# Electrification

## Growth of a new business model

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The electrification of transport is one of the chief trends of the 21st century. A lot of work is being done to explore various aspects of EVs and their role in transportation and energy systems. Batteries are the crucial technology supporting the decarbonisation of transport. The Cover Story throws light on vehicle designs and application in the electric mobility space, how batteries are one of the critical systems alongside the powertrain in EVs and how fuel cell electric vehicles (FCEV) are gaining considerable momentum in recent times.



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Fast charging infrastructure needs to be developed on a large scale across the country to ensure enough charging stations are located for EV users

The ongoing climate change and steady increase in pollution is alarming to mankind. The worldwide environmental protection movement, volunteered by most countries to reduce global greenhouse gas emissions, is driving the phase change of the automotive industry from internal combustion engines (ICE) to Electric Vehicles (EVs). At the same time, the rising consumer sentiments towards buying carbon neutral vehicles, as a conscience step, in building a sustainable future is also pushing the EV industry into mainstream business for all global carmakers. From a technology perspective, the investments done in the past two decades are showing signs of feasibility and mass application, be it on batteries or charging. EVs will be at the top of acceleration in this decade (2020-30), keeping in mind stringent enforcements by governments and peer pressure to sustain in the market.

However, the business challenges are still aplenty:

(a) Total cost of ownership of EVs comparable with ICE vehicles
(b) Charging infrastructure availability to the public
(c) EVs with higher km range per charge
(d) Safety in terms of electric and crash

Some of these challenges relate to technology and design advancements in major systems like power source – battery, power converters, etc. In addition, the evolving technology challenges, like different chemistries in battery, consolidation of converters, improving efficiency of drive motors and adaptation to traction application.

## Batteries: The most critical EV component

Among all the systems in EVs, the battery plays a major role because it powers the vehicle for traction. A few factors that make batteries the most critical component are size, weight, cost and life. An EV's range is proportional to the size of the battery and how much energy it can store in the given package volume, which in the real world, is a constraint with vehicle dimensions. In addition, the weight of the battery gets significantly high when the size increases. The weight adversely affects the vehicle dynamics parameters, like centre of gravity, weight distribution, strength & stiffness of the vehicle, which in turn, reflects in acceleration, braking and ride performance. The cost of the vehicle, depending on the chemistry, size, structure, robustness, etc, accounts for 30-40% of the vehicle. Hence, the battery is one of the critical systems alongside the powertrain in EV. Therefore, accommodating the right battery size coupled with similarly efficient vehicle architecture and other design components is important.

## Vehicle designs and applications in e-mobility

Electrification divides the vehicle design into two sub-categories based on the application. The first one is passenger EVs for personal/family use and the second is last mile delivery/logistics. As EVs give a clean slate for design, both categories will require the carmakers to wear different lenses while managing vehicle architecture to fulfil requirements for the end goal. Passenger EV buyers would expect the driving experience and luggage space to suit their driving style & lifestyle with a performance that is superior to the current age ICE vehicle. Last mile delivery EVs, whereas would expect a larger cabin space to accommodate either passengers or goods and may not expect to cross a pre-defined speed threshold. New EV platform concept, ie, skateboard chassis, houses batteries on the vehicle floor, has evolved over a period and looks promising from the future mass development and industry adoption perspective. Reducing the overall weight and increasing the strength are the key parameters to affect design and performance.

## Powertrain in EVs and its significance

Terminologies used in the EV industry vary according to the region and EV players. EV powertrain or e-drive refers to traction motor and gearbox. The traction motor is a critical component as it converts electrical energy from the battery to wheels as tractive force for mobility. Designing a motor, characterised for traction application is challenging with issues in cooling and noise, vibration and harshness (NVH). There is another challenge related to scarcity of available material. Currently, rare earth permanent magnet materials are used in Permanent Magnet Synchronous (PMS) motor. The industry is innovating newer materials to adapt in motor design with no or minimal use of permanent magnets. Choosing the right specification of battery & powertrain is equally comparable to the conventional engine-gearbox combination as its design affects vehicle traction performance, efficiency and response.

## Power conversion system

In power convertors, the requirements are driven primarily from the embedded and electronics front and then converged with mechanical design via packaging and cooling design. The widely used technology in power convertors is a wide band gap of semiconductor (SiC/GaN) for higher power efficiency, being compact in size & lightweight. Nowadays, the consolidation of modules is gaining focus, which aims to combine two or more converters into a single unit, which not only saves significant package space in vehicles but also reduces the overall weight by avoiding or reducing separate enclosure and cooling system modules. These single/combo units also achieve higher volumetric power density targets. However, it is a challenging task to package multiple PCBs in a small volume and design an effective cooling system module.

## EV charging infrastructure to play a key role in EV adoption

The EV charging time is always looked as one of the major challenges in transition from the ICE to EV vehicles. Home charging is usually alternating current (AC) charging similar to other AC appliances (3-pin socket) in our homes. However, this charging is slow charging, takes a longer duration to completely charge the vehicle, and hence, is preferred for overnight charging. Fast charging is direct current (DC) charging, which helps to reduce the charging duration considerably. There are advancements in progress to further reduce the charging time by increasing the DC power for fast charging. This may help EV users to recharge the battery in less than 30 minutes, but it will come with its own set of challenges. The cost of fast charging is currently very high and repeated use would make the running cost of EVs greater than that of ICE vehicles. In addition, fast charging has a negative effect on battery life and can affect range in longer runs. It may also lead to battery overheating and would require active cooling of the battery while fast charging. Frequent fast charging may lead to battery wear out before specified lifetime of it.

Battery swapping may offer a potential opportunity to avoid issues related to fast charging and could become the preferred mode of charging in densely populated areas, where home charging is not possible. It could be done at the stations like refuelling. Initially, fleets and city transport vehicles were more inclined to adopt this type of charging wherein optimising cost of charging and time to charge were key to success and economic parameters. The other option is wireless charging, either when parked or while driving for ease and on-the-go charging, that may require appropriate infrastructure and technology. Charging infrastructure availability plays a vital role for customers to adapt to EVs, and it is indeed increasing as most fossil fuel vendors are venturing into the charging infrastructure business.

## Intelligent battery systems for higher efficiencies

An intelligent battery system depends on factors, like battery architecture, thermal management system, monitoring & controlling. The selection of the appropriate form factor of cells, usage of lightweight materials for the structures, reduction of cost and weight through efficient packaging, optimised cooling system, intelligent prediction, optimised battery performance through intelligent Battery Management System (BMS), real time monitoring, pro-active control through digital twin and cloud BMS are some key parameters to consider. These aspects of intelligent battery system will significantly improve the efficiency of battery system all around in terms of structural, thermal, safety, life expectancy and offer modularity & scalability as a complement.

As mentioned earlier, battery and EV powertrain are the major components directly impacting an EV performance. Apart from those, the power converters contribute a lot to improve the EV performance, as they convert and transfer the power, whether it is internal or external charging. The other influencing factors are the high voltage vehicle architecture and vehicle aerodynamic design. Moving to high voltage vehicle architecture like 800V or 1200V may reduce the power transmission losses. Vehicle aerodynamic design shall improve the traction and dynamic performance irrespectively. If the above mentioned factors and components design are taken care of, then it may improve EV performance considerably.

## EVs to become mainstream soon

Mass EV manufacturing and adoption are inevitable, and laying the transition path will require a lot of investments in terms of infrastructure and building trust amongst customers on EV through technology. This has already started happening across the world at different scales. Customers are eager to accept EVs if they are affordable, offer good range (~500kms) and can be charged in less time (<30 minutes). The technology is also rapidly evolving to make for higher energy density battery, more efficient motors and more compact power converters.

New-age vehicles are more digitalised than ever to provide assistance in safer driving, offer comfort and concierge services. EVs are no exceptions and may require more digital design for systems monitoring, control and comfort. Human machine interface (HMI) or display on dashboard are becoming larger and more interactive & connected. This trend will continue as the scale of autonomous driving keeps going up. A few challenges rounding the EV industry would be more evident when mass production scales up. Lithium usage will phenomenally rise towards the end of this decade and further, as battery production will be scaled up to meet higher demands. The permanent magnet and rare earth metal availability for motor manufacturing will become an issue. New technologies have to be explored to address the blockers and to make available technologies like Switch

The powertrain is a major component directly impacting EV performance

Reluctant Motor (SRM) as a commercially viable solution.

The infrastructure for community and public charging or swapping stations have to be developed at a fast pace. Developed countries are ahead in this & are working to provide infrastructure rigorously. Most big oil producers and vendors are investing in building charging stations, collaborating with EV ecosystem players and are working to create large infrastructure platforms for this transition. However, there are a few challenges involved in this, as the technologists have to define which efficient technology will be widely used. Until then, investments in charging related infrastructure are done with a lot of hesitation and uncertainty.

At the same time, alternative technologies like fuel cell electric vehicle (FCEV) can't be ignored, as they are gaining considerable momentum in recent times. However, they still have a smaller market size compared to EVs but they are seeing rapid growth. In addition, from the perspective of fuel filling convenience and range, FCEVs are potentially more promising. From the regulations perspective, OEMs are aligning to zero emission targets based on markets and business strategies. EV programs have been given a lot of importance within each company to meet the overall $CO_2$ targets to avoid the penalties. At the same time, companies at all levels, like OEMs, tier 1 & technology services and manufacturing sectors channelise investments towards EV technology. Companies within the same domain or different domains are making synergy to innovate and mass produce EVs, which shows the healthy way forward as a whole industry.

## The emerging new business model in the EV mobility space

**Ownership/subscription/ride sharing/pay-per-use:** Consumers will have a choice between these mobility options based on their usage applications. EV subscriptions for specific period or pay-per-use without owning the vehicle may offer a great cost advantage to customers. Subscription business models are growing in western countries owing to the higher initial cost of EVs and maintenance free usage plans.

**Home charging / public fast charging / battery swapping / battery lending / battery as a service / vehicle to grid:** Charging infrastructure players will offer multiple options as per the convenience of the consumer. Swappable battery infrastructure has a high potential in the Indian context as the EV industry is revolving around 2W and 3W in large percentages. Battery swapping in 4W & commercial vehicles is also becoming popular around the world to equate the time duration for EV charging and ICE refuelling. Battery lending may gain momentum as battery costing is around 25% of the vehicle cost, and it will ease the cost of ownership to EV customers. The battery has the potential to become a separate service due to the various reasons currently discussed. Home charging infrastructure requires to be developed for large communities like apartments, especially in urban areas.

At the same time, public fast charging infrastructure needs to be developed on a large scale across the country to ensure enough charging stations are located for EV users. In addition, there is a huge potential that all parking spaces will offer the option of either EV fast charging or wireless charging. Vehicle to Grid (V2G) concept is gaining traction because of the advantages it offers in multiple ways. However, it may require a robust infrastructure to become a clean energy, like solar energy to charge EV battery and battery to home or grid.

**Second life of battery/battery recycling/scrapping:** End-of-life battery could be reused for less critical applications, providing them a second life. It will reduce the scrappage of battery and shift the batteries from e-mobility application to stationary application. Servicing of automotive batteries will be a new business model in the future to give them a second life. Most of the metals used in battery chemistry, including lithium, could be recovered from scrapped batteries and reused to make new batteries. It has large business potential because of the scarcity and high cost of the metals used in the battery. The battery recycling industry has a wider scope as they may get scrapped batteries other than automotive application too, like mobiles, electronic toys and household. In addition, the users may get monetary benefit while scrapping the used batteries.

**Digital connectivity:** Services like trip recommendation and route optimisation, nearest available charging station by blending the real-time data and the predictive system data within the vehicle would add value to EV users. The business model around digital connectivity has diversified a lot and would continue to offer a great experience to EV end-consumers. □