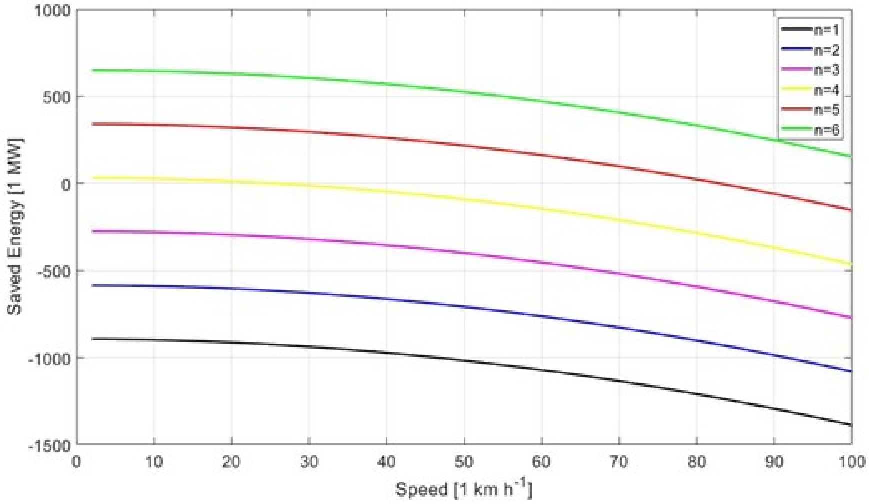

Figure 5.11: Volvo FMX, saved energy. Source: Own elaboration.

Volvo FMX truck $2.5h = 150$ minutes (compare Tab. 5.2). Breaking this down to the charging of the individual packs, we calculate $0{,}31h = 19$ minutes for the Volta Zero (with its three individual battery packs) and $0{,}43h = 26$ minutes for the Volvo FMX (with its six packs).

Remembering that our time spot is 30 minutes, both trucks can fast charge only 1 pack.

Now let us see how much time it will take with the swap technology for swapping the battery in a modular way.

The optimal time for making a swap of a module considering the existing technologies is 8 minutes. Since only Amble is performing this type of swap (compare Ch. 2), we can imagine our ZWAP station performing the modular swap as swapping in a row, thus, saving the time of alignments. It is therefore reasonable to assume 3 minutes more for each module swapped after the first one.

This leaves us with the following charging schedule according to the number of battery packs swapped.

According to Tab. 5.3, the gained time for having a complete charge with the swap compared to the fast charge is therefore 43 minutes for the Volta Zero truck (57 minutes - 14 minutes), equal to a reduction of 75%. For the Volvo FMX truck, the gain is even 127 minutes, equal to reduction of 85%.

With a modular battery, not only the battery swap reduces the time needed to receive a charged battery. Moreover, it offers the possibility to take out empty, not used batteries. For the case of transition between two geographically end

Number of Modules	Volta Zero	Volvo FMX
1	8 minutes	8 minutes
2	11 minutes	11 minutes
3	14 minutes	14 minutes
4	-	17 minutes
5	-	20 minutes
6	-	23 minutes

Table 5.3: Swapping Times for Modular Battery Packs. Source: Own elaboration.

locations of interest, a stop in the middle for the swap is an option to recharge or to reconfigure the truck load.

Leaving out a battery module allows to increase the cargo load or reduce the energy need for the loaded cargo. Battery swap with full replacement of batteries allow for extended trips with a fixed level of cargo.

Chapter 6

Discussion

6.1 Roadmap and Implementation

In this section, we will analyse the next steps that ZWAP-It will have to take. The period analysed will be the next 5 years and we will focus on the activities considered key to the success of our business.

6.1.1 Timeline and ToDos

The first task to do is necessarily related to the collaboration with Eurofork, because our technology and related business is strictly dependent on the technological capability of our swap station. In the first months, we will look for the possibility to develop the station with Eurofork.

In order to achieve this in the next few years, we should pay a lot of attention to the expansion of our team. The team needs a Chief Technology Officer (CTO) in the short term to take over the development and improvement of our software.

Alongside this figure, the company needs the casting of two software engineers, who will have the task of assisting the CTO. They will develop a data centre that will allow the ZWAPmeter to be integrated both with our ecosystem and with each vehicle we serve. In the long term, however, the team will have to expand to a significant size. This starts with those to be employed in the ZWAP Lab. There, a laboratory director will have to be hired, a figure who will lead the research and development centre and be an active bridge to the universities. For these reasons, this role will preferably be a professor from the Politecnico with whom an internship programme will be set up.

We also need the help of volunteers to be employed in our customer training , for which future job opportunities can be created. Furthermore, we will select a marketing director who can capture as much of the market as possible in the early stages. This will encourage the adoption of our solution.

In terms of period planning, ZWAP-IT will hence be looking for a CTO over the next 6 months to set the next steps in the development of our technologies. This will be followed by the search for and recruitment of 2 software engineers by the end of 2022. In the following 12 months, we will then look for a director of the research and development centre within the Politecnico.

2023 will be the year, when the internship programmes in cooperation with the university are supposed to start. The expected flow is 14 students/graduates per year. They will have the opportunity to expand our team of employees. A marketing director will be finally employed in early 2023.

An initial analysis suggests that the help of the Polytecnico will be crucial for achieving our goals and that ZWAP-IT must carve out a space for itself in the world of innovative start-ups in the coming months. An additional international character is expected to attract talents from Italy and abroad.

The steps we want to take with the expansion of our team will be directly related to the company's ability to raise money. The challenge is to raise at least 800,000 euro. This is planned to be done through the university's channels and the possible help of its incubator in the initial stages of the venture. The main motive is creating a strong identity in the technological world. Subsequently, funding will be sought through public funding and international funds from the EU, e.g. the Programme for Environment and Climate Action (LIFE).

As add-on projects, more future-oriented research shall be carried out. This can include the possible use of smart-contract technology used in blockchains as a means to ensure the transparency of our service, elimination of inefficient third parties and documentation of each transaction . These projects shall be funded through foundations and programs such as the Roddenberry Foundation.

We will also be developing crowdfunding campaigns that will not only raise money but also create awareness through the offering of educational courses and experiences in our company. In the short term, the venture will evaluate the possibility of having angel investors join. These can be a key resource for raising the necessary capital.

These phases will have to be substantially accompanied by the collaboration with Eurofork. As a potential scenario, the corporate will have the possibility to acquire part of the venture as an strategic investment, which would allow us to share assets and facilities.

To kick off operations, ZWAP-IT will have to set the headquarters, where the work of the management, the collaborations and the meetings will be carried out. The office will be searched in the city of Turin and will have to accommodate the work of five to eight team members with ample space for future meetings.

It is important to remember that the policy of ZWAP-IT is to share spaces and allow as much as possible a remote work. For the development of the first laboratories, we will ask for a space within the university in order to facilitate the flow of information and resources already present in the university.

The next steps regarding the incorporation of the company include looking for accounting and legal consulting services. This will be the step allowing us to organise payroll and finances in the long run.

Another relevant part is the choice of the bank with which we will carry out our financial operations. This deserves particular attention because of the future intensified collaborations with the same bank. Acknowledging the current trends in global finance, the possibility of introducing crypto payment and building crypto assets is an option that could precisely cut the transaction and investment costs otherwise typically required by banks.

6.1.2 Financial Outlook

Next to the operational planning and the administrative requirements to start the new venture, a crucial elements are the actual business numbers. From the presented business cases in Ch. 5 we have already learned that the battery swap model can be profitable.

For a simplified representation of the business model, we will assume that the battery swap itself is sufficiently attractive to customers in order to make them pay a monthly service fee. This will not consider the potential gains from trading electricity in favourable terms.

In this outlook, we are going to lay down some fundamentals to approximate the future size of the business and the corresponding capital needed. We will assume the year 2022 as the base year for operational start and hence consider the year 2027 as the horizon for the 5-year planning.

First, we will identify the core key performance indicators (KPI) of our business model. This allows us to focus on a limited number of variables to look at, while at the same time this is sufficiently representative of our case.

We have identified three metrics that we want to use to do the financial planning:

- Subscriptions,
- Service fee
- team size.

Subscriptions: This variable directly represents the size of our served market. For the sake of this analysis, we will channel all potentially different type of subscriptions into this number. The targeted levels refer to our ambition as well as the market realities we see today and in the future.

For the first year of operation, 2022, we want to serve the first 50 customers with our subscription model. This helps us to test the business strategy and also connect directly to the customers. We can learn what is going right and wrong and then subsequently slowly but steadily upscale. What we are doing is also collecting potential subscribers without directly adding them to our pool.

In the second year of operation, we will directly jump to serve the first 500 customers. This gives us a visible foot in the market. It also will enable us to grow the customer significantly. For the following years, we target to triple or later double the number of subscriptions, each year.

Our target size for the fifth year after we kick-off operation is 50,000 subscriptions. This is well in line with the expected market growth of the segment. Once fully established at this size, future leaps will even be larger, assuming external scaling strategies like venture capital or strategic partnerships.

Service fee: The monthly subscription fee will be launched with an initial price of 40 Euro. This is both, competitive towards the market and profitable for the ZWAP-IT business. We also plan to hold this price in the second year of operation, 2023.

With the first targets in subscriptions met, we are prepared to gradually decrease the service fee. Reasons to do that are the increasing competition from other providers of battery swap stations and new customer groups with higher price sensitivity.

Over the course of four years, i.e. until 2027, we expect the service fee to reach a level of 30 Euro per month. This amount seems acceptable given the proposition of a quick battery recharge and an improved battery monitoring during the subscription period.

Future reductions in the price are not considered. With a reasonable forecast, it is highly likely that the business model will register a significant twist anyway in the coming 7 years.

Team size: We take the team size as a direct approximation for the size of the business. This includes administrative efforts, customer acquisition, technical equipment etc.

Over the years, we assume that the team will not grow proportionally to the customer basis. This is justified by our approach to highly automate the business and build a scalable infrastructure from the beginning.

Nevertheless, a certain team growth is needed and targeted. After establishing the core team in 2022, with three people, we gradually add human resources. A small team is more easily to manage and also gives higher incentives to the individual contributors.

Similar to the observation of the customer growth, a significant growth in team size is expected after the financial establishment of the business in 2027.

The numerical assumptions for the 5-year planning up to 2027 are summarised in Tab. 6.1.

	Subscriptions	New Subscription	Monthly Fee	Team Size
2021	0	0	-	1
2022	50	50	€40	3
2023	500	1,500	€40	5
2024	2,000	4,500	€38	8
2025	6,500	13,500	€36	11
2026	20,000	40,500	€33	15
2027	50,000	150,000	€30	20

Table 6.1: 5-year plan after operational kick-off. Source: Own elaboration.

Note that for the regular year 2024-2026, the number of subscriptions in a year is assumed to be the customer base in the year before plus the new subscriptions. Before that, remember that we artificially limited the subscription base before broad-scale operation began in 2023.

From 2027 on, we included a certain percentage of customers leaving our community for natural (death, migration) or market reasons (neglecting their car, competitor offers). We assume a pessimistic 15% of historic customers to leave.

With the discussed basic parameters, we can look at classical financial KPI. As most indicative for the potential and success of the ZWAP-IT business model, we look at three numbers:

1. Revenues,
2. Cost,
3. Cash flow.

Annual revenues: The income side is linked to the number of active subscriptions. For reasons of simplicity, we calculate revenues in a three-step process. First, we calculate the revenue per customer. To do so, we multiply the monthly service fee with the number of subscriptions. The result is the revenue per customer per month.

The second step is calculating the annual revenue per customers. To get this, we multiply the monthly revenue with ten. This represents the ten months out of the year that are the typical reference for an annual subscription. Hence, a discount of two out of every twelve months is given.

In the third and last step, this annual revenue per customer (or per subscription) is then multiplied with the total customer base (or number of active subscriptions). The result is the annual revenue.

Note that this calculation does not count in the new subscriptions acquired throughout the year. This follows or low-profile, pessimistic approach to assume the lower-bound profitability in our scenario.

Annual Cost: As already described, we assume the team size to be a representative indicator for the venture's cost. In our case, we consider an annual cost of 100,000 Euro per team member.

This covers the financial compensation that will be limited in the first years. Moreover, it is expected to cover additional cost directly related to the person's work like technical equipment, software licenses etc.

Operational expenses for marketing and sales, accounting and legal consulting are also covered by this, as our assumption includes a grown business to be directly linked to a team expansion.

The cost reality with differentiated salaries and explicit attribution of operational cost can be specified in the deep-down business planning process.

Cash flow: The cash flow is defined as the difference between annual revenue and cost. This is sufficient at year's scale. Of course, a more detailed cash flow planning is important to guarantee liquidity during the year, not only in a theoretical year's total.

In our case, we assume an initial seed investment of 500,000 Euro to prepare the proper start of the business. This includes the writing of the business plan, the development of the smartMeter and the monitoring software as well as the setting up of the ZWAP Lab.

Therefore, 2022 has the highest negative outlook in terms of capital needed. The initial investment is added to the running cost of 300,000 Euro for this year (3 team members x the estimated 100,000 Euro per team member) and gives a negative cash flow of -800,000 Euro for this year.

The resulting financial planning is summarised in Tab. 6.2.

Figure 6.1 illustrates the estimated financials for the typical period of 5 years after initiating the venture.

The derived 5-year outlook shows three main properties, all of them can be seen in Fig. 6.1.

First, the targeted growth of the subscriptions is exponential. As discussed, this reflects both our venture's ambition but also the market reality of a booming EV market. In absolute terms, the target numbers go up to a 10% market share, which is desirable.

	Cumulated Cash Flow	Annual Revenue	Cost
2022	-€800,000*	€20,000	€300,000
2023	-€1,100,000	€200,000	€500,000
2024	-€1,140,000	€760,000	€800,000
2025	€100,000	€2,340,000	€1,100,000
2026	€5,200,000	€6,600,000	€1,500,000
2027	€18,200,000	€15,000,000	€2,000,000

Table 6.2: 5-year financials after operational kick-off. Source: Own elaboration. *Note: includes an initial investment of €500,000.

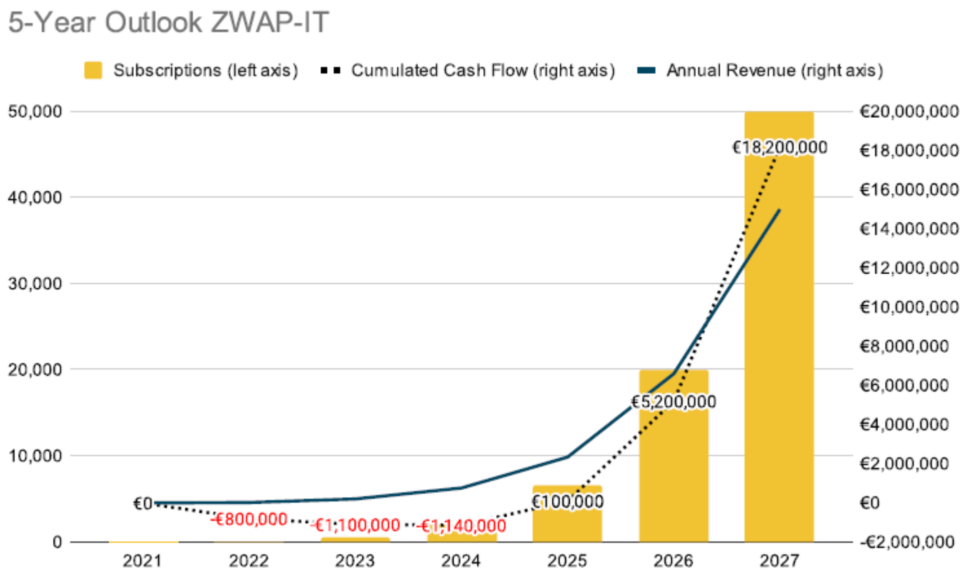

Figure 6.1: 5-Year Outlook. Source: Own elaboration.

Second, the cumulated cash flow follows a typical hockey-stick curve [22]. This means that it initially goes negative because of the initial investment needed. It even increases negatively up to its maximum in the year 2024 with a -1,140,000 Euro. However, the year after, cumulated cash flow turns positive and then keeps strongly increasing.

The bottom of the cash flow curve also indicated the capital requirement of the venture. In that case, a total investment of about 1.2 million Euro is needed to ignite the growth.

Third, the market potential is significant. In five ears of operation, ZWAP-IT can be built into an annual two-digit million Euro business. This underlines the attractiveness of the market and the venture.

Currently, both public and private investors do not only look into the financials when deciding about putting their money. Moreover, they look for impact and so-called clean technology. In the last part of this discussion, we will hence elaborate on the sustainability of ZWAP-IT.

6.2 Sustainability

Sustainability is the common theme that connects every operation, idea or development at ZWAP-IT. We have decided to operate in the two most emission-intensive sectors in the world: the energy sector and the transport sector. We want to be part of the green movement that the world and the new generations need.

Electric mobility will certainly be the future of our transport and therefore of our economy and our flow of ideas. This is thanks to a shared awareness and increasingly stringent laws imposed by more developed nations. Nevertheless, ZWAP-IT wants to substantially differentiate itself from other proposals on the market through our:

- Green business model,
- Digital office, and
- Batteries management.

Green Business Model: If we exclude the production of the swap station, which is carried out by a third-party company, and the purchase of 5% of battery packs compared to the whole pool served, production is solely related to the development of the ZWAP-Meter. This is a key element in making our fleet intelligent and therefore more sustainable thanks to our algorithms that cut energy waste. This is thanks to the innovation of the service offered that makes the cooperation of assets between customer and company possible.

All of this translates into a sustainable model that does not create waste and useless used material. The use of existing resources is another important characteristic of this comprehensive philosophy.

We want to achieve sustainability not only in terms of the internal operations of our system and our company, but also across the ecosystem we create. This is why the use of electricity from renewable sources is preferred over non-renewable sources. This will even be true despite the premium price they cost.

Digital office: The change and revolution that a technology like swapping brings must be extended to the whole ecosystem involved. This also includes our team and our way of working. In order to limit waste in any form, ZWAP-IT embraces the idea of flexibility and freedom given by its service also in the workplace.

In fact, the office will be the place, where important meetings and contracts will be signed. It will always be fully utilised in order to maximise the use of the asset but our employees will work mostly remotely. This, again, will be considerably cutting the waste that comes from moving. Remote working will be applied wherever possible, including in laboratories, where we believe that the robotisation of equipment can be used effectively remotely.

As described before, each operation will be transparent for customers and then documented. This had caused considerable paper consumption in previous ventures but each of our documents will exist only digitally if legally feasibly and then promptly be saved in our servers. Cloud technology will be used whenever possible. The same documents related to customers and their data on batteries that may be required will be available in our application. Finally, each operation will be encrypted in order to ensure the authenticity.

Batteries management: The efficiency proposed by our service is directly related to the improvement of the battery life cycle. Thanks to the life cycle management, batteries could extend their life by 50% and minimise the dangers related to the state of the battery and subsequent charging. This is because each battery is charged only at optimal currents and in controlled environments (compare Arora et al., 2021).

The sustainability of our business model is further enhanced by the added value that the batteries in our stock have once the service relationships are over. In fact, the documented information and tests on the batteries give a higher value to the cars ensuring a better market price for the sale of used EV.

Battery efficiency is further safeguarded by our service entrance tests. They identify unsuitable batteries that are then disassembled and used in minor applications, or recycled. If the battery has totally unusable parts, these are subjected to the classic recycling process. For lithium ion batteries, this allows the recovery of 95% of the basic components.

Overall, the sustainability aspects of the ZWAP-IT business model render the whole venture not only financially attractive but also valuable for employees and society.

Chapter 7

Conclusion

7.1 Main Results

At the beginning of the thesis, the following two research questions were raised:

i *How does a battery-swap approach to e-mobility compare to (fast-)charging in terms of efficiency and cost?*

ii *What is a feasible business model including a road to implementation for such a battery-swap venture?*

After the review of the existing literature and an extensive research and process of business modelling. The questions can be answered in a favourable way.

First, battery swapping is a suitable approach to reduce the cost of recharging batteries for EV. It is superior regarding slow charging in terms of time and competitive regarding fast-charging technologies.

Especially for heavy commercial vehicles, it provides an attractive alternative to reduce spare times and enhance efficiency. When the batteries are built in a modular way - as is typical for newer EV cargo trucks - the selective replacement offers new way of performance increase.

Particularly noteworthy is improvement through a controlled battery charge management. The innovative approach to use battery pooling allows a complete life-cycle management. This, in turn, leads to a better utilisation of the battery capacity and reduced cost.

From a pure technological perspective, battery swapping is hence an approach that will remain on the technological roadmap. However, to become successful in a market application, also the right implementation is needed.

The second question regarding a feasible business model to implement the battery swap could also be properly addressed. Using the BMC method and an elaboration on the business-related numbers, it was shown that a venture is possible and profitable.

Because the technological foundation is convincing in terms of efficiency and cost, the battery swap service is mainly depending on the right selection of the starting point. The examples discussed include the two widest-spread EV in the Italian passenger EV market and a public bus lane in Turin.

With the general feasibility of the business model laid down, the remaining part will include the actual transfer of the concept presented in this thesis to the creation of start-up venture. This shall mainly include the specification of the business plan according to the market and banking requirements, not academic standards.

While the core objectives of this thesis have been addressed, room remains for an extension or adaption of this work. To prepare this, limitations and an outlook are discussed in the folliwing.

7.2 Limitations

A first limitation is related to the specifics of the equipment available in the market. Unfortunately, there is no confirmation yet regarding the exact design of the BSS.

Contact was initiated to reach out to Eurofork. There has been no straight response yet. It is expected that along the aftermath of the thesis, the specifics will be learned and that institutional contacts like the Politecnico can support in the communication with external companies.

Recall that within the business case analysis, we have made certain assumptions on the demand side. To make the case even stronger, several aspects are important to be considered.

We need to check whether the numbers taken from Turin are representative for the whole Italian market. Within the initial selection of Turin, we have already placed some assumptions about its representative character. Beyond that, also the strategic location of the region cannot be denied. Because of this, an update and revision of the actual market numbers will be an ongoing process.

Likewise, the market numbers for assumed prices need to be reviewed on a regular basis. In the dynamic energy market in Europe and the global shortage in resources, a constant update and market observation is crucial for future success.

Overall, the thesis has been transparent to the extent possible, where the assumed figures are exemplary or crucial. It is not expected for the relevant market numbers to change in a scale that renders the whole analysis outdated.

Within the study, a number of assumptions has moreover been made. As in their nature, those build the foundation of the subsequent analysis and, hence, may affect the results in a larger or smaller manner.

The assumption that EV owners and operators will be willing to accept a battery sharing model is crucial. In order to prove that assumption, a deeper study with EV owners is necessary. However, the market is already developing tools to facilitate the performance measuring of used batteries.

The Austrian company *Aviloo*, for example, is offering a complete check of the EV battery for 180.- Euro.[1] They send over a kit to directly connect to the OBD connection of the EV and monitor the measurement via a mobile application.

The presumable strongest simplification was the financial outlook. A proper business model had to include a distinct consideration of the revenue and cost side. However, as argued along the thesis, the simplifying assumptions were always taken at cost of profitability, i.e. a more precise investigation should render the results even more positive.

7.3 Outlook

For this thesis we have put the focus on the actual feasibility and profitability of the battery swap according to our innovative proposal. In short run, this means using existing technology and equipment to enter the market fast. In the long run, however, the ZWAP-IT venture will get more involved into the development of individually improved BSS according to their needs.

Battery swap in general is a way to increase operational efficiency, when the utilisation of vehicles is higher. This becomes possible through not wasting time with a charging process, which is particularly significant with heavier vehicles.

In the case of operating a public fleet of buses, this can mean to serve the same line with or smaller intervals between arrivals or serving the exact same schedule with a smaller number of buses.

The actual decision how to use those benefits from the ZWAP-IT service will be up for discussion in the future. A close cooperation between the venture and the partners and clients will bring up solutions that yield favourable results for all parties.

Because of the innovative core of ZWAP-IT, future research will not only be limited to battery swapping. For example, there are also other approaches to make e-mobility more attractive, also for heavier vehicles.

[1] urlhttps://aviloo.com/batterytest.html

In their study, [24] analyse a scenario with a platooning strategy for seven trucks and conclude that this can lead to a 15% reduction in battery pack size. An electric semi-truck with a range of up to 300 miles can become feasible, both technologically and economically, according to their results.

Another path of research will include the psychological aspects of understanding customer expectations. This will include their attitude towards sharing, sustainability and individual mobility.

Appendix A

EV Models in Italy

This appendix contains information about the five EV with the highest sales in the Italian market according to the Electric Vehicle Database:[1]

1. Renault Zoe
2. Smart EQ forfour
3. Tesla Model 3
4. Volkswagen e-Up!
5. Fiat 500e

[1] `https://ev-database.org/`.

A.1 Renault Zoe ZE50 R110

Figures A.1 and A.2 show the Renault Zoe EV and its corresponding specifications.

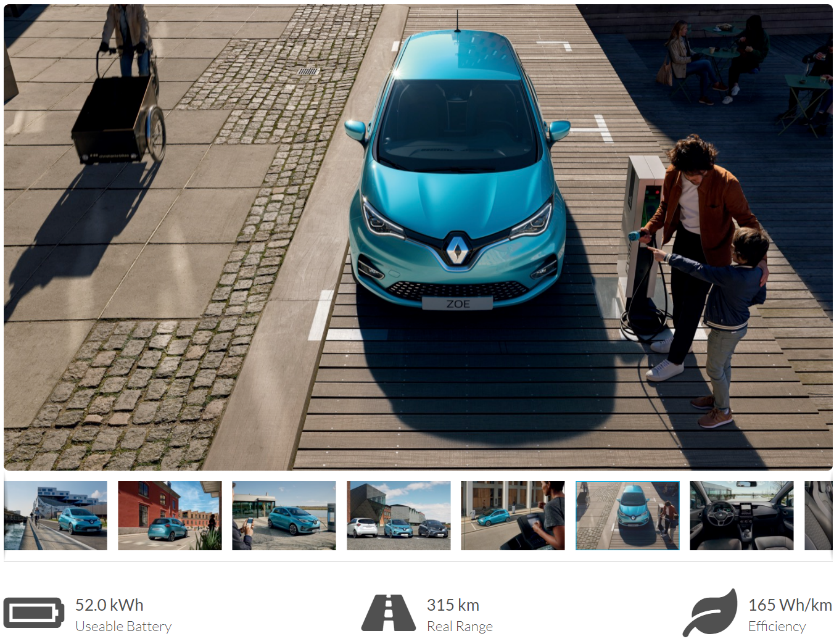

Figure A.1: Renault Zoe. Source: `https://ev-database.org/`.

Performance

Acceleration 0 - 100 km/h	11.4 sec	Total Power	80 kW (109 PS)
Top Speed	135 km/h	Total Torque	225 Nm
Electric Range	315 km	Drive	Front

Battery and Charging

Battery Capacity *	54.7 kWh	Battery Useable	52.0 kWh
Europe			
Charge Port	Type 2	Fastcharge Port	CCS
Port Location	Front - Middle	FC Port Location	Front - Middle
Charge Power	22 kW AC	Fastcharge Power (max)	46 kW DC
Charge Time (0->315 km)	3 hours	Fastcharge Time (32->252 km)	56 min
Charge Speed	110 km/h	Fastcharge Speed	230 km/h

Figure A.2: Renault Zoe - Specifications. Source: `https://ev-database.org/`.

A.2 Smart EQ forfour

Figures A.3 and A.4 show the Smart EQ forfour EV and its corresponding specifications.

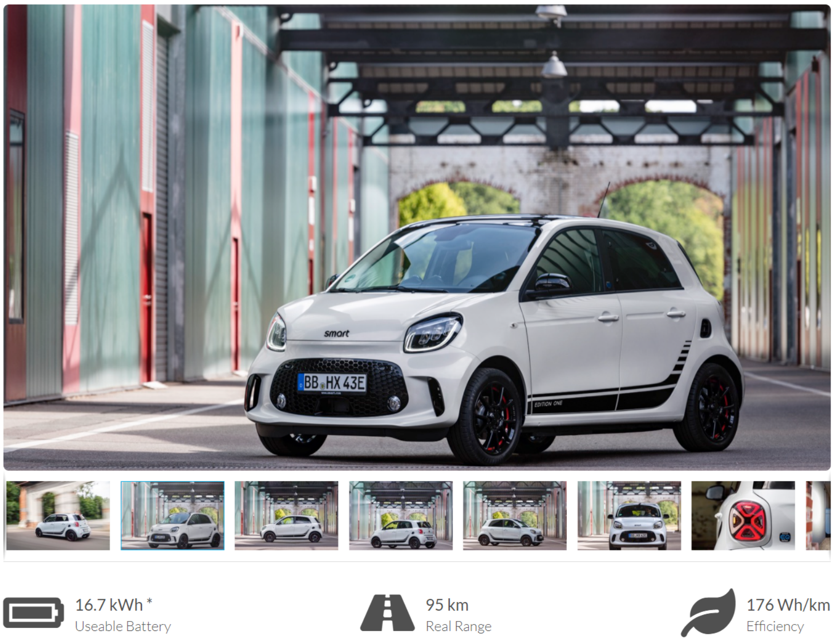

Figure A.3: Smart EQ forfour. Source: `https://ev-database.org/`.

Performance

Acceleration 0 - 100 km/h	12.7 sec	Total Power	60 kW (82 PS)
Top Speed	130 km/h	Total Torque	160 Nm
Electric Range	95 km	Drive	Rear

Battery and Charging

Battery Capacity	17.6 kWh	Battery Useable*	16.7 kWh
Europe			
Charge Port	Type 2	Fastcharge Port	-
Port Location	Right Side - Rear	FC Port Location	-
Charge Power	4.6 kW AC	Fastcharge Power (max)	-
Charge Time (0->95 km)	4h30m	Fastcharge Time	-
Charge Speed	22 km/h	Fastcharge Speed	-

Figure A.4: Smart EQ forfour - Specifications. Source: `https://ev-database.org/`.

A.3 Tesla Model 3 Performance

Figures A.5 and A.6 show the Tesla Model 3 EV and its corresponding specifications.

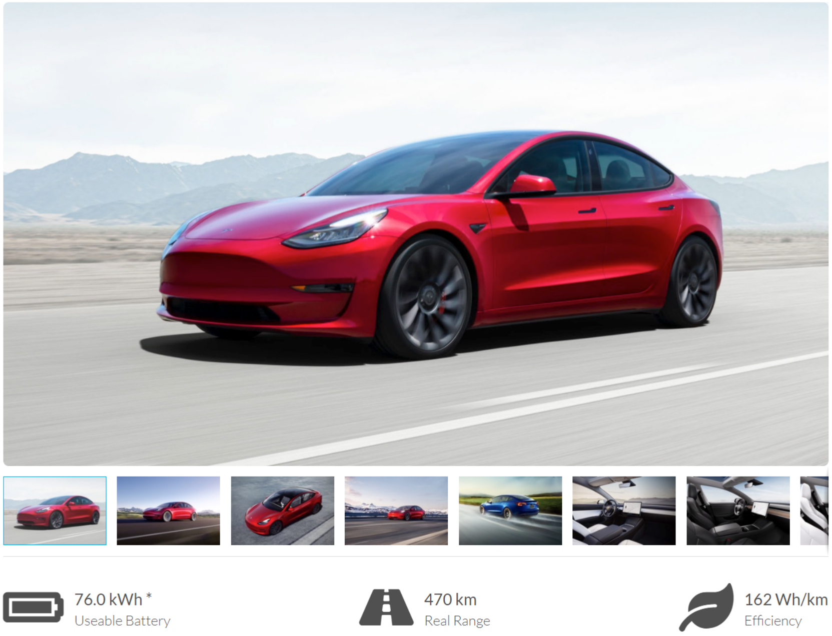

Figure A.5: Tesla Model 3. Source: `https://ev-database.org/`.

Performance

Acceleration 0 - 100 km/h	5.6 sec	Total Power *	239 kW (325 PS)
Top Speed	225 km/h	Total Torque *	420 Nm
Electric Range *	340 km	Drive	Rear

Battery and Charging

Battery Capacity *	55.0 kWh	Battery Useable*	50.0 kWh

Europe

Charge Port	Type 2	Fastcharge Port	CCS
Port Location	Left Side - Rear	FC Port Location	Left Side - Rear
Charge Power	11 kW AC	Fastcharge Power (max)	170 kW DC
Charge Time (0->340 km)	5h30m	Fastcharge Time (34->272 km)	21 min
Charge Speed	64 km/h	Fastcharge Speed	680 km/h

Figure A.6: Tesla Model 3 - Specifications. Source: `https://ev-database.org/`.

A.4 Volkswagen e-Up!

Figures A.7 and A.8 show the Volkswagen e-Up! EV and its corresponding specifications.

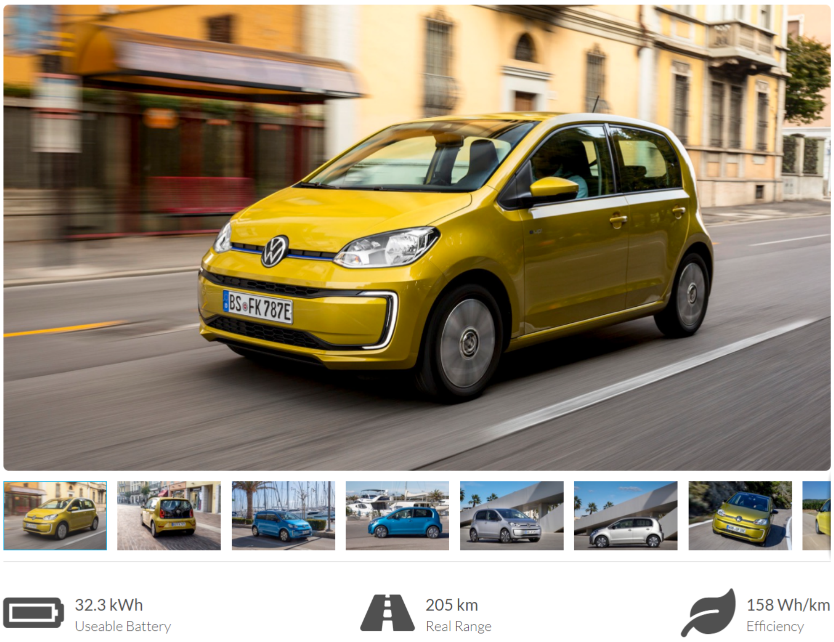

Figure A.7: Volkswagen e-Up! Source: `https://ev-database.org/`.

Performance

Acceleration 0 - 100 km/h	11.9 sec	Total Power	61 kW (83 PS)
Top Speed	130 km/h	Total Torque	210 Nm
Electric Range	205 km	Drive	Front

Battery and Charging

Battery Capacity	36.8 kWh	Battery Useable	32.3 kWh

Europe

Charge Port	Type 2	Fastcharge Port	CCS
Port Location	Right Side - Rear	FC Port Location	Right Side - Rear
Charge Power	7.2 kW AC	Fastcharge Power (max)	40 kW DC
Charge Time (0->205 km)	5h30m	Fastcharge Time (21->164 km)	48 min
Charge Speed	39 km/h	Fastcharge Speed	170 km/h

Figure A.8: Volkswagen e-Up! - Specifications. Source: `https://ev-database.org/`.

A.5 Fiat 500e Hatchback 42 kWh

Figures A.9 and A.10 show the Fiat e500 EV and its corresponding specifications.

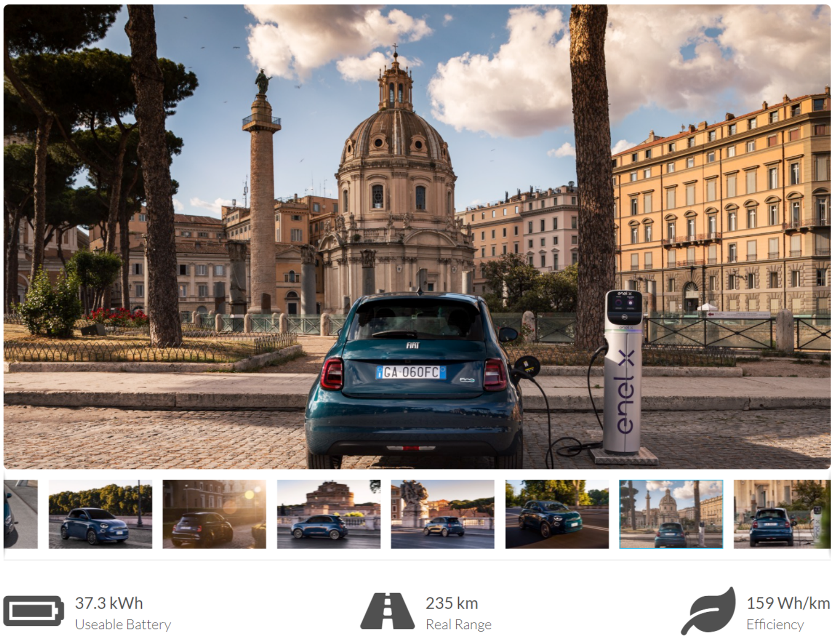

Figure A.9: Fiat 500e. Source: `https://ev-database.org/`.

Performance

Acceleration 0 - 100 km/h	9.0 sec	Total Power	87 kW (118 PS)
Top Speed	150 km/h	Total Torque	220 Nm
Electric Range *	220 km	Drive	Front

Battery and Charging

Battery Capacity	42.0 kWh	Battery Useable*	37.3 kWh

Europe

Charge Port	Type 2	Fastcharge Port	CCS
Port Location	Right Side - Rear	FC Port Location	Right Side - Rear
Charge Power	11 kW AC	Fastcharge Power (max)	85 kW DC
Charge Time (0->220 km)	4 hours	Fastcharge Time (22->176 km)	25 min
Charge Speed	55 km/h	Fastcharge Speed	370 km/h

Figure A.10: Fiat 500e - Specifications. Source: `https://ev-database.org/`.

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