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WHITE PAPER

Unlocking the Electric Vehicle Market

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PAC, March 2022

Commissioned by

Infosys

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BACKGROUND

There is a consensus that the world needs an alternative to fossil fuel-based combustion engines for vehicles. Indeed, the health of the planet's ecosystem has been put under severe stress in the past few decades due to excessive CO_2 emissions and other forms of pollution, and the automotive industry is a significant contributor.

Nowadays, OEMs are trying to reduce their environmental footprint. For instance, they are modernizing their production facilities, thereby making plants more efficient and decreasing the energy consumption as well as the CO_2 emissions (e.g., Toyota's Tsutsumi Plant). Still, the focus lies on reducing the emissions emitted by the fossil fuel-based vehicles produced. After creating engines that consume less fuel, the industry looked for alternative fuels. In this regard, there have been many concepts and PoCs to create engines that use fuel based on vegetable oil, hydrogen, or even ethanol. The most prominent idea though was the electric vehicle (EV), which relies on battery cells to feed its electric motors and has become so popular that practically all OEMs have started to offer vehicles that run on electricity.

However, the shift towards EVs was and still is arduous, although the market is evolving faster, thanks to new developments, governmental incentives, emission regulations, and changing customer requirements. OEMs had to rethink the core of their cars – the engine – to adapt it to a new energy supply. At the same time, battery cells for vehicles were necessary, along with adapted internal systems and mechanisms that go with it. Since traditional automotive manufacturers and their suppliers had little knowledge about battery and electric engines, they sought new partnerships and players that could help them in their endeavors. Paired with the necessity to build connected, software-defined cars, OEMs are looking at an extensive ecosystem of partners and collaborators with different purposes and specialties to build modern vehicles. Still, the vehicle manufacturers are concentrating solely on their own offerings and the lack of standardization and collaboration amongst the different players is hampering the pace of adoption of the electric vehicle.

SCOPE

This report is presented in four chapters. The first chapter presents the main challenges in the current EV market. The second chapter summarizes key market drivers, which help to overcome the current challenges. The third chapter presents a perspective on new, innovative approaches to address the current challenges. The last chapter summarizes what else is necessary from our perspective to overcome the current challenges.

CURRENT CHALLENGES OF THE ELECTRIC VEHICLE MARKET

Although the public is aware of the impact of combustion engines on the environment, the EV market is still facing challenges that are hampering wider adoption. This is mainly due to barriers in the current charging process, the capacity of the electric grid, and the management of battery cells. All of these are essential elements that are indispensable to scale the underlying infrastructure that will bring the EV market to the next level.

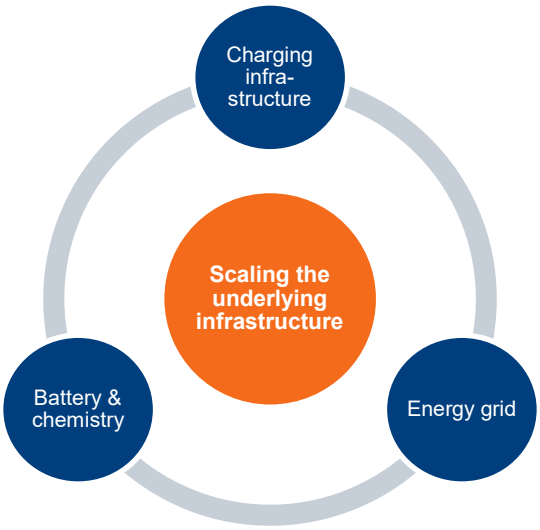


Fig. 1: Barriers to scaling the EV infrastructure

CHARGING THE ELECTRIC VEHICLE

One of the main challenges the EV industry is still facing relates to charging.

For one, customers are still facing long charging times, as it usually takes several hours to charge the battery of an EV, and fast chargers are still a distant reality. Once ready, most electric cars can travel less than 200 km. For daily, private use this distance is plenty enough. Nonetheless, it means that planning long trips of one day or more is practically impossible with an electric car. Consequently, many consumers are discouraged from acquiring an electric vehicle – this is especially true for transport companies that have their fleets run long distances.

In addition to long charging times, a lack of charging infrastructure on the road is another challenge. It is true that most EV owners decide to install a charging station in their garages and only few consumers rely solely on public infrastructure. Nonetheless, a stronger dissemination of the electric car can only be achieved if users have the confidence that their car can easily be charged while travelling long distances. As such, the development and continuous upgradation of the charging infrastructure is a hurdle that local governments must overcome in order to increase the use of EVs for private consumption – especially when looking at the ambitious goals they have set for the coming years in terms of EV adoption.

At PAC, we noticed that the industry is taking action to improve the charging infrastructure and shorten charging times (e.g., in China, Volkswagen collaborates with JAC, FAW, and Star Charge; in Europe, Daimler, Volvo, and Traton created a joint venture that offers fast charging stations for electric trucks). This is certainly welcomed by local governments and also proof of the potential that the EV industry holds.

THE ELECTRIC GRID

In the journey towards e-mobility, the utilities industry plays an important role, as an increase in electric vehicle usage will inevitably lead to higher energy consumption. This means that utility companies need to prepare their electric grids to cope with higher loads, especially during peak times, when the electric grid is already under a lot of stress. This additional burden could lead to costly system failures. Moreover, many utility companies will need to invest in upgrading their grid to best accommodate the charging infrastructure for electric vehicles, which will incur additional costs.

Another difficulty relates to the sustainability of electric vehicles. While many are counting on EVs to reduce the environmental impact of mobility, it is a fact that the energy used for EVs is not always green or renewable energy. In fact, most of the electricity produced currently still stems from coal and natural gases – two methods that release a substantial amount of CO_2. With worldwide electricity consumption increasing due to EVs, utility companies need to invest more in environmentally friendly energy sources to offset the effects of electric vehicles. In Europe, we already see many such initiatives with energy providers such as EnBW announcing investments of €12 billion to expand its electric grid and promote sustainable energy generation.

THE BATTERY

As the battery is the main cost driver for the purchase price of an EV, European OEMs had to rely on specialists from Asia to source the batteries required for their vehicles. Many vehicle producers preferred that option as they lacked the knowledge to produce vehicle batteries on their own and were unable to find European battery manufacturers with the necessary skills and infrastructure to cope with the increasing demand of the market. Combined with the expensive battery manufacturing processes, many consumers considered EVs to be too

expensive. With further development, the production cost of electric vehicle batteries is slowly decreasing to a point where electric cars are becoming more affordable for consumers. Nonetheless, many improvements on the battery front are still necessary to increase the demand for electric vehicles.

The charging method, battery chemistries, and battery properties, for instance, are key elements when it comes to EV range and loading capacity. At the same time, the speed at which a battery charges/discharges and its overall lifespan are dependent on several factors. Indeed, the weight (i.e., the number of passengers or the amount of cargo) of the vehicle and the driving style (e.g., speed, braking etc.) strongly influence the battery capacity. As for the lifespan, voltage, current, and temperature are crucial measures to determine the well-being of the battery and ascertain its current state of charge, state of health, remaining useful life etc. However, the industry is still struggling with the recycling of batteries. Currently, there are few companies that are able to handle broken or old batteries. This is important as this aspect will play a significant role in the environmental impact of EVs.

One way to overcome the challenges mentioned earlier would be battery swapping: instead of charging a used and empty battery for several hours, it is replaced with a fully charged one in a matter of minutes. Although this method is being discussed by many in the industry, we at PAC are yet to see initiatives to deploy this on a larger scale, with companies rather investing more in the enhancement of batteries and charging infrastructure. We believe that battery swapping stations will be successful once there is more standardization with regards to battery technology. However, most OEMs consider batteries to be an important IP asset. Additionally, the design of the battery can differ from one vehicle type to another, which makes it more difficult for battery swapping stations to serve several vehicle types at once.

DRIVERS OF THE ELECTRIC VEHICLE MARKET

The EV market needs further enhancements in several aspects such as charging and battery management to increase its market penetration. Many innovations have already occurred in the past few years (e.g., use of the more efficient lithium-ion (Li-ion) battery instead of the nickel metal hydride battery, faster charging stations etc.) and building on that, many parties are pushing the mobility market to further invest in electric vehicles.

ENHANCING THE GRID

With a stronger dissemination of EVs, utility companies have new business opportunities.

Firstly, the utilities industry is an important partner for the charging infrastructure. Indeed, many energy providers have invested important resources to be able to offer dedicated services related to the construction, installation, and management of charging stations (e.g., Enel's subsidiary Enel X has announced a joint venture with Volkswagen to deploy 3,000 high power charging stations in Italy by 2025). With this, utility companies are not only relevant market players for the end consumers, but also for businesses that manage electric fleets, for governments, and for vehicle manufacturers.

As mentioned earlier, the increased use of EVs will force many to modernize their electric grid to successfully handle the additional demand. By introducing sensors and grid management software, energy providers can obtain valuable information on the state of their grids and additional insights on customer habits. The overall impact of modernization on the industry will not be small. On the one hand, thanks to AI, ML, and analytics, operators will be

able to significantly improve the monitoring, tracking, and prediction of energy usage and demand. On the other hand, utilities will be able to offer more flexible pricing policies to encourage EV owners to charge at off-peak times, while also offering new services and opening up new possibilities for collaboration with the rest of the mobility market.

BATTERY PRODUCTION & BATTERY MANAGEMENT SYSTEMS

It was mentioned before that the battery is the most critical part of any EV. As OEMs are preparing for a rising demand in EVs, most vehicle manufacturers are increasing their investments in battery production. Tesla, for instance, is currently building a factory near Berlin, Germany, which will produce battery packs for various Tesla car models. Daimler has invested in the Automotive Cells Company (ACC), a joint venture between Saft, a subsidiary of oil and gas company Total, Stellantis, and Opel. Operating from France, ACC's goal is to become Europe's first battery producer. The company Volkswagen (VW) holds a 20% share in Northvolt, a Swedish battery manufacturer that was founded by two former Tesla employees. VW is helping Northvolt to expand its production capacity by upgrading the facility in Skellefteå, Sweden, and building an additional production facility in Germany. At PAC, we believe that all these examples show that vehicle manufacturers are looking at the long-term solution: they want to safeguard their future EV production. At the same time, they are entering the competition for the leadership position in battery technology.

Battery management systems (BMS) play an important role in proper functioning and performance of the battery. They monitor the charging and discharging process of the vehicle battery and track the battery's state and well-being by evaluating different factors (e.g., temperature, voltage, current, state of health etc.). Car manufacturers' first tier suppliers are constantly enhancing their BMSs to guarantee a safe EV and increase the battery's capabilities. Bosch, for instance, developed a dedicated cloud service in 2019 to prolong the battery lifespan. After being transmitted to the cloud, the battery data is analyzed via machine learning algorithms to make more accurate forecasts on the battery's remaining service life and performance. Furthermore, Bosch's system recognizes faults and defects early on and sends out a notification to the driver or the fleet operator. The cloud service also optimizes the recharging – a process that can damage the battery cells' performance and capacity if not done properly. In addition to that, Bosch offers a charge timer that enables drivers to plan the recharging process for when demand for electricity is low. It also includes a specially developed recharging process that enhances both fast and slow charging and controls electricity and voltage levels during the recharging process, thus prolonging battery life.

The example of Bosch shows how critical IT has become for the functioning of EVs. For example, in November 2021, Audi announced a software update for its Audi e-tron that increased the range of the battery by 20 km. We see many other firms (e.g., Infineon, BMSTAR etc.) that are employing modern technologies such as cloud computing and AI to improve BMS, thereby prolonging the vehicle battery's lifespan, and other useful applications. In the coming years, we expect to see even more investments in IT tools, which are intended to increase the operational efficiency as well as the driving experience of the user.

SOCIETAL SUPPORT

The European Green Deal

The political sphere has understood that climate change – although it is too late to fully stop it – must be slowed down. Many initiatives have been launched to improve international cooperation to address issues related to climate change, the latest example being the 2021 United Nations Climate Change Conference (a.k.a. COP26) that took place in Glasgow in November 2021. Of course, mobility is always one of the subjects addressed and many countries have already committed themselves to completely phasing out vehicles with internal combustion engines by 2030 or 2040.

In Europe, the Commission is working to make the continent climate neutral by 2050. To do so, the European Green Deal, a series of policy initiatives that touch upon various subjects and sectors (e.g., construction, biodiversity, food, energy etc.), was created at the end of 2020, stipulating that from 2035 onwards all new cars sold in the EU must be zero-emission. Another part of the European Green Deal is the Sustainable and Smart Mobility Strategy, a combination of 82 initiatives to guide the EU's future endeavors regarding transport and mobility systems and their green and digital transformation. Amongst others, the European Union wants to increase the collaboration between relevant companies and develop policies which will encourage not only producers but also consumers to adopt EVs (e.g., increase in carbon prices, 30 million additional charging stations installed by 2030, new construction standards so that charging stations can be added easily, if necessary etc.). In addition, the Sustainable and Smart Mobility Strategy is also considering how to support the development of zero-emission airplanes and marine vessels.

For the battery cells used by EVs (and potentially also by zero-emission airplanes and marine vessels), the European Green Deal includes a Strategic Action Plan on Batteries and is also looking at the work of the European Battery Alliance. In 2020, a new EU regulatory framework for batteries was presented. It includes ideas regarding carbon footprint requirements of the battery construction, the obligation of battery replaceability, a mandatory minimum number of recycled materials, and much more.

In our opinion, creating such a framework will not only push the OEMs and their suppliers to innovate their battery technology, but it can also become a motivation for some companies to take on a leadership role in the EV ecosystem and further promote their solutions as the standard.

Customer expectations

With regards to customer habits and expectations, the appearance of the coronavirus has accelerated the ongoing trends. During the pandemic and the lockdowns, nature was able to reclaim some of its space: some endangered animal species recovered, the air of major metropolitan regions got cleaner, and pollution decreased. These apparent effects have made people more aware of the influence of humans on the environment, turning sustainability into an even higher priority in purchase decisions. Consequently, consumers are paying even more attention to the emissions of the vehicles they decide to purchase and understand electric motors are a better option in comparison to internal combustion engines. Combined with the necessity to provide better customer experience, connected electric cars give companies in the EV ecosystem the opportunity to better engage with consumers, adapt to their needs, and offer new services.

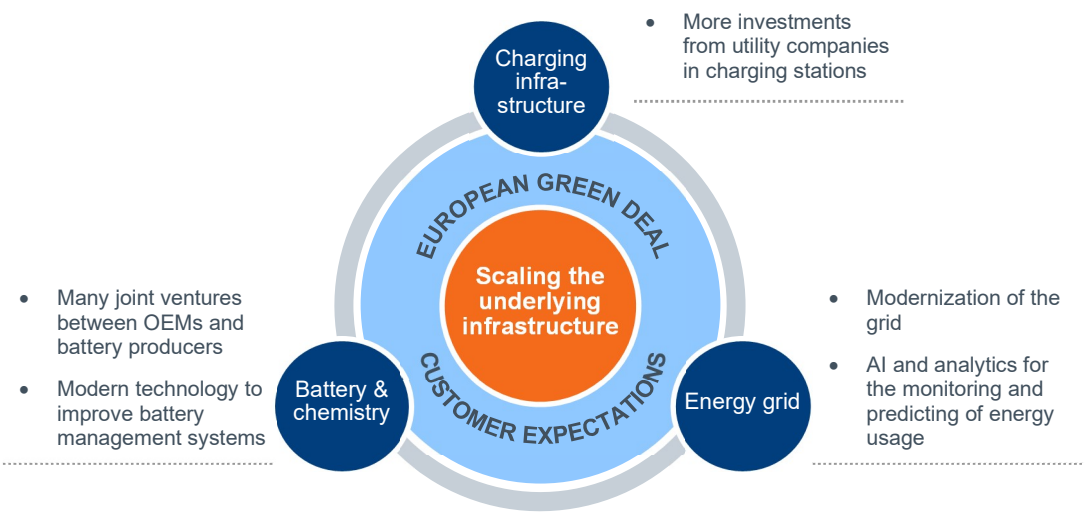
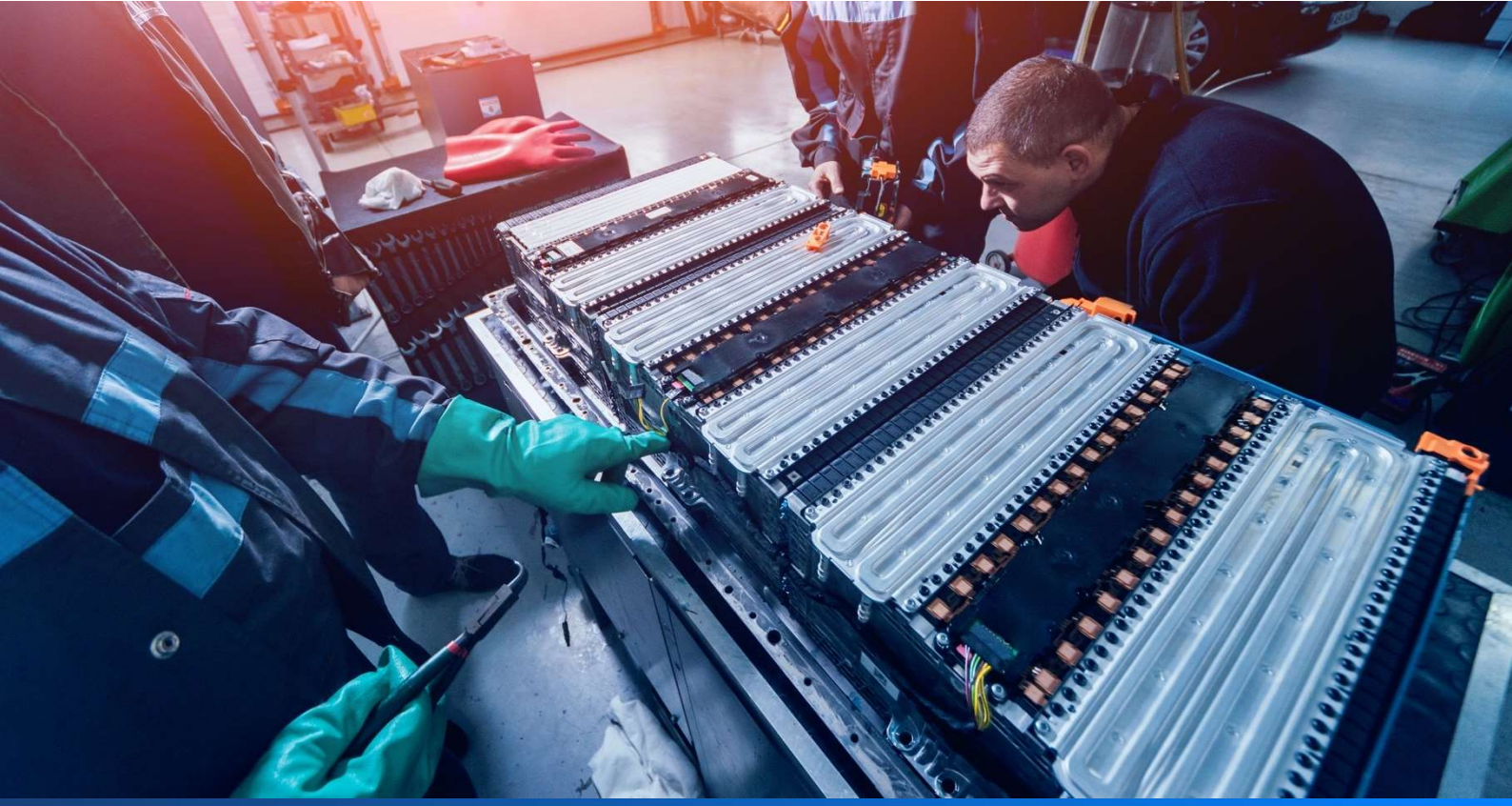


Fig. 2: Drivers of the EV market



FUTURE EVOLUTIONS ON THE ELECTRIC VEHICLE MARKET

Many ideas already exist to further evolve the electric vehicle and the necessary infrastructure. Therefore, the growing EV market will certainly be at the center of several innovations and modernizations that may even affect the mobility market. Some of these novel ideas are already in development now.

MODERNIZING THE CHARGING INFRASTRUCTURE

Automated charging stations

As a major part of the EV ecosystem, it remains to be seen how charging stations will be enhanced in the future. Siemens has already presented its solutions at one of the major mobility fairs, the IAA Mobility 2021 in Munich. The German tech provider collaborated with Einride, a Swedish specialist in electric and autonomous vehicles, to develop the Autonomous Charging System. Siemens' charging station relies on cameras and image processing to find the location of the EV's socket and autonomously connects with it to charge the battery.

The potential behind this idea is manifold. Firstly, the Autonomous Charging System (ACS) will come in handy once autonomous cars are at a level where they are able to find a suitable parking slot with charging facilities, immediately after dropping the passengers off at the right location. Secondly, Siemens is targeting electric trucks that are meant to be charged during drivers' break times. Enabling a full charge during this short amount of time requires a higher

power supply than with electric cars and therefore also a thicker and heavier cable that is difficult to carry for humans. Siemens' Autonomous Charging System is meant to prevent that situation.

While this is only one example, at PAC we see several attempts to modernize charging stations. From automation to integrated payment solutions, we expect to see more investments in this area in the future.

Electrified roads

In 2014, the Swedish government launched an innovative project, eRoadArlanda, which is also related to the charging infrastructure. With the help of several industry partners (e.g., Elways, a specialist in electrifying roads, Swedish construction company NCC, utility company Vattenfall, truck company DAF etc.), the Swedish Transport Administration finalized a 2 km long electric road at the end of 2017. By installing an electrified charging rail in the middle of the road, vehicles with a corresponding movable arm can link to the rail and energy is transferred to the EV. The rail itself is powered in sections as the vehicle passes over it.

With an electrified road of this kind, the Swedish government hopes to find an economical and sustainable solution to charge EVs. Currently, the project is still in the assessment phase and different technologies are being tested out. However, in the long term, the plan is to expand the electrification to certain sections of major, frequently used roads, thereby increasing the range of EVs, while also allowing for smaller batteries with a shorter range, since they could easily be charged during operation.

It is still too early to tell whether electrified roads could become the standard in the future, however the project has shown promising results and proves again that the collaboration between different types of companies will be essential for the EV market.

ELECTRIC VEHICLES TO MANAGE THE ELECTRIC GRID

At first glance, EVs represent an additional burden on the electric grid. Currently, the range is still not particularly large, which means that electric vehicles need to be charged frequently. However, at the same time, EVs often remain docked at a charging station even though they are already fully charged. This provides an opportunity for utility companies to rely on electric vehicles for better grid management.

There are three main scenarios that can help reduce the strain on the grid:

- During peak times or unanticipated spikes, it would be useful if utility providers could access EV batteries to meet the high electricity demand.
- In case of generator failures, charged electric vehicles connected to the grid could be used as substitutes for a limited time until the problem with the generator is fixed.
- To regulate the electric grid, EVs could supply the grid with an immediate power input to steady the system's electrical frequency and voltage.

Apart from easier grid management, energy providers also have another way of engaging with their customers and might even be able to create new business models (including use-as-a-service models) in which the EV owner might gain some financial or service benefits.

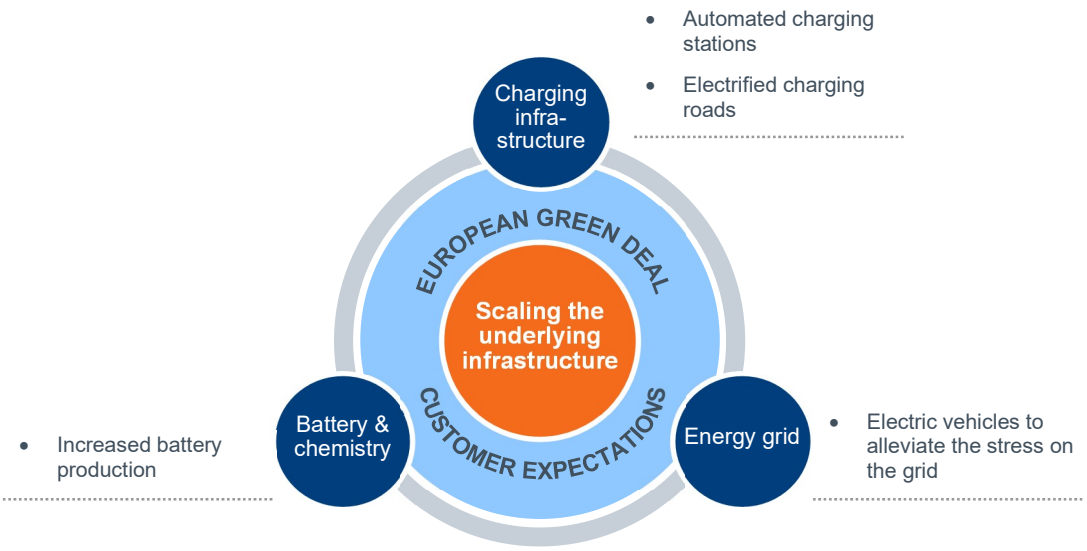


Fig. 3: Future evolutions of the EV market

THE INFOSYS CENTER OF EXCELLENCE FOR ELECTRIC VEHICLES

Infosys' engineering practice has been around for more than three decades, with a full range of product development and manufacturing offerings. Our product experience comes from working with clients in multiple domains and verticals including Automotive, Aerospace, Transportation, and Hi-tech. Our solutions, accelerators, capabilities, and alliances/partnerships span across lifecycles and ecosystems.

Anticipating the changing demands of the industry, we invested in setting up the Infosys Center of Excellence for Electric Vehicles. This CoE leverages decades of existing experience to curate and nurture the competencies needed for new age EV companies. We envision the EV market to be an ecosystem play requiring multi-disciplinary capabilities spanning across the vehicle, connectivity, technology, platform, suppliers, charging infrastructure, and manufacturing.

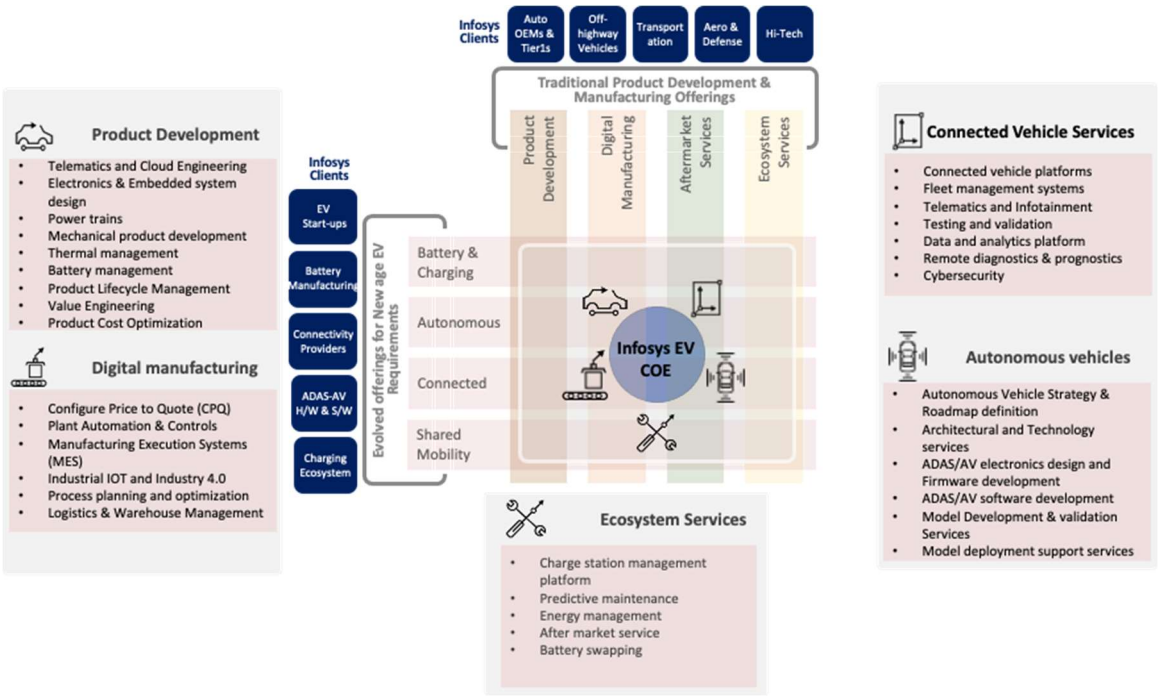


Fig. 4: The Infosys Center of Excellence for Electric Vehicles

Our unique value proposition as an end-to-end systems integrator in the EV domain is our multi-industry core engineering expertise which blends with new age EV competencies, leveraging best practices and a strong partner ecosystem to deliver best-in-class solutions.

"Our unique value proposition as an end-to-end systems integrator in the EV domain is our deep digital engineering expertise in many industries which blends with new age EV competencies, leveraging best practices and a strong partner ecosystem to deliver best-in-class solutions."
(Dr. Ravi Kumar G. V. V., Head, Advanced Engineering Group, Infosys)

CONCLUSION

The electric vehicle industry provides many opportunities. As presented in this paper, manufacturers, suppliers, energy providers, tech companies, and many more profit from the rising popularity of EVs. Modern technology is helping the relevant players to alleviate the factors hampering a wider dissemination of EVs and all are showing a high willingness to invest. Yet, we believe that the main hurdle the EV industry needs to overcome is scale. Whether it be for the charging infrastructure or battery technology, many players have entered the field and are working on new ideas. However, only few are operating at scale.

In fact, the high number of partnerships and joint ventures in the market shows that no one player can do it alone and a partner ecosystem is of paramount importance to be able to meet the ever-growing demand and therefore succeed in the EV market. The industry is bringing players from different domains to the field, and each has an important role to play. Nonetheless, the OEMs are still mainly focused on developing their own offerings. Consequently, no company is really sticking out as a market leader and standard setter.

We mentioned before that, especially in terms of battery technology, more standardization could benefit the market as a whole and facilitate the creation of new business opportunities. However, creating such a standard will require one player to stick out and establish itself as the main reference on the electric vehicle market. We believe that the success of the EV industry will have more difficulty to take off without such a leader. However, to do so, it will be imperative to find partners who can grow together along with the vehicle manufacturer.

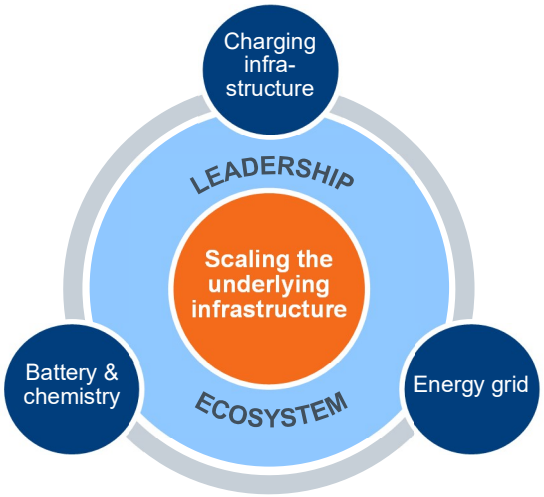


Fig. 5: Leadership and ecosystem approach as key to scaling the EV market infrastructure

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