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BUSINESS SCHOOL**

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Dan, Yang

MASTER THESIS

VERSLUMO STRATEGIJOS ELEKTROMOBILIŲ GREITOJO ĮKROVIMO SRITYJE: PASAULINIAI VERSLO MODELIAI IR INFRASTRUKTŪROS PLĖTRA	ENTREPRENEURIAL STRATEGIES IN EV FAST-CHARGING: GLOBAL BUSINESS MODELS AND INFRASTRUCTURE EXPANSION
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SUMMARY

VILNIUS UNIVERSITY BUSINESS SCHOOL

DEEPTECH ENTREPRENEURSHIP [6211LX013]

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ENTREPRENEURIAL STRATEGIES IN EV FAST-CHARGING: GLOBAL BUSINESS

MODELS AND INFRASTRUCTURE EXPANSION

Supervisor – Doc. Dr. Eglė Radvilė Terminė

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Number of bibliography and references – 61 sources.

The FMT described in brief: This thesis investigates the role of entrepreneurial strategies and innovative business models in expediting the global advancement of electric vehicle fast-charging infrastructure. It meets the growing need for networks that can grow and stay financially stable as more and more people buy electric vehicles. The research looks at global trends in the EV market, fast-charging technologies, and policy frameworks. It also talks about problems like high installation costs, grid capacity limits, and other issues. It looks at business models like pay-as-you-go, subscription plans, battery swapping, and ultra-fast charging hubs to see how well they would work in different market and regulatory situations. Real-world examples from top companies and startups in China, the EU, and the US show how to improve infrastructure and make operations more efficient. A scoring model uses things like EV adoption, infrastructure density, and policy incentives to figure out how likely a startup is to succeed and how much potential the market has.

Problem of the FMT: How can innovative business models and entrepreneurial methods help build rapid charging networks that can grow and make money in different regions around the world?

Main objective of the thesis: To study the relationship between technology, business

models, and policy in building EV fast-charging infrastructure and to create a practical framework for successful network expansion.

Main tasks:

1. Review the main fast-charging technologies and their impact on infrastructure growth.
2. Compare business models and strategies in China, the EU, and the U.S.
3. Analyze case studies of leading companies and startups.
4. Use a scoring model to evaluate market potential and startup viability.
5. Suggest practical recommendations for startups.

Research methods: The FMTP has literature review, case study analysis, and a scoring model. Data for scoring model is taken from academic papers, industry reports, and public sources like International Energy Agency (IEA) and International Council on Clean Transportation (ICCT).

Results obtained: The research shows there is no single best strategy for building EV fast-charging networks. Success depends on adapting plans to local conditions, including demand, infrastructure readiness, policy support, and competition. In fast-growing markets, flexibility and cost efficiency are critical, while mature markets require innovation, digital integration, and high service quality. Several recommendations were given depending on the location and business model of the choice.

Conclusions of the FMT: Some of the main conclusions from this work:

1. Fast-charging networks are very important for EV adoption. Countries with more chargers show that infrastructure drives the market.
2. Standardization matters. Using common charging protocols and roaming agreements makes charging easier and improves station use.
3. Government support speeds up growth, while unclear or fragmented policies slow progress and make it harder for startups.
4. Regional strategies are different: China grows quickly in the short term, the U.S. has strong long-term potential because of high potential income, and Germany offers stability with clear rules.

SUMMARY

VILNIAUS UNIVERSITETO VERSLO MOKYKLA
AUKŠTŲJŲ TECHNOLOGIJŲ VERSLAS [6211LX013]

DAN YANG

VERSLUMO STRATEGIJOS ELEKTROMOBILIŲ GREITOJO ĮKROVIMO SRITYJE:

PASAULINIAI VERSLO MODELIAI IR INFRASTRUKTŪROS PLĖTRA

Darbo vadovė – Doc. Dr. Eglė Radvilė Terminė

Magistro darbas parengtas Vilniuje, 2026 m.

Magistro darbo apimtis – 74 puslapiai.

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Literatūros šaltinių kiekis - 61 psl.

Trumpas Magistro darbo aprašymas: Šiame darbe nagrinėjama, kaip verslumo strategijos ir inovatyvūs verslo modeliai gali paspartinti elektromobilių greitojo įkrovimo infrastruktūros plėtrą visame pasaulyje. Atsižvelgiant į sparčiai didėjantį elektromobilių naudojimą, analizuojama, kaip išnaudoti augantį poreikį kuriant tinklus, kurie būtų lengvai plečiami ir finansiškai tvarūs. Tyrime pateikiama pasaulinės elektromobilių rinkos tendencijų, greitojo įkrovimo technologijų ir įvairių apžvalga. Išryškunami pagrindiniai iššūkiai, tokie kaip didelės įrengimo sąnaudos, ribotas tinklo pajėgumas ir kitos problemos. Analizuojami įvairūs verslo modeliai: „mokėk pagal naudojimą“, prenumeratos tipo planai, baterijų keitimas ir itin greito įkrovimo stotys. Vertinama jų tinkamumas skirtingose rinkose ir reguliavimo aplinkose. Pateikiamos praktinės įžvalgos apie infrastruktūros plėtros ir veiklos efektyvumo strategijas iš Kinijos, Europos Sąjungos ir Jungtinių Valstijų skirtingų atvejų analizės. Sukurtas vertinimo modelis, kuris padeda analizuoti rinkos ir startuolių potencialą pagal tokius rodiklius kaip elektromobilių įsisavinimas, bendra infrastruktūra ir skatinamosios priemonės.

Magistro darbo problema: Kaip verslumo strategijos ir inovatyvūs verslo modeliai gali padėti sukurti elektromobilių greitojo įkrovimo tinklus, kurie būtų finansiškai sėkmingi skirtingose pasaulio rinkose?

Magistro darbo tikslas: Ištirti technologijų, verslo modelių ir politikos sąveiką kuriant elektromobilių greitojo įkrovimo infrastruktūrą ir parengti praktinį tinklų plėtros modelį.

Tyrimo uždaviniai:

1. Apžvelgti pagrindines greitojo įkrovimo technologijas ir jų poveikį infrastruktūros plėtrai.
2. Palyginti verslo modelius ir strategijas Kinijoje, ES ir JAV.
3. Atlikti pirmaujančių įmonių ir startuolių atvejų analizę.
4. Taikyti vertinimo modelį rinkos, bei startuolių potencialui įvertinti.
5. Pateikti praktines rekomendacijas startuoliams.

Tyrimo metodai: Darbas remiasi literatūros analize, atvejų tyrimu ir kiekybiniu vertinimo modeliu. Duomenys gauti iš mokslinių publikacijų, pramonės ataskaitų ir viešų šaltinių, tokių kaip Tarptautinė energetikos agentūra (IEA) ir Tarptautinė švaraus transporto taryba (ICCT).

Gauti rezultatai: Tyrimas parodė, kad nėra vienos geriausios strategijos elektromobilių greitojo įkrovimo tinklams kurti. Sėkmė priklauso nuo gebėjimo pritaikyti planus prie vietos sąlygų, įskaitant paklausą, infrastruktūros pasirengimą, politinę paramą ir konkurenciją. Sparčiai augančiose rinkose svarbiausia lankstumas ir sąnaudų efektyvumas, o brandžiose rinkose, tai inovacijos, skaitmeninė integracija ir aukšta paslaugų kokybė. Buvo pateiktos kelios rekomendacijos, atsižvelgiant į lokaciją ir pasirinktą verslo modelį.

Išvados: Svarbiausios darbo išvados:

1. Elektromobilių greitojo įkrovimo tinklai yra labai svarbūs elektromobilių plėtrai. Šalys, turinčios daugiau įkrovimo stotelių, rodo, kad infrastruktūra yra pagrindinis rinkos augimo veiksnys.
2. Standartizacija yra būtina. Bendri įkrovimo protokolai ir tarpusavio tinklų naudojimo susitarimai palengvina naudojimą ir didina stotelių naudojimą.
3. Vyriausybės parama spartina plėtrą, o neaiški ar fragmentuota politika stabdo progresą ir didina riziką startuoliams.
4. Regioninės strategijos skiriasi: Kinija sparčiai auga trumpuoju laikotarpiu, JAV turi didelį ilgalaikį potencialą dėl aukštų pajamų, o Vokietija užtikrina stabilumą dėl aiškių taisyklių.

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LIST OF ABBREVIATIONS

AC – Alternating Current

AFIR – Alternative Fuels Infrastructure Regulation

BEV – Battery Electric Vehicle

BMS – Battery Management System

CCS – Combined Charging System

DC – Direct Current

DCFC – Direct Current Fast Charging

DSO – Distribution System Operator

EV – Electric Vehicle

EU – European Union

GB/T – Guobiao Standards (China)

ICEV – Internal Combustion Engine Vehicle

ICCT – International Council on Clean Transportation

IEA – International Energy Agency

IEC – International Electrotechnical Commission

kW – Kilowatt

kWh – Kilowatt-hour

LCFS – Low Carbon Fuel Standard

NEVI – National Electric Vehicle Infrastructure Program

NACS – North American Charging Standard

PAYG – Pay-As-You-Go

PHEV – Plug-in Hybrid Electric Vehicle

PV – Photovoltaic

RTP – Real-Time Pricing

SAE – Society of Automotive Engineers

STEPS – Stated Policies Scenario

TOU – Time-of-Use

TEN-T – Trans-European Transport Network

V2G – Vehicle-to-Grid

VC – Venture Capital

VDC – Volts Direct Current

VPP – Virtual Power Plant

XFC – Extreme Fast Charging

INTRODUCTION

Electric cars are becoming a big element of transportation systems all around the world. They assist lower carbon emissions and make transportation more sustainable. For instance, in 2024, there were more than 17 million electric automobiles sold around the world. This was a big jump from the 3 million sold in 2020. This quick increase illustrates that electric cars are no longer just for a small group of people; they are now a popular choice for many. As more electric cars hit the road, the need for faster charging stations is also expanding significantly. These stations let drivers charge their cars quickly, which helps ease range anxiety, which is a big worry for those who drive electric cars. China, the European Union, and the United States are leading the way in this change by building big charging networks. But it's still hard to construct these networks because of the high costs of installation, the constraints on grid capacity, and the fact that each region has its own rules. A lot of research looks at the electric vehicle market, charging technologies, and government incentives. There is, however, not much study that looks at how different company models and entrepreneurial methods perform in real life in different parts of the world. It is also not apparent how these techniques will help fast charging networks grow and do well. Most studies only look at technology or policy, and only a few look at all three: market potential, infrastructural readiness, and startup strategy. The FMTP fills the gap by looking at case studies of already existing companies and using a comparative scoring model to look at market circumstances in China, the EU, and the US.

Relevance: This thesis looks at how business strategies can help expand EV fast-charging networks globally. Technology for fast charging has improved a lot, but expanding the fast-charging station networks remains expensive and not straightforward. Companies face problems such as high costs, grid limits, and different rules in each region. Understanding how technology, business models, and government policies work together is important for creating successful strategies.

Research Question: How can innovative business models and entrepreneurial methods help build rapid charging networks that can grow and make money in different regions around the world?

Main goal of the research: To study the relationship between technology, business models, and policy in building electric vehicle fast charging infrastructure and to create a practical framework that explains how these networks can be successful.

Main tasks:

1. Review the main fast charging technologies and their impact on infrastructure growth.
2. Compare business models and strategies in China, the EU, and the U.S.
3. Analyze case studies of leading companies and startups.

4. Use a scoring model to evaluate market potential and startup viability.
5. Suggest practical recommendations for startups.

Research Methods: The FMTP has literature review, case study analysis, and a scoring model. Data for scoring model is taken from academic papers, industry reports, and public sources like International Energy Agency (IEA) and International Council on Clean Transportation (ICCT).

Structure of the Work: The first part reviews EV market trends, charging technologies, and business models. The second part explains the research method. The third part presents case studies and scoring model results. The last part gives conclusions and recommendations.

Limitations: The study uses secondary data and a simplified model, so it may not show all details of real operations. Policy changes and market conditions can also affect results.

1. LITERATURE REVIEW

This section seeks to give a comprehensive overview of the electric vehicle (EV) market by analyzing the global EV market trend from 2020 to 2025, thereby clarifying the evolution and prospects of the future EV market. This quick growth makes the need for EV charging infrastructure very high.

The study of EV charging infrastructure looks at a few important areas that affect how EV charging stations are designed and run. These are the demand for electric vehicles, the technology for charging them, the business model, and the rules and regulations. Existing studies indicate that the pace of development and standards for electric vehicles (EVs) vary significantly across regions, particularly in China, the European Union, and the United States. For the near future, multiple standard stations and adapters are suggested, but for the long term, built-in support for local standards is thought to be more reliable. Managing energy is another important topic because peak demand charges can make running costs very high. This study shows that power sharing, grid load balancing, and on-site battery storage are just a few of the ways to lower these peaks and make more money. The future of charging station systems is smart charging systems that change how much power they give out based on how much the user needs and the state of the grid.

From a business point of view, the research looks at different models, like pay-as-you-go pricing, subscription-based charging, battery swapping, and ultra-fast charging. Networks Policy frameworks like the European Union's AFIR regulation call for open access, card payments, and clear pricing. Similar rules in other parts of the world also try to speed up deployment and make sure everyone is treated fairly. This study also highlights how some convenience features, like easy payment, roaming between networks, and clear price information, can boost adoption and use.

The research indicates that EV charging infrastructure integrates technology, business, policy, and user behavior. To build reliable and cost-effective fast charging EV networks, it is important to understand these factors.

1.1 Global Electric Vehicle Market Growth and Trends

The global electric vehicle (EV) market grew quickly from 2020 to 2025. New EV sales went from being a small part of the market to a major part in many areas. In 2020, EV sales made up less than 5% of all new car sales around the world. Only 3 million new EVs were registered around the world (Global EV Outlook 2021, 2021). Still, by 2024, they made up more than 25% of new registrations, and more than 17 million EVs were sold that year (Global EV Outlook 2025, 2025). These numbers show that more and more people are willing to buy electric vehicles (EVs).

By the end of 2024, there were about 58 million electric cars in the world, which was more than three times the number in 2021. This showed that both consumer markets and fleets were growing quickly. In 2024, this growing stock replaced more than 1 million barrels of oil each day. This had an early but measurable effect on energy demand patterns (Global EV Outlook 2025, 2025). Veza et al. (2024) point out that people's worry about the environment and the pollution caused by internal combustion engine vehicles (ICEVs) is becoming one of the main reasons why the global EV market is growing.

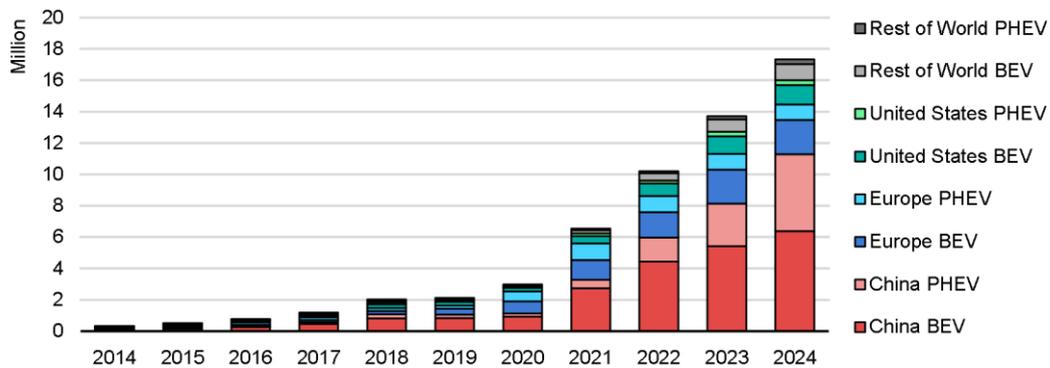
Some researchers have forecasted the electric vehicle market for the global market in the next five years. For example, Zhao, Fang, and others (2023) used historical data on EV sales in China to make predictions about future sales. They used the Markov model and the DRHT-QETS model to say that EV sales will go up from 2025 to 2030. They also said that total vehicle sales will reach about 32.53 million units by 2030. The International Energy Agency (IEA) says that the global stock of electric vehicles (EVs) is likely to reach about 250 million by 2030 under the Stated Policies Scenario (STEPS). Aside from the academic side, the European Parliament set a goal in June 2022: to reach climate neutrality by 2050, it will ban the sale of new gasoline and diesel vehicles by 2035. This will encourage people to use electric vehicles (European Parliament, 2022). This shows that EU policymakers are behind the electric vehicle market and believe that electric vehicles will continue to improve in the future. Overall, most people think that EV development is a good thing.

Figure 1 shows that between 2020 and 2024, the total sales of battery electric vehicles (BEVs) were much higher than those of plug-in hybrid electric vehicles (PHEVs). At the moment, BEVs make up most of the world's electric vehicle sales. This shows that people and governments prefer pure electric vehicles to hybrids. According to Hossain et al. (2024), PHEVs are used by people who don't want to fully switch to BEVs yet. Because they are a developing technology that combines the reliability of traditional internal combustion engines with electric driving.

It was also said that the main places where EVs are sold are China, the US, and Europe. The main reasons for this trend are these countries have invested a lot on charging infrastructure, also the expansion of the fast-charging station network has made BEVs easier to use. Because it reduces the fear of range limits. Second, advances in lithium-ion battery technology have made batteries cheaper and electric vehicles cheaper, making them more affordable for most people (Hossain et al., 2024; Safayatullah et al., 2022). Also, policymakers in these countries made it easier for people to buy electric vehicles (Global EV Outlook 2025, 2025; Hossain et al., 2024). For instance, China doesn't charge EVs any vehicle purchase tax for a long time. These things have all helped BEVs become the most popular type of electric vehicle in the world.

Figure 1. Global electric car sales, 2014-2024 (IEA , 2025)

Global electric car sales, 2014-2024



IEA. CC BY 4.0.

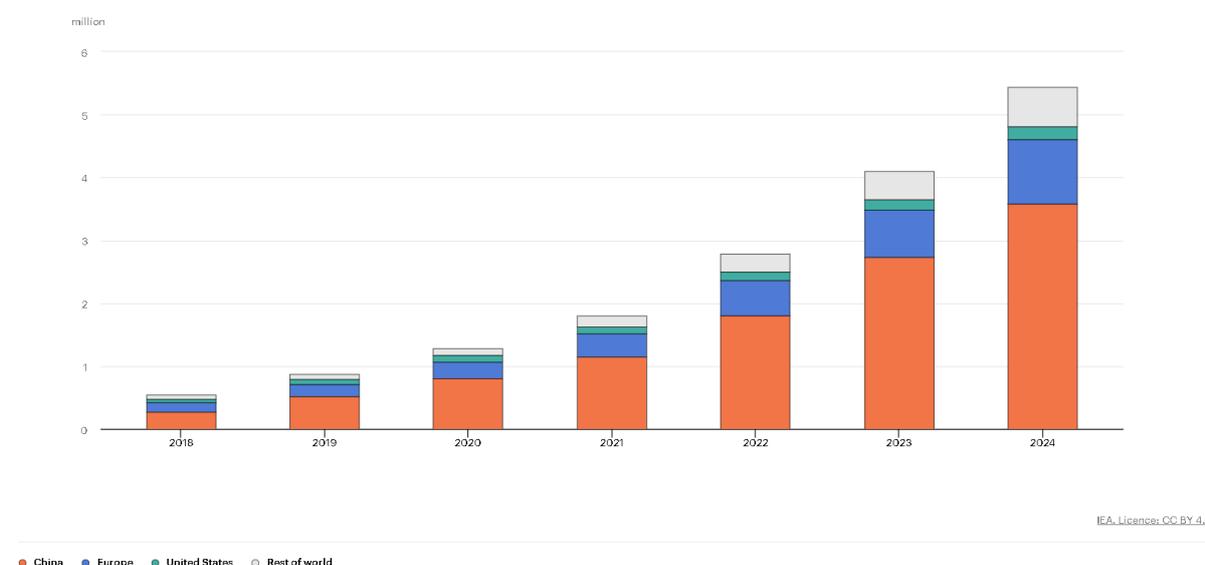
Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid vehicle. Includes new passenger cars only.
Sources: IEA analysis based on country submissions and data from the European Automobile Manufacturers Association (ACEA), European Alternative Fuels Observatory (EAFO), EV Volumes and Marklines.

Source: IEA, 2025

But the EV market is still growing at different rates in different parts of the world. It was explained by regional patterns. China was the biggest driver of global growth. In 2024, almost half of all new cars sold were electric, and from July 2024 on, sales of electric vehicles (EVs) outpaced sales of regular cars. China sold more than 11 million electric vehicles in 2024. That's more than all the electric vehicles sold around the world in 2022. It shows how China is the clear leader in sales of electric vehicles around the world. Europe kept a high share of electric vehicles (about one in five new cars), but growth slowed from late 2023 to 2024 because some countries cut subsidies and the regional CO₂ target didn't get stricter. Still, the share of electric vehicles stayed high compared to historical levels. In 2024, the United States sold about 1.6 million electric vehicles (EVs), but its share was still lower than Europe's and China's because of changing policies and uneven access to charging stations (Global EV Outlook 2025, 2025).

Figure 2 shows the number of public charging points in China overtime. It grew much faster than in other countries between 2020 and 2024. Since 2020, about 65% of the growth in public charging has happened in China. There are about 5.44 million public charging points in 2024. In 2024, public charging points made up about 20% of all stocks in the world. The Netherlands, Germany, and France had the most public charging points in the European Union (Global EV Outlook 2025, 2025). By 2024, there were about 0.2 million public charging points in the US, more than double the number in 2020. But it's still less than in other parts of the world.

Figure 2. Global stock of public charging points by region, 2018-2024 (IEA , 2025)



Source: IEA, 2025

There is a positive link between the rates at which people buy electric cars and the rates at which charging infrastructure is being built. The first step in the growth of the electric vehicle (EV) market is to build charging infrastructure. It's important to find a balance between building charging infrastructure and electric vehicles (Liu et al., 2023). The rapid growth of electric vehicles (EVs) around the world not only boosts sales of these vehicles, but it also creates a need for infrastructure to support them, especially fast charging stations. Since more people buy electric cars, they need shorter charging times and better coverage in more areas to reduce their worries about running out of charge and make long-distance travel easier (Bernal et al., 2024). It offers great chances and problems for the fast charging industry for electric vehicles.

1.2 Evolution of EV Fast Charging Technologies

Both EV makers and charging infrastructure companies are now very concerned about improving the performance of electric vehicle charging and making the user experience better. EVs would be more popular if it to find charging stations was easier to find or it simply had faster charging. This problem can be solved by making three main areas better: battery technology, charger type, and charging methods. This work focuses on the types of chargers and charging methods that are used at charging stations.

There are two main types of electric vehicle charging technology: slow charging and fast charging. These systems are based on how quickly they can charge and how much power they can provide. EV charging also be categorized into conductive charging, inductive

charging, and wireless charging (Safayatullah et al., 2022). Conductive charging is the most popular option on the market right now. It can be done with either alternating current (AC) or direct current (DC). AC charging is mostly used for slow charging, while DC charging is important for building fast-charging infrastructure for businesses and the public.

Level 1 and Level 2 are the two main types of AC charging. Level 1 and Level 2 connectors on AC power supplies connect to the onboard charger of an electric vehicle. Level 2 connectors work with both AC and DC. If the vehicle is wired correctly, they can connect directly to the battery pack, which means they don't need to go through the vehicle's onboard charger (Botsford & Szczepanek, 2009). A Level 3 connector lets high-power fast chargers send DC power straight to the EV battery pack.

DC charging usually refers to Level 3 charging. It can send DC power directly to the EV battery pack at a much higher power level (usually ≥ 50 kW). This is what we usually call fast charging. The California Air Resources Board (ARB) has set standards for fast charging in its Zero Emissions Vehicle (ZEV) mandate program. One of these standards is that a ten-minute charge must let a car drive 100 miles. Because DC charging stations use a lot of power, they can cut down on the time it takes to charge a battery. The charging power of a DC charging station depends on how well the EV battery system can accept it, the type of connectors it has, and how much power the charging station can put out (Botsford & Szczepanek, 2009; Deb et al., 2021).

Figure 3. Comparison of different electric vehicle charging levels

Specification	Level 1	Level 2	Level 3	Extreme Fast Charging (XFC)
Charging Power	1.44 kW - 1.9 kW	3.1 kW – 19.2 kW	20 kW – 350 kW	>350 kW
Charger Type	Onboard - Slow charging	Onboard - Semi-fast charging	Offboard - Fast charging	Offboard – Ultra-fast charging
Charge Location	Residential	Private and commercial	Commercial	Commercial
Charging time	200 km: +/- 20 hours	200 km: +/- 5 hours	80% of 200 km: +/- 30 min	Approximately 5 min with high energy density
Power Supply	120/230 Vac, 12 A – 16 A, Single phase	208/240 Vac, 12A - 80A, Single phase/Split phase	208/240 Vac & 300-800Vdc, 250-500A Three phase	1000Vdc and above, 400A and higher Polyphase
Supply Interface and Protection Type	Convenience outlet (Breaker in cable)	Dedicated EV supply equipment (Breaker in the cable and pilot function)	Dedicated EV supply equipment (communication & event monitoring between EV and charging station)	Dedicated EV supply equipment (communication & event monitoring between EV and charging station)
Standards	SAE J1772, IEC 62196-2, IEC 61851-22/23, GB/T 20234-2		IEC 61851-23/24 IEC 62196-3	IEC 62196 SAE J2836/2 & J2847/2

Source: Acharige et al., 2023

AC charging is more popular and more available option. It works best in homes and semi-public spaces. In this system, the electric car gets power in the form of alternating current. The car's onboard charger must change this into direct current before it can be stored in the battery.

The vehicle's internal hardware limits this onboard conversion process, which slows down the charging speed. From figure 3 we can see that Level 1 charging uses a regular 120 V outlet. Also it only gives off a small amount of power, about 1.9 kW. It can take an electric vehicle (EV) anywhere from 6 to 10 hours to charge all the way. Most home electrical systems can use this setup to charge overnight. People often call it "trickle charging" because it charges slowly. This is good for people who drive the same route every day and park for a long time. Level 2 can work at higher voltages, usually 240 V, and give off as much as 19.2 kW of power. Also, it takes three to five times less time to charge than level 1. People often use it in parking lots, workplaces, and apartment buildings. Charging at Level 2 costs more and is a little harder to set up. That makes it a popular choice for people who commute every day and fleet operators.

The DC fast charging or level 3 charger sends high voltage DC power to the EV, which lets it charge up to about 80% in 20 to 30 minutes. It is a better and more powerful choice that can quickly recharge energy. DC charging stations change AC power into DC power so that it can go straight to the battery. This makes it possible to get around the onboard charger's limits and lets power move much faster. But during busy times, Level 3 chargers might overload the local distribution grid. These systems are set up in places with a lot of people, like shopping malls, highway rest stops, and city transit hubs. For long trips and times when you need to use a lot of power right there, DC charging is a must.

Extreme fast charging (XFC) is a new trend in development. It can take an impressive amount of power, more than 350 kW. The goal is to get the battery to 80% full in less than 15 minutes! This would make electric vehicles (EVs) more competitive with gas-powered cars, which can fill up in just a few minutes (Zeng et al., 2023). To achieve these charging speeds, it requires higher charge rates. But it could lead to reduced lifespan (Acharige et al., 2023; Deb et al., 2021, p. 2022; Safayatullah et al., 2022). To find a solution, scientists have looked into three main areas: battery materials, charging methods, and ways to keep the temperature stable.

The first thing to do is improve the battery itself. Researchers are working on better electrodes and electrolytes that can handle faster charging. Making these changes to batteries takes time and money, but they can make them safer and work better (He et al., 2023).

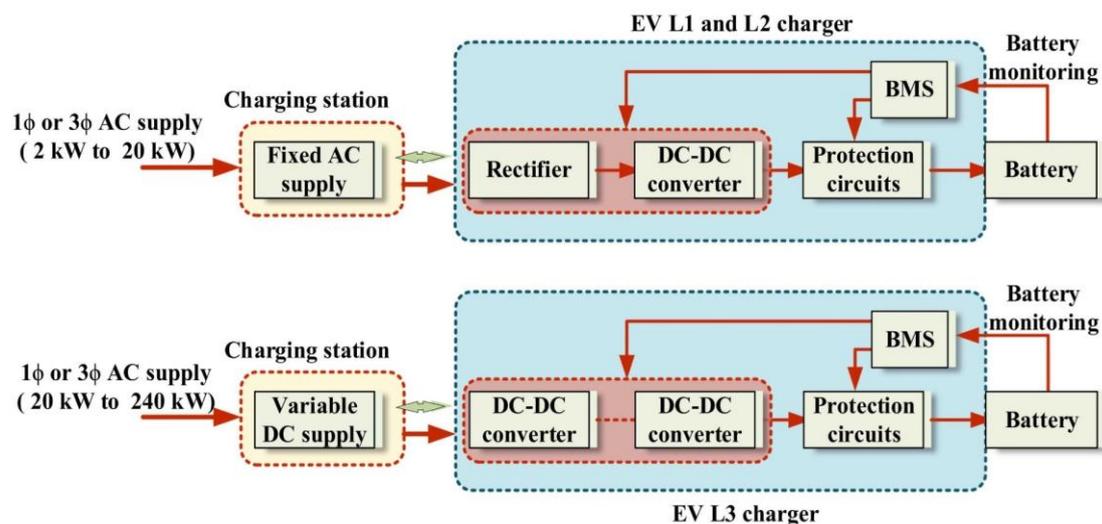
The second area is to improve the way the battery charges. Most of these ways use software, which makes them cheaper and easier to use. But they need to be changed for each type of battery, and they might not work as well as the battery gets older (Zhu et al., 2023).

The third thing to do is control the heat. Keeping the battery warm while it charges helps. Zeng et al. (2023) recently discovered that maintaining the battery at approximately 45°C during charging and rapidly cooling it during discharging may improve its performance. They used a cold-plate system to control the flow of heat, and they got good results even when

charging quickly. Because of these differences, charging might not be even, which makes the battery less efficient and shorter. By changing the insulation for each cell based on its temperature, engineers can make the pack more stable. This makes the battery last longer and work better in general (Zeng et al., 2023).

Still, many current strategies assume that all battery cells work the same way, which isn't always true. As batteries get older, they work in different ways. Future research should include regular testing and smart algorithms to make sure that XFC systems keep working well over time.

Figure 4. EV L1, L2 and L3 charging methods



Source: Singh et al., 2024

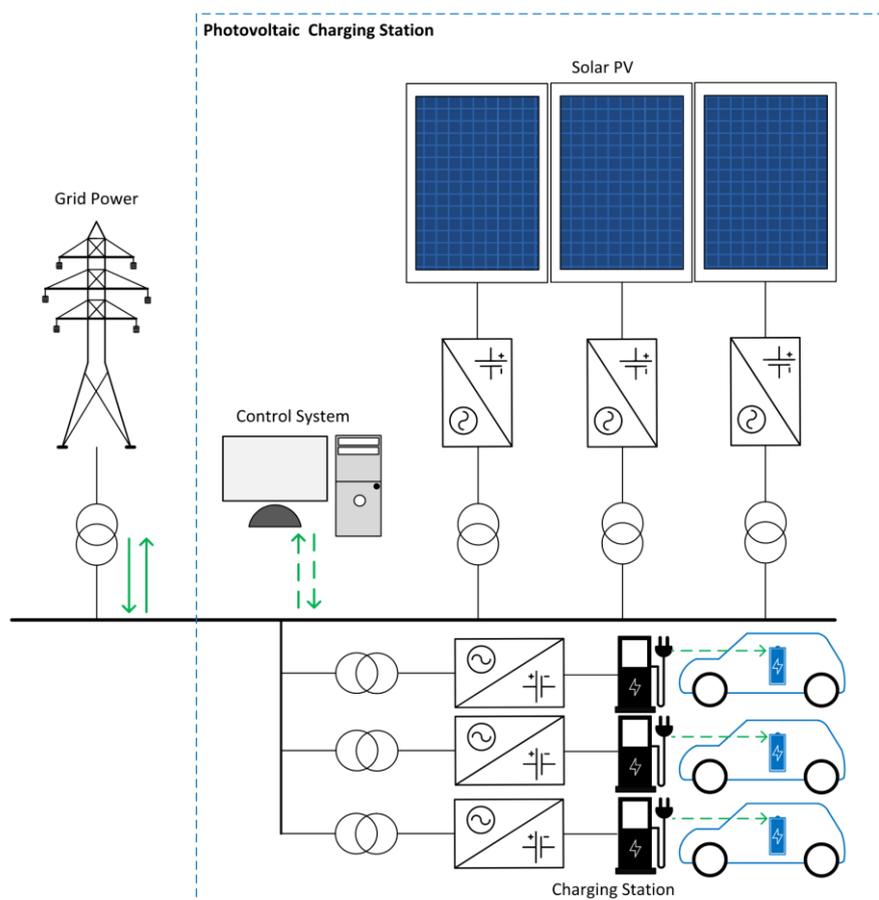
Figure 4 in the referenced article gives a complete diagram of the architecture of EV charging systems at the three main levels: Level 1 (L1), Level 2 (L2), and Level 3 (L3). The diagram shows how electrical energy moves from the supply source to the battery. It also shows the most important parts of each charging process.

The system has a fixed AC supply, battery monitoring systems, rectifiers, DC-DC converters, and protection circuits for L1 and L2 charging. These parts work together to change AC to DC and control the voltage and current levels to make sure that charging the battery is safe and efficient. The Battery Management System (BMS) is very important for keeping an eye on the health of the battery, controlling the charge rates, and stopping overcharging or thermal runaway. The L1 charger works with a lower voltage supply and is good for home use with low power. The diagram shows it as a simple setup with basic parts for rectification and conversion. The L2 charger, on the other hand, uses a higher voltage supply and more advanced circuitry to speed up charging. The diagram shows how multiple DC-DC converters and protection circuits work together. This shows how Level 2 systems are more complex and can do more things.

The L3 charging system uses a variable DC supply and has an off-board converter that changes AC into DC before sending it to the car. With this setup, you can get a lot more power and charge your devices much faster. We can see from the picture that the L3 systems are modular, which means they can be changed to work with different types of vehicles and power levels. For a diverse EV fleet and changing user needs, this flexibility is very important. Also, the high-speed charging process is safe and reliable because it has advanced protection circuits and a BMS (Singh et al., 2024).

Using standardized connectors, communication protocols, and safety features makes sure that different vehicle models and charging networks can work together. The International Electrotechnical Commission (IEC), the Electric Power Research Institute (EPRI), and the Society of Automotive Engineers (SAE) are just a few of the groups that help set these standards and push for global harmonization.

Figure 5. Architecture of a photovoltaic EV charging station with grid and control integration

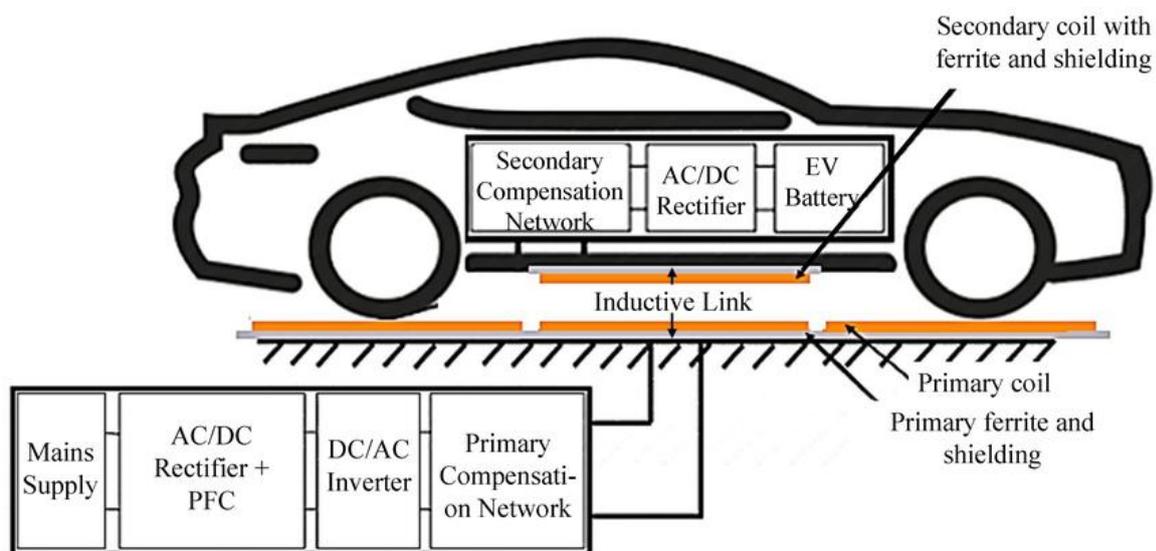


Source: Rashid et al., 2024

The effects of AC and DC charging technologies go beyond how they affect individual users. They also affect how the grid works, how energy is managed, and how long the

technology will last (Singh et al., 2024). AC charging is usually easier to add to existing grid infrastructure because it needs less power and is spread out. It helps utilities handle peak loads and make the best use of energy by supporting load balancing and demand response strategies. DC charging is harder to integrate because it needs a lot of power, but it can help the grid in new ways through vehicle-to-grid (V2G) technologies, as shown in Figure 5. DC charging stations can turn electric vehicles (EVs) into mobile energy storage units by allowing power to flow in both directions. This helps with grid stability, integrating renewable energy, and emergency backup systems. Rashid et al. (2024) also say that photovoltaic (PV)-based EV charging infrastructure can help ease the strain on the grid and cut carbon emissions from EV charging. It also offers a reliable way to manage energy. Nonetheless, extensive commercial implementation is still limited by ambiguous policies, intricate technologies, and high expenses (Safayatullah et al., 2022).

Figure 6. Block diagram of an EV wireless charging system



Source: ElGhanam et al., 2021

There are three main types of charging: conductive, inductive, and wireless. Conductive charging is still the most popular technology in today's EV markets. Inductive and wireless technologies are still in the early stages of being widely used (Rajendran et al., 2021; Safayatullah et al., 2022). Conductive charging transfers power by making physical electrical contact between the charger and the vehicle. It can be split into onboard charging (slow charger) and off-board charging (fast charger). As a result, inductive and wireless technologies are getting a lot of attention as the way forward for development. Inductive technology is safer for electrical use than conductive technology. But it charges much more slowly than conductive technology (Rajendran et al., 2021). Wireless charging for electric vehicles sends power

without a physical cable (Fig. 6).

Figure 6 shows this. When an inverter powers a ground-side transmitter coil, it makes an alternating magnetic field. A receiver coil on the side of the vehicle picks up that magnetic field and makes an alternating voltage. The vehicle's power electronics change the induced voltage into DC and send it to the battery through the battery management system. For short air gaps and tightly coupled coils, the main physical mechanism is magnetic induction. For longer transfer distances and better tolerance to misalignment, the coils work at the same resonant frequency, which is called resonant magnetic coupling. Static wireless charging systems charge a car that is parked. The transmitter coil is either on a parking pad or buried in the ground. The car parks over the pad so that the two coils line up. The system detects the car, starts the power transfer, and controls the session through a communication link. Dynamic wireless charging systems put transmitter coils in the lanes of a road. While driving, a moving vehicle with a receiver coil picks up energy. Dynamic systems try to make batteries smaller or give them a longer range for use in transit, but they need a lot of money to build and manage traffic (Vishnuram et al., 2023).

Wireless charging has the benefits of being easy and automatic. Drivers don't handle cables that are heavy or exposed to the weather. This ease is important for both private users and fleet operations where there are a lot of short stops. Wireless pads may be more durable and require less maintenance on connectors. Wireless charging works for both shared and self-driving cars, allowing them to charge without anyone being there and park themselves. Embedded pads in public places can let people charge their devices when they stop for a short time, which may ease concerns about limited range and let some vehicles have smaller batteries. Wireless charging makes things easier for people at home and in public. Wireless pads at home mean that the user doesn't have to plug in every day. Pads help automate charging and fleet scheduling in controlled fleet depots. Frequent top-up charging through short stops at stops or terminals can keep buses, trams, and shuttles in service longer without having to stop for a long time. These operational models can cut down on downtime and make better use of the fleet. Wireless charging also allows for new features in infrastructure and energy management. It can work with smart grid functions, let you schedule loads, and work with local renewables and storage. Dynamic charging on highways can lower the peak draw from any one site by spreading the demand across the road. Wireless systems can be modular, which means that infrastructure can be rolled out in stages to keep up with demand growth (Singh et al., 2024).

There are some big problems and technical limits. When there is misalignment or bigger gaps, wireless systems usually have lower end-to-end efficiency than well-designed wired chargers. For small gap, well-aligned systems, typical static wireless efficiencies come close to plug-in AC levels, but they are still lower than the best DC fast chargers. Losses turn into

heat in coils and nearby structures. This needs thermal management, which can lower the system's overall efficiency and raise the cost of running it (Singh et al., 2024; Vishnuram et al., 2023). Power density is another thing that limits it. Long-distance travel with high-power DC fast charging gets very high power levels from just one connection. Wireless pads that give off the same amount of power need big coils, precise alignment, and advanced cooling. Plug-in DC fast chargers are still the best option for quick refueling situations because they can deliver more power and are easier to connect to and control from the grid (Zhu et al., 2023). Cost and installation are other things that make it harder. Grounded transmitter pads need civil works, power electronics, and communication links. It costs a lot to add new features to old parking lots or roads. Adding receiver hardware to a vehicle after it was made or retrofitting it costs more. Standardization and interoperability are still being worked on. These factors make it more expensive to roll out widely than to set up plug-in stations that use established standards and are easier to install (Singh et al., 2024; Vishnuram et al., 2023). On the other hand, safety and electromagnetic compatibility make design standards stricter. Wireless charging systems must keep people from being exposed to time-varying magnetic fields that are within legal limits. High-frequency fields can make currents flow through metal objects or heat things that are close by. To keep things from getting too hot on the pad, it needs to be able to find foreign objects and turn off automatically. Adding shielding and design to lower stray fields makes things more complicated and expensive. Standardization and interoperability are still being worked on. Different research groups and manufacturers use coils of different sizes, operating frequencies, and communication protocols. International and industry standards are changing to set limits on safe exposure, test methods, and interoperability layers. Users encounter fragmentation and uncertainty in selecting infrastructure or vehicles in the absence of comprehensive standards (Vishnuram et al., 2023).

Wireless charging changes the way loads are distributed on the grid, but it doesn't take away the need for grid planning. Wireless charging can lead to more frequent and spread-out charging events, which could level out demand or cause a lot of small peaks instead of a few big ones. Smart scheduling and connecting to local storage or renewable energy sources can help, but planners still need to think about transformer capacities, feeder headroom, and local voltage regulation (Singh et al., 2024). The choice of technology will depend on the deployment scenarios. Static wireless charging is a clear convenience improvement for private garages and reserved parking, and it doesn't cost much to set up for each car. Wireless pads help automate charging logistics and keep vehicles on the road longer for urban fleets and shared mobility. Until wireless systems can match wired DC fast charging in power density and efficiency at a reasonable price, wired DC fast charging is still the best option for highways and long-distance travel (Singh et al., 2024). Wireless charging is a promising technology that makes things easier and helps with automation. It is already possible to use it for static

charging with low to moderate power and for specialized fleet use. The main problems are that it is less efficient than wired fast charging, it costs more to install and retrofit, it doesn't have enough power density for high-speed charging, and it needs broad standards and careful safety design. How widely wireless charging can be used alongside plug-in solutions will depend on ongoing research in coil and electronics design, standards work, and pilot deployments (Singh et al., 2024; Vishnuram et al., 2023; Zhu et al., 2023).

With so many different charging technologies available, different international standards have made things even more complicated. Countries have different charging standards based on things like voltage levels, safety needs, and how the market works. Because of this difference, there are now different charging standards all over the world.

Based on a number of international and national standards, such as IEC 61980, IEC 62196, IEC 61851, and IEC 62840. The way AC charging systems work is different in different parts of the world. The SAE J1772 standard is used for AC charging systems in the US, where they use 120V of domestic power. The IEC 62196 standard is used for AC charging systems in Europe, where they use 230V of domestic power. The GB/T 20234 standard is used for AC charging systems in China, where they use 220V of domestic power. These regional standards have caused countries to set up their own charging systems that don't work with each other.

Recent developments show that DC fast charging is getting closer to a single standard and more power. The Combined Charging System (CCS) is now one of the best solutions. It works with both AC and DC power, and most new electric vehicle models in Europe and North America use it. Theoretically, CCS DC pins can handle up to about 500 A and 1000 V, which would allow for peak power of about 350–400 kW. In the meantime, in China, the GB/T fast charging DC connectors follow the GB/T 20234-3 standards. Tesla is a special case because it is making its own connectors. It can connect to both AC and DC charging for all levels of charging. At first, its supercharger network could only deliver about 120 kW of power. Now, each car with a V3 Supercharger station can deliver up to 250 kW. The company is adding CCS support to many of its locations, though (Acharige et al., 2023; Barman et al., 2023).

But high-power charging, especially DC fast charging, needs more complicated infrastructure, such as complicated electrical installations, strong grid connections, and advanced safety features (Acharige et al., 2023). Also, DC charging stations often have advanced monitoring and control systems to keep track of voltage changes, thermal loads, and user authentication. This makes sure that they work safely and reliably in a variety of situations (Barman et al., 2023).

1.3 Business Models in EV Fast Charging Industry

Because EVs are growing so quickly, there is a big need for reliable and fast charging

infrastructure. To make long-distance travel possible and ease range anxiety, Direct Current Fast Charging (DCFC) stations are very important. The business case for fast charging, on the other hand, is not simple. High installation costs, limited grid capacity, and unpredictable usage rates make it hard to know if the business will be profitable. If the right business models are in place, EV charging can also help the power system by providing flexibility services like demand response and ancillary services (Anggraini et al., 2025). For these models to work in the long term, they need to find a balance between technical needs, economic incentives, and regulatory frameworks. This part talks about the most common types of business models, pricing strategies, and how they work with energy markets. It also points out trends and areas where more research is needed.

There are different ways that EV fast charging business models make money, spread risk, and deal with grid limits. According to Anggraini et al. (2025) and Yong et al. (2023), the main models are Pay-As-You-Go (PAYG), subscription-based charging, battery swapping, ultra-fast charging networks, smart charging for homes, and connecting to renewable energy sources. We will now look at each model in detail.

1.3.1 Pay-As-You-Go (PAYG)

Pay-As-You-Go is a popular business model for public EV fast charging because it is simple and clear for users. Drivers pay for each session based on how much energy they use (kWh), how long they use it, or a mix of the two. This method does away with subscriptions and allows for ad-hoc access, which is important for people who use it only sometimes and for people who move between networks. Anggraini et al. (2025) stress that PAYG fits well with the rules in big markets like the European Union's Alternative Fuels Infrastructure Regulation (AFIR) and the U.S. National Electric Vehicle Infrastructure (NEVI) program, which require clear pricing and open access. These rules make PAYG more stable by requiring clear per-kWh disclosure and card-based payment options. This makes it easier for customers to use and encourages them to do so. PAYG is also appealing for markets that are still getting used to EV charging because it is so easy to use. But its long-term economic viability depends on how often it is used and how the tariffs are set up. Bernal et al. (2024) say that operators who only use PAYG face big risks because of high capital costs for DC fast charging and the possibility of demand charges under regular electricity tariffs. If there aren't any ways to handle peak loads, short bursts of high power can cause demand charges that are too high, which can hurt profits even when energy sales are strong.

To deal with these problems, operators are more and more combining PAYG with dynamic pricing and smart energy management. Yong et al. (2023) demonstrate that incorporating Time of Use (TOU) or Real-Time Pricing (RTP) into Pay-As-You-Go (PAYG)

systems can reallocate charging sessions to off-peak hours, thereby alleviating grid stress and decreasing operational expenses. This approach is especially useful in areas with a lot of renewable energy, where flexible demand helps keep the system stable. Studies also show that hybrid PAYG tariffs that combine per-kWh rates with idle fees can help improve charger turnover and stop people from staying too long, which is very important for busy urban areas and highway corridors. Anggraini et al. (2025) contend that integrating PAYG with on-site battery storage and renewable generation can alleviate demand charges and facilitate more competitive pricing, establishing a route for financial sustainability without compromising user convenience. These new ideas are part of a larger trend toward grid-aware business models. In these models, charging operators make extra money by taking part in flexibility markets or demand response programs. PAYG is still the basis of public charging economics, but these adaptive strategies are what will make it work in the long run. There is a lot of agreement in the literature that PAYG's long-term success depends on clear pricing, compatibility with other systems, and integration with smart grid solutions. PAYG can provide both easy access for users and strong station economics when used with dynamic tariffs and storage. This can help fast-charging networks grow in different regulatory and market settings (Anggraini et al., 2025; Bernal et al., 2024; Yong et al., 2023).

1.3.2 Subscription-Based Charging

Charging based on subscriptions is a model that gives operators steady income and makes it easy for regular users. Customers pay a regular fee, usually once a month or once a year, in exchange for lower rates or unlimited access within certain limits. This method makes revenue less volatile than Pay-As-You-Go because it makes sure that there is a steady stream of income even when station usage changes in the short term. Khanda et al. (2025) show that combining subscription plans with service-level guarantees makes operations more efficient by improving charger allocation and station throughput. Subscriptions are good for drivers who charge often, like fleet operators or people who drive to work every day. They offer price certainty and often come with perks like priority access or the ability to roam across multiple networks. Integration with roaming services makes things easier and helps people travel across borders, which is especially important in areas with broken infrastructure. These features make subscription models appealing for companies with large fleets of electric vehicles and for drivers who want costs that are easy to predict and access that is always available (Khanda et al., 2025).

Subscription-based charging, on the other hand, has problems when demand is low or adoption rates are low. Wu et al. (2025) say that global station use is usually between 20 and 40 percent, which can hurt profits unless you have a lot of active subscribers. In markets where

EV adoption is low, fixed subscription fees may not be enough to pay for the high costs of building and maintaining fast-charging stations. One more problem is that subscriptions don't automatically make people use energy more efficiently. Without dynamic pricing or managed charging programs, subscribers may charge during peak hours, which puts more stress on local networks and costs operators a lot of money. To solve this problem, some providers add smart charging features to their subscription plans. This lets users schedule charging during off-peak hours or take part in demand response programs (Weihua Wu et al., 2025). Khanda et al. (2025) stress that using subscriptions with service-level guarantees and flexible scheduling can help the environment and lower peak loads. Combining subscriptions with mobility platforms like ride-hailing or car-sharing services also makes things more efficient by matching user demand with network capacity. These strategies are part of a larger trend toward hybrid business models that mix stable income with flexible pricing and energy management. Subscription-based charging can bring in steady income, improve the customer experience, and help fast-charging networks grow over time if it is backed by interoperability, smart energy management, and clear policy frameworks.

1.3.3 Battery Swapping

Battery swapping is a charging method that quickly replaces a dead battery with a fully charged one. This is a useful way to cut down on downtime compared to regular fast charging. This method works best for fleets that are used a lot, like taxis, delivery trucks, and ride-hailing services, where quick energy replenishment is important for keeping things running smoothly. The model depends on stations that have automated handling systems and enough batteries in stock to make sure they are always available. Because the station needs to keep a pool of charged batteries while also managing the charging of returned units (Cui et al., 2023; Yongzhong Wu et al., 2022), it is important to plan the size of the inventory and the charging schedules carefully. Adding energy storage systems to the station design makes it work even better by letting batteries charge when electricity prices are lower and lowering the peak demand on the grid. This integration makes operations more stable in areas with variable energy tariffs and makes them more cost-effective (Yongzhong Wu et al., 2022). Battery swapping also helps drivers who are worried about running out of gas by giving them predictable service times, which is very important for businesses that can't afford long charging delays. When used in busy cities with a lot of traffic, the model can save money by lowering the cost per swap and making better use of stations. These traits make battery swapping a good addition to fast charging in places where speed and dependability are important.

Battery swapping has many operational benefits, but it also has many problems that make it hard to do from an economic and technical point of view. The infrastructure needs a lot of

money to be spent on robotics, battery storage racks, safety systems, and strong electrical connections so that multiple units can charge at the same time. Having a lot of batteries in stock ties up money, and making money depends on getting high usage rates and good scheduling to cut down on idle time (Yongzhong Wu et al., 2022). Standardization is another important factor because differences in battery design between manufacturers make it harder for operators to use the batteries together. Without standardized specifications, stations have to either limit service to certain types of vehicles or deal with multiple battery formats, which makes logistics more difficult and costs more (Cui et al., 2023). Advanced planning models can help with these problems by finding the best station layout, inventory levels, and charging cycles to balance service quality with cost recovery. Smart scheduling systems and predictive maintenance make things even more reliable by making sure batteries are always available and cutting down on unplanned downtime. To get past these problems, we need help from the government and cooperation between businesses. Financial incentives, technical standards, and collaborations between automakers and energy suppliers can hasten implementation and mitigate investment risks (Cui et al., 2023). In these situations, battery swapping can quickly recharge batteries, meet the needs of high-demand groups, and work with fast-charging networks by giving users who need quick service and a reliable solution.

1.3.4 Ultra-Fast Charging Networks

Ultra-fast charging networks are made to give electric cars a lot of power, usually between 150 kW and 350 kW, so they can charge quickly. The goal of this business model is to make long trips easier and to help drivers who need to charge quickly during the day. These networks help make electric travel more practical by cutting charging time to less than thirty minutes, which takes away range worries (Anggraini et al., 2025). These stations are set up by operators along main roads and in busy areas where a lot of cars pass by every day. Most sites have multiple chargers so that more than one car can charge at the same time. This cuts down on wait times and improves service (Attaianese et al., 2023). Many operators put battery storage and sometimes solar panels on the site because using a lot of power can make electricity bills go up. This lets them save energy when prices are low and use it later when demand is high (Bernal et al., 2024). These steps help keep the station running well and keep costs down. Ultra-fast networks also work with roaming systems, which let drivers use different stations without having to make new accounts. This makes it easier to charge and gets more people to use the service.

It's expensive to run these networks because the equipment and connection to the grid cost a lot. To make up these costs, operators need to use them all the time. Researchers have found that electricity demand charges can be very high, so it's important to keep an eye on

how much energy you use. To avoid sudden spikes in power use, operators use tools like dynamic pricing, power sharing between chargers, and battery storage. These methods cut costs and can also bring in new money by signing up for programs that pay for flexible energy use (Bernal et al., 2024; Mohammed et al., 2024). The customer experience is another part of the business model. A lot of stations have places to rest, stores, and apps that show the current status and prices of chargers (Mohammed et al., 2024). These services make charging more enjoyable and encourage people to come back. Government programs and clear technical rules also help lower risk and speed up growth. Ultra-fast charging networks can become a big part of the electric vehicle market if they are used with good energy management and customer service. They work well for people who need to charge their cars quickly and for long trips, while slower charging can still be used at home and at work. This combination of services makes it easier for electric vehicles to fit into everyday life and will help them become more popular in the future.

The overview of different business models for EV fast charging shows how companies try to make charging simple and profitable in different ways. Pay As You Go is popular because it's easy and works with open access rules, but it can be expensive when a lot of people use the stations. Subscription plans bring in steady money and help keep customers, but they need smart systems to keep things running smoothly when a lot of cars charge at once. Battery swapping is a great idea for taxis and delivery cars because it lets drivers change batteries quickly, but it costs a lot to build and needs standard battery designs. Ultra-fast charging stations make long trips easier because they charge very quickly, but they need a lot of money and good connections to the grid. These models cost different amounts, grow at different speeds, and need different amounts of help from the government. When trying to figure out which markets have good infrastructure, fair energy prices, and strong demand, it might help to know these differences.

1.4 Dynamics of Startups in the EV Fast Charging Industry

Startups are very important to the growth of networks that charge quickly. They get a lot of venture capital to set up high-power chargers, make software that works well with the grid, and come up with new ways to run their businesses. Recent reports from the government and the private sector show that billions of dollars are going to charging networks and technologies that make them work. At the same time, city-level policy roadmaps are pushing for public-private partnerships and standardized processes to speed up the rollout. In addition, the niche markets around EV charging stations are also growing. For example, the company Voltpost is changing streetlight poles into chargers for electric cars. ChargeLab is a company that makes software for managing electric vehicle charging stations (Glasner, 2024). This combination of

venture capital and government support creates momentum, but it also puts businesses at risk of problems like differences in regulations, high costs, and policies that change from region to region (Brady-Phillips, 2024; Glasner, 2024).

One way that entrepreneurs are using fast charging is by using modular or off-grid fast charging, which makes it less likely that they will need to use public utilities and speed up the building of on-site facilities. Battery-integrated DC fast chargers and mobile or off-grid charging units cut down on delays in connecting to the grid and can meet demand that is event-based or not being met. Recent studies show that combining battery energy storage systems (BESS) with DCFC can speed up timelines, handle peak loads better, and avoid expensive grid upgrades (Çelik et al., 2025). Case studies and modeling exercises from national laboratories show that city pilots that draw curbside power from buildings instead of utility street connections can cut the time it takes to get permits and connect to the grid by 12 to 18 months (Poudel et al., 2024). From an entrepreneurial standpoint, these strategies enhance time-to-market; however, they transfer complexity to energy logistics, storage sizing, and on-site asset management. Researchers say that storage integration solutions can make long-term profits better by stabilizing operating costs and allowing companies to work in flexible markets (Ahmad et al., 2025).

Another way for a startup to grow is to build a lot of very fast charging stations in busy city areas or along major travel routes. New businesses try to find the best spots for these stations and work with other businesses to provide drivers with extra services. The new V3 Supercharger Station from Tesla in California is big and close to stores and restaurants to make it as easy as possible for customers. Most charging stations only use 12% to 18% of their capacity, but industry cost analyses usually assume that they will be used at full capacity (100%) for 24 hours to figure out the most money they could spend. So, it's very important to keep the cost of electricity down. In the long run, switching from traditional electricity to renewable energy can save money (Deb et al., 2021). Companies also work on making the technology that controls power and charging speed better. Studies show that it is hard to plan these stations because they need to be well-connected to the electricity grid and sometimes need extra storage or renewable energy to keep the system stable. Technical studies explain the requirements and designs for charging high-power direct current. The number of chargers needed and how companies can make money will depend on how often people use these stations, how big car batteries are, and how powerful chargers are. (Gnann et al., 2018; Mohammed et al., 2024; Zentani et al., 2024).

When it comes to planning locations and how the grid works as a whole optimization and queueing models show that the best placement must co-optimize driver travel times, station capacity, and distribution-network losses. This may mean moving chargers to existing energy nodes to increase their use. Research that combines heuristic siting, bilevel optimization, and

resilience analysis shows that startups can benefit from analytics that take into account transport demand, land use, and grid constraints. These results are in line with other studies that have called for renewable co-location and storage to help smooth out peaks at fast-charging hubs (Choi et al., 2025; Gharbia & De Nunzio, 2024; Mohammed et al., 2024). Smart charging and V2G are smart ways to deal with problems with the grid and tariffs. Reviews and experiments show that coordinated charging and even moderate shares of bidirectional capability can lower system costs and make money from flexibility services. This supports hybrid models for startups that combine charging with storage and energy services, as long as communication standards and DSO rules are clear and safe from hackers (Acharige et al., 2023; Franzelin et al., 2025).

Startups that focus on software are also a big part of the electric vehicle fast charging market. These businesses make platforms that help keep electricity costs down, let customers switch between charging networks, and support V2G energy services. It's very important that systems work well together and follow the same rules. This makes it easier to roam, safer to make payments, and better to use stations. Research elucidates the technology spanning hardware to cloud systems, and studies indicate that V2G functionality can provide enhanced flexibility and novel revenue opportunities, contingent upon clear regulations and standards (Acharige et al., 2023; Franzelin et al., 2025; Karima Boukir et al., 2025). But this kind of bidirectional charging system has its own problems. Some early electric vehicle models don't have this feature. Some manufacturers limit these features on new electric vehicles because they are worried about the terms of the battery warranty (Franzelin et al., 2025).

A major reason why electric vehicle charging infrastructure is becoming more popular and profitable is that technology is getting better at lowering costs and making things more reliable. Silicon carbide and gallium nitride are two special materials that are now used in fast charging equipment. They make chargers smaller and work better. These materials help keep energy from being lost and let more power through. Studies show that silicon carbide works best at very high voltages and gallium nitride works better at lower voltages. It's important to choose the right material because it affects how well the charger works and how much it costs to build and keep up (Gupta & Ahmadi, 2024; Vaughan-Edmunds, 2024). These choices are based on engineering design, but they also affect the business models that new companies can use. The choices you make about technology affect not only performance but also the amount of capital needed, the way operating costs change, and the speed at which the network grows. High-efficiency, high-power-density parts lower costs per site and make it possible to install them in small spaces. Reliable systems lower maintenance costs. So, for startups that want to grow quickly in many places, the right parts and technologies determine how scalable they are, how much money they need, and how long they can stay profitable.

Capital structure, location, and cost control are all important for startups to succeed. A

recent economic study says that owners can make more money when they work with public entities and manage demand charges through pricing and storage. Policy and planning reviews show that standardized permitting, smart-charging incentives, and open data all make better use of resources and lower soft costs. These findings indicate that adaptable financing, grid-aware design, and conducive regulation are critical for overall economic advantages and effective growth (Bernal et al., 2024; Brady-Phillips, 2024). According to previous studies, the main problems for new businesses are high costs for infrastructure, different rules in each area, and how customers act. A comprehensive review of Energy Reports details how inconsistent regulations, arbitrary site selection, and inadequate capacity planning impede private investment. A synthesis focused on policy shows that even with national funding, small businesses can be put off by things like permitting, utility coordination, and tariff design. Classic research on fast-charging needs shows that usage, wait times, and prices must be balanced to reach payback. This shows that access to sites with a lot of traffic and clear tariffs are necessary for entry (Mojumder et al., 2025; Sarda et al., 2024).

In real life, a lot of new businesses use more than one strategy. They use battery-integrated DCFC to avoid having to upgrade the grid right away, and they use software to limit demand charges and allow roaming. According to national lab modeling and planning guidance, "portfolio" strategies like these lower the risk of deployment and fit with public funding rules that favor reliability, fairness, and speed of delivery (Borlaug et al., 2023; Poudel et al., 2024). In general, the way EV fast-charging startups work is a balance between speed and system integration. The best positions combine capital and discipline in choosing locations with technology that works with other systems and operations that are based on data. Standardized permitting, open protocols, storage-coupled designs, and public-private financing are the best ways to get around the most common entry barriers, which are capital intensity, interconnection delays, fragmented standards, and uncertain utilization. The academic and policy literature aligns on a singular conclusion: scalability will be achieved through interoperable, grid-aware fast charging that is straightforward to implement, user-friendly, and economically viable across various regions (Acharige et al., 2023; Brady-Phillips, 2024; Sarda et al., 2024).

1.5 Government Policies and Incentives

China's policy for EV infrastructure has changed from giving direct purchase subsidies to focusing on integrating EVs into the grid and expanding the charging network. When national subsidies ended in 2022, ministries made rules to speed up bidirectional charging and V2G pilots. They also made time-of-use tariffs to encourage flexible charging. In 2024, updates to GB/T standards made safety and interoperability requirements for conductive charging and

communication protocols stronger. This made sure that all manufacturers' products would work with each other. In 2024, rural charging programs will start to fill in the gaps between regions. By 2027, a national plan will have more than 100,000 high-power chargers. These steps make the rules more clear, which helps startups plan their corridors and make sure their hardware works (Jin, 2023; Wang & Zhang, 2025).

The European Parliament and Council passed the Alternative Fuels Infrastructure Regulation (Regulation (EU) 2023/1804), which sets mandatory goals for charger coverage and power levels. By 2025, fast-charging stations must be available every 60 km along core Trans-European Transport Network (TEN-T) corridors, and by 2030, they must be available throughout the entire network. The rule also requires clear pricing, open payment systems, and real-time availability data, which makes things less confusing and better for users. These clear technical and service standards let startups know what types of connectors they need, how long they need to be up, and what data protocols they need to use. This lets them make solutions that work with other systems and get co-funding from national programs.

The Bipartisan Infrastructure Law's NEVI formula program gives \$5 billion to corridor charging in the US. Federal guidelines set minimum power levels, uptime, and connector standards. States carry out these plans by asking for proposals and working together, while the Joint Office helps with technical issues. NEVI opens up highway markets for new businesses, but changing connector protocols and regular updates to planning guidelines make it risky for companies to plan ahead. To protect themselves, they should use flexible hardware and find new ways to make money, like storage or fleet services (U.S. Department of Transportation, 2024).

International organizations help these national efforts by giving them data and policy standards. The IEA's Global EV Outlook 2025 keeps track of charger deployment and policy tools, showing how infrastructure growth is linked to clear rules and funding. ICCT turns these goals into cost and coverage models, which give operators tools to predict how many chargers they will need and where to put them. The European Commission makes sure that all member states follow the rules and are in line with each other through AFIR enforcement and monitoring. This lowers market uncertainty and helps cross-border interoperability (Global EV Outlook 2025, 2025).

Startup strategies are greatly affected by policy frameworks. The EU's corridor mandates push companies to use sites with high usage and open payment systems, while China's standards and rural incentives push companies to make sure their hardware works and to diversify their locations. In the US, federal funding linked to strict technical standards encourages investment in highway DCFC. However, because there is still some uncertainty about connector standards, being able to adapt is very important. Academic reviews show that clear, consistent policies lower entry barriers by making permitting easier, standardizing

protocols, and improving grid coordination. All of these things make the grid more useful and boost investor confidence (Gnann et al., 2018; Sarda et al., 2024).

Pricing strategies in the EV fast-charging market are changing along with rules and the economics of the grid. Energy-based tariffs are still the most common way to charge drivers. They give drivers clear cost signals and are in line with rules in places like the EU, where AFIR requires clear per-kWh disclosure and open payment systems. Many operators now use dynamic adjustments that take into account wholesale electricity prices or time-of-use tariffs. This encourages charging during off-peak hours and eases the load on local grids. Reports from the IEA show that networks that use dynamic pricing have better load distribution and lower demand-charge exposure, which is important for staying financially stable (Global EV Outlook 2025, 2025). More and more, people are using hybrid models that charge by the hour or by the kWh, in addition to simple energy pricing. These structures make it less likely that people will stay at high-power stations for a long time and help operators recoup their capacity costs. Studies on smart charging show that load-aware pricing, when used with automated control, can greatly lower peak demand and put off expensive upgrades to the grid, which will make the system more efficient and the station more profitable.

Subscription and membership programs add to another level, giving you discounts, priority access, or bundled roaming benefits. AFIR and NEVI require ad hoc access for all users, but memberships are still a good way to build loyalty and keep revenue streams steady. Like this, roaming agreements between networks increase coverage and use, but they also add settlement costs that operators often make up for with small surcharges or bundled pricing. These agreements are especially useful for new businesses that want to quickly grow demand during the early stages of deployment (EU Alternative Fuels Infrastructure Regulation 2023/1804, 2023; U.S. Department of Transportation, 2024).

Fleet and depot contracts are a separate pricing category, usually based on a mix of energy and capacity fees with service-level guarantees. These deals guarantee steady income and make it possible to invest together in site improvements or on-site storage, which can lower demand charges. In China, policy pilots for V2G and differentiated tariffs give startups a chance to make money by offering flexible services. In Europe, DSOs and aggregators are testing compensation schemes for balancing and managing congestion. Initial research indicates that even minimal V2G involvement can lower system expenses and facilitate more competitive retail rates at public hubs (Chen & Zhang, 2024).

Co-location strategies also have an effect on prices. Operators can cross-subsidize tariffs and smooth out grid peaks by using ultra-fast chargers with retail or solar-plus-storage. Batteries make it possible to charge more during peak times without cutting into profits, and partnerships with retailers bring in extra money that helps keep kWh rates competitive. The IEA's global assessments show that having a variety of site economics speeds up coverage

and makes new entrants more financially stable (Global EV Outlook 2025, 2025).

Last but not least, equity and transparency requirements affect how tariffs are set up. AFIR requires card-based payments and real-time price disclosure. NEVI requires clear pricing and uptime standards, and China's rural charging programs focus on making charging affordable and reliable. These rules limit hidden fees and encourage new businesses to use simple, clear tariffs with clear signs for idle or reservation charges. Academic reviews consistently emphasize that such clarity diminishes consumer friction and enhances trust, which is crucial for increasing utilization and attracting investment (Sarda et al., 2024).

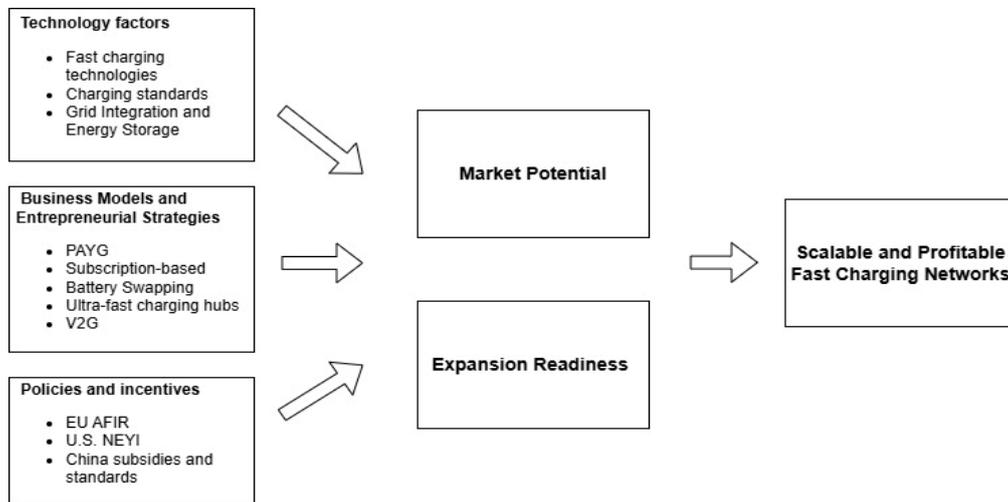
Summary

In the past few years, the global market for electric vehicles has grown very quickly and now makes up a large part of new car sales. Electric cars made up less than 5% of global sales in 2020, but by 2024 they made up more than 25%, with over 17 million sold. China is the leader in this growth, followed by Europe and the US. In 2024, China sold more than 11 million electric cars, which is more than the total number of electric cars sold around the world just two years earlier. Europe is also adopting quickly, thanks to clear rules and incentives. The US is still growing, but at a slower rate because of differences in policy and uneven access to charging stations. This trend is heavily influenced by what the government does. For instance, the European Union wants to stop making new gasoline and diesel cars by 2035 to help the environment. China, on the other hand, gives tax breaks and grants to people who buy electric cars. These steps, along with more people worrying about emissions, have made battery electric cars the most popular choice among consumers. Plug-in hybrid cars are still an option for the time being, but their market share is falling as fast charging networks grow and range anxiety goes down.

Figure 7 shows this. The advancement of rapid charging technologies is a crucial element in the adoption of electric vehicles. There are three levels of charging systems. Level 1 and Level 2 use alternating current and are good for charging slowly or at a medium speed, which can take several hours. Level 3 uses direct current, which lets you charge quickly, getting to eighty percent in about twenty to thirty minutes. New extreme fast charging hopes to cut this time down to five to ten minutes with power levels over 350 kilowatts. This would make charging almost as fast as filling up a gas car. Standards like CCS in Europe and North America and GB/T in China make sure that vehicles and chargers work with each other. Tesla uses its own connector but is moving toward open standards. Wireless charging is also getting better and is more convenient, but it isn't as efficient, safe, or cheap as wired systems. High power charging puts a lot of stress on batteries and the electricity grid, so things like thermal management, smart charging protocols, and using renewable energy are becoming more and

more important. Researchers are working on better battery materials, better ways to charge them, and ways to control the temperature to make fast charging safer and less damaging.

Figure 7. Framework for Technology, Business Models, and Policies for EV Fast-Charging Expansion Base on the Literature Review



Source: compiled by author

The fast charging industry has different ways of making money and making things easier for users. Pay as you go, subscription plans, battery swapping, and ultra-fast charging networks are some of the most common models. Pay as you go is easy and flexible for users, but it needs a lot of people to use it to cover costs. Subscription plans bring in steady money and keep customers coming back, but they need a lot of active users. Battery swapping cuts down on wait times and is popular in China for fleets and high-end users, but it needs a lot of money and standardization of battery design. Ultra-fast charging makes long-distance travel possible, but it also puts a lot of strain on the grid and costs a lot of money. This is why it's important to combine it with storage and renewable energy. To save money and give themselves more options, startups often use modular hardware and software services. Examples include smart charging platforms, roaming agreements, and vehicle-to-grid services. These strategies are heavily influenced by government policies and clear standards in China, the EU, and the US. These policies lower risk and help infrastructure grow. In China, strong incentives and rural programs speed up deployment, while in Europe, rules make sure that everything works together and is open to everyone. The federal government in the United States helps pay for corridor charging, but complicated permitting and state-level rules make it harder to grow. In general, the research shows that advances in technology, new ideas in business, and government support all work together to make fast charging networks scalable and long-lasting.

Research gap

The literature review indicates that numerous studies on electric vehicle (EV) fast charging concentrate on individual components rather than offering a comprehensive perspective. Most of the time, technology research is about making charging faster, batteries safer, and standards like AC, DC, and extreme fast charging. These studies show how to shorten charging times and keep batteries healthy, but they don't show how these technical improvements affect business results like cost recovery or profit. Policy studies look at things like government incentives and rules, such as the Alternative Fuels Infrastructure Regulation in Europe or the NEVI program in the US. These papers demonstrate the influence of regulations on infrastructure development; however, they seldom connect policy mandates to business models or operational strategies. Market studies show how many people are using EVs, how many chargers there are, and how the market is growing in different parts of the world, such as China, Europe, and the US. But they don't say how startups can use this information to choose where to put up stations or what services to offer. Business model research talks about things like pay-as-you-go, subscription plans, battery swapping, and ultra-fast corridor hubs. However, most papers only look at these models on their own and don't compare them in different regions or with different grid limits. Consequently, there exists a deficiency in research that integrates technology, policy, market demand, and business models into a cohesive framework. Another gap is that most studies don't do sensitivity analysis to see how changes in electricity prices, demand charges, or policy delays affect success. This makes it hard to guess how long it will last. In general, there isn't enough research that would bring them all together into one decision-making tool. This gap is important because to build fast charging networks that are both scalable and profitable, you need to know how technical choices, economic factors, policy rules, and market conditions all work together. Future research should tackle this issue by developing frameworks that connect these components and offer explicit direction for startups and operators intending to expand networks in various regions.

In light of the identified literature review gap, a potential framework has been formulated to integrate the primary factors that affect the scalability and profitability of fast charging networks. The framework starts with five important factors that have already been found: market demand, infrastructure readiness, economic conditions, energy costs, and regulatory incentives. It helps people make strategic choices about technology and how to run a business. For instance, the decision between high-power direct current fast charging, modular systems, or battery-integrated solutions depends on how much power the grid can handle, how much they cost, and what policies support them. Pricing strategies like pay-as-you-go or subscription models are based on how people act and what the law says. These results, when combined,

show whether a charging network can grow while still making money. A qualitative and quantitative analysis is necessary to enhance the practicality of this framework. This method uses both qualitative case studies and quantitative analysis to come up with indicators that can be measured. These indicators let you test the framework in real life and make it easier to compare the potential of different markets and the viability of different startups in a structured way.

2. METHODOLOGY

This study includes qualitative case study analysis with a quantitative model to assess the feasibility of expanding EV fast-charging networks. Data is gathered from secondary sources, such as corporate reports, industry analyses, and scholarly publications. The case studies show how businesses in different areas build infrastructure, and the model gives a clear way to compare market conditions in different countries.

The goal of this study is to systematically look at how market conditions and strategic approaches in China, the United States, and the European Union affect the growth of electric vehicle fast-charging networks. The research seeks to elucidate the business strategies and success factors of various companies by integrating qualitative case studies with quantitative scoring models, focusing on elements such as market demand, infrastructure readiness, policy support, and ecosystem maturity. In the end, goal is to create a way for startups to compare their options in the market and figure out the best ways to run their businesses.

The research methodology has combination of qualitative case analysis with a quantitative comparative scoring model.

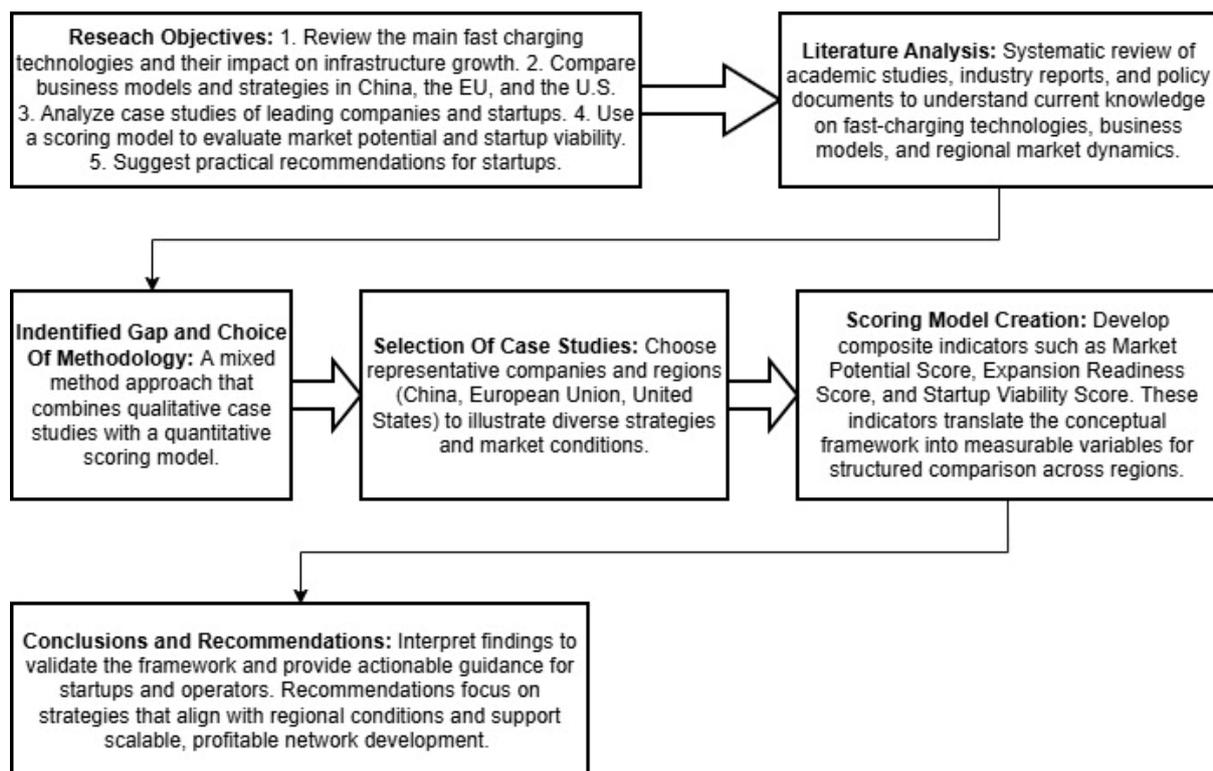
The research questions are:

- What are the major factors of successful EV charging companies from different countries and regions?
- What are the major factors of successful EV charging startup companies from different countries and regions.
- What's the business strategies to help startup companies expand fast-charging networks?
- How does government policy support affect the speed of fast-charging infrastructure development?
- How does market potential and startup viability differ between China, the United States and Germany?

Figure 8 shows the main steps of the final master thesis (FMTP) process, which will help answer the research questions. The diagram clearly shows the main steps of the research process. The research objectives encompass the examination of fast charging technologies and their impact on infrastructure development, the comparison of business models and strategies across China, the European Union, and the United States, the analysis of case studies from prominent companies and startups, the application of a scoring model to evaluate market potential and startup feasibility, and the provision of actionable recommendations. The next step is the literature analysis, which means reading and analyzing academic papers, industry reports, and policy documents in a systematic way to learn more about fast charging technology, business models, and market trends. After this, the research gap is found and the

method is chosen. A mixed method approach is employed as it integrates qualitative case studies with quantitative scoring, facilitating both comprehensive insights and quantifiable outcomes. The next step is to choose the case studies. China, the European Union, and the United States are the main markets for electric vehicles. Different strategies and conditions are shown by picking companies and regions. After that, the scoring model is made. This model uses things like the Market Potential Score, the Expansion Readiness Score, and the Startup Viability Score. These indicators make the conceptual framework into numbers that can be compared across regions. The last step is to make conclusions and suggestions. The results are used to back up the framework and give advice to new businesses and people who run them. The suggestions are mostly about ways to make networks that are both scalable and profitable.

Figure 8. Methodological Framework for the Research Process of EV Fast-Charging Expansion



Source: compiled by author

2.1 Chosen companies for case study

The case study analysis looks at businesses and startups that use different strategies and business models. Two examples of companies that run big networks in the US and the EU are Tesla and Ionity. In China, BYD and Teld are two companies that use vertically integrated and public-private partnership models. Kempower and Volta were chosen to show how new businesses use modular hardware and different ways to make money. These examples show how choices about technology, policy, and business can affect growth.

2.2 Startup Viability model

A scoring model was created to go along with the qualitative analysis. This model was used to find out how attractive and ready the market was. Three composite indicators were used: the Market Potential Score (MP Score), the Expansion Readiness Score (ER Score), and the Startup Viability Score (SVS). These indicators sum up things like demand, infrastructure, economic strength, policy incentives, market saturation, and ecosystem readiness. The scale of some variables were changed so that they could be compared across regions.

The MP Score shows long-term potential and takes into account things like the rate of EV adoption, GDP per person, VC investment, and the share of the EV market. The ER Score looks at how ready the market is in the short term. It takes into account the growth of EV sales, the number of fast chargers per 100,000 EVs, the level of urbanization, and the number of charging network operators. SVS looks at other things as well, like how easy it is to do business, the innovation index, and the number of people who use the internet, to see how good the environment is for startups. These variables were chosen because they are the main factors that affect the growth of infrastructure and the success of new businesses.

Table 1 shows the variables that were used in the model. The Market Potential Score (MP Score), Expansion Readiness Score (ER Score), and Startup Viability Score (SVS) were all made up of weighted sums of certain variables. We scaled each variable so that they could be compared across regions. This is because the original units are very different (for example, GDP per capita in USD versus EV adoption rate in percentage).

Table 1. Variables Used in the Model

Component	Variable	Definition	Unit	Source
Market Demand	EV Adoption Rate	Share of EVs in total vehicle number	%	IEA Global EV Outlook; ICCT

Continuation of Table 1.

	EV Sales Growth	Year-over-year (YoY) growth in EV sales	%	IEA; ICCT; National Automotive Reports
Infrastructure	Fast Chargers per 100k EVs	Number of public chargers per 100,000 EVs	Stations/100k EVs	IEA; Open Charge Map
	Urbanization	Share of population living in urban areas	%	World Bank; UN Urbanization Data
Economics	GPD per Capita	Economic output per person	USD	World Bank; IMF
Energy Costs	Commercial Electricity Cost	Average cost of electricity for businesses	USD/100 kWh	IEA; National Energy Agencies
	Fuel Price Differential	Different in cost per km between gasoline and electricity	USD/1000 km	IEA; National Energy Reports
Policy and Incentives	EV Purchase Subsidy	Average government incentive per EV purchase	USD/vehicle	National Policy Documents; ICCT
	Charging Infrastructure Grants	Government funding per station or per kW	USD/kW	National Energy Policy Reports
Market Saturation	EV Market Share	Share of EVs in new car sales	%	IEA; ICCT
	Charging Network Operators	Count of major operators in the region	Operator count	Industry Reports; Market Analysis
Startup Ecosystem Readiness	Ease of Doing Business Rank	Global ranking of business environment	Rank	World Bank
	Global Innovation Index	Composite score of innovation capacity	Index	WIPO; Global Innovation Reports
	VC Investment	Venture capital invested in EV sector	USD Billion	Crunchbase; PitchBook; Industry Reports

Continuation of Table 1

	Digital Marketing potential	Share of population with internet access	%	World Bank; ITU
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Source: compiled by the author based on IEA, ICCT, World Bank, IMF, Crunchbase, WIPO.

Market Demand is calculated as the average of three indicators: the electric vehicle adoption rate, the annual growth of electric vehicle sales, and the electric vehicle density. This means that Market Demand reflects both the current level of adoption and the speed of market expansion, as well as the concentration of electric vehicles in the population.

Infrastructure is measured as the average of two factors: the number of fast chargers and the level of urbanization. This approach captures the availability of charging facilities and the degree of population concentration, which together influence how easily charging networks can be deployed.

Economics is calculated by combining GDP per capita and the fuel price differential, and then dividing by twice the commercial electricity cost. Fuel Price Differential (USD/1000 km) was estimated by author by comparing the cost of driving 1000 km using gasoline versus electricity, based on average fuel consumption (liters per 100 km) and EV energy consumption (kWh per 100 km), multiplied by respective fuel and electricity prices from IEA and national energy reports. It reflects the purchasing power of consumers and the economic advantage of electric vehicles compared to conventional fuel, while adjusting for the cost of electricity, which affects operating expenses for charging stations.

Market Saturation is determined as the average of electric vehicle market share and the number of different charging network operators. This measure indicates how competitive and mature the market is, considering both the penetration of electric vehicles in new car sales and the diversity of infrastructure providers. Then MP score is calculated as:

$$MP\ Score = \omega_1 \cdot MarketDemand + \omega_2 \cdot Infrastructure + \omega_3 \cdot Policy\ Incentives + \omega_4 \cdot MarketSaturation - \omega_5 \cdot Energy\ Costs$$

Meanwhile the ER Score is calculated as the weighted sum of four indicators: Ease of Doing Business Rank, Global Innovation Index, Venture Capital Investment, and Digital Marketing Potential. Each indicator is multiplied by its assigned weight, and the sum represents the overall readiness of the market for startup expansion:

$$ERS\ Score = \omega_5 \cdot Ease\ of\ Doing\ Business\ Rank + \omega_6 \cdot Global\ Innovation\ Index + \omega_7 \cdot VC\ Investment + \omega_8 \cdot Digital\ Marketing\ Potential$$

Then SVS is calculated as:

$$SVS = \omega_9 \cdot MP\ Score + \omega_{10} \cdot ERS\ Score$$

The MP Score is calculated as a weighted sum of four composite indicators: Market Demand, Infrastructure, Policy Incentives, and Market Saturation. Market Demand itself is the average of EV adoption rate, EV sales growth, and EV density, which reflects both the current level of adoption and the speed of market expansion. EV density has been estimated by author (EVs deployed from IEA and population from World Bank). Infrastructure is based on the average of fast charger availability and urbanization, showing how easily charging networks can be deployed. Policy Incentives include subsidies and grants that support EV adoption and infrastructure development. Market Saturation considers EV market share and the number of charging network operators, indicating the level of competition and maturity in the market. The ER Score represents startup ecosystem readiness and is calculated as the weighted sum of Ease of Doing Business Rank, Global Innovation Index, Venture Capital Investment, and Digital Marketing Potential. These indicators measure how favorable the environment is for new companies to enter and grow. The SVS combines the MP Score and ER Score using assigned weights to provide an overall measure of startup viability in a given region. Weights were applied to reflect the relative importance of each component. For example:

- Market Demand indicators such as EV adoption rate and EV sales growth received higher weights because they directly indicate demand.
- Infrastructure factors like fast chargers and urbanization were weighted moderately because they influence deployment speed.
- Economic and policy factors, including GDP per capita and incentives, were given supportive weights as they affect investment feasibility.
- Market Saturation variables, such as EV market share and the number of operators, were included to capture competitive intensity.

The weights used in the model were assigned through a combination of expert judgment and reference to established frameworks. An expert panel composed of industry analysts and academic advisors reviewed the relative importance of each variable based on existing literature and regional market context. This approach aligns with the rEV Index methodology by Economist Impact, supported by bp, where experts determine the influence of each dimension in measuring EV readiness (Economist Impact, 2021). The Composite Indicators Toolkit from the European Commission supports this method, noting that expert based weights remain common when statistical data alone cannot fully capture conceptual priorities (Michela Nardo et al., 2008). Additionally, academic guidance such as Becker et al.'s work on composite indicators confirms that expert informed weighting is acceptable in index development, particularly when choices are transparent and supported by sensitivity analysis (Becker et al., 2017).

3. RESEARCH RESULTS

3.1 Case studies

This part looks at the top companies and new businesses in China, the European Union, and the United States that are working on fast EV charging. The goal is to find out how technology and business model choices affect network size, reliability, and growth. Tesla (U.S.), BYD and Teld (China), Ionity (EU), Kempower (EU), ChargePoint (U.S.), Volta (U.S., Shell brand), and NIO Power (China) are some of the companies involved. The period covered is from 2024 to 2025, and the selection is based on either a large market share or a significant new idea.

TESLA (U.S.)

Tesla is one of the most well-known companies in the electric car business, and it has built one of the biggest networks of fast chargers in the world. The company started its charging program to solve one of the biggest problems with electric cars: the worry about how far they can go. Drivers should know that they can drive for a long time without worrying about where to charge. Tesla decided to fully control this issue by owning and running its own charging stations. This choice was very important because it meant that Tesla could keep the same level of quality and service everywhere. When a driver gets to a Tesla station, they know what to expect: chargers that work, clear directions, and quick service.

There are a lot of details in the design of Tesla stations. The company plans where to put cabinets, cables, and parking spaces so that charging is safe and easy. Tesla also checks the health of each charger with high-tech monitoring systems. The system sends out alerts if something goes wrong, and technicians can fix it right away. Regional warehouses keep spare parts on hand so that repairs don't take long. These steps help Tesla keep a very high uptime, which means that the stations are almost always open. One of the main reasons drivers trust Tesla's network is that it is reliable.

Tesla's choice to let other car brands use its network was another big change. The Supercharger network used to be only for Tesla cars. With the North American Charging Standard (NACS), a lot of other electric cars can now charge at Tesla stations. This wasn't just a new plug. Tesla also made it easier for everyone to pay and prove their identity. Drivers can now plan their trips without worrying about brand restrictions. This has brought in more customers and made better use of the station. Tesla also controls power sharing at places with a lot of traffic. The system sends power to the places where it is needed most when a lot of cars come at once. This keeps the wait times short and makes the experience better for

everyone.

The quality of Tesla's infrastructure has a big impact on its success. The company has put its stations in the right places: along highways for long trips and in cities for everyday use. It's easy to find the stations, pay for them, and they often have roaming options. This wide and reliable coverage makes electric cars more useful by cutting down on the uncertainty of how far you have to travel. One of the main reasons people choose electric cars is that there are good public charging stations. Tesla got this early on and spent a lot of money on building a network that drivers can rely on. Infrastructure isn't just about how many chargers there are; it's also about how easy they are to use and how reliable they are. Tesla's attention to these details has made its network a model for others (Global EV Outlook 2025, 2025).

Policy has also helped Tesla get bigger. The NEVI program makes it clear how charging stations should work in the US. These rules say that payment systems must be open, data must be reported, and uptime must be at least a certain amount. They also want stations along main roads so that drivers can easily cross state lines. Tesla can join public programs and get help with growth because it already meets most of these standards. Clear policy lowers risk and makes it easier to plan. It also makes all operators follow the same rules, which makes driving better. This means that Tesla's stations fit in with national plans and can get money and help from local governments. Policy incentives have made it possible for companies that invest in quality and interoperability to grow faster and with less risk (EV Charging Infrastructure Interoperability, 2023; U.S. Department of Transportation, 2023).

In short, Tesla's success is due to two strong things: good infrastructure that is easy to find and policies that reward high standards. These things make Tesla the best at fast charging and help explain why its network is growing faster than many of its competitors. Drivers trust and use the system every day because it has smart technology, good planning, and clear rules.

Ionity (European Union)

Ionity is one of the biggest players in Europe's market for charging electric vehicles. BMW, Mercedes-Benz, Volkswagen Group, and Ford all worked together to make it. Ionity's main goal is to build a reliable, high-power charging network across Europe so that drivers can drive long distances without having to worry about where to charge. This is a very important idea because there are a lot of countries in Europe and drivers often cross borders. Electric cars can't be used for long trips easily if there aren't any charging stations on highways. Ionity is working on this issue by putting up stations along the TEN-T corridors. These are the main roads that link countries in Europe. Government also supports upgrading the roads in the TEN-T area to make room for more EV charging stations (EU Alternative Fuels Infrastructure

Regulation 2023/1804, 2023).

Ionity's stations are built to work well. Most of them can charge very quickly, with up to 350 kW of power, which is enough for electric cars with 400-volt and 800-volt systems. The company uses the Combined Charging System (CCS), which is what people in Europe use. This means that almost all new electric cars sold in the area can use these stations. The stations' design is simple and easy to understand. It's easy for drivers to pay, and the prices are clear. Ionity also works with roaming partners, so drivers who use other charging networks can still use Ionity stations without having to make new accounts. This is very important for trust and ease of use.

Ionity has been able to grow because it has a lot of money behind it. The company got a big green loan of €600 million to grow its network. This money helps Ionity build more stations quickly and keep them up to high standards. Another reason is that it has a clear plan. Ionity doesn't just put stations anywhere; it focuses on corridors where there is a lot of traffic and drivers need to charge quickly for long trips. This corridor approach makes the network useful for more than just marketing; it can also be used for real travel needs.

Policy incentives in Europe have a big impact on Ionity's success. The Alternative Fuels Infrastructure Regulation (AFIR) was put in place by the European Union. It makes the rules for charging stations clear. These rules say that there must be fast charging stations every 60 kilometers on main roads. They also want stations to have clear prices, open payment systems, and a minimum amount of power. These rules make the business world more stable for companies like Ionity. They lower risk because operators know exactly what needs to be done and where stations should go. This makes it easier to plan and encourages people to put money into things. It would be very hard to build a network across many countries without these rules because each country could have its own standards. The EU Alternative Fuels Infrastructure Regulation 2023/1804 (2023) solves this problem by making one set of rules for all EU members.

Infrastructure quality is another reason why Ionity has done so well. The company doesn't just build stations; it builds stations that drivers can count on. They are put in the right places, have a lot of power, and always work. Ionity wants to have 1,000 sites and 7,000 chargers across Europe by 2025. The network is growing quickly. This kind of coverage makes it possible to drive electric cars for long distances. Drivers know where to find a station when they need one. International research shows that one of the main reasons people buy electric cars is because they have good public charging infrastructure. This trend is directly supported by Ionity's focus on corridor coverage and high standards (Global EV Outlook 2025, 2025).

Ionity has been successful because of two strong factors: a clear and helpful policy that sets rules for coverage and service, and high-quality infrastructure that meets real travel needs. Ionity has grown quickly and become one of the most trusted networks in Europe

because of these things working together. Ionia has built a network that makes it easy for drivers to cross borders with confidence by following a corridor strategy and working within a stable regulatory framework. This method shows how policy and infrastructure can work together to make electric mobility possible on a large scale.

BYD (China)

BYD is one of the biggest makers of electric cars in the world and the top seller of electric cars in China. The company doesn't just make cars; it also makes batteries, power electronics, and charging systems. BYD has a big advantage because it can control the whole process, from designing batteries to making charging technology. BYD can quickly change its cars and charging stations to work with a new high-voltage platform or a faster charging system. One reason BYD has grown so quickly in China is that it can come up with new ideas and put them into action quickly.

BYD makes both passenger cars and commercial vehicles. It makes electric buses, trucks, and delivery vans that need a lot of charging infrastructure to keep fleets running. These cars and trucks usually have big batteries and need a lot of power to charge them quickly. BYD has begun to roll out megawatt-class chargers for heavy-duty trucks and high-end passenger cars. These chargers can give a lot of power and cut the time it takes to charge large battery packs down to just a few minutes. This technology is important for logistics companies and public transportation operators because it helps them keep vehicles on the road and cut down on long wait times.

The demand for BYD's products in China has a big impact on how well the company does. The biggest market for electric vehicles is in China. More than half of all new cars sold in China in 2024 were electric. Because so many people are using it, there is a steady and strong demand for charging services. Charging stations are used a lot when there are millions of electric cars on the road. This makes them profitable and encourages more investment. This is good for BYD because its customers need reliable charging for both personal and fleet vehicles. International studies show that the most important factor in the growth of charging infrastructure is the high adoption of electric vehicles. Even the best technology can't work without a lot of demand. Demand in China is not only high, but it's also growing quickly. This gives BYD a strong foundation for its charging strategy (Global EV Outlook 2025, 2025).

The availability of infrastructure is another reason for BYD's success. China has put a lot of money into public charging networks. There are hundreds of thousands of fast chargers in the US, and the number keeps going up every year. This makes electric cars useful for everyday use and for long trips. Because BYD's cars can use China's charging standards, they can use this network. To help its business customers, the company also builds its own

stations in important places like bus depots and logistics hubs. Good infrastructure makes electric cars more appealing to buyers because it lowers their fear of not having enough range. It also helps BYD promote its high-power charging technology because people can actually use it. International reports show that one of the main reasons why so many people in China are buying electric vehicles is because the country's infrastructure is so good. This is related to BYD's growth because its cars and charging systems are made to work well in a market where public charging is common (Global EV Outlook 2025, 2025).

China's supportive policies, like subsidies for buying electric vehicles and grants for charging stations, help BYD, but the most important things are still market demand and infrastructure. More electric cars mean more charging stations, and more charging stations make electric cars easier to use. This is a good cycle. BYD can fully take advantage of this cycle because of its integrated approach. It can make cars that charge faster, build stations where they are needed, and give fleets and private customers all the help they need.

BYD's success in charging infrastructure is due to two strong factors: a large and growing market for electric vehicles and a dense, reliable network of charging stations. Because of these things, BYD can use cutting-edge technologies like megawatt charging and support both passenger cars and heavy-duty vehicles. BYD is a leader in making electric vehicles and shaping the future of fast charging in China because of high demand and strong infrastructure.

TELD (China)

TELD is one of the biggest charging companies in China and a major player in building networks on a city scale. The company's goal from the start was to make charging easy and available to everyone in cities. TELD works closely with local governments and grid companies to find the best places for stations. This cooperation is very important because it helps TELD get land and power connections faster than a lot of other companies. These partnerships help cities with limited space and high demand for electricity cut down on delays and make it possible to grow.

TELD is mostly interested in busy places like business districts, shopping centers, and transportation hubs. It also puts chargers near taxi stands and ride-hailing zones because these cars need to be charged a lot. TELD offers charging at depots and along delivery routes for logistics companies. TELD serves both private drivers and commercial fleets because it has a mix of locations. The business uses smart systems to control power and cut down on wait times. For instance, it charges users who don't use the chargers and limits the number of sessions to keep them free for new users. TELD also keeps an eye on stations from afar and sends technicians right away when there is a problem. These steps help keep uptime high

and build trust with users.

One reason TELD has grown so quickly is because its infrastructure is good and covers a lot of ground. China has put a lot of money into public charging, and TELD has been a part of this growth since the beginning. The company runs hundreds of thousands of chargers in many cities. Electric cars are useful for everyday use because they can go so far. Drivers know they can find a TELD station nearby, which makes them less worried about running out of power and encourages more people to buy electric cars. Studies from around the world show that good public infrastructure is one of the main reasons why so many people are buying electric vehicles. TELD's success shows how important it is to make networks that are not only big but also work well and are easy to use. The company's stations are easy to get to, have clear payment options, and work with common standards. Because of this level of care, TELD is a well-known brand in China's charging market (Global EV Outlook 2025).

Policy incentives are another reason why TELD has done well. Grants, subsidies, and clear rules have helped build charging infrastructure in China at both the national and local levels. Municipal programs often give land and help with grid connections, which cuts costs and speeds up deployment. TELD's business model is in line with national policies that promote open access and clear pricing. These incentives make it safe to invest. TELD can plan projects that will take a long time to finish without having to worry about rules changing at the last minute. Reports from around the world show that policy support is a major factor in China's charging growth. It would be very hard to build such a big network in a short amount of time without these programs. TELD has used this support well by making its plans fit with the government's goals for clean transportation and city mobility (International Council on Clean Transportation, 2025).

TELD also spends money on technology to make things work better. It uses dynamic power sharing to send electricity to places where it is needed most, and it adds battery storage to places where the grid is full or the tariffs are high. These solutions help keep costs down and keep stations running even when there are a lot of people using them. TELD's way of doing things shows that building a lot of charging stations isn't the only thing that matters; managing them well is also important. TELD has a strong foundation thanks to good infrastructure and strong policy support. Smart operations keep the network going. TELD has been successful because it has a strong and reliable infrastructure network and policies that lower risk and speed up growth. TELD has become one of the most important companies in China by working with local governments, using smart technology, and focusing on places where there is a lot of demand. Its story shows that electric mobility can grow quickly and serve millions of drivers every day when infrastructure and policy work together.

Kempower (European Union)

Kempower is a Finnish company that makes modular fast charging systems for electric cars and trucks. Kempower is different from many traditional charging providers because they focus on flexibility and scalability instead of installing fixed-capacity stations. Its charging cabinets are made up of modules that can be added or taken away as needed. This means that operators can start with a smaller investment and grow without having to buy a whole new system. The company also uses satellite dispensers, which let them put the charging points far away from the main cabinet. This design makes it easier to fit stations into small spaces and change the way they are parked. These features are very helpful for public charging stations and fleet depots, where the amount of space and power needed can change over time.

Kempower uses both hardware and smart software. Its control system keeps an eye on each charger and changes the power level as needed. If one car can take in a lot of power and the other can't, the system sends more power to the first car and less to the second. This makes better use of available space and increases overall efficiency. The software also helps operators deal with times of high demand. Many countries have high fees for using too much power at once in their electricity tariffs. Kempower's system can keep peaks down by spreading power across sessions or by using battery storage when it's needed. This is important because if demand charges aren't handled properly, they can make fast charging very expensive.

Infrastructure flexibility is a big part of why Kempower is doing well. Building a charging network isn't just about putting in a lot of chargers; it's also about putting in chargers that can change with the times. Traffic patterns, vehicle technology, and the amount of power available on the grid can all change quickly. With Kempower's modular approach, operators can respond quickly and without spending a lot of money. For instance, a site close to a mall might start with four chargers. The operator can add more modules and satellites to the site without having to rebuild it if more people in the area start using electric vehicles. This flexibility lowers the risk of investing and speeds up deployment. International studies show that infrastructure that can easily grow is a key factor for long-term charging growth. Kempower's design directly supports this idea by making it easier and cheaper to add capacity (Global EV Outlook 2025, 2025).

Kempower has been successful because it focuses on managing energy costs. Fast charging uses a lot of electricity in a short amount of time, which can make bills very high if peak demand isn't controlled. Demand charges make up the biggest part of the cost of a charging station in many places. Kempower's software helps operators avoid these costs by controlling when and how power is sent. It can plan charging for times when electricity is

cheaper, cut back on power during times when it is more expensive, and add battery storage to even out demand. These features make stations more profitable and get more operators to put money into fast charging. Reports from around the world agree that one of the biggest problems for charging networks is keeping energy costs low. One of the main reasons Kempower is growing in Europe and moving into North America is that it can solve this problem (International Energy Agency, 2025).

Kempower also benefits from Europe's strong digital infrastructure and culture of innovation. Both public and private operators like it because its software works with fleet management systems, payment platforms, and roaming networks. The company has made itself a leader in technology, not just a supplier of hardware. This strategy works well in markets that value smart solutions and long-term growth.

All of these things together explain why Kempower has become a successful company in the fast charging business. The company lowers investment risk, keeps operating costs down, and helps electric mobility grow quickly by providing modular hardware and smart energy management. When building a charging network for the future, its approach shows that flexibility and smart control are just as important as high power.

ChargePoint (U.S. / EU)

ChargePoint is one of the biggest companies in North America and Europe that charges electric cars, but its business model is very different from those of companies that own big networks of stations. ChargePoint is a platform that links up a lot of different charging providers and makes it simple for both drivers and businesses to use them. This idea is important because charging was not well organized in the early days of electric mobility. Drivers had to have different accounts and apps for each network, which made long trips stressful and hard. ChargePoint fixed this problem by making a system that works with roaming and open standards. With ChargePoint, drivers can use one account to get to thousands of stations on different networks. This ease of use is a big reason why the platform has grown so quickly and why so many operators want to join its network.

ChargePoint also has advanced tools for businesses and people who run fleets. Its software helps keep an eye on chargers, set prices, and control energy use. Remote diagnostics make repairs faster and cut down on downtime. Dynamic pricing lets operators change prices based on the time of day or how much demand there is for a service. This helps balance usage and boost revenue. ChargePoint works with route planning and scheduling systems for fleets. This means that businesses can charge delivery vans or buses without having to stop working. ChargePoint is more than just a charging network; it's a technology partner that helps operators run stations smoothly and keep their fleets on schedule.

One big reason ChargePoint has done well is that policies at the state and regional levels support it. The Low Carbon Fuel Standard (LCFS) program in California gives credits for electricity that is sent to electric vehicles. Charging operators can sell these credits to make more money. ChargePoint helps site owners keep track of and report this information, which makes it easier for them to take advantage of LCFS incentives. This policy makes it easier for businesses to join ChargePoint's platform and install chargers because they can make money in addition to charging fees. Some states, like New York and Oregon, have made rules that say public chargers must be able to accept payments from any device and work while traveling. These rules push the market toward interoperability, which is what ChargePoint is all about. EU rules support roaming in Europe by encouraging open access and clear pricing for travel across borders. ChargePoint's platform meets these needs by using open protocols like OCPP and OCPI. This makes it appealing to operators who want to follow the rules and make the user experience better. These rules make it easier for companies that focus on connectivity and ease of use to do business, and ChargePoint is a leader in this area (California Air Resources Board, 2024; EU Alternative Fuels Directive, 2014).

Another reason for success is that the infrastructure is easy to get to. ChargePoint doesn't build all the stations itself, but its platform makes the ones that are already there work better. ChargePoint makes it easier for drivers to use more stations by linking many networks together into one system. This is what is meant by "effective infrastructure." This means that even though the total number of chargers stays the same, drivers will have an easier time finding them because they can use one account to access more stations. Studies from around the world show that how easy it is to get to and use a charger is just as important as how many there are. Drivers want easy ways to pay, clear prices, and good service. ChargePoint's platform gives you these features. This makes electric cars more useful and encourages people to buy them. Roaming is already common in Europe, and ChargePoint has expanded there too, making it easier for people to travel between countries and run fleets. ChargePoint helps break down one of the biggest barriers to EV growth by focusing on software and integration: the difficulty of charging across different networks (Global EV Outlook 2025, 2025).

ChargePoint's success shows that creating a strong charging ecosystem is more than just putting in hardware; it's also about linking networks and making them easy to use. ChargePoint has made a system that makes it easier for people to use infrastructure and helps electric mobility grow by combining technology, aligning regional policies, and making things easier for users. This method shows that smart integration and interoperability can be just as useful as physical expansion when it comes to making electric cars useful in everyday life.

Startup Case Studies

Startups are important in the EV charging industry because they come up with new technologies and ways of doing business. This part talks about four well-known examples: Volta, Wallbox, and NIO Power. Each company shows a different way to deal with infrastructure problems and make money in a market with a lot of competition.

Volta (U.S.)

Volta had a very different idea when it came to entering the U.S. charging market than most other companies. Volta didn't build high-power corridor hubs. Instead, they put chargers in stores and made money by putting up advertising screens. The idea was simple: stores would get more customers by offering free or cheap charging, and Volta would make money from the digital ads that showed up on the charging units. This model worked well in the beginning because electric cars were still new and free charging was a big draw for drivers. Retail partners liked the idea because it brought in more customers, and advertisers liked the idea because it let them reach more EV owners.

Most of Volta's stations had Level 2 chargers or lower-power DC fast chargers. They were put in malls, grocery stores, and places where people go to have fun. While they were shopping, drivers could plug in, and the charging session was usually free or very cheap. This got people talking about Volta in a good way and helped it grow quickly in cities. But as the electric vehicle market grew, it became clear what this model couldn't do. Drivers began to expect quicker charging, especially on long trips. Retail sites often didn't have enough room or power to support high-power chargers. Because of utility requirements and local permits, it was hard and expensive to upgrade these sites.

One of Volta's biggest problems was the cost of energy. Fast charging uses a lot of electricity in a short amount of time, and in many states in the U.S., demand charges are very high. These fees apply when a site uses a lot of power all at once, even if it's only for a few minutes. This was a big problem for retail sites because they couldn't predict how much traffic they would get. When a lot of cars came at once, the demand for power went up, and the price for that month went up a lot. Advertising money couldn't always cover these costs. The business model fell apart when there was no advanced energy management or battery storage. Research indicates that demand charges pose a significant risk to the economics of public charging in the United States. Operators who can't handle peaks often have a hard time making money (International Energy Agency, 2025).

Another reason was that the market was full. As more companies built high-power hubs along highways and in cities, there was more competition. Networks like Electrify America,

EVgo, and Tesla had faster charging and roaming options. People who needed to charge their cars quickly for long trips liked these networks better than slower retail chargers. Because of this change, Volta's usage went down and its advertising model became less appealing. Reports from around the world show that when markets grow, drivers choose networks that are fast, reliable, and easy to pay for. When conditions are like this, retail-based models that don't have high-power capability lose ground (Global EV Outlook 2025, 2025).

Volta tried to make changes by adding some DC fast chargers and looking for partners, but the costs were high and the company was under a lot of financial stress. Shell bought Volta in 2023, and the retail advertising model was no longer used by 2025. Shell changed its focus to high-power hubs at gas stations, which worked better with planning long-distance travel and corridors. This change shows that the future of public charging in the U.S. depends on good energy management and high standards of service. In the beginning, free or low-cost charging supported by ads might work, but it won't work when electricity prices go up and competition gets stronger.

These changes help us understand why Volta's original plan worked at first but didn't work in a more developed market. The main reasons were high energy costs and a market that was getting too full. The case teaches us an important lesson: pricing models for businesses must take into account tariff structures and how competition works. It's hard to stay profitable when the market grows and user expectations change if you don't have solutions for peak demand or invest in high-power infrastructure. Volta's story shows that new business models can bring in early users, but that technical and economic realities also affect long-term success.

Wallbox (EU)

Wallbox is a Spanish company that makes smart charging solutions for electric cars. It has grown quickly in Europe and North America. Wallbox is different from other companies that focus on big highway stations because it specializes in charging at home, at work, and in semi-public places. Its products have small hardware and smart software that work together to make charging easy and quick for everyday use. This plan takes into account an important fact: most electric vehicle (EV) drivers charge their cars at home or at work, not at highway stations. Wallbox has become a leader in the growing market for charging stations in homes and businesses by focusing on these areas.

Wallbox chargers are made so that they are easy to set up and use. They can be controlled by apps, balance loads dynamically, and work with solar panels or battery storage. These features help users save money on charging and use renewable energy when it's available. Wallbox also has options for offices and apartment buildings where several chargers need to share power without overloading the grid. This flexibility is important because cities

often don't have a lot of electrical capacity. Wallbox's technology makes sure that charging stays safe and effective even when a lot of cars are plugged in at once.

European building rules that make infrastructure ready are a big reason why Wallbox has been successful. Starting in January 2025, EU law says that non-residential buildings with more than 20 parking spaces must have at least one EV charger. Wallbox knew this change was coming and made products like the eM4 charger to meet these needs. This proactive approach has made it easier and cheaper for businesses and property owners to follow the new rules. Wallbox has a strong position in the European market because it has aligned its product strategy with policy trends. These rules make sure that there is always a need for charging equipment, and many operators choose Wallbox because it can provide reliable, scalable solutions (European Commission, 2023; Wallbox, 2025a).

Managing the cost of energy is another important thing to think about. Prices for electricity change throughout the day, and demand charges can make fast charging very expensive. Wallbox solves this problem with smart charging features that set charging times for off-peak hours and work with virtual power plant (VPP) programs. Wallbox and Leap worked together to launch the Rewards program in California and New York in 2025. This program lets people earn credits by changing the times they charge their devices to help keep the grid stable. Drivers save money and help utilities handle peak loads by taking part in demand response. These incentives make Wallbox chargers more appealing to businesses and homeowners because they lower operating costs and create new ways to make money. These features give Wallbox a clear edge over its competitors in markets where energy costs are a big deal (Wallbox, 2025b).

Platform integration is another reason for success. The Wallbox app lets owners see how much energy they're using, set charging goals, and see how much money they're saving through demand response programs. Fleet managers can see data from many locations, plan charging, and make sure that everything is running smoothly. Smart meters are becoming more common in Europe, and the EU is working on rules for Electrification Action Plans and smart charging. Wallbox's products work directly with smart meters, grid systems, and utility data. This ecosystem approach lets operators plan their setups based on real price signals and grid needs instead of just putting in hardware. It makes charging more reliable and smarter, and it gets sites ready for future updates like dynamic tariffs or vehicle-to-grid features. Wallbox also puts money into public charging solutions. The Supernova fast charger can deliver up to 150 kW and is made for cities and small hubs. In 2025, Wallbox and Francis Energy worked together to put Supernova chargers in cities all over the U.S. These chargers are small and can be put together in different ways, which makes them easier to put in retail parking lots and community spaces. This expansion adds to Wallbox's products for homes and offices, making a full ecosystem for charging electric vehicles. Wallbox expands its market

reach and helps the switch to electric mobility in different settings by providing both private and public solutions (Andrea Cazzaniga et al., 2025).

Wallbox has been successful because it knows what users want and what is going on in the market. It has smart technology, policies that are in line with each other, and ways to save money. Wallbox has made useful, affordable, and future-proof solutions by focusing on the infrastructure needs of buildings and giving people tools to keep track of their energy costs. Its approach shows that the growth of electric mobility depends on more than just big highway stations. It also needs smart charging systems that are built into everyday life. Wallbox shows how new ideas and rules can work together to speed up the use of electric cars.

NIO Power (China)

NIO Power is a leader in battery swapping technology and has built the biggest swap network in China. Drivers can switch out a dead battery for a fully charged one in just a few minutes instead of waiting for fast charging. Standardized battery packs, advanced robotics, and centralized monitoring are all parts of this system that help keep stations safe and running smoothly. Each swap station has automated lifting systems, strict safety checks, and is built for quick vehicle entry and exit. NIO also uses smart software to keep an eye on the health, temperature, and usage patterns of each battery pack to make sure they all meet performance standards.

The network has grown very quickly. NIO had more than 3,300 swap stations on highways and in cities by the middle of 2025. These stations served over 550 cities and thousands of counties. The company's "Power Up Counties" campaign wants to put swap stations in every county in China. Three assembly plants in Wuhan, Kunshan, and Hefei can make up to 1,000 stations a year, which helps with this growth. NIO also has many sites that have both swap stations and fast charging points, which gives drivers more options. This large-scale deployment shows how important infrastructure is to NIO's success. When there are swap stations near highways or in cities, it makes electric mobility more practical for everyday use and long trips by reducing range anxiety. International studies show that having a lot of infrastructure that is easy to get to is one of the best ways to get people to buy electric vehicles. NIO's strategy is in line with this idea.

Strong demand in the market is another reason why NIO is doing well. China is the biggest market for electric vehicles (EVs) in the world. In 2024, more than half of all new car sales will be EVs. This high adoption rate makes sure that swap stations are always busy, which is important for a model that costs a lot of money. Millions of electric vehicle (EV) users who care about convenience and saving time are good for NIO. Taxi fleets and ride-hailing services like battery swapping a lot because it keeps cars on the road and cuts down on downtime (Li

Fusheng, 2025). International reports say that the most important thing for charging infrastructure growth is a lot of people using electric vehicles (Global EV Outlook 2025, 2025). NIO is in a good position in this growing market because it can serve both private drivers and fleets.

Incentives from the government have also been very important. The Ministry of Industry and Information Technology in China has come up with rules to encourage battery swapping in addition to regular charging. These policies include money for building stations and subsidies for EV models that can be swapped. For multi-brand swap stations, cities like Shanghai give subsidies that cover up to 40% of the cost of the equipment. For single-brand stations, they give 20%. Hefei gives battery-swap vehicle buyers incentives to buy them and operators energy subsidies. These steps lower the risk of investing and speed up growth. Local governments also give taxi drivers bonuses for using swap stations, which makes the demand for them even higher. These incentives show that policy is not only helping the market for battery swapping, but also changing it.

NIO has made its rollout stronger by working with other companies. Real estate developers, energy companies, and local governments are all part of its "Power Up Partners" program. Partners give NIO access to land and the grid, and NIO provides the equipment and runs the business. This shared investment model speeds up deployment and lowers the risk of losing money. It also makes sure that stations are put in good places, like on highways and in cities, so that drivers can get to them more easily.

These things all work together to explain why NIO Power is now the world's top battery-swapping company. Swapping can thrive in this environment because of strong infrastructure coverage, high market demand, and policies that support it. NIO's approach shows that for technology to be successful, it needs to be innovative, big, and in line with government policy. NIO has built a network that supports millions of drivers and sets a standard for future mobility systems by focusing on convenience, reliability, and partnerships.

3.2 Analysis of market potential and startup growth

Not only does technology affect the growth of electric vehicles (EVs), but so do market conditions. Market potential for fast-charging networks means how ready a region is to support big infrastructure and bring in money. The level of readiness depends on a number of things, including the rate of EV adoption, the availability of charging infrastructure, the strength of the economy, and the ability to innovate. Before entering a market, startups need to know these things because they affect how quickly they can grow and how much money they can make.

The EV adoption rate tells you how many people already drive electric cars. More people want charging stations when the rate is higher. The growth of EV sales shows how quickly the

market is growing. These signs work together to help us guess what people will want in the future. The charging network's level of advancement can be seen in infrastructure indicators like the number of fast chargers per 100,000 EVs and the average charging speed. The author figured out how many fast chargers there were for every 100,000 EVs by dividing the total number of public fast chargers by the total number of EVs in use. Economic indicators like GDP per capita and VC investment can tell you if the market has enough money to support new projects. Innovation and how easy it is to do business are also important because they affect how quickly startups can get started and grow.

3.2.1 China: The High Demand Market with Policy Support

The electric vehicle market in China is the biggest and grows the fastest in the world. The rate of EV adoption is now 50.1%, and annual sales growth is 47.1%. This shows that there is a lot of demand for charging infrastructure. This fast growth opens up a lot of doors for new businesses because more people using charging stations means more money for them.

There are about 150 fast chargers in China for every 1000 EVs. This number is very high compared to most other places, but it's still not enough for the new electric vehicles (EVs) that are coming out quickly. This gap lets new businesses build charging stations, but it also causes problems like high costs and a limited city power grid.

The economy is doing okay. The GDP per person is about \$13,300, which is less than in the US or Germany, but the size of the market makes up for this. Venture capital investment is very high at \$37.7 billion, which is the most of the three regions looked at. This shows that investors trust China's electric vehicle ecosystem and are willing to back new ideas.

Another big plus is government policy. China gives money to people who buy electric vehicles and to companies that build charging stations. These incentives make it easier for new businesses to get started and grow faster. But there is a lot of competition because big companies like Teld and BYD already control the market. To be successful, new companies need to focus on niche strategies like battery swapping, mobile charging units, or rural coverage.

The composite scores show that China is still a dynamic market. The Market Potential Score is 67.27, the Expansion Readiness Score is 13.46, and the Startup Viability Score is 45.74. These numbers show that China has the best short-term growth potential because there is a lot of demand and government support. For new businesses, speed and the ability to change are the most important things. This market is growing quickly, and those who can quickly set up infrastructure and deal with operational problems will benefit the most.

3.2.2 United States: Infrastructure Leader with Lower EV Adoption

The US and China are not the same. The percentage of people who own electric vehicles (EVs) is still low at 10.5%, and sales are only growing by 11% each year. This means that the market is growing, but not as quickly as it could be. This lower rate of adoption has an effect on short-term demand for charging stations, but the country's strong fundamentals make it a good place to invest for the long term.

Charging infrastructure in the US is only somewhat ready, with 12.5 fast chargers for every 1000 EVs. This, along with cutting-edge technology and strong digital platforms, makes it easier for businesses to offer premium services and integrated solutions. High urbanization (84%) also helps because charging networks work better in cities with a lot of people.

Another important factor is the strength of the economy. The GDP per person is about \$85,800, which is the highest of the regions looked at. This means that consumers have a lot of money to spend, which keeps demand for high-quality services high. Investors are also interested in EV infrastructure and related technologies, as shown by the \$22 billion in venture capital investment.

Government programs like the NEVI initiative pay for public charging stations and highway corridors. But it is still hard to deal with complicated rules because they are different in each state. Startups have to deal with different rules and permission processes, which can make it harder for them to grow.

These conditions are shown in the composite scores. The Market Potential Score is 24.28, the Expansion Readiness Score is 20.68, and the Startup Viability Score is 22.84. These numbers show that the US has a lot of potential for long-term growth because of its strong economy and infrastructure. However, short-term growth is limited because fewer people are buying electric vehicles. Startups should focus on coming up with new ideas and working with car makers and energy companies. Smart charging software, integrating renewable energy, and providing a premium user experience are some of the things that can help businesses do well in this market.

3.2.3 Germany: Stable Market with Clear Regulations and Strong Purchasing Power

Germany has a mature European market with strong fundamentals for the growth of electric vehicles. The adoption rate for EVs is 20.9%, and sales are growing by 38.9% each year, which shows steady growth. Germany is a good market for companies that want stability because its growth is higher than the US's but slower than China's.

The infrastructure is ready. Germany has 22.14 fast chargers for every 1000 EVs, which

makes it easy to charge them. 78% of the population lives in cities, which is also a good thing because it makes charging networks work better. These conditions are good for startups that want to focus on urban charging hubs or fleet services.

Another benefit is a strong economy. The GDP per person is about \$55,800, which means that people have a lot of money to spend. Investors are also interested in EV technologies and infrastructure, as shown by the \$37.1 billion in venture capital investment. Even though this amount is a little less than China's, it still offers good chances for funding.

Germany has clear rules to follow thanks to the European Union's Alternative Fuels Infrastructure Regulation. These rules make it easier for everyone to use the same things and for new people to join in. This clear rule makes it easier for new businesses to plan and lowers their risk. But there is a lot of competition because Ionity and Fastned, two well-known companies, already own highway corridors. New businesses might want to focus on niche solutions, like energy-efficient technologies or services for fleets of commercial vehicles.

The composite scores take these things into account. The Market Potential score is 41.27, the Expansion Readiness score is 11.32, and the Startup Viability score is 29.29. These numbers show that Germany is a good place to live because it has good infrastructure, strong buying power, and rules that are easy to understand. Startups should focus on being trustworthy and following the rules, but they should also think of new ways to help cities and fleets. Growth in this market may not be as fast as it is in China, but making money and staying stable over the long term are big pluses.

Table 2 shows the main pros and cons of each area. China has a huge market for electric vehicles (EVs) and good government support, but it also has problems with its grid and a lot of competition. The US has high incomes and advanced technology, but electric vehicle (EV) adoption is still low and the rules are hard to follow. Germany has clear rules and a lot of buying power, but growth is slower and competition is still strong.

Table 2 Advantages and Disadvantages of Each Region

Region	Advantages	Disadvantages
China	<ul style="list-style-type: none"> • Largest EV market (50.1% adoption) • Fast growth (47.1%) • Highest VC investment (\$37.7B) • Strong government support 	<ul style="list-style-type: none"> • High competition • Grid constraints • Increasing land cost

Continuation of Table 2

United States	<ul style="list-style-type: none"> • Best infrastructure readiness • High GDP per capita • Strong innovation ecosystem • Federal funding programs 	<ul style="list-style-type: none"> • Low EV adoption (10.5 %) • Regulatory complexity • Slower short term demand
Germany	<ul style="list-style-type: none"> • Clear EU regulations • Good infrastructure • High purchasing power • Stable market 	<ul style="list-style-type: none"> • Moderate VC investment • Strong competition • Slower growth

Source: summarized by author

Table 3 shows how the three regions' market demand and infrastructure indicators compare to each other. It has the five main measures that were talked about. These signs help show how ready each area is for large-scale charging. China stands out because it has a lot of electric vehicles (50.1%) and they are growing quickly (47.1% per year). This is because there are a lot of fast chargers and cities are growing quickly. This combination shows that there is immediate demand in the market and a lot of room for infrastructure growth. The United States is different: EV adoption is still low (10.5%) and growth is slow, but urbanization is very high (84%). This suggests that there may be opportunities for charging strategies in urban areas. Germany has a moderate adoption rate (20.9%) and a high density of electric vehicles (EVs), as well as good charger coverage and urbanization. These things suggest that the environment is stable and mature, with well-developed infrastructure but slower growth than in China.

Table 3. Model data for each region for market demand and infrastructure

Region	Market Demand			Infrastructure	
	EV Adoption Rate (%)	EV Sales Growth (%)	EV Density (Vehicles/10,000 ppl)	Fast Chargers per 100k EVs	Urbanization (%)
US	10.5	11	20	12.5	84
China	50.1	47.1	260.5	150	66
Germany	20.9	38.9	312.8	22.1	78

Table 4 shows how the economies, government support, and market maturity differ in the three areas. It includes things like income levels, electricity costs, fuel price differences, purchase subsidies, infrastructure grants, the market share of electric vehicles, and the

number of charging operators. China has a very high EV market share and strong policy incentives, which create strong demand. However, it is important to keep costs down because the country has a lower income level. The US has the highest income and relatively low electricity costs, which makes it a good place for premium services, even though EV adoption is still low. Germany has clear rules and a lot of buying power, but the cost of electricity is higher and growth is slower, so you need to plan ahead. These differences show how the economy and policies of each area affect the chances of expanding the charging network.

Table 4. Model data for each region for economics, policy incentives and market saturation

Region	Economics			Policy incentives		Market Saturation	
	GDP per Capita (USD/1000)	Commercial Electricity Cost (USD/100 kWh)	Fuel Price Differential (USD/1000 km)	EV Purchase Subsidy (1000 USD / Vehicle)	Charging Infrastructure Grants (1000 USD/kW)	EV Market Share (%)	Charging Network Operators
US	85.8	13.0	63.0	7.5	1.3	9.6	8.0
China	13.3	10.0	62.0	2.7	0.8	51.1	19.0
Germany	55.8	28.0	76.0	6.0	1.1	18.8	5.0

We used the data from Tables 2–4 to make the score model, and the results are in Table 5. Table 5 shows that the United States has a strong economy and good infrastructure, but growth is limited in the short term. The Market Potential Score is 24.28, which means that the country has a high GDP per person, good infrastructure, and a strong ability to come up with new ideas. These things show that the US is a good place to invest in the long term and for businesses that focus on technology. The Expansion Readiness Score, on the other hand, is 20.68. This means that short-term readiness is moderate because the EV adoption rate is 10.5% and annual sales growth is 11%. This means that demand will rise slowly. To get ready for future growth, new businesses entering this market should focus on coming up with new ideas, working with car makers, and using renewable energy.

Table 5. Model data for each region for startup ecosystem readiness and score computation results

	Startup ecosystem readiness	
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Continuation of Table 5

Region	Ease of Doing Business Rank (2019)	Global Innovation Index	VC Investment (USD Billion)	Digital marketing potential (%)	MP Score	ER Score	SVS
US	6.0	62.4	170.0	92.5	24.28	20.68	22.84
China	32.0	56.3	50.0	77.0	67.27	13.46	45.74
Germany	22.0	58.1	8.0	93.0	41.27	11.32	29.29

China is a different story. The Market Potential Score is 67.27, which is high because there is a lot of demand and the government gives businesses money to move there. This is even though the GDP per capita is lower than in the US or Germany. The Expansion Readiness Score is 13.46, but the EV adoption rate of 50.1% and annual growth of 47.1% show that China is the best market for short-term growth. Strong policy support and high adoption rates make it possible for charging infrastructure to grow quickly and be used a lot. With \$37.7 billion in venture capital investment, this region has the most of the three, which shows that investors are very confident. The biggest problem is that big companies like Teld and BYD are competing with them. Battery swapping and mobile charging units are two examples of new ideas that can help new businesses succeed. These ideas help fill in gaps in infrastructure and make up for the limits of the grid in cities that are growing quickly.

Germany is in the middle of these two markets. The Market Potential Score is 41.27 and the Expansion Readiness Score is 11.32. This means that the environment is balanced, with good infrastructure, strong buying power, and clear rules under European Union law. The rate of EV adoption is 20.9%, and it grows by 38.9% each year. This is slower than in China but faster than in the US. Germany is a good place for startups that value reliability and compliance. Growth is slow, but specialized solutions like urban charging hubs, fleet services, and energy-efficient technologies can help businesses make money.

Companies that want steady growth instead of rapid growth will benefit from clear rules and standards for interoperability, which lower risk and make planning easier. We can see the strategic implications when we look at these scores side by side. Startups that want to grow quickly and meet demand in a market that is growing quickly should go to China. The US is a great place for technology leadership and high-end services, but it will take time for people to start using them. Germany is a good place for new businesses that want stability, clear rules, and a lot of trust from customers. These insights show that the MP Score and ER Score are not just numbers; they are a guide for making choices. Startups need to make sure that their plans fit with these facts: in China, they need to be fast and cost-effective; in the US, they need to be innovative and digital; and in Germany, they need to be reliable and follow the

rules. This will give them the best chance of success in a fast-changing and competitive field.

The scoring model lets users pick where to grow first. Scores for market potential and startup viability show how much demand there is, how strong the policies are, and how easy it is to do business in each region. Different actions should be taken based on these scores. In an area with a lot of market potential and good government support, the best thing to do is to move quickly. Sites should load quickly, have clear prices, and be easy to get to. If you live in an area where not many people use your product but they have a lot of money, the best thing to do is to grow slowly. Sites should work with local partners to share risk and focus on better service and energy control. In a place where the rules are clear and demand is steady, the plan should use those rules to build trust and lower soft costs. For example, it could use standard connectors and payment systems from the start.

Different charging models work best in different situations, and how well they work depends on how people use them, the infrastructure, and government support. PAYG works best for public places with a lot of people and a mix of users, like shopping malls, highway stations, and city centers. This model is easy to understand and use, which is important for people who drive or travel a lot. In Germany, for instance, PAYG follows EU AFIR rules that require open access and clear per-kWh pricing. This makes it perfect for malls where drivers only shop for a short time. Subscription plans are better for people who use the service a lot, like company fleets or people who commute every day, because they offer predictable costs and can include discounts during off-peak hours. In the US, subscription models help fleets keep costs down in areas with high electricity rates. They are also common at work sites where employees park for long periods of time. Battery swapping is great for fleets that need to turn around quickly, like taxis and delivery trucks. This model works well in China because the government supports it and the battery designs are the same across the board. It saves time compared to fast charging and keeps cars on the road longer. Ultra-fast charging hubs are great for long trips and highway driving because they let drivers quickly recharge while they're on the road. In Europe, these hubs are put along major travel routes to meet AFIR standards. In the US, they are often found near interstates and rest areas. Home charging is good for people who own their own cars and have a dedicated parking space and a steady supply of electricity. It charges slower, but it's easy to use overnight. In places like Germany, it's common in houses but not as useful in apartments without shared infrastructure. Charging at the mall is a good option for medium-speed charging because drivers spend 30 to 90 minutes shopping, which is the same amount of time as Level 2 or moderate DC charging. This also brings in more money for retail partners. Fleet depots need high-power charging or battery swapping because cars often come back at the same time and need to be ready for the next shift. Smart energy management and sometimes on-site storage help these sites avoid peak tariffs. These examples show that in order to build charging networks that can grow and make

money, you need to match business models to user needs and local conditions.

The overall results show a clear link between business models and how operators handle power at each site. When a lot of cars come at once, peak power use can make the bill go up. This is a common reason why sites lose money even when energy sales are good. This shows that operators who share power between chargers can lower these peaks and keep more of their profit. Adding a battery on site helps store electricity when it's cheap and release it when it's busy. This also keeps the local grid safe and makes service more reliable. In real life, a simple energy plan can make a big difference. The plan can have a goal for how much power is used on average during the day, a limit on how much power can be drawn at once, and clear rules for session length and idle fees. A station can go from a weak cost position to a stronger one with these tools, without having to change the hardware. Also, how customers feel about your business directly affects how much they use it and how much money you make. The review and the cases show three easy ways to make fast charging stations work better. First, it's easy to pay with cards and phones. Second, roaming between networks so that a driver doesn't need a lot of accounts. Third, show the price clearly before charging begins. These things make it less stressful for drivers and cut down on the time they have to wait. Drivers don't waste time going from station to station when the app has information about price and charger status. This makes things go faster and makes users happy. More features are needed for a group of vehicles. Delivery vans, taxis, trucks, electric buses, and other fleets should show how much energy they use, how much it costs per route, and how long they stay at each stop. With this information, a fleet can plan to charge when demand is low, which will lower their exposure to demand charges. So, good digital tools help both the trust of users and the income of the station.

The choice of connector has an impact on cost and scale over time. CCS is common in Europe, and the rules say that people should be able to pay with cards and have open access. NACS is growing quickly in North America, but CCS is still widely used. The standard in China is GB/T. Stations that support the common local connector get less use and fewer service calls. Building multi-connector sites costs more, but they keep the station safe from changes in the types of cars on the road. Adapters work for a little while, but built-in support is better for speed and safety. The thesis shows that operators who follow local rules and share information about connectors for each site get more use and fewer complaints from users.

Choosing a location is not an easy choice; it's not just about picking a busy road. The best sites have a good mix of traffic flow, easy access to the grid, and fair land prices. This means working with property owners who can give you space close to power and who see the value in having more people walk by. Retail partners can help drivers and split the costs of land use, lights, and security. Building owners can put curbside units on their property that get power from the building. This is easier to get permission for in many cities. Municipal partners can

give people access to public land near transit hubs that is easier to get power to and easier to get permits for. Our results also show that the rate of urbanization in each region is important. In big cities, drivers can stop for a quick top-up many times. This pattern works well for smart pricing and power sharing.

Targets for use are important for size. A lot of places in early markets don't use even half of their capacity. The goal is to get more people to use it without hurting the user experience. Good tools are roaming, idle fees after a full charge, and price signals that move sessions away from busy times. It also helps to have clear wait time information. Drivers will spread out if they see that one station is busy and another is free. This makes the average use of the network go up and the length of the queue go down. A simple monthly report for each site should keep track of usage, peak draw, idle time, and complaints from users. Then, each month, managers can do something about the worst metric. This makes things work better without needing a lot of new money.

Digital systems connect the business and technical sides. Remote monitoring finds problems early and lets staff know about them. Predictive maintenance looks for simple patterns in data, like a rise in temperature or a drop in power, to plan service before something breaks. Smart charging lets the operator change the power at each bay to keep the station within the target for peak draw. When allowed, price changes can follow time-of-use tariffs or real market prices. Open data feeds to public maps keep network status up to date, which helps drivers and cuts down on calls to the help desk. All of these tools make things cheaper and more trustworthy. A small group with the right software can run a lot of stations and keep them up and running.

Policy fit lowers risk. In Europe, rules say how much power, space along main roads, open payment, and price display are required. In the US, federal rules set the power and uptime for funded sites, but state permits can give them more time. Standards and local grants in China help both city sites and battery swap stations. Before opening a site, operators should check their policies. The check can make sure that the connector needs, payment rules, uptime goals, and reporting formats are all correct. Next, there should be a study of tariffs that looks at demand charges and differences in time of use. If the risk is high, the site design can include a smaller first phase or an onsite battery that keeps peaks from getting too high. This is often enough to keep the station margin safe.

It's easier to get financing when plans have clear rules and sites show how to use them safely. Green loans and public-private partnerships help big hubs lower their capital costs. Retail partners can split the costs of land and services. Leasing hardware or sharing cabinets between sites can help startups save money. Modular cabinets let you add more space as needed. Investors like networks that have standard connectors, open payment options, high uptime, and clear data on how they are used. A simple monthly dashboard for lenders helps

show progress and keep support strong.

Access and equity are also important. Drivers in cities who don't have home charging need public charging stations that are reliable and not too expensive. People who live in the country need coverage on main roads and in town centers. The China section of the thesis talks about policy programs for rural areas. A fair growth plan sets aside some areas for low-income neighborhoods and puts stations close to public transportation. This helps meet policy goals and builds trust. Clear prices help keep things clear. Clear rules for when to be idle keep bays open for the next driver. These steps help the network reach more people and keep the public's support high.

The picture will change as time goes on. Extreme fast charging will make sessions shorter for new cars with better batteries. Heavy-duty vehicles will use very powerful systems at logistics hubs and depots. These changes will put more stress on local grids. More places will need batteries on site and better thermal management for chargers. Standards will change, and more areas will be able to use cross-network roaming. Flexible design is the best answer. Use cabinets that can hold extra power modules. Make sure your software is ready for new price signals and connector types. Teach employees how to deal with new rules and new car features.

The FMTP results point to a useful way for new businesses to go. Set clear goals and start with a small portfolio of two or three types of sites. Use PAYG pricing and make it easy to pay with a card at public places. Give fleets a basic plan with discounts during off-peak times. Choose connectors that work with most local cars and rules. By default, add power sharing, and think about putting a small battery at sites with high tariffs. You can join roaming networks or make your own for partners. Set a monthly usage goal and change prices and idle rules to move sessions away from peaks. Get permits faster and lower soft costs by working with the city and property partners. Give users and lenders information in a way that is easy to understand. The network can grow steadily and keep its unit economics positive by following these tips.

Lastly, the results should help make a short list of things to do in each area. In China, focus on city sites, fleet services, and swap partnerships where the law allows them. In Europe, put stations along major travel routes that follow spacing rules, make prices and uptime public, and encourage use by allowing roaming. In the US, pick places with easy access to the grid, make strong digital tools, add on-site storage where prices are high, and work with retailers to share costs and bring in customers. Publish clear prices, use open payment, keep data feeds up to date, and track uptime in all areas. These steps put the review's insights and scores into action every day to help the business grow and make money.

The future of the industry looks like both types of markets will have an impact on global strategies. Companies that can quickly deploy and handle operational problems like grid

constraints and land availability will continue to be drawn to mature markets. These markets often reward being flexible and keeping costs down, as well as new ideas like mobile charging or battery swapping. On the other hand, technology-driven approaches, premium services, and integration with renewable energy will be more popular in high-potential markets with strong fundamentals. These markets will probably be the most profitable in the long run, especially as more people use them and infrastructure spreads.

It is clear that China is the best place for a startup to grow quickly and have a lot of demand, based on the pros and cons of each region. It has a large EV market, strong government support, and a lot of VC investment, all of which make it easy to grow quickly. But because of competition and gaps in infrastructure, new strategies are needed. The United States is a great place for a startup that wants to be a leader in technology and offer high-quality services. High-quality solutions are possible because of advanced infrastructure, a strong buying power, and ecosystems that encourage innovation. The problem is that EV adoption is taking longer, which could mean less profit. Germany is the most predictable market if you want stability and clear rules. Companies looking for steady growth will find it appealing because of its strong standards, good infrastructure, and buying power.

The most important thing for startups to learn from these scores is that there is no one "best" market. Depending on their goals and skills, there are different ways to be successful. Companies that want to grow quickly should focus on markets where short-term readiness is high and there are strong policy incentives and investor interest. People who want to be leaders in the long term should put money into markets with high MP Scores. These markets have a lot of room for new ideas and people with a lot of money to spend. Startups can lower their risk, get funding, and position themselves well in a competitive and fast-changing industry by aligning their strategy with these insights.

CONCLUSIONS

1. From literature review it's shown that fast-charging station startups should adopt common charging protocols (CCS in EU, NACS in U.S.) to maximize utilization and customer convenience. Standardization reduces fragmentation and aligns with policy objectives for inclusive infrastructure.
2. Fast-charging networks are very important for EV adoption. Different country analysis in this work revealed that countries with more fast chargers per 1000 EVs, such as Germany (22) and China (150) show faster market growth, which means infrastructure is a key factor for EV expansion.
3. Case studies show that vertically integrated models (e.g., BYD) and group based approaches (e.g., Ionity) enable cost sharing and interoperability, while modular and software driven solutions (e.g., Kempower) improve flexibility and reduce upfront investment.
4. Policy analysis indicates that regions with strong government support, such as China, demonstrate faster infrastructure growth through subsidies, grants, and regulatory clarity. In contrast, markets with fragmented policies (e.g., U.S.) require startups to navigate complex permitting processes, which slows expansion.
5. Scoring model show that market potential and startup viability vary significantly by region. Composite indicators (MP Score, ER Score, SVS) reveal distinct strategic profiles:
 - China offers the highest short-term growth opportunities due to strong demand, rapid EV adoption, and policy support, but faces intense competition and grid limitations.
 - United States provides long-term potential driven by high purchasing power and advanced infrastructure, though slower EV adoption delays profitability.
 - Germany represents a stable market with clear regulations and strong consumer trust, favoring strategies focused on reliability and compliance.
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Recommendations

After looking at the case study and the scoring model results, it's clear that there isn't one best way to build fast charging networks for electric vehicles. How well companies change their plans to fit the needs of the area is what determines success. Strategies need to take into account the differences between markets, such as demand, infrastructure readiness, policy support, and competition. In markets where growth is fast and incentives are strong, startups should focus on being flexible and keeping costs down. In these markets, being able

to deploy quickly and run efficiently are very important for success. Companies in more mature markets should focus on new ideas, integrating digital technology, and providing great service. Smart energy solutions, advanced software systems, and tools that put the customer first can all help a business get ahead of its competitors.

Working with tech companies, energy companies, and local governments can lower risk and make things easier to grow. These partnerships make it easier to deal with grid problems, get land, and add renewable energy to the mix. Governments are also very important. Clear rules, financial rewards, and support programs speed up the building of infrastructure and make the investment environment stable. Businesses should think of digitalization as a long-term investment. Tools like Enterprise Resource Planning (ERP), Customer Relationship Management (CRM), and predictive maintenance systems make things work better and more reliably. They also make it possible for new business models, like charging-as-a-service, which can bring in more money and make customers happier.

Finally, it's important for strategy to fit with what is actually happening in the market. Businesses that change their models to fit the needs of the area will lower their risk and increase their chances of growth. In high-demand markets, this means focusing on speed and cost-effectiveness; in advanced economies, it means focusing on innovation and premium services; and in stable regions, it means focusing on reliability and compliance. Companies can build charging networks that are both long-lasting and competitive in an industry that is always changing by following these rules.

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