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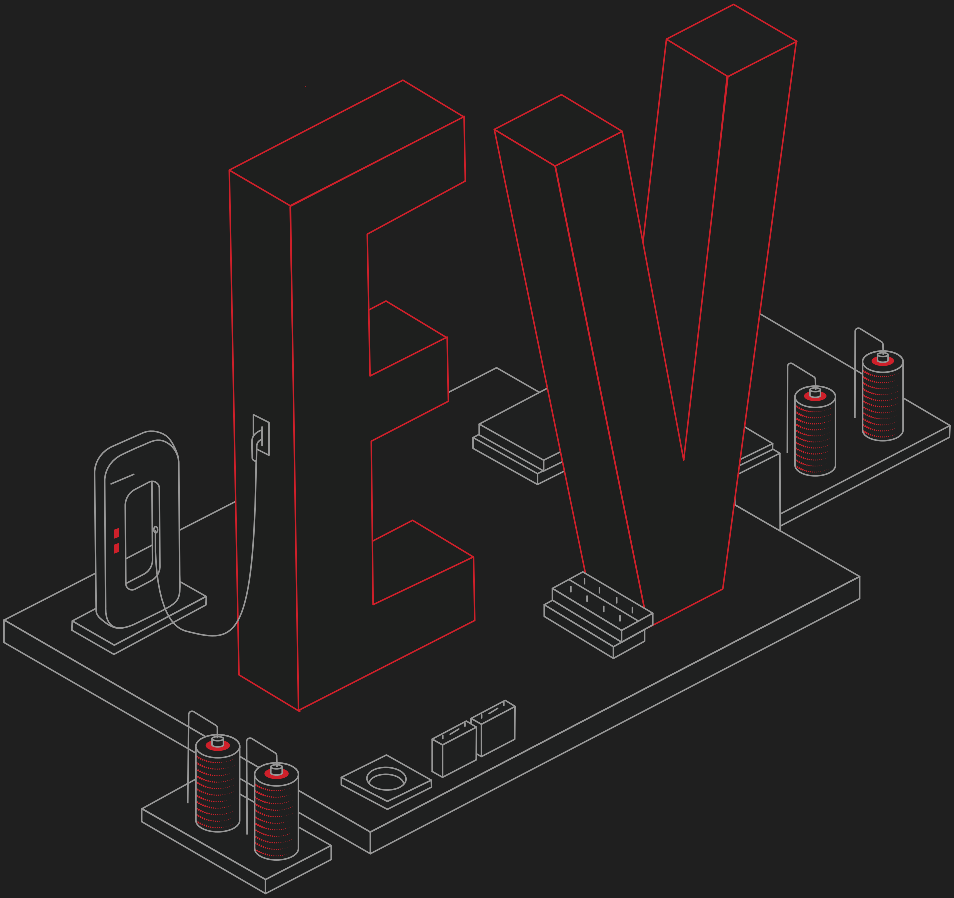
Next is the only level

Electric Vehicles

Charging towards a bright future



July 2020

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Message from the Authors

While the concept of Electric Vehicles is over a century old, they came into limelight about a decade ago, when technology was finally mature enough to deliver an electric vehicle that could match the performance of an ICE counterpart. Over the past decade, the economics of this technology has massively improved; and today, EVs make economic sense across multiple use cases. The inevitability of EV transition is accepted by the world, however, timeline for mass adoption is still a topic for debate.

India represents the fourth largest automobile market in the world and the second largest two wheeler market with ~20 mn units. It is also a country with massive dependency on oil imports, with a USD 112 bn oil import bill in FY19. Pollution in many Indian cities has reached alarming levels. All these factors put together make a strong case for EV adoption in India. Pricing and infrastructure, though, continue to remain a challenge. The genesis of this whitepaper was to evaluate the relevance of EVs in India today.

The whitepaper is intended to give its readers a comprehensive understanding of the EV industry. It lays down the structure of the ecosystem and its important constituents. It briefly touches upon the global EV industry and evolution of key markets.

Our focus has been to evaluate the EV opportunity in the Indian context. The whitepaper summarizes the current state of the Indian EV industry – including policy measures, current OEM traction, battery industry and charging infrastructure. The whitepaper also assesses the economic viability of EVs across different vehicle segments and various use cases today. How the EV adoption will pan out in India is a question that fuels a lot of debate across industry participants. We have tried to assess the four critical factors that will eventually impact the EV penetration in the country. We have looked at various scenarios to determine the 5-year outlook for these critical factors.

The process of creating this whitepaper has introduced us to finer nuances of the EV industry in India. The different vehicle segments are differently suited for electrification and each will undergo an inflection point at a different time. The electrification in India will certainly be led by light electric vehicles (2Ws and 3Ws), at least, in the medium term. Policy, Battery Prices, Charging Infrastructure, Supply Chain Localization – all factors need to come together for EVs to take off at full throttle. Even through a conservative lens, we see a bright future for EVs in India. Even the current COVID-19 environment is unlikely to affect the medium term EV adoption, it will rather accelerate the same.

We believe that EVs in India will represent an INR 500 bn opportunity by 2025. We all accept that the future is electric, it is now time to embrace electrification as an opportunity to create a self-reliant and cleaner India.

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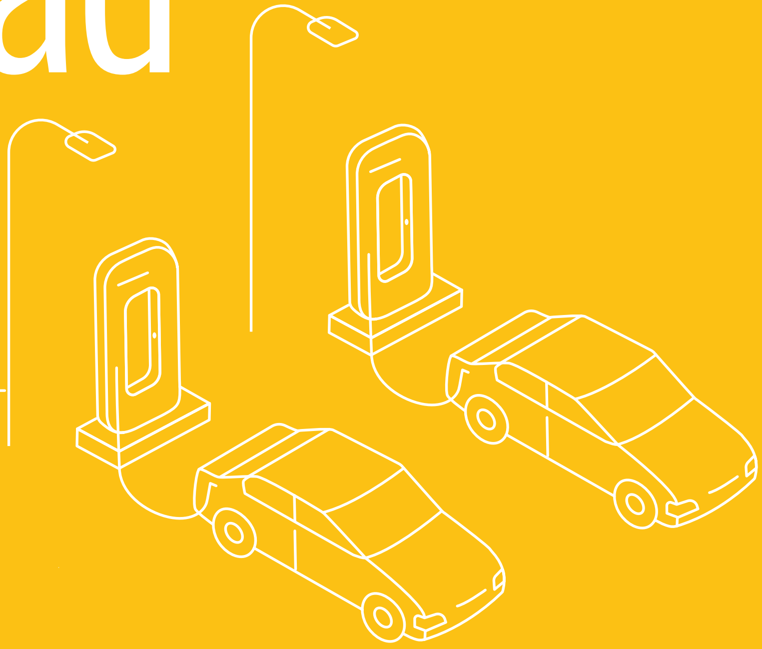
JULY 2020

The Road Ahead



Electric Vehicles

A future we need to embrace

Electric vehicles came into existence before their ICE counterparts. However, by the end of the 19th century, Internal Combustion Engines (ICE) were able to offer significantly superior performance including higher top speed, a longer driving range at a fraction of the cost. This completely transformed the automobile industry.

ICE technology is extremely complex, if one takes into account the enormous number of parts operating in sync with each other. It has undergone a massive evolution over a century and remains one of the most evolved technological developments of the humankind.

Electric vehicles on the other hand are very intuitive with far fewer parts. Yet, even today, there are doubts about how quickly and effectively they can replace the ICE technology. All along, the problem has revolved around one major aspect – the battery technology. Or, to be more precise, the technology's ability to store a large amount of energy in a small battery economically. Range and refuelling (charging) time are two factors where an ICE engine is (or was) superior to an electric vehicle. In almost every other aspect, electric vehicles are technologically superior to ICE vehicles.

Electric vehicles are simpler - a battery plus motor and controller is all that's replacing the entire engine and its related systems in ICE vehicles. Electric vehicles are more powerful (at least when it matters i.e. at low speed operations). Electric vehicles are greener and they can enable a zero-emission ecosystem, provided, that the grid shifts to renewable energy. Electric vehicles are smarter – electronic controls are 3-5x higher in EVs (as compared to ICE) and that translates into features beyond anything that consumers have seen before in an ICE vehicle. For a consumer, electric vehicles are a delight to drive. Electric vehicles are key enablers to Connected, Autonomous and Shared future of mobility.

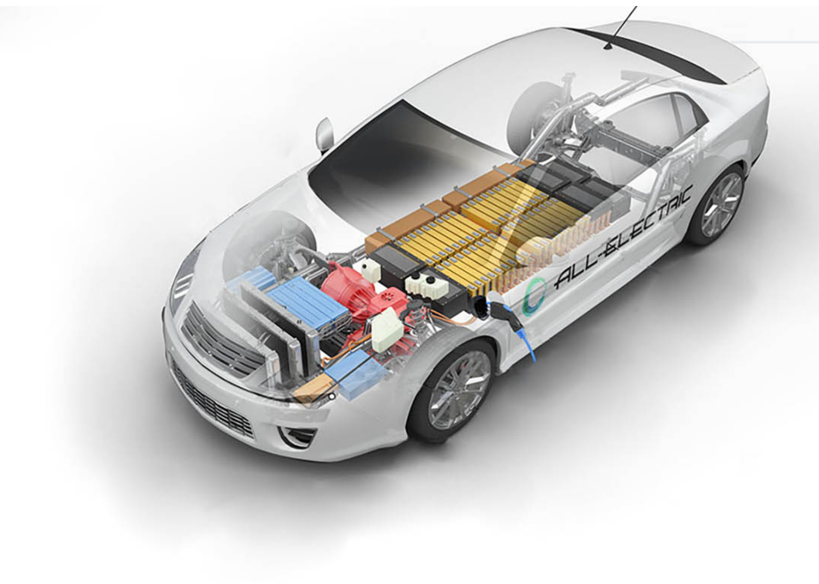


EXHIBIT 1 ↘

ELECTRIC VEHICLE

Moving Parts	**24**
Wearing Parts	**11**
High torque at low RPM	
Battery to Wheel efficiency	**80-90%**

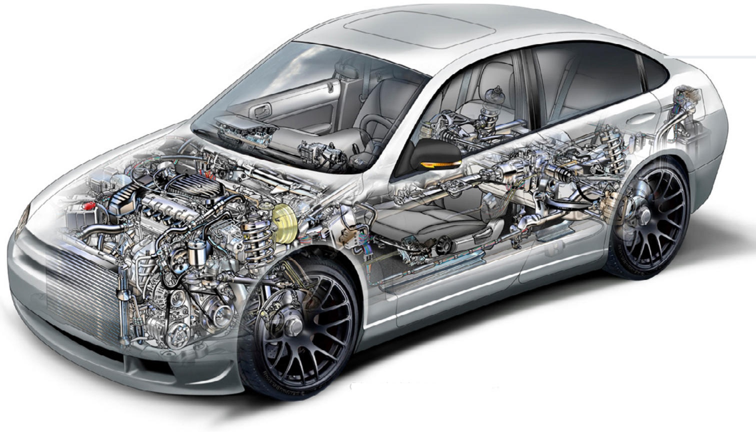


EXHIBIT 2 ↘

ICE VEHICLE

Moving Parts	**150**
Wearing Parts	**24**
High torque in specific RPM range	
Tank to Wheel efficiency	**25%**

While the superiority of EVs over ICE vehicles is unquestionable, there are challenges around the gaps in economic parity and the sub-developed state of the ecosystem. These challenges can only delay the transition but cannot derail it. The only difficult question now is: By how much longer?

The ICE to EV transition has begun in the real sense

1 /

Policy makers are aggressively pushing for EV adoption

Climate change has emerged as an existential question before the world over the past decade. While electric vehicles may not immediately address the vehicular pollution problem, they are certainly a key enabling step towards the ultimate vision of clean energy.

Policy makers around the world are trying to support the electric vehicle ecosystem with the primary objective of pollution control. The policies are largely focussed around financial support to make EV economics favourable for adoption by customers. EVs are being encouraged with favourable policies like capital expenditure assistance, tax and permit exemptions, protection for domestic manufacturers, across the world.

2 /

Battery technology has bridged the economic gap vs ICE

Battery technology has taken a massive leap in the last decade. The ability to store (and extract) large amount of energy in (and from) a small battery economically, has brought the EV dream closer to reality. The battery prices have fallen by almost 85% in the past decade, from USD 1,000/kWh to USD 150/kWh. The prices are expected to decline further to USD 100-120/kWh by FY25. Even at the current price points, electric vehicles offer lesser Total Cost of Ownership (TCO) vs ICE for multiple use cases.

3 /

There is a rapid increase in traction across all parts of the EV ecosystem

Climate change has emerged as the existential question before the world over the past decade. While electric vehicles may not immediately address the vehicular pollution problem, they are certainly a key enabling step towards the ultimate vision of clean energy.

Policy makers all around the world are trying to support the electric vehicle ecosystem with the primary objective of pollution control. The policies are largely focussed around financial support to make the EV economics favourable for adoption by customers. EVs are being encouraged with favourable policies like capital expenditure assistance, tax and permit exemptions, protection for domestic manufacturers and many more, across the world.

Close to USD 30 bn have been invested in Li-ion battery manufacturing, and the industry capacity has increased from close to zero in 2010 to 300 GWh in 2020. A variety of cell technologies are being developed and scaled up to create batteries with higher energy density and lower cost. Raw material supply chain is being established to secure supply of key raw materials like Lithium, Cobalt, Nickel, etc.

Majority of OEMs have embraced the fact that the electric revolution is indeed starting, and many of them have laid down concrete plans for electrification over the next 5-10 years.
A large number of new OEMs have come up. Most of the current market leaders, including Tesla, BYD, Niu, Nio, etc. are pure-play EV OEMs.

Charging infrastructure is being developed to support the EV adoption. Along with OEMs like Tesla, who are creating their own infrastructure, several Charge Point Operators (CPOs) have emerged – many of them are being backed by traditional energy companies, including oil refining and marketing companies.

How long the EV transition will take is a function of a variety of factors. In order to create the most favourable environment for EV adoption, the battery prices need to reduce further, policy makers must extend strong support through the early phase of EV adoption and all supporting parts of the ecosystem like charging infrastructure, battery technology and the concomitant supply chain need to evolve in sync with the overall EV adoption.

The EV transition has taken off well on a global scale. It might take a few years, but it is on track to happen for sure.

4 /

India must go electric – But we need to do it right and do it now

Electric vehicles have garnered reasonable attention in India. The domestic EV ecosystem has started to flourish with a strong policy backing. Electric vehicles are a viable solution for urban India's severe air pollution problems and are also expected to help solve the issues around the country's long-term energy requirements.

India is a unique automobile market - 84% of vehicles sold in India are 2W/3Ws. These smaller vehicles are easier to electrify, since they need smaller and simpler batteries and are much closer to economic parity vs ICE. India also has the world's fastest growing shared mobility market. Commercial/fleet use cases are already at economic parity vs ICE. The Indian auto and ancillary market is among the largest in the world and it constitutes 9% of India's GDP. It is imperative that electrification is proactively encouraged to ensure that this industry consolidates its strong position in the global auto market.

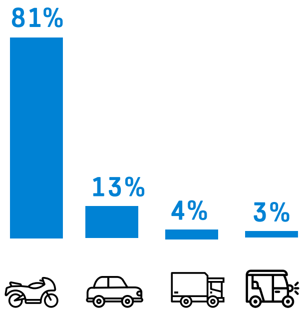
There are several short-term hurdles in the path of mass EV adoption in India. The industry players and policy makers need to invest time and money for the EV ecosystem to truly flourish.

5 /

3 million EVs by FY25 – A dream within India's reach

2Ws and 3Ws are expected to lead the EV adoption in India. These categories are closer to economic parity and smaller battery size means lesser upfront cost differential as well. In 4Ws, adoption would be slow and is expected to be more concentrated in commercial segment. Overall, in a base case adoption scenario, wherein battery price reduction is slower than projected trends, and policy support remains limited – India is likely to see 3 mn+ EV sales by FY25. With cheaper batteries and right policies, the EV adoption could be significantly higher.

INDIAN AUTO INDUSTRY COMPOSITION (BY VOLUME)



99.6% of gasoline and 67% of diesel demand is from the automotive sector

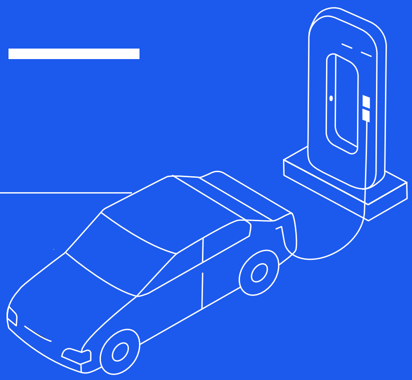
14 / 20 of the world's most polluted cities are in India

India imported USD 112 Billion worth of crude oil in FY19 — Equivalent to 4% of the country's GDP

01

Electric Vehicle Ecosystem —

An interplay demanding coherent development



Each player in the EV ecosystem has an important role to play for EV adoption to take off quickly and sustainably in India. The EV ecosystem comprises of the following parts —

1 /

POLICY

The role of policy makers is central to the evolution of electric vehicles. China has taken a massive lead over the rest of the world in EV adoption, with strong backing from its New Electric Vehicle Policy. Lack of economic parity is a major hurdle in adoption of EVs today. Policy makers are trying to bridge this gap through subsidies to encourage EV adoption. Policy makers need to simultaneously adopt other levers also to encourage EV adoption further.

The Indian policy has taken a number of positive steps towards promoting EV adoption, and FAME-II is a significant leap among those. Mandated adoption targets, localization of key components, clear guidelines on regulations and standards and EV adoption in public transport are some of the key levers that policy makers in India need to leverage.

2 /

BATTERY

The battery not only constitutes 30-40% of the cost of the vehicle but is also the key to solving other hurdles like range anxiety, charge time reduction, safety of EVs, etc.

Availability of battery’s raw material is a critical hurdle for the Indian EV industry. India does not have any meaningful reserves of key raw materials like Lithium and Cobalt. Cell manufacturing is highly cost and R&D intensive and requires scale. For now, India is completely dependent on cell imports and the role of domestic industry in battery value chain is limited to battery pack assembly.

3 /

GRID

There are two key considerations for the grid

A / Its ability to handle increase in the peak load

B / Its composition – Fossil fuel based vs renewable based

While the generation and transmission part of the grid is capable of handling the increase in peak electricity demand driven by EV adoption, the distribution part of the grid will have to undergo structural changes to handle peak loads at high EV adoption. Majority of households in India are connected through 200 kVA transformers which cannot handle more than 20 cars being simultaneously charged by a 7.4 kWh AC charger.

Also, the composition of the grid must shift towards renewables for EVs to truly address the pollution problem. India's coal dependent grid is amongst the most inefficient ones in the world and that makes this shift even more important, as inefficient fossil fuel based power plants also mean higher carbon emissions.

4 /

OEMs

OEMs have a strong influence on the future of EVs and they are the ultimate drivers of this disruption. The 2W segment has seen a lot of activity, with emergence of new players as well as increased activity by the incumbents. In case of 3W, the e-rick segment has grown rapidly and has even started to shift to Li-ion batteries. E-autos are expected to be launched soon. 4W market was largely being driven by Mahindra and Tata Motors with their fleet targeted variants. In 2019, Hyundai, MG Motors and Tata Motors came up with new EV models aimed at the retail segment. In CVs, the bus segment is seeing most action, mainly on account of public sector demand.

5 /

CHARGING INFRASTRUCTURE

Charging infrastructure development in India is still slow, mainly because the adoption of EVs (especially 4Ws) has not gained enough momentum.

Innovative business models have come up that offer energy-as-a-service (most of them are based on battery swapping). Home charging will be the primary method in the near term as public charging infrastructure will get developed in sync with the overall EV adoption.

6 /

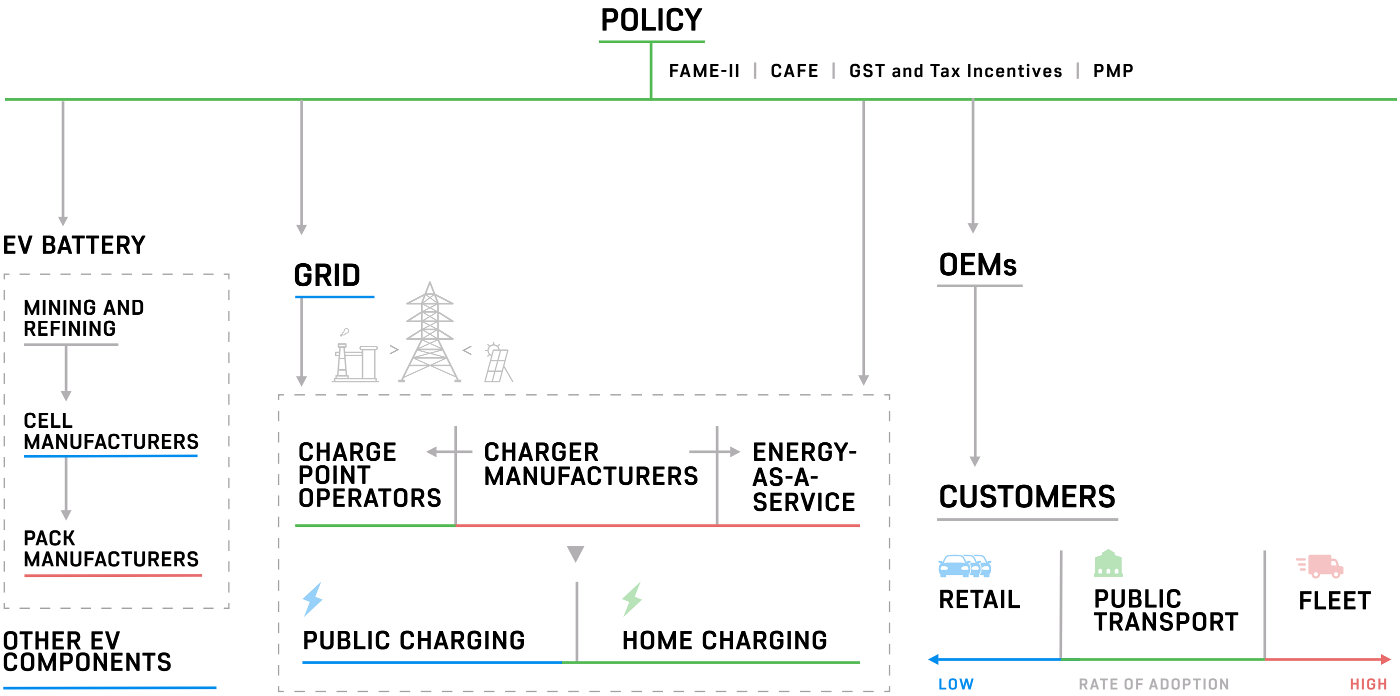
CUSTOMERS

Finally, the most important stakeholder in the ecosystem – the end customer. Customers need economic parity and a good product. TCO parity is an imperative and the upfront cost differential needs to go down to attract customers to adopt EVs. Fleets and public transport systems are gaining traction rapidly but the retail customer is still slightly further away from EV adoption – especially in segments where the upfront cost differential is very high.

EXHIBIT 3

Electric Vehicle Ecosystem

🟥 HIGH TRACTION
🟩 MEDIUM TRACTION
🟦 LOW TRACTION



POLICY

FAME-II | CAFE | GST and Tax Incentives | PMP

EV BATTERY

- MINING AND REFINING
- CELL MANUFACTURERS
- PACK MANUFACTURERS

OTHER EV COMPONENTS

GRID

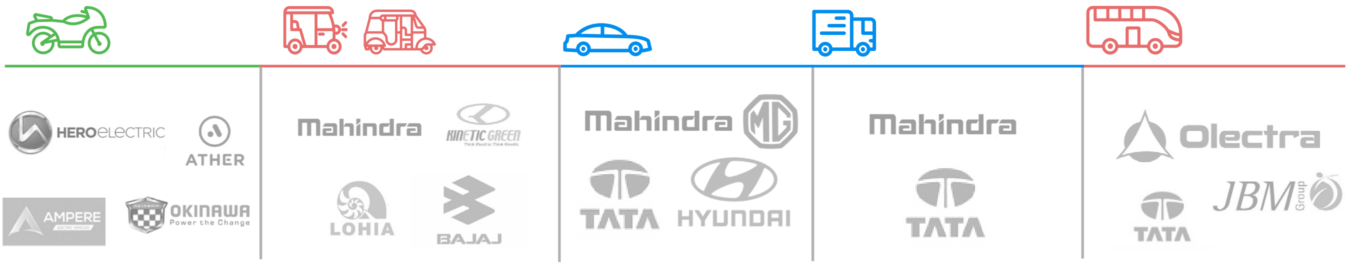
- CHARGE POINT OPERATORS
- CHARGER MANUFACTURERS
- ENERGY-AS-A-SERVICE
- PUBLIC CHARGING
- HOME CHARGING

OEMs

CUSTOMERS

- RETAIL
- PUBLIC TRANSPORT
- FLEET

Key OEMs



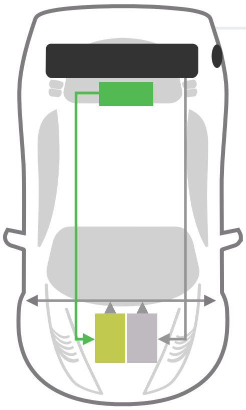
02

Electric Vehicles — 101

EXHIBIT 4

Types of EVs

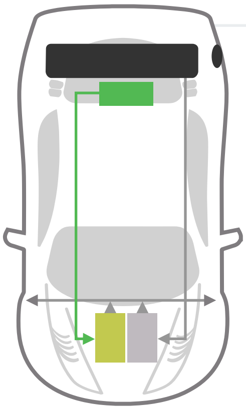
The transition from ICE to EVs is happening in multiple phases - from mild hybrids to full hybrids to plug-in hybrids (PHEVs) to battery electric vehicles (BEVs) to fuel cell electric vehicles (FCEVs). Hybrids is an interim stage of this transition, with the shift eventually being driven by BEVs in the long term. FCEV is being aggressively researched upon as an alternative to BEVs, but the technology is still far from commercial adoption.



Mild Hybrid

Mild hybrids have an additional 48V battery over the ICE architecture. The battery gets charged through regenerative braking. The role of the battery is limited to provide power assist to the engine, idle stop-start and tertiary vehicle functions like AC, infotainment, etc.

e.g. **SUZUKI BALENO**

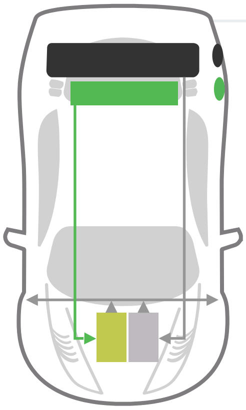


Full Hybrid

Full hybrids can be classified as series or parallel hybrids. A series hybrid uses the internal combustion engine as a generator that creates the electricity that turns the wheels of the vehicle via an electric motor in the axles. A parallel hybrid uses both, the energy generated by the ICE and the electric motor to power the vehicle. Additionally, a full hybrid can operate like a pure BEV when energy requirements are minimal at low speeds.

e.g. **TOYOTA CAMRY**

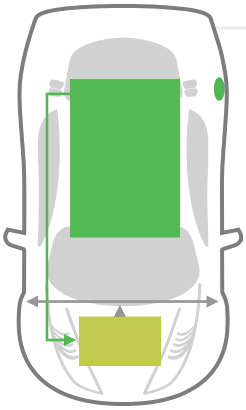
🟩 BATTERY PACK
🟨 ELECTRIC MOTOR
▨ ICE ENGINE
■ ICE FUEL TANK
● FUEL FILLER
● CHARGE PORT
🟦 HYDROGEN FUEL TANK
🟥 FUEL CELL STACK



Plug-in Hybrid

They are similar to full hybrids but have much larger batteries which can be charged by plugging in. These vehicles can run in full electric mode. When the battery gets depleted, the vehicles switch to a series/parallel hybrid propulsion system.

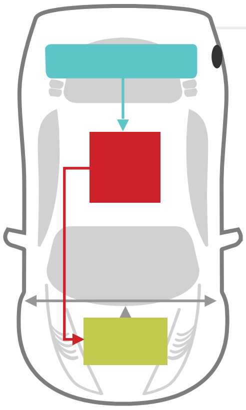
e.g. **MITSUBISHI OUTLANDER;
VOLVO XC90**



BEV

Battery electric vehicles are purely driven by electric motor(s).

e.g. **TESLA MODEL 3;
HYUNDAI KONA**



FCEV

Fuel cell electric vehicles are similar to BEVs, but instead of a battery they have Hydrogen fuel cells that generate electricity.

e.g. **TOYOTA MIRAI**

🟩 BATTERY PACK
🟨 ELECTRIC MOTOR
⬜ ICE ENGINE
⬛ ICE FUEL TANK
● FUEL FILLER
● CHARGE PORT
🟦 HYDROGEN FUEL TANK
🟥 FUEL CELL STACK

Electric Powertrain

Simpler, Smarter and More Powerful

An electric powertrain is fundamentally superior to an internal combustion engine. An internal combustion engine burns fuel and creates tiny controlled explosions inside the engine cylinders. These explosions push the pistons which are connected to a drive shaft through a large number of interlocking components. The whole powertrain is complex and somewhat inefficient. A large portion of energy gets lost as heat produced in the engine.

On the other hand, an electric powertrain has one or more motors that drive the wheels by taking electric energy from the battery. It produces motion without generating any significant heat, and hence, is more efficient than ICE vehicles.

When compared to an ICE, an electric powertrain is superior in three ways

1 /

It is more Powerful

An ICE produces enough torque only in a certain RPM range. On the other hand, an electric motor can produce full torque from zero RPM. At lower speeds, electric motors deliver more torque than ICE. Torque is essentially what gets the car going. With more torque at lower speeds, an electric car gives more acceleration than a comparable ICE car.

ICE do perform better at very high speeds. However, for the speed range that matters the most, an electric powertrain is more powerful.

2 /

It is Simpler

With less torque at low speed, ICE needs help from a transmission to step down engine RPM to wheel RPM. A transmission system adds further complexity to an ICE powertrain.

Electric powertrains do not need any transmission. At most, they have a couple of operating modes that have different motor efficiency profiles which have no impact on acceleration.

The simplicity of a powertrain makes electric cars vastly easier to service as well.

3 /

It is Smarter

ICE control systems have come a long way in accuracy and performance. An electric powertrain provides even better opportunities to monitor vehicle performance and adjust it.

Electric powertrains are best suited for future automobile trends like autonomous driving, connected vehicles, etc. With the endless possibilities that electric vehicles bring, they are less like traditional automobiles and more like laptops or smartphones on wheels. Similar to laptops and smartphones, software updates will become an increasingly regular part of EV ownership.

Key components of an EV

Battery and motor are the two key components that are replacing the engine in an ICE vehicle. The technology to store a large amount of energy in a small battery in an economical and safe manner has been the primary hurdle in EV adoption. Battery costs constitute up to 35% of the vehicle cost – making battery the most critical component of an electric vehicle.

The motor is the second most critical component in an EV. The motors also need sophisticated controllers in order to derive best performance and energy parameters. These three components have been covered in detail in the following section, along with an overview of other key components.

EXHIBIT 5 ↘

Key components of an electric vehicle and their respective cost contribution

Electric Car

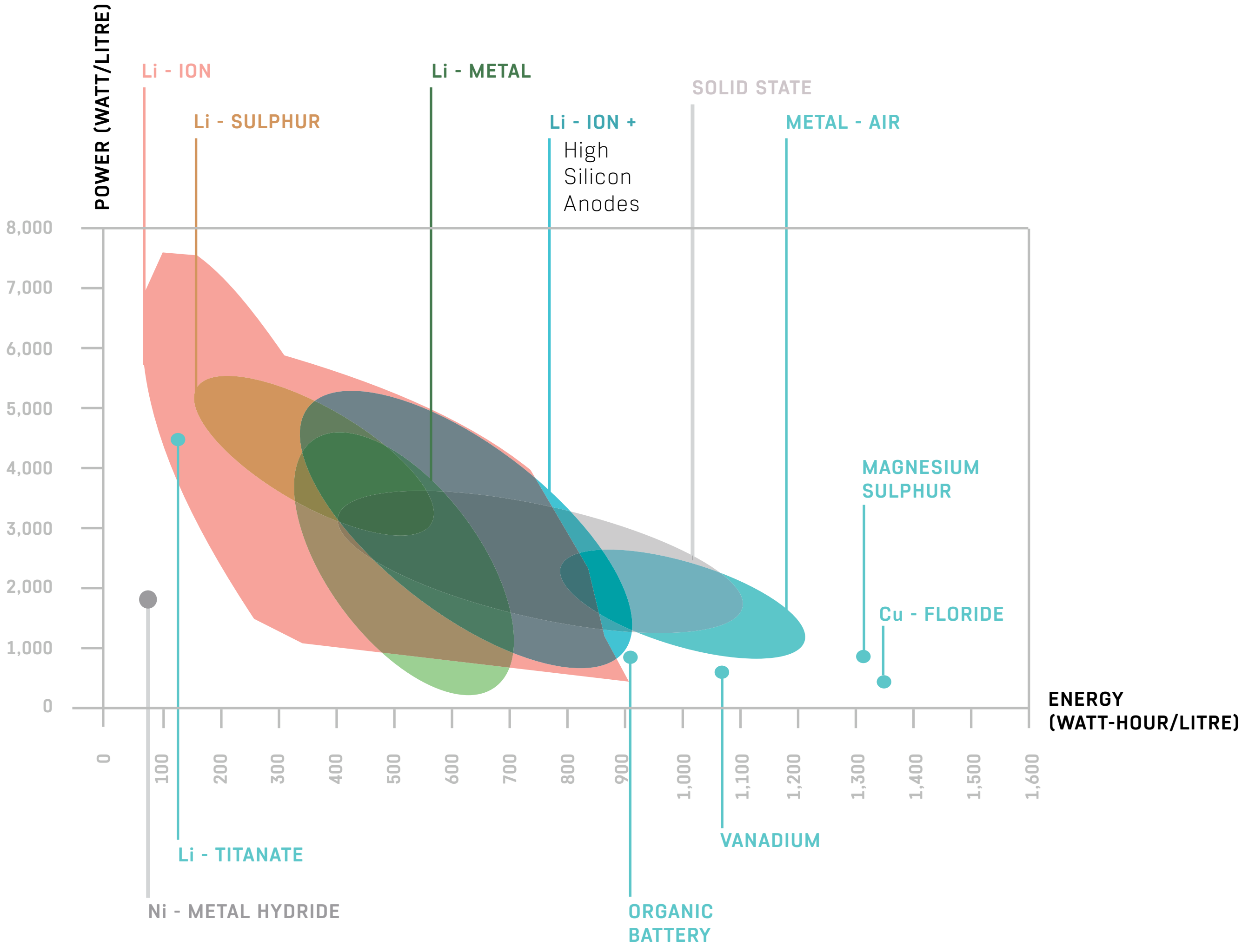
Battery 35%	32%	CATHODE	Panasonic LG Chem SAMSUNG SDI CATL
	18%	CURRENT COLLECTORS	
	18%	SEPARATOR	
	15%	ELECTROLYTES	
	11%	ANODE	
	6%	OTHER	
Drivetrain 25%	40%	ELECTRIC MOTOR	MAGNA Nidec BOSCH Continental
	30%	CONTROLLER	
	30%	OTHER	
Chassis and Body Parts 20%	Systems, Equipments, Other Components 20%		APTIV LEAR CORPORATION AISIN faurecia ZF

EV Battery — 101 Li-ion is the future of EVs

Li-ion is the most mature battery technology currently and there is nothing that can potentially replace it, at least in the next 5 years. Li-ion presents a wide range of power–energy performance that is significantly better than previous battery technologies like Lead Acid, Nickel Metal Hydride, or Nickel Cadmium. There are a number of chemistries which theoretically can be safer and more efficient than Li-ion but none of them are close to commercial deployment.

EXHIBIT 6 ↘

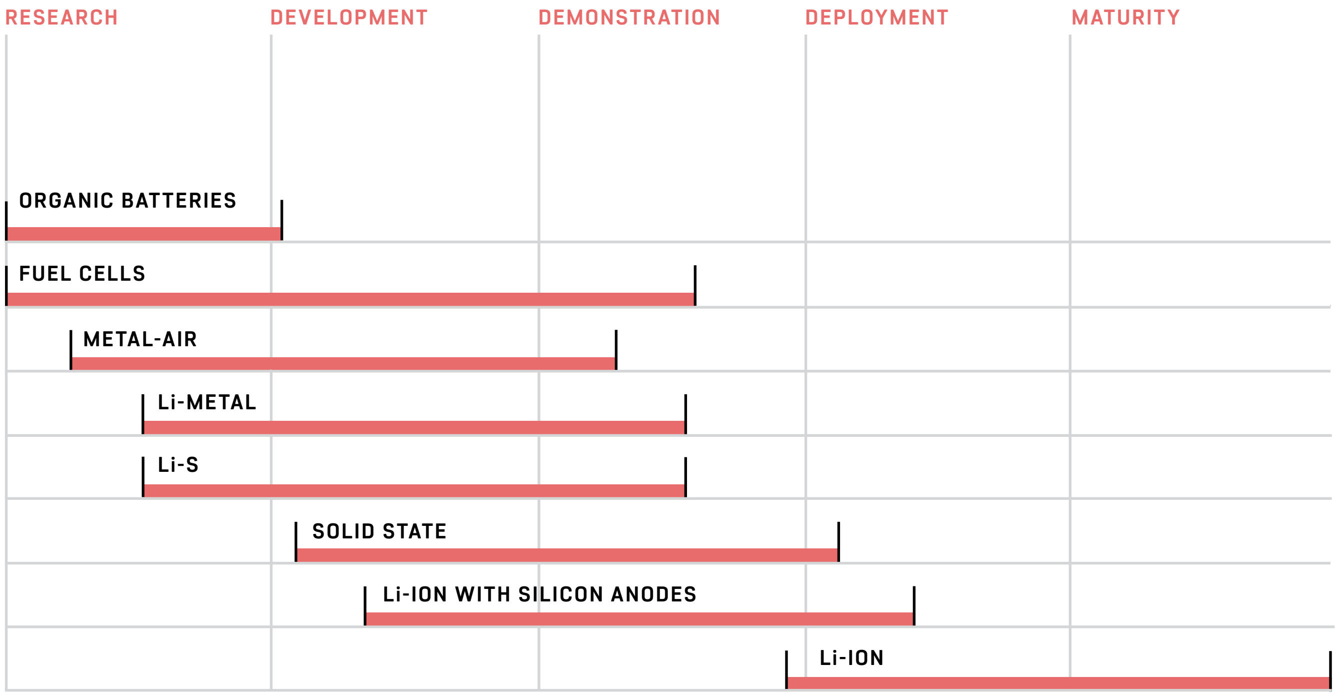
Power/Energy density map for different battery chemistries



The chart below shows stages at which various battery chemistries currently are. While the chart doesn't relate to a timeline, an understanding of the evolution of Li-ion technology shall add perspective to the development timelines. Li-ion technology was invented in the 1970s, the first commercial applications were developed in 1991, the first electric vehicle batteries were commercialized in the late 2010s, and today in 2020, a large-scale commercial application is taking shape. While the rate of technology metamorphosis has accelerated significantly over the last few years, it is safe to say that the development, successful piloting/demonstration, scale up and finally, the deployment of alternate chemistries keeps Li-ion insulated for at least 5 years.

EXHIBIT 7

Advanced technologies in different stages of the development cycle



The industry has already backed Li-ion

While the debate around technological superiority or maturity can be endless and identifying a clear winner could be difficult, the industry at large has accepted Li-ion as the future of EV batteries in the medium term.

~300 GWh

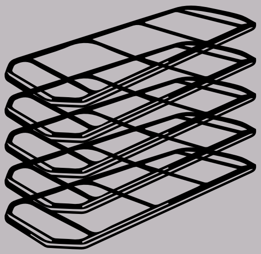
Li-ION CAPACITY ACROSS THE GLOBE

Only <50% is currently utilised

100 GWh

TOTAL CAPACITY

Top 5 Gigafactories



$ 30Billion

WORLDWIDE, SINCE 2010

Total investments in manufacturing Li-ion batteries

$ 60 - 100Million

Li-ION BATTERY MANUFACTURING PLANT

Capital Expenditure/GWh

115

Gigafactory projects in the pipeline

EXHIBIT 8 ↘

Li-ion — the race within

Li-ion is not one chemistry. It is a broad set of competing chemistries, each having its unique advantages and disadvantages.

NCA

Supports low discharge currents, great capacity/cycle life and physically resistant

SPECIFIC ENERGY	SPECIFIC POWER	CYCLE LIFE	SAFETY
180 - 200 Wh/Kg	500 - 1000 W/Kg	800 - 2000 CYCLES	LOW

Li Ni Co Al Oxide

Used in
Tesla

NCM

Low resistance of Manganese and high energy of Nickel

SPECIFIC ENERGY	SPECIFIC POWER	CYCLE LIFE	SAFETY
160 - 220 Wh/Kg	480 - 800 W/Kg	800 - 2000 CYCLES	MEDIUM

Li Ni Co Mg Oxide

Used in
Volkswagen, BMW, MG

LFP

Excellent safety and long life span but moderate specific energy and elevated self-discharge

SPECIFIC ENERGY	SPECIFIC POWER	CYCLE LIFE	SAFETY
130 - 140 Wh/Kg	>1000 W/Kg	2000 - 5000 CYCLES	HIGH

Li Fe Phosphate

Used in
Mild hybrids & heavy duty vehicles

LTO

Rapidly chargeable batteries that are extremely safe

SPECIFIC ENERGY	SPECIFIC POWER	CYCLE LIFE	SAFETY
50 - 100 Wh/Kg	>1500 W/Kg	1000 - 3000 CYCLES	HIGH

Li Ti Oxide

Used in
Mitsubishi and Honda in select models; Buses

LMO

Used in flash lights, no built in protective circuit and high current discharge at low temperature

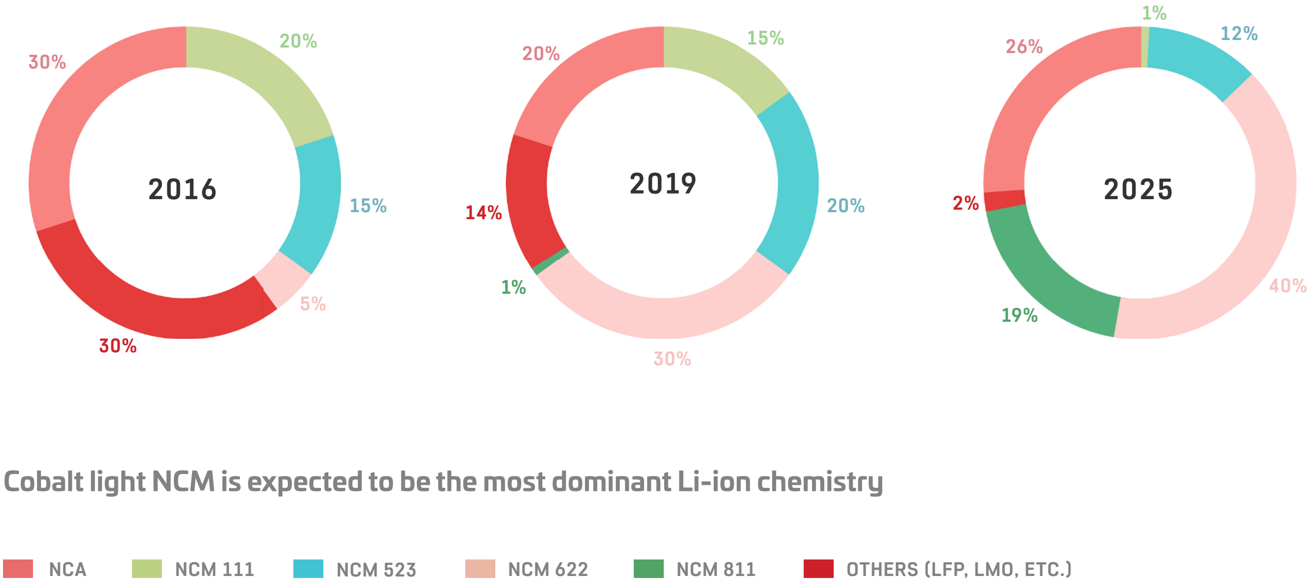
SPECIFIC ENERGY	SPECIFIC POWER	CYCLE LIFE	SAFETY
100 - 200 Wh/Kg	160 - 720 W/Kg	500 - 2000 CYCLES	MEDIUM

Li Mg Oxide

Used in
Early EVs & Flashlights

EXHIBIT 9 ↘

Change in cathode chemistry mix



NCM and NCA would account for majority of the Li-ion battery market going forward. At present, a large portion of the Chinese EV market is powered by LFP, but even that is expected to decline. Within NCM, the cell composition will move from 1:1:1 (1 part of Nickel for every 1 part of Manganese and 1 part of Cobalt) to NCM 8:1:1.

Reduction of Cobalt content in batteries is a core focus area for battery developers. Cobalt reserves are limited and not enough to support 100% electrification. 50% of the reserves and 70% of production of Cobalt is concentrated in the Democratic Republic of Congo (DRC). Thus, there are significant geopolitical risks associated with Cobalt supply. Tesla, in collaboration with Panasonic, managed to reduce 60% of its Cobalt dependency and aims to completely eliminate Cobalt from its batteries.

However, Nickel rich cathodes come with their own problems. Nickel rich batteries tend to heat up rapidly, thus, safety concerns are higher. With lower Cobalt, the life cycle of a battery gets negatively impacted. Lower Cobalt formulations require special dry environments, thus, increasing operating costs and becoming a bottleneck in scaling up. However, with superior BMS developments and battery pack architecture with advanced cooling systems, there is a shift to minimize Cobalt usage. A number of global OEMs have already shifted to intermediate NCM formulations like 6:2:2 and 5:2:3. With more technological developments, NCM 8:1:1 would also witness large scale adoption.

Battery — Cell to Pack

A cell is the most basic unit of a battery pack. Each cell has an anode and a cathode separated by a separator. A number of cells put together form a module and a number of such modules put together build a battery pack.

ANODE	The negative terminal in a Li-ion cell generally consists of Graphite. When the cell is charged, Li-ions get stored in Graphite layers.
CATHODE	The positive terminal consists of Lithium along with other metals like Nickel, Cobalt, Manganese in the case of NCM chemistry; Ferrous, Phosphorus in the case of LFP, etc. Lithium ions migrate from the anode to the cathode during discharge to create an electric current. During the charging process, this process reverses.
ELECTROLYTE	It enables the flow of ions between the cell terminals. Typically, it is a non metallic, liquid conductor. Currently, the most commonly used electrolyte is Lithium Hexafluorophosphate.
SEPARATOR	Separator is made out of permeable material that isolates the two terminals of a cell. It prevents the flow of electrons through it but allows the passage of Li-ions.
CURRENT COLLECTORS	Each terminal of a cell has a current collector. The movement of Lithium ions from the anode to the cathode creates a charge at the positive current collector. The electric current then flows to the vehicle. During the charging process, the electric current flows to the negative current collector where the charge is stored.

EXHIBIT 10

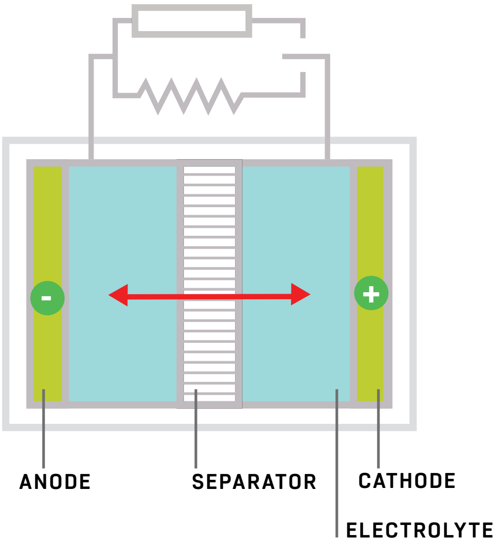
Li-ion Cell — Correlation between components and characteristics

CAPACITY	⊕	⊖	▯
SAFETY			▯
FAST CHARGE	⊖		
POWER			▯
SUSTAINABILITY	⊕	⊖	▯

⊕ **CATHODE**
⊖ **ANODE**
▯ **ELECTROLYTE**

FIGURE 1

Battery cell illustration — The diagram below depicts a Li-ion cell and its different components. Each component has a specific role to play in the overall battery characteristics.



Cell form factors

The three most common form factors for cells are — Cylindrical, Prismatic and Pouch

A /
CYLINDRICAL

This format has battery material (electrodes and separator) rolls that are continuously wound into a round Aluminum housing. It is relatively smaller compared to other form factors, increasing the number of cells needed for a battery pack which leads to a requirement of a more sophisticated battery management system. Panasonic manufactures NCA cells for Tesla in this form.

B /
PRISMATIC

In this format, multiple sets of battery materials (electrodes and separator) are wound and inserted into a rigid Aluminum can. The insertion of the materials into the can and the welding of the can adds to the complexity and cost of this format but provides significantly higher safety. Samsung manufactures prismatic cells for BMW's model i3.

C /
POUCH

In this format, battery material rolls are stacked and wrapped around with a thin Aluminum polymer foil. The thin cell housing reduces the cell weight and results in higher specific energy. It also allows for more flexibility in designing battery packs. However, the Aluminum pouch format provides less safety features due to lesser rigid cell housing. LG Chem manufactures pouch cells.

FIGURE 2
Different cell form factors

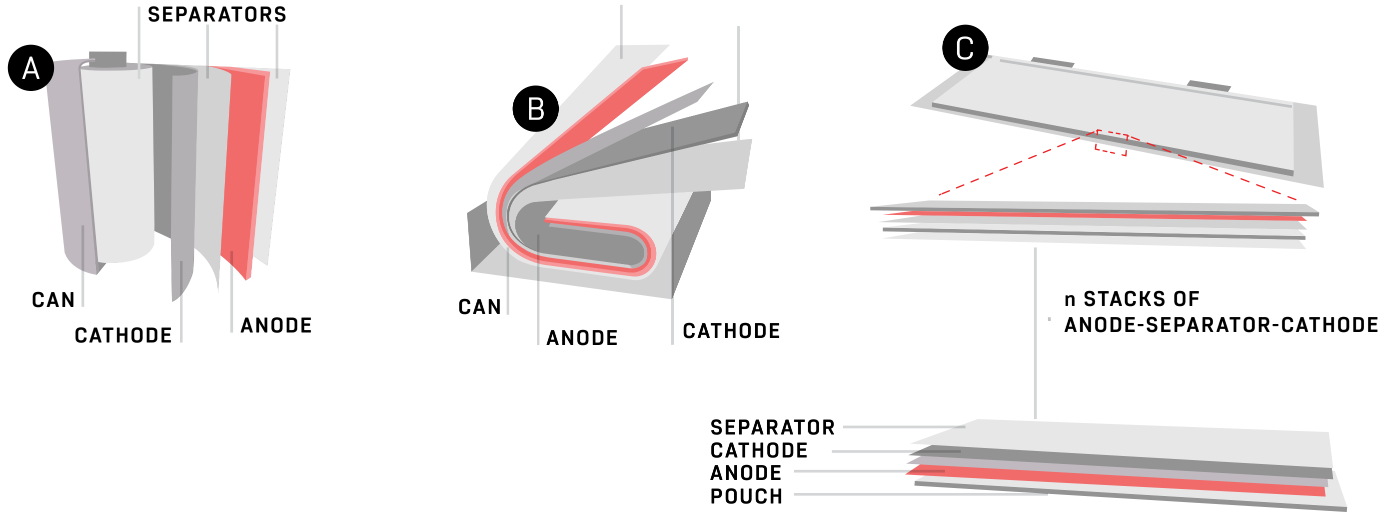


EXHIBIT 11

Comparison of cell form factors

	CYLINDRICAL	PRISMATIC	POUCH
Arrangement	Wound	Wound	Stacked
Mechanical Strength	High	Medium	Low
Thermal Management	Most Efficient	Less Efficient	Less Efficient
Battery Pack Design Flexibility	Low	High	High
Safety	High	High	Low
Energy Density	Low	High	Medium
Cell Cost	Least Expensive	Less Expensive	Most Expensive

Battery Packs

Cells are put together into modules, which are put together to form a battery pack. While the cell chemistry largely dominates the pack characteristics, battery pack design itself has significant scope to create efficiency.

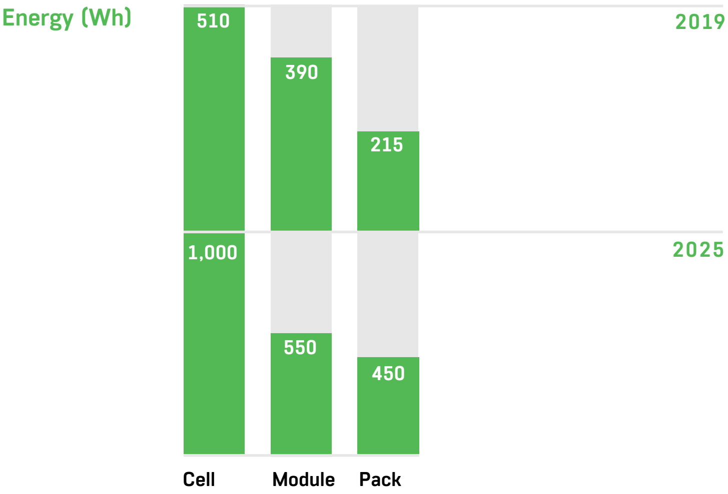


EXHIBIT 12 ↘

Cell to pack efficiency potential with developments in cell chemistry and cell-module-pack design

Led by improvements in —

Cell Chemistry

Cell Design

Module Package

Battery Package

Battery Management System

The brains behind the battery

Battery Management System (BMS) is the brain of a battery pack. BMS measures critical parameters and controls them to keep the battery safe and operate efficiently. Batteries, without a good BMS, are suboptimal in performance, life and safety. The single most important function of a BMS is cell protection. Li-ion cells can get damaged if overcharged or if discharged below a threshold level. Overcharging results in overheating which not only causes structural damage but also creates a huge risk of explosion and fire. Each time a battery is drained out below a critical level, its capacity gets reduced to an extent permanently. BMS ensures that the battery's charge doesn't go above or below certain threshold limits.

The second important function performed by a BMS is energy management. The BMS measures how much energy is left – State of Charge (SOC). It monitors the rate at which energy is getting used and how long will it last. Accurate assessment of SOC is critical for effective battery management.

BMS plays a critical role while charging a battery, ensuring that the battery is charged in a safe manner without impacting its life. During hot summers in North India, e-rick drivers experience longer charging times – that's essentially a result of the BMS slowing down charging to ensure that cell temperatures are within a safe limit. BMS also does cell balancing. This ensures that all cells are charged or discharged together, thus, preventing a few cells from getting stressed which could result in premature charge termination and a reduction in the overall cycle life of the battery. Typically, in a fast charge, 80% of the battery gets charged in one-third of the charging time. The remaining 20% takes longer because the BMS is conducting cell balancing.

The robustness of a BMS plays an important role in the performance of the battery. Two batteries with the same hardware can deliver significantly different performance, depending on how sophisticated their BMS is. Tesla, for example, has a BMS capable of monitoring each and every cell in its battery pack. On the other end of the spectrum, simple BMSs comprise a basic protection circuit. Majority of BMSs that are used in EVs today monitor a set of modules rather than each and every cell or module resulting in limited control over battery pack.

Key BMS Blocks

Thermal Management Block

Reads temperature and starts cooling or heating operation to maintain the temperature in the optimal range.

Also, it sends signals to ECU if the temperature goes beyond allowable limits. These systems can include both passive and active cooling systems.

Battery Algorithm Block

Estimates state of health and state of charge. Based on the measured values, it calculates current stage with respect to full charge, which is essential for ensuring that the battery is not overcharged.

Measurement Block

Measures cell temperature, current voltage at different places and the ambient temperature.

Capability Estimation Block

Sends information of the safe levels of charge or discharge to ECU and charger unit.

Cell Equalization Block

Compares the highest and lowest cell voltages to apply cell balancing techniques.

Battery Thermal Management

Charging, discharging and ambient temperature are the three factors that impact battery temperature. EV batteries at a lower temperature (<0ºC) are inefficient because of slower reactions which results in lesser power. At higher temperatures (>40ºC), Lithium plating can occur causing irreversible damage to the batteries. The ideal temperature to maintain is between 20ºC and 30ºC. The cooling system does this job with the help of signals from the BMS. The choice of cooling system varies with the heat generation characteristics of the battery.

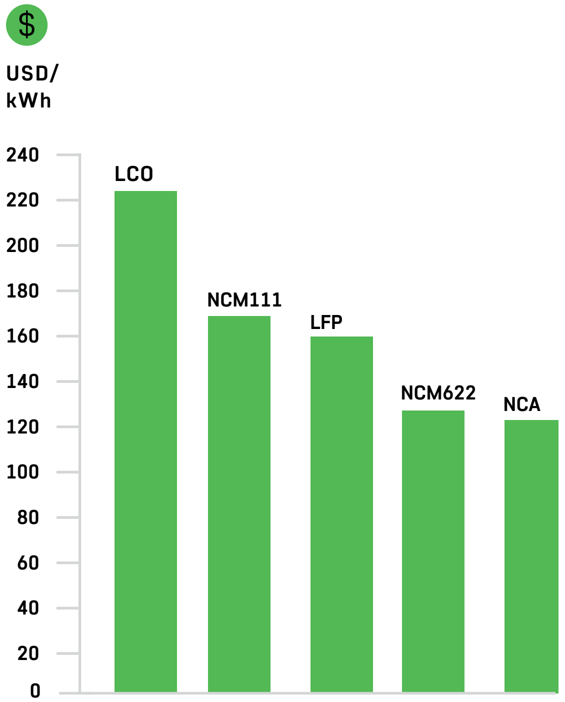
Air cooled systems are lighter and inexpensive but also have lower effectiveness in terms of cooling. They use ambient air and force the air to flow through the battery.

Liquid cooled systems are heavy and expensive compared to air cooled systems. These systems are more effective in cooling the batteries. However, as the number of cells increase, it's difficult to design these systems efficiently. Thermal design is a critical aspect of battery design. While air cooled batteries are cheaper, they have limitations when it comes to large and compact batteries. Bus batteries, despite being large in size, have the benefit of being less compact and can be designed with air cooling.

However, a battery designed for fast charge, like a 3C LFP bus battery would require liquid cooling. Car batteries above 30 kWh usually come with liquid cooling given their compact design. (C or charge speed is a ratio of charging power to battery capacity; e.g. if a 30 kWh battery is charged at a 60 kW power, it is being charged at C=2). The extent of liquid cooling also varies. Depending on the requirement, it could be limited only to the battery pack exterior or could be designed at a cell/module level.

Battery Economics

A battery has three cost components — Cells, BMS and Balance of Pack. Cells constitute 60-70% of the cost, the BMS constitutes 10-15% and the Balance of Pack which includes thermal management and mechanical components like housing, etc. constitutes the remaining 15-20%. The cost split between these systems depends upon the size of the battery pack. Larger battery packs tend to have higher costs skewed towards cells as the Balance of Pack cost does not increase linearly with the battery size.



Basis estimated prices in 2018

EXHIBIT 13 ↘

Comparative battery cost — impact of cobalt

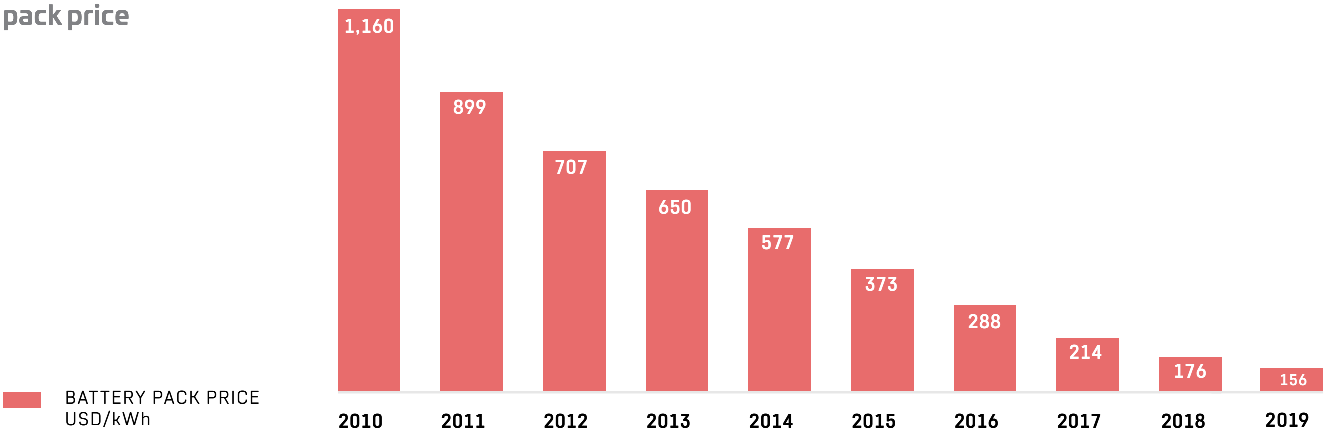
Assumes the following raw material prices

COBALT METAL	USD **50,000** / tonne
LITHIUM HYDROXIDE	USD **15,000** / tonne
NICKEL	USD **15,000** / tonne
COPPER	USD **7,000** / tonne

Battery pack prices have rapidly declined over the past 10 years. According to the widely cited study by Bloomberg, the battery pack prices have dropped from USD 1,160 / kWh to USD 156 / kWh between 2010 and 2019. But more than the precise price points, the data highlights the important facts about the rapid decline in battery prices. As far as the price of batteries in the market is concerned, it actually varies widely depending upon chemistry, scale of demand and design. Especially in India, battery prices are considerably different when compared to the global average numbers. There are two main reasons for that: a) The global average battery prices are heavily influenced by top manufacturers like Tesla – Panasonic who have completely different cost structures on account of material partnerships and massive scale of operation and b) The data represents the large size battery industry (>10kWh) and is not very indicative of the small size battery industry (<10 kWh) which is more prevalent in India.

EXHIBIT 14

Global Li-Ion battery pack price



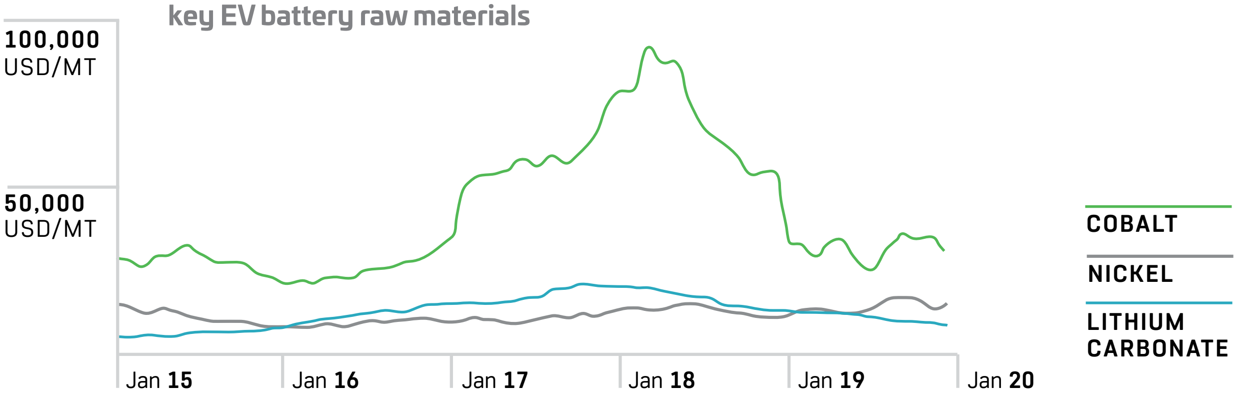
In the Indian market today, the battery pack price is largely in the range of USD 180/ kWh to USD 250/kWh. The prices vary depending on chemistries, cell quality, BMS design and thermal design. 2W batteries with a basic BMS and air-cooling cost between USD 190-220 /kWh. A smart BMS can add up to USD 50 to the battery cost. Car battery packs cost between USD 180-210/ kWh. Fast charging batteries are expensive due to the chemistry as well as sophisticated thermal management systems. At the lower end of the price spectrum are batteries made from low grade cells or second life batteries from China that are as cheap as USD 150-160/kWh.

Raw materials are key to battery economics. Lithium and Cobalt are two important raw materials for cell manufacturing. These materials are rare and exhibit reasonably volatile pricing trends.

There are only 8 countries that produce Lithium and of them three – Chile, Australia and China account for 85% of the total production. Four companies – Talison, SQM, Albemarle and FMC control a majority of the Lithium production.

EXHIBIT 15

Historical price movement for key EV battery raw materials



Analysis by Benchmark Mineral Intelligence suggests that taking into account operational supply and projected supply, there could be supply vs demand gap for Lithium from 2027.

70% of global Cobalt production is currently concentrated in the DRC. Russia, Cuba, Australia and Canada are the next largest suppliers that cumulatively account for 13% of the global production. While the mines are concentrated in limited regions, unlike Lithium, Cobalt production is quite fragmented amongst the producers with the top 3 companies producing less than 40%.

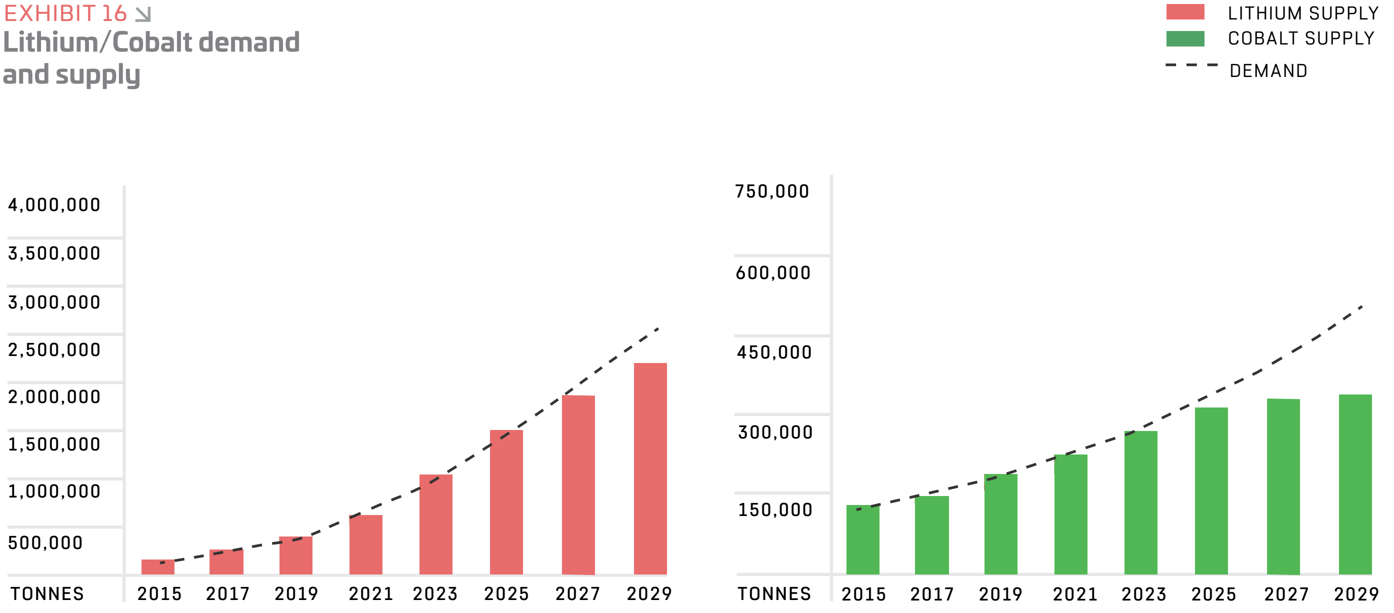
There are several key issues with Cobalt supply.

The DRC is a politically unstable region and has witnessed large scale supply disruptions. In addition, the DRC is mired with controversies surrounding artisanal mining and child labour. Multiple key industry stakeholders have clearly highlighted plans to minimize Cobalt usage in order to avoid sourcing from the DRC.

Unlike Lithium, Cobalt is extracted as a by-product during the production of Copper or Nickel. 90% of the Cobalt produced in the world today is generated as a by-product. This means that all Cobalt expansion projects are dependent on Copper and Nickel demand dynamics.

Apart from the source concentration (in the DRC), 50-60% of Cobalt refining capacity is concentrated in China today.

EXHIBIT 16 ↘
Lithium/Cobalt demand and supply



Battery chemistries of the future

1 /

LI - ION WITH SILICON ANODES

Silicon has much higher specific capacity of (amount of charge delivered per unit weight of electrode) 3,600 mAh/g as compared to 370 mAh/g of Graphite, since a Silicon lattice structure can hold a much larger number of Li-ions as compared to Graphite. Thus, Li-ion batteries with Silicon anodes can have 20-40% higher energy density with the same cathode chemistry.

However, the problem with this technology is Silicon swelling. Accumulation of Li-ions during charging causes anode to expand. In case of Graphite, the change in volume is only 10%. Silicon, on the other hand, undergoes a volume change in excess of 300%. This large volume expansion creates stress on anode material, causing it to fracture or crumble and detach from the current collector. The expansion affects the rest of the cell structure as well, especially the solid electrolyte interphase.

Leading companies working on Silicon anode technologies are Sila Nanotechnologies (USA), Nexeon (UK) and Wacker Chemie (Germany).

2 /

METAL AIR

Metal-Air batteries use metal as anode and air as cathode. These batteries have exceptionally high energy densities. Li-Air has the highest theoretical energy density of ~11,500 Wh/kg.

Other metals suitable for such batteries are Iron, Zinc, Magnesium, Aluminum, Sodium and Potassium. Metal-Air batteries can either use a solid electrolyte or a liquid electrolyte. The manufacturing process involving solid electrolytes faces similar challenges as those discussed in Solid State batteries.

Currently, focus is on Metal-Air batteries with liquid electrolytes. Lithium, Sodium and Potassium are highly reactive in liquid electrolyte and thus, need a solid electrolyte. Hence, more researched Metal-Air chemistries include Aluminum, Zinc and Manganese.

Aluminum-Air chemistry has been keenly explored given the abundant availability of Aluminum and its safety of usage. Phinergy (invested by Alcoa and Indian Oil) is a leading Israel based company in the Aluminum-Air space. In India, Log9 Materials (invested by Sequoia) is also engaged in the same space.

The key challenges for Metal-Air batteries are —

A/ Unwanted solid electrolyte interphase layer formation – leading to loss in battery performance

B/ Dendrite growth on the anode leading to short circuits

C/ Finding an electrolyte that meets all the desired properties and stability of the cathode materials

3 /

SUPERCAPACITORS

Capacitors have two electrodes separated by a dielectric material. Energy is stored electrostatically in a capacitor as against through chemical reactions in batteries. Capacitors have a very high power density, therefore, they can be charged rapidly and also, can provide very high power.

However, traditional capacitors have very low energy density of <5 Wh/kg, making them unsuitable for energy storage applications. Supercapacitors have electrodes made with special materials like Graphene – which enable them to hold a much larger amount of energy without losing on high power density. Currently, supercapacitors with energy densities as high as 60-200 Wh/kg have been developed and they make a strong case for adoption in electric vehicles provided that the technology can be scaled up.

High quality materials that can hold such high energy (which is often associated with higher cell voltage) and can also withstand the high voltages is the key bottleneck in development of supercapacitors. Technological developments in Graphene chemistry is an encouraging sign for supercapacitors, yet the technology is a distant possibility.

While supercapacitors might take a long time to be able to replace batteries, they are already being used as a power assist in vehicles.
The applications leverage the high power density of supercapacitors to assist the battery while accelerating rapidly and then recharges the capacitors during regular operation.

4 /

Li - METAL

Lithium metal batteries use Lithium anodes rather than Graphite as in the case of Li-ion batteries. Lithium is much lighter than Graphite and has twice the energy density vis-à-vis Li-ion batteries. However, the main issue with the Li-Metal battery is its low life cycle. This is largely attributed to metal deposit formation that depletes active Lithium and creates unwanted Solid Electrolyte Interface (SEI). Li-Metal batteries are most likely to get commercialized along with the development of solid-state batteries, as they are difficult to design using a liquid electrolyte due to the high reactivity of Lithium in an aqueous medium. In that sense, Li-Metal batteries would not only be a subset of solid-state batteries but probably the largest subset as well.

5 /

ORGANIC BATTERIES

Organic batteries use organic radical polymers as an electrode, eliminating metals from batteries. They are eco-friendly as the materials are biodegradable. Theoretically, organic batteries can offer the same or even better performance as compared to Li-ion batteries. They are also suitable for more efficient form factor designs as the organic electrode materials are flexible.

Organic batteries could be the ultimate destination for the evolution of battery technologies but these batteries are still decades away from commercial applications.

6 /

SOLID STATE BATTERIES

The current Li-ion batteries use liquid or polymer gel electrolytes. These electrolytes are flammable and are the main reason behind the safety concerns related to Li-ion batteries. In solid state batteries, this liquid/ polymer gel electrolyte is replaced by a solid electrolyte which is non-flammable, takes up lesser space and is a faster conductor of ions, thereby making solid state batteries lighter, smaller, safer and more powerful. A battery with a Li-anode and a LiI/Al_2O_3 electrolyte can offer 2.5x the energy density of traditional Li-ion batteries.

The technology is not yet ready for large-scale commercial production. One of the key problems with this technology is the formation of metal deposits when Lithium anodes are used, often causing such deposits to penetrate the electrolytes. Identifying uniform material for electrolytes and producing it commercially at low cost is a key hurdle for solid state batteries. Also, solid state batteries cannot function at low temperatures as the solid electrolyte's conductivity decreases with temperature.

Major OEMs like Ford, Hyundai, Nissan, Toyota, and Volkswagen have invested in this technology. Leading companies in this space are Sakti3 (USA) – Funded by Dyson, QuantumScape (USA) – Funded by Volkswagen.

7 /

LITHIUM SULPHUR

Lithium Sulphur (Li-S) batteries use Sulphur as a cathode material and Lithium as an anode. The biggest advantage of Li-S battery is its high energy density of 600 Wh/kg. In addition to the high energy density, Sulphur is abundantly available in nature and is also safe for use, unlike the current cathode materials which are not only scarce but are also unsafe. Li-S batteries can be used with very high depth of discharge and do not require any top up charging, which means they can be stored or left uncharged for a long time without having any effect on battery health.

The biggest challenge with this technology is that the underlying chemical reaction is complex and its mechanism is not fully established. This makes it difficult to model the cell performance and hence, the batteries require extremely complex algorithms.

There are several other issues with Li-S technologies like volume expansion of the cathode, unwanted reactions with electrolytes and polysulfide shuttling that results in degradation of the battery.

Oxis Energy is the leading company in this space. Other notable players working on this technology are Sion Power and Sony.

EXHIBIT 17 ↘

Snapshot of new battery technologies

Limitations

+ CATHODE
− ANODE
▯ ELECTROLYTE
⚡ SPECIFIC ENERGY

Li-ion NCM

CURRENT TECHNOLOGY

Safety and energy density limitations

− **Graphite**
+ **Li+NCM**
▯ **Non-metallic Liquid/Polymer Gel**
⚡ **200-300 Wh/Kg**

Li-Sulphur

Complex reaction

Volume expansion at cathode

− **Li**
+ **Sulphur**
▯ **Non-metallic Liquid/Polymer Gel**
⚡ **600-700 Wh/Kg**

Li-Metal

Metal deposits lead to low cycle life

− **Li**
+ **Metal Compounds**
▯ **Solid**
⚡ **600-700 Wh/Kg**

Solid State

Metal deposits at anode

Low performance at low temperatures

− **Graphite**
+ **Li+NCM**
▯ **Solid**
⚡ **500-600 Wh/Kg**

Metal Air

Formation of unwanted layer at electrode

Dendrite growth on anode

− **Li/Al/Zn**
+ **Ambient Air**
▯ **Non-metallic Liquid/Polymer Gel**
⚡ **1000-1200 Wh/Kg**

Li-ion with Si anodes

Silicon swelling causing cell damage

− **Silicon**
+ **Li+NCM**
▯ **Non-metallic Liquid/Polymer Gel**
⚡ **250-400 Wh/Kg**

Super Capacitors

Provides high power but low energy density

Can be used in combination with batteries

− **NA**
+ **NA**
▯ **NA**
⚡ **60-200 Wh/Kg**

Organic Batteries

Poor electrical conductivity

High solubility of interactive species

− **Organic Polymers**
+ **Organic Polymers**
▯ **Organic**
⚡ **NA**

Fuel Cell

Too nascent to be a threat for batteries

A /

FUNCTIONING

A fuel cell is fundamentally different as compared to a battery. While a battery only stores electricity and needs recharging, a fuel cell produces energy by consuming fuel (Hydrogen). In these cells, Hydrogen reacts with Oxygen to form water and the reaction creates a flow of electrons in an external circuit, resulting in an electric current which is used to drive the motor.

Current fuel cell cars come with a battery as well, since the fuel cell design is not robust enough to cater to the sudden power demand on rapid acceleration. Even if the fuel technology was to become flexible enough to cater to large variations in power demand, batteries would be needed for storing electricity generated through regenerative braking, an auxiliary system (for heating up, etc.) during start-up of the fuel cell and to power other low voltage systems within the car.

B /

CHALLENGES

Prima facie, the fuel cell technology looks clearly superior to battery technology and one might think that batteries do not have a long-term future. However, there are several challenges associated with Hydrogen economy.

The majority of Hydrogen that is used today comes from fossil fuels by a process called reforming. To use fossil fuel to produce Hydrogen only for use in EVs would not make sense as it would only be shifting the source of pollution away from the tail pipe to Hydrogen production plants. Also, the overall system would be less efficient than ICE vehicles on a well to wheel efficiency.

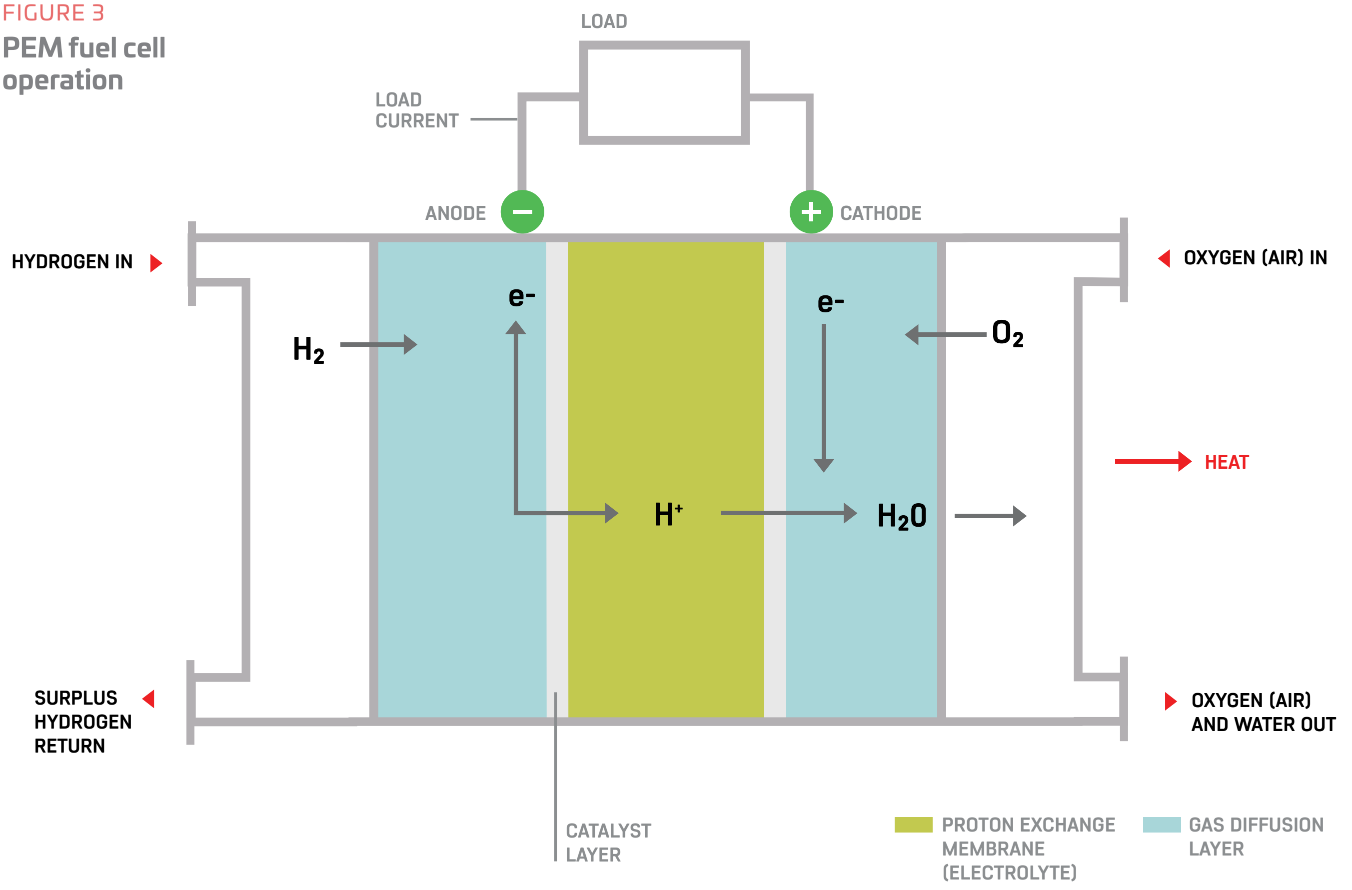
The sustainable option to cater to Hydrogen demand is through water. Water can be converted into Hydrogen and Oxygen through electrolysis. The electricity for electrolysis can come from the grid. Again, for truly addressing the pollution problem the electricity has to come from renewable sources.

Advantages of a fuel cell

Hydrogen has a specific energy of ~40,000 Wh/kg as compared to Li-ion which is in a range of 160-280 Wh/kg. Hence, fuel cells are extremely suitable to offer higher driving range. The weight compounding problem (weight of vehicle increasing with range of vehicle) is not an issue with fuel cell technology. Also, refuelling of Hydrogen can be done very quickly, unlike the long charging time needed for batteries.

FIGURE 3

PEM fuel cell operation



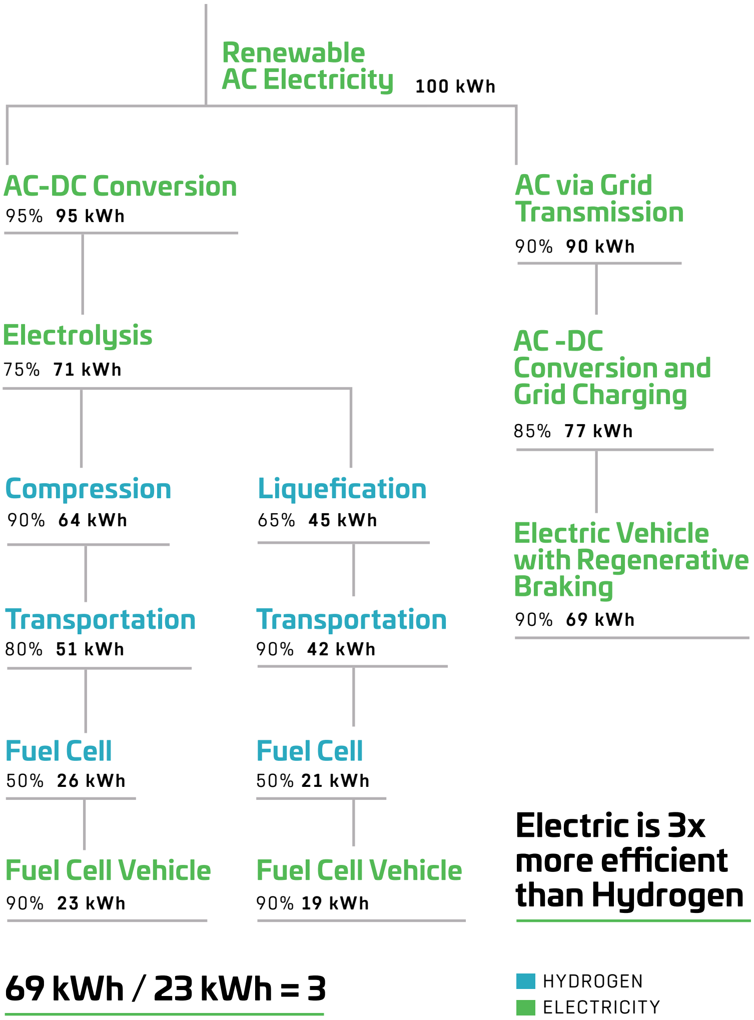
Is fuel cell a superior technology?

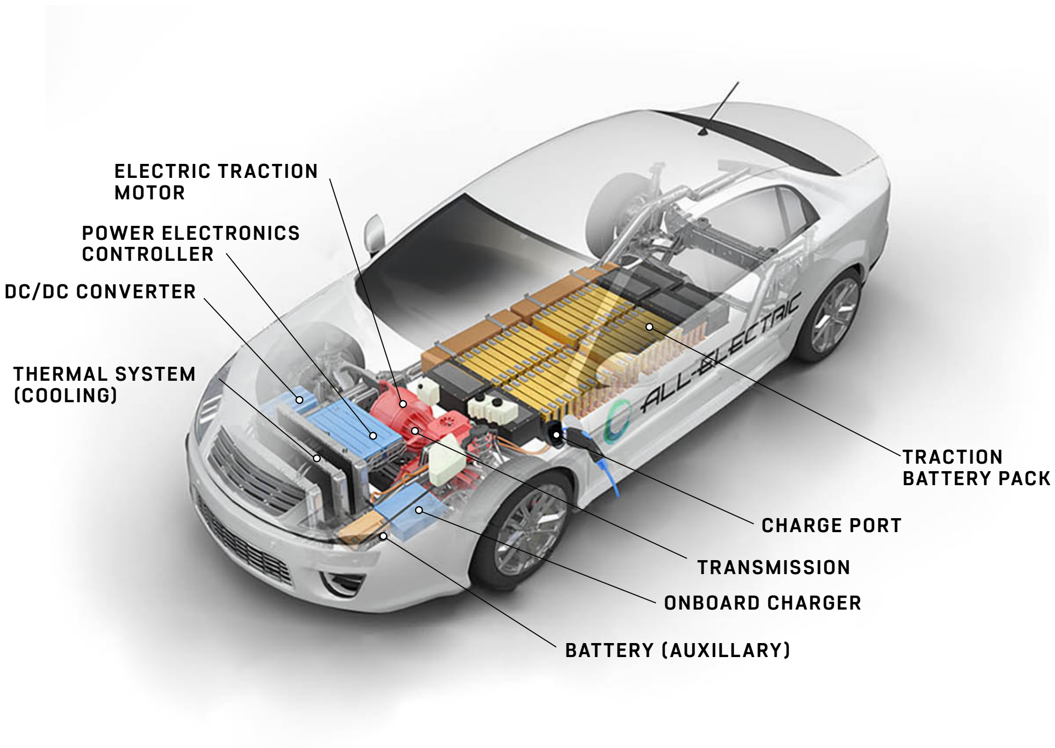
The answer is probably yes. But on a well to wheel ecosystem comparison, the advantages of fuel cells against batteries are negated both in terms of efficiency and feasibility of creating an ecosystem.

A number of countries and companies have increased their fuel cell focus. Japan has taken a lead in pushing for a Hydrogen economy. Countries like the USA, France and China are also doing work to develop fuel cell technologies. However, the space is very nascent and the ecosystem is non-existent. Thus, fuel cells are unlikely to be a threat for battery based electric vehicles in this decade at least. In the long term, one will have to wait and see how the fuel cell landscape evolves.

EXHIBIT 18 ↘

In terms of well to wheel efficiency, the BEVs have an edge over the fuel cells as shown in the figure below





Introduction to other key components and systems

1 /

MOTORS

An electric motor performs the same function as an engine does in an ICE vehicle – it propels the vehicle. It is the second most critical component after the battery, and along with the battery, replaces the engine in an ICE vehicle. Different types of motors have different characteristics and it is important to choose the right type of motor for an electric vehicle.

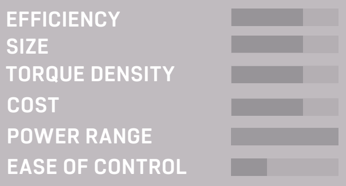
The most commonly used motors in EVs are Brush-Less Direct Current (BLDC) Motor, Permanent Magnet Synchronous Motor (PMSM) and Induction Motor (IM).

Apart from these, Switched Reluctance Motors are becoming increasingly popular for application in electric vehicles. They have higher power density, higher efficiency and longer power range. Tesla, which traditionally has been using Induction Motors, introduced a new motor technology in Model 3 - Permanent Magnet Synchronous Reluctance Motor. A similar technology is used by BMW for their model - BMW i3.

BLDC **Brush-Less Direct Current Motor**

A BLDC Motor has a rotor made of permanent magnets and a stator that is electronically commutated

BLDC motors can be configured in two ways – in-runner (rotor inside stator) or out-runner (rotor outside stator)



- ✓ More efficiency than an Induction Motor
- ✓ More compact and lighter
- ✓ Higher torque density

- ✕ Higher cost because of permanent magnets
- ✕ Shorter constant power range
- ✕ Decreased torque with increased speed

APPLICATIONS

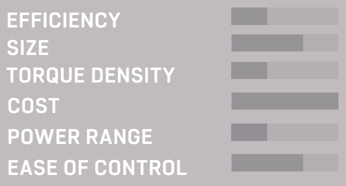
Light electric vehicles like 2W/3W

EXAMPLES

Out-runner: Hero Electric Optima
In-runner: Ather 450x

PMSM **Permanent Magnet Synchronous Motor**

A PMSM is similar to BLDC with the key difference in type of input current. It works on AC current



- ✓ No torque ripple
- ✓ More energy efficient than BLDC Motors
- ✓ Suitable for in-wheel application
- ✓ Operable in a wide speed range

- ✕ Costlier than BLDC Motors
- ✕ Iron loss at high speeds during in-wheel operation resulting in heat

APPLICATIONS

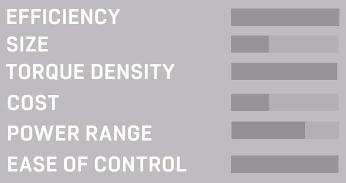
High performance applications like cars and buses

EXAMPLES

Nissan Leaf, Hyundai Kona, Toyota Prius

IM **Induction Motor**

In an IM, AC current in the stator induces current in the rotor which creates a magnetic field that chases the stator's magnetic field. These motors do not use permanent magnets



- ✓ Cheaper, easier to design and more robust
- ✓ No dependency on rare earth magnets

- ✕ Low starting torque under traditional v/f operation method; for high starting torque need complex controllers that work on FOC
- ✕ Requires complex inverter circuit

APPLICATIONS

Performance oriented applications from 2W to buses

EXAMPLES

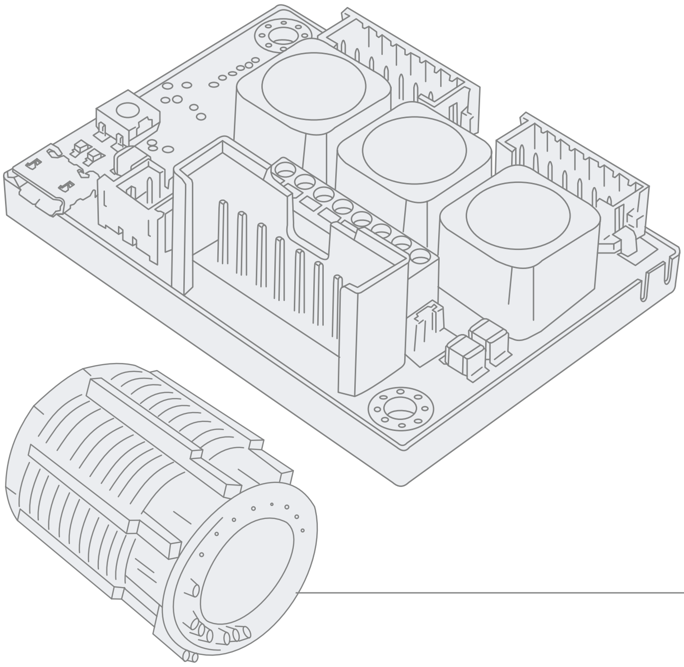
Tesla Model S, X

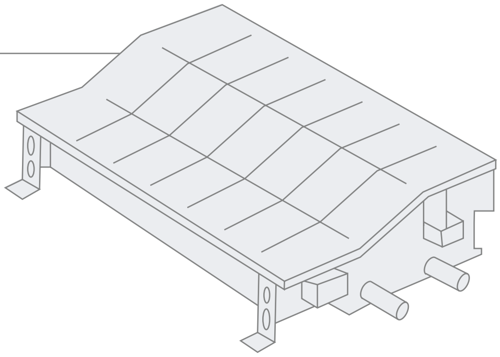
2 /

CONTROLLERS

The controller is somewhat of an intermediary between a battery and a motor. It is essentially the brain of an EV powertrain as it estimates how much energy needs to be supplied to the motor for the EV to function smoothly on a road. The controller receives an indication of how much power is demanded by the driver basis the movement of the accelerator pedal. The controller then assesses the demand, considers the current operating parameters, and calculates how much energy should flow from the battery to the motor.

The controller takes care of a variety of other functions within the EV powertrain as well. Reverse rotation, when required, and regenerative braking are examples of some of the other functions. A good controller is essential for the efficient use of energy stored in a battery, a smooth drive and vehicle safety.



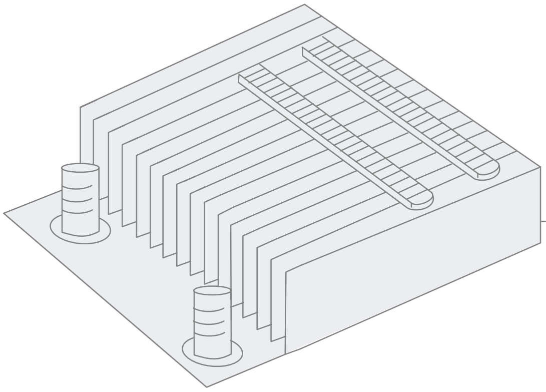


3 /

E- AXLES

E-axles combine motor, power electronics and transmission into a single casing. This allows for neat packaging, simple integration of various components and improved efficiency. It acts as the powertrain of an electric vehicle. The design of E-axles vary based on the type of vehicle configuration and the components used for integration. Designing an E-axle with optimal thermal management will be a key consideration for OEMs, as the performance of the motor will be impacted by this. This component provides an opportunity for traditional axle companies to continue their business but with additional investments for developing advanced design capabilities.

In addition to the components discussed here, electric vehicles also require extensive design changes to the components that are common with ICE vehicles. For example, the chassis design of an EV is completely different to an ICE vehicle. Wiring harness specifications are very different as the voltage levels in EVs are very high. The impact an EV has on traditional ICE components has been elaborated in a later section.

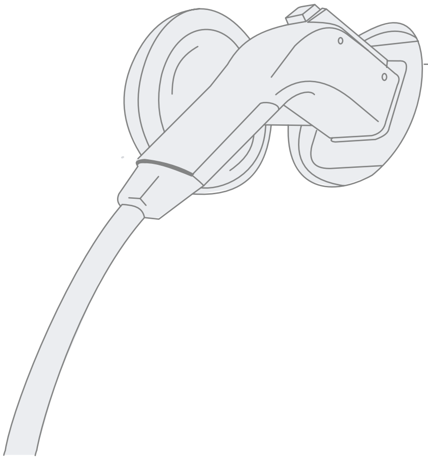


4 /
INVERTERS

An inverter converts DC current from a battery into AC current for a motor (for AC motors only). The inverter can change the speed at which the motor rotates by adjusting the frequency of the alternating current. It can also increase or decrease the power or torque of the motor by adjusting the amplitude of the signal.

5 /
DC-DC CONVERTERS

DC-DC converters are used to either step up or step down the voltage as per the requirement of various components within the EV architecture. The electric vehicle battery stores electricity at a very high voltage. Step down DC-DC converters are used to supply energy to smaller systems like infotainment devices. In case a DC motor is being used to drive the electric vehicle, it often requires a higher voltage than the battery voltage and a step up DC-DC converter can be used.



6 /
ONBOARD CHARGERS

On-board chargers enable users to charge vehicles by plugging them into an AC source, either at home or at public charging stations. These are essentially rectifiers that convert AC to DC that have several safety and control logics built in. Onboard chargers have basic configuration and take time to charge a vehicle. When a vehicle is charged using a Fast DC charger, the onboard charger is bypassed and the battery is charged directly.

EV Charging

Charger Schematic — Charging Basics

Unlike an ICE vehicle, which can be refuelled within minutes at a gas station, EVs need to be charged, and this charging process is significantly slower than refuelling. EV charging is an important aspect of an EV ecosystem, considering the customer's anxiety towards driving range and charging time.

EV chargers, also known as EVSEs (Electric Vehicle Supply Equipment), are used to charge a vehicle. The speed at which an electric vehicle can be charged is dependent on the power of a charger.

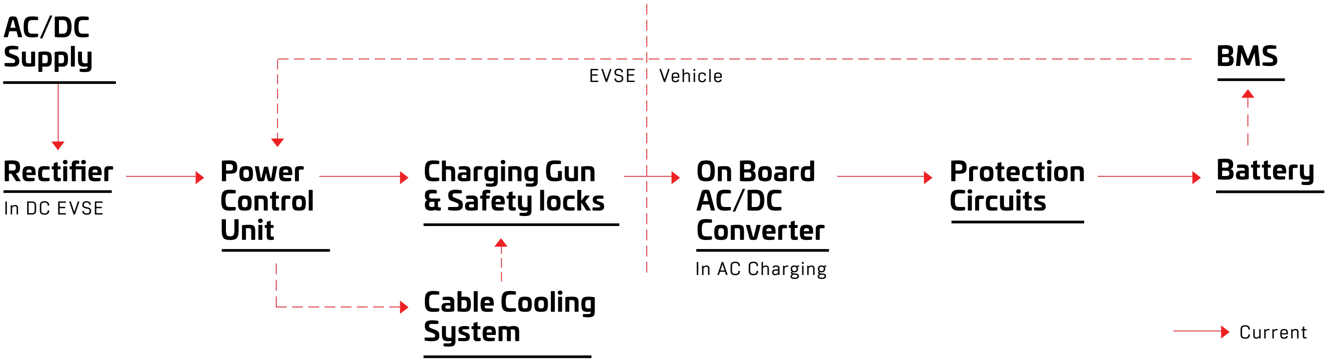
The charging speed is often limited by the battery design. Charging a battery faster than the maximum specified rate can damage the battery.

The major components of an EV charger are rectifier, power control unit and charging gun. A rectifier is only present in DC chargers and is used to convert AC power into DC power. After the power is converted to DC, the power control unit takes signal from the BMS of the vehicle and supplies the requisite power to charge the battery. There are safety locks that ensure that the current does not flow from the device, till it is connected to the vehicle.

DC Chargers with high power output (~100 kW+) may require liquid cooled cables and high stress materials.

EXHIBIT 19

EV charging operation using EV Chargers



EV chargers are characterized mainly on the following four parameters —

Power and Voltage levels

Based on the power and the range of voltages that are supported by EV chargers, they are classified into three levels. A) <3.3 kW are Level 1 chargers, B) between 3.3 and 22 kW are Level 2 chargers, and C) >22 kW are Level 3 chargers.

AC or DC

If AC power is used, then the vehicle needs to have a device that can convert the power to DC. Generally, all vehicles have an onboard AC-DC converter to enable charging using AC or DC. AC chargers don't require a rectifier and are cheaper.

However, in case of AC chargers, there are limitations on the peak power with which vehicles can be charged, which limits the rate of charging and increases the time required to charge.

Mode

The mode of an EV charger is defined to decide its charging application and level of communication between the charger and the vehicle. Globally, there are four modes

MODE 1

Connection with the vehicle is through a standard socket without any other communication

MODE 2

Connection with the vehicle is through a standard socket, along with other communication and safety features

MODE 3

Connection between the AC charger and the vehicle is through a wall mounted AC charger, with communication and safety features between them

MODE 4

Connection between the DC charger and the vehicle is through a wall mounted DC charger, with a high level of communication and safety features between them

Charger Types

A charger type typically refers to the output socket and the connector used by a charger. It also includes the high-level communication protocols between the charger and the vehicle which are required for Mode 4 charging. Globally, there is a wide variation between the different types of sockets used, due to discretion of manufacturers and OEMs and also due to presence of several international bodies governing the relevant standards. International Electrotechnical Commission (IEC) is the leading international standardization organization for EV chargers. These standards are generally adopted by different trading zones and national organizations.

Efforts to consolidate charging standards are underway in Japan and China. They plan to develop a new standard which is backward compatible with both, GB/T and CHAdeMO standards.

EXHIBIT 20

Popular global charging standards

AC CHARGERS

1 /

Type 1 AC Charger

USED IN
Japan & USA

MAXIMUM POWER
7.4 kW

2 /

Type 2 AC Charger

USED IN
The EU (except France and Italy)

MAXIMUM POWER
4.4 kW

3 /

Type 3 AC Charger

USED IN
France & Italy

MAXIMUM POWER
22 kW

DC CHARGERS

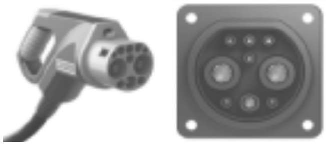
4 /

CHAdeMO

COMMUNICATION PROTOCOL
Control Area Network (CAN) for Communication

USED IN
Japan, Parts of USA & Europe

MAXIMUM POWER
400 kW DC Charging



5 /

GB/T

COMMUNICATION PROTOCOL
Control Area Network (CAN) for Communication

USED IN
China

MAXIMUM POWER
237.5 kW DC Charging

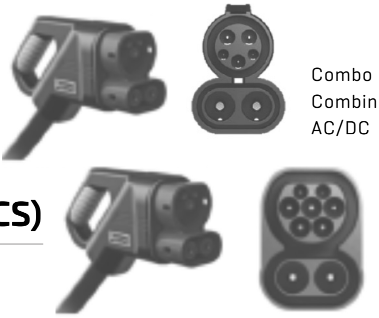
6 /

Tesla Super Charger

COMMUNICATION PROTOCOL
Control Area Network (CAN) for Communication

USED IN
USA, Europe for Tesla users

MAXIMUM POWER
135 kW DC Charging



7 /

Combined Charging System (CCS)

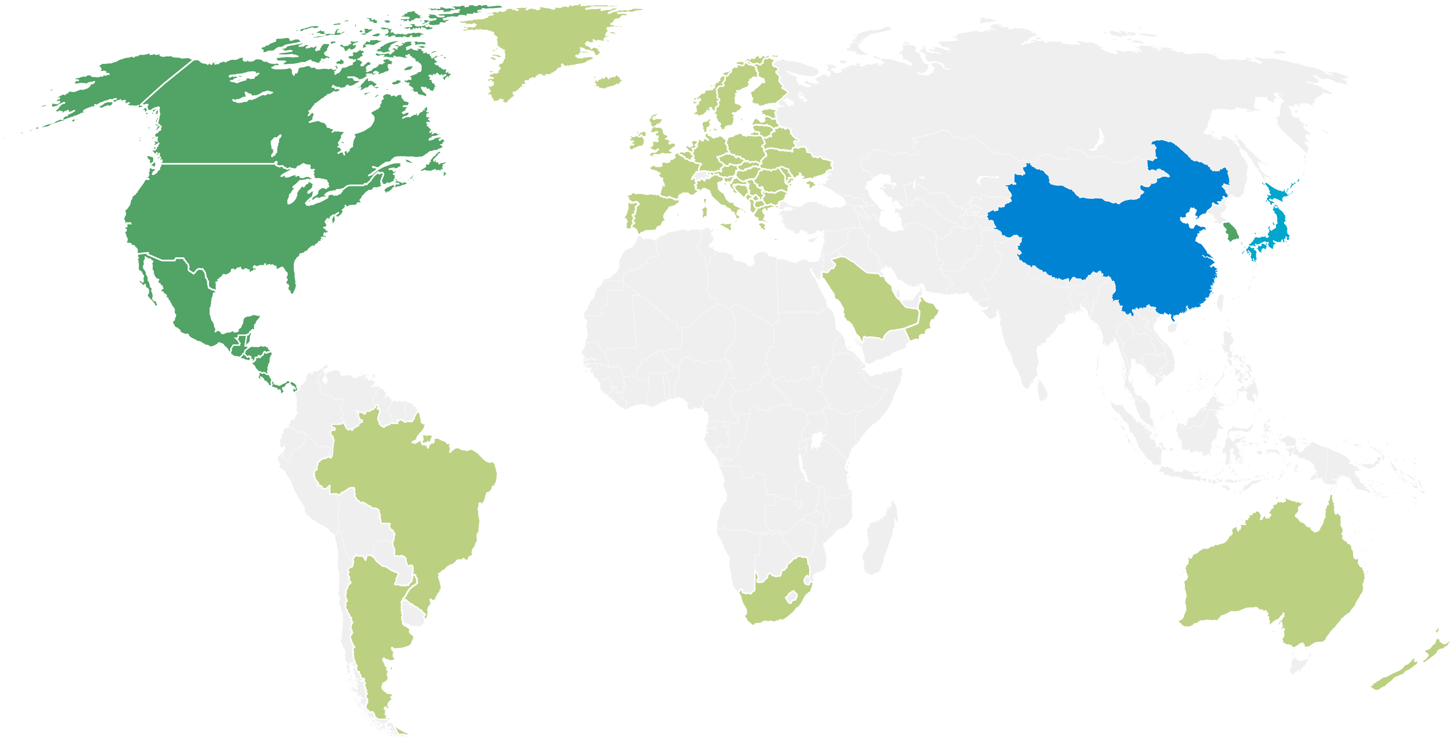
COMMUNICATION PROTOCOL
Power Line Communication (PLC) for communication which is more complex and compatible with Vehicle to Grid (V2G) Charging

MAXIMUM POWER
43 kW AC & 400 kW DC

USED IN
Europe & USA

EXHIBIT 21

Region-wise EV charging standards



CCS 1

NORTH
AMERICA &
SOUTH KOREA

Tesla

USA

CCS 2

EUROPE
ARGENTINA
BRAZIL
SOUTH AFRICA
SAUDI ARABIA
OMAN
AUSTRALIA
NEW ZEALAND

GB/T

CHINA

CHAdeMO

JAPAN

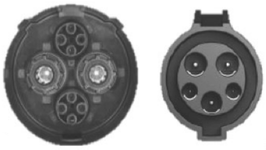


EXHIBIT 22

EV charging standards summary

PARAMETER	SLOW CHARGERS		FAST CHARGERS	
LEVEL	Level 1	Level 2	Level 3	Level 3
AC OR DC	AC	AC/DC	AC	DC
POWER RANGE	<3.7 kW	3.7 – 22 kW	22 – 43.5 kW	<400 kW
MODE	Mode 1 and 2	Mode 3	Mode 3	Mode 4
TYPE	Domestic sockets	IEC Type 1 IEC Type 2	IEC Type 2 IEC Type 3	CCS Combo 1 & 2 CHAdeMO, GB/T DC and Tesla connector
PLACE OF USE	Home	Home/Public	Public	Public
VEHICLES	2W, 3W, Cars	2W, 3W, Cars	Cars and Buses	Cars and Buses
CUSTOMERS	OEM/Retail	OEM/Retail, Charging Operators	Charging Operators	Charging Operators

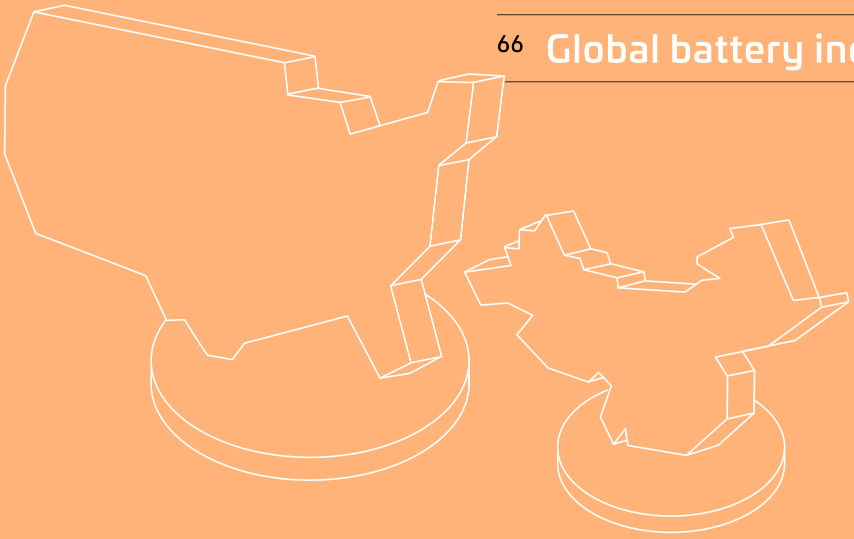
India's stance on EV Charging

India has still not formally adopted any specific charging standard. Over the years, the central government has tried to come up with guidelines to assist the charging ecosystem.

The government has been flexible around standards and OEMs have been making their choice independently. As the industry picks up and adoption increases, a formal charging standard might be adopted by the country.

03

Global EV Industry



Global EV Industry

Electric Vehicles — A common dream across the world

The first electric cars were developed in the early 1800s and after almost 200 years, Electric Vehicles are finally taking off at a global level. Global electric car parc (vehicles on road) crossed 7 million units in 2019 with annual sales crossing 2.2 million units. China has moved way ahead in the EV adoption race with a whopping 53% share of the global electric car sales in 2019. Europe and the USA are the next largest markets with 26% and 14% market share respectively. Norway, Iceland and Netherlands remain leaders in EV penetration with electric cars representing 56%, 25% and 14% respectively of their annual car sales.

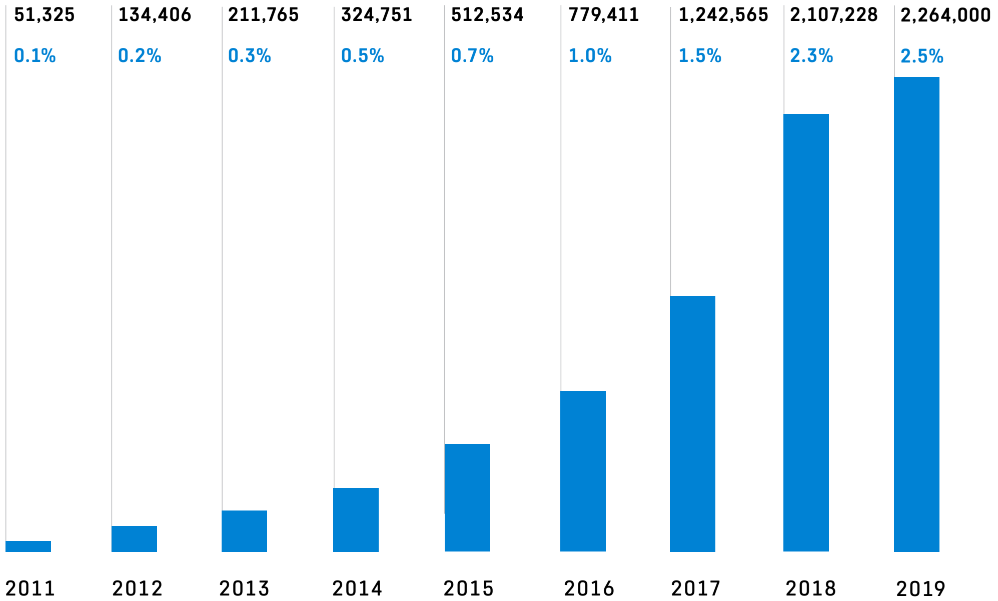
Tesla has been a game changer for electric vehicles. It changed the perception of EVs from just a green car that is good for the environment to an incredibly powerful and smart product. A large number of things have changed since Tesla entered the EV space. Government policy directions are clearer, and technology has reached a point where EVs are closer to TCO parity vs ICE vehicles. This has fuelled traction in large OEMs for developing EV platforms.

Tesla leads the EV sales chart with 367K units sold in 2019 - a 50% growth over 2018. BYD is the second largest player with 229K unit sales. BAIC, BMW, and Nissan are the other leading OEMs in the EV space currently. Tesla's Model 3 (13%), BAIC EU-Series (5%) and Nissan Leaf (3%) were the three top selling models of 2019.

SOURCE Statista, EVVolumes.com

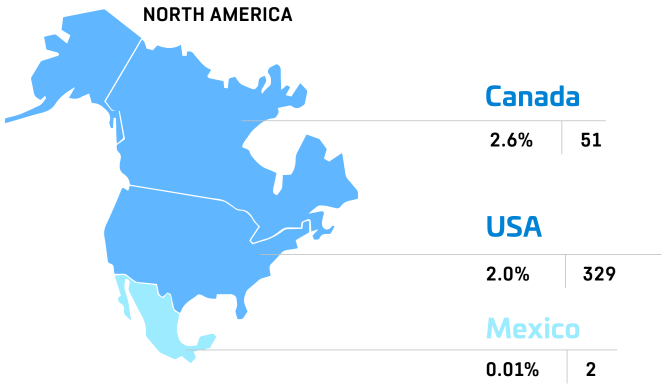
EXHIBIT 23 ↘

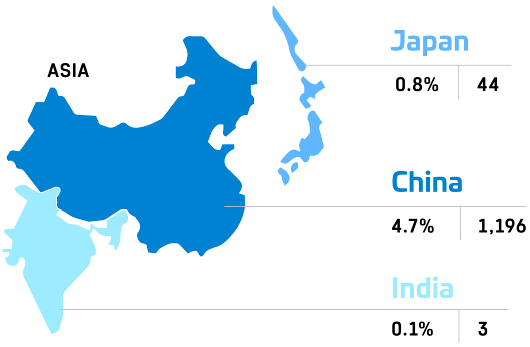
Snapshot of global EV industry

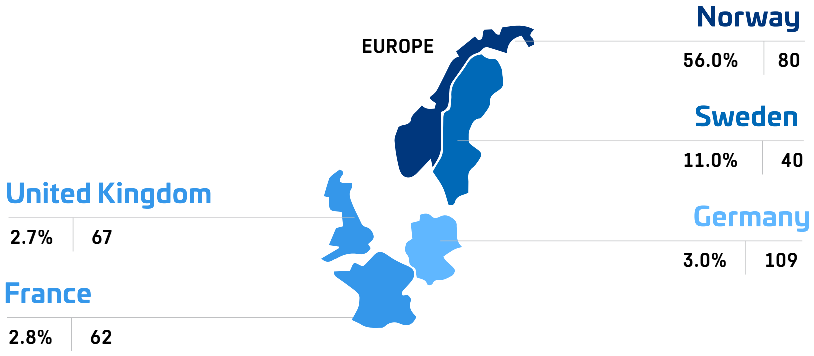


XX% EV PENETRATION

▬ GLOBAL EV SALES







EV sales penetration

LOW HIGH

EV sales penetration	EV sales (in'000 units)

Maps are not to scale
They are representational

EXHIBIT 24 ↘

Snapshot of key OEMs

OEM	GEOGRAPHIES PRESENT	KEY MODELS	2019 UNIT SALES (in 000)	TARGET
Tesla	US, Europe, China	Model 3, Model S, Model X	367	**2020** - 1 mn sales
BYD	China	Yuan, E series, Tang	229	**2025** - Global #1 player
BAIC	China	EU-Series, EC-Series, IX-Series	160	**2025** - 100% of its PV sales
SAIC	China	Baojun E-series, Roewe Ei5	134	**2025** - Electrify all models
BMW	Japan, US, China, Europe	i3, 530Le, 225xe Active Tourer	129	**2025** - 20% of its PV sales
Nissan	Japan, US, Europe	Leaf	82	**2025** - 1 mn sales
Volkswagen	US, China, Europe	e-Golf, Passat GTE	77	**2023** - 1 mn sales **2025** - 3 mn sales
Hyundai	S Korea, Europe	Ioniq, Kona	71	**2025** - 0.5 mn sales & 44 new models
Toyota	Japan	Prius PHEV	56	**2025** - 0.5 mn sales **2030** - 5 mn+ sales
Kia	S Korea, Europe	Nero EV, Nero PHEV	55	**2025** - 0.5 mn sales & 11 new models
Mitsubishi	Japan, Europe	Outlander PHEV	53	**2025** - 2 mn sales from JV platform
Renault	Europe	Zoe	48	**2022** - 12 new models
Volvo	Europe	XC60 T8 PHEV	42	**2025** - 50% of its PV sales
Chevrolet	S Korea, US	Chevy Bolt	35	**2023** - 20 new models **2026** - 1 mn sales
Daimler	Europe	E300e/de, Fortwo	23	**2025** - 20% of its PV sales
Audi (VW)	US, Europe	e-Tron	21	**2025** - 0.8 mn sales
Jaguar	US, Europe	i-Pace	17	**2025** - 100% of its PV sales
Honda	Japan	NA	NA	**2030** - 60%+ of its PV sales
Ford	US	Mustang Mach-E (Upcoming)	NA	**2025** - 6 models

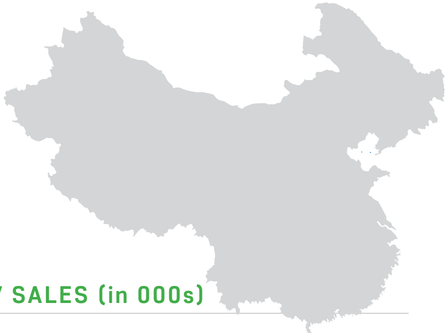
Evolution of Key Markets

1 / CHINA

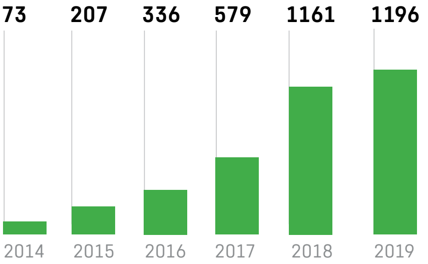
China is winning the Electric Vehicle race

China has outpaced the world in EV adoption by a huge margin. From just under 20,000 electric car sales in 2013, today, China represents 53% of the global electric car market with sales of 1.2 million units in 2019. A generous central subsidy program pumped in close to USD 60 billion into the electric vehicles ecosystem over the past decade. To put that number in context, India's FAME – II scheme's subsidy budget of USD 1.4 billion (over 3 years) is almost equal to the annual subsidy that China's largest EV manufacturer, BYD, receives from its government.

China's central subsidy program started in 2009 covering 10 cities and 1,000 electric cars. Since then, every year the program has expanded to provide a larger momentum to the industry. However, in 2019, subsidies were reduced for the first time. The subsidy structure is further supported by a variety of other policy initiatives.



EV SALES (in 000s)



INFRASTRUCTURE

270,000 + EV Chargers

200 + GW Battery Capacity

4.7 % 2019 EV Penetration

A /

Direct Subsidies —

I /

When the subsidies were launched way back in 2009, they offered benefits to the tune of USD 8,000 per vehicle which covered 30-50% of vehicle's cost. Initially, there were minimal technical/performance restrictions on vehicles to be eligible for subsidy. However, over the years, greater focus has been given to higher range vehicles.

II /

China was aiming to phase out subsidies from 2020. However, the changed subsidy structure has affected the Chinese EV industry in 2019. The EV sales in 2019 have grown by a mere 4% y-o-y compared to 62% y-o-y growth in 2018. Sales in the months of Sep-Nov 2019 were down by more than 30% y-o-y. However, the scenario slightly improved in Dec 2019, in which the EV sales decline was 22% y-o-y.

III /

Due to this decline, the government has decided to reduce the pace of subsidy cuts and has planned not to have any cuts in 2020.

EXHIBIT 25 ↘

EV sales in china y-o-y change in 2019

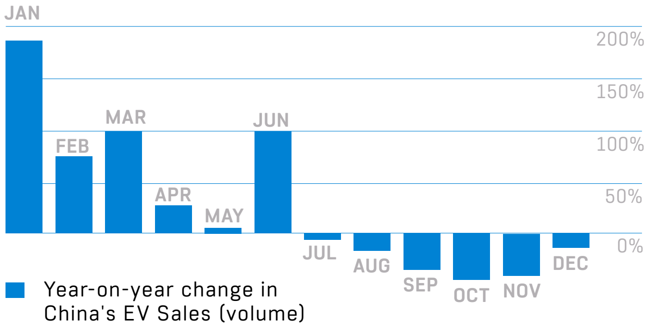
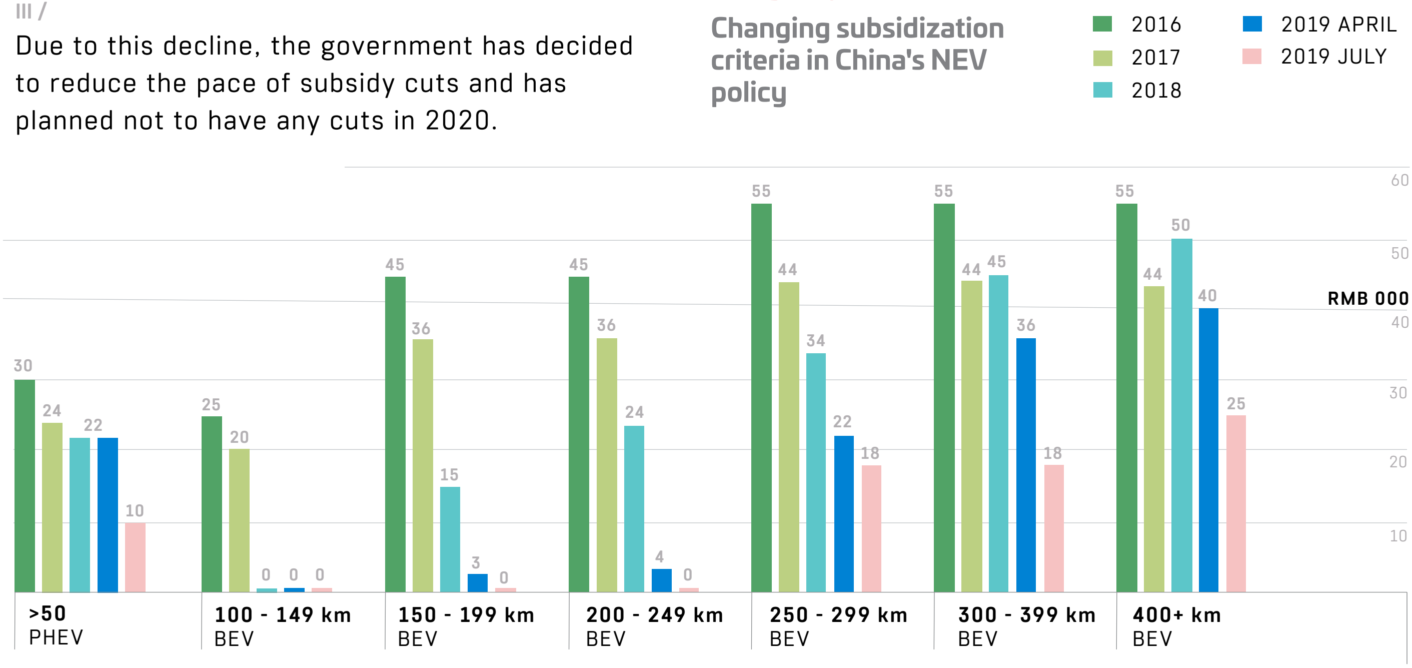


EXHIBIT 26

Changing subsidization criteria in China's NEV policy



B /

EV quota and CAFC —

The electric car quota policy requires automakers to generate EV credit points starting from 2019. Automakers are required to earn credit points from NEVs equivalent to 10% of the total vehicles produced in 2019, rising to 12% in 2020.

By 2020, they are required to meet the corporate average fuel consumption (CAFC) target of 5 litres per 100km.

Meeting these two policy guidelines necessitates the OEMs to achieve significant adoption of EVs into their overall sales.

D /

Focus on charging infrastructure —

China has put up massive charging infrastructure that is denser than all major (EV adopted) countries. China has 270K publicly accessible charging points (50% of the world), followed by the USA which has 55K points.

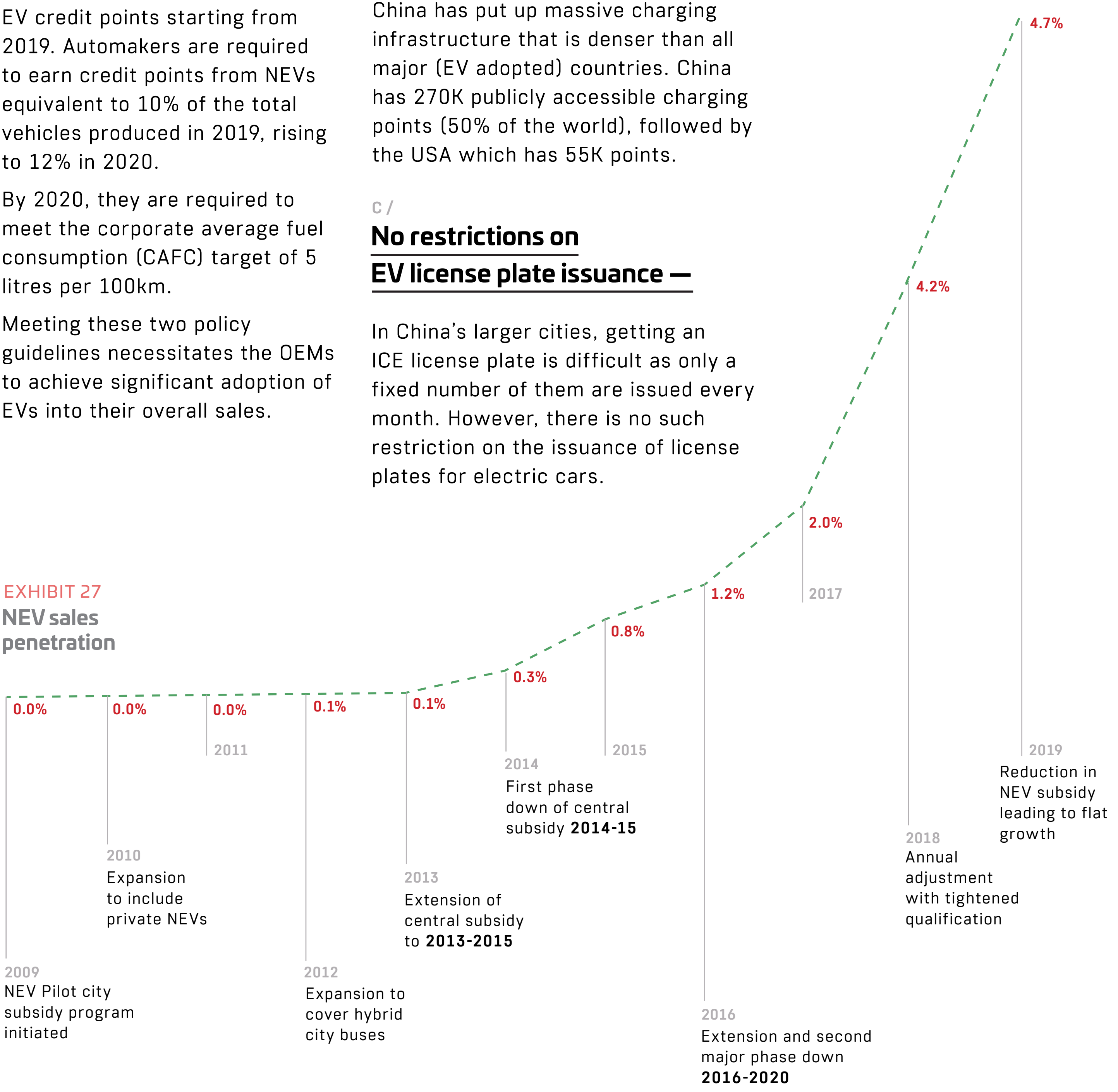
C /

No restrictions on EV license plate issuance —

In China's larger cities, getting an ICE license plate is difficult as only a fixed number of them are issued every month. However, there is no such restriction on the issuance of license plates for electric cars.

EXHIBIT 27

NEV sales penetration



2009
NEV Pilot city subsidy program initiated

2010
Expansion to include private NEVs

2012
Expansion to cover hybrid city buses

2013
Extension of central subsidy to **2013-2015**

2014
First phase down of central subsidy **2014-15**

2016
Extension and second major phase down **2016-2020**

2018
Annual adjustment with tightened qualification

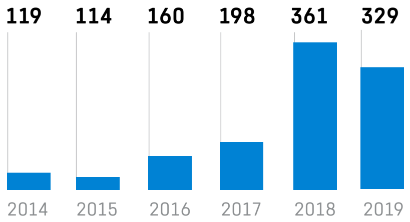
2019
Reduction in NEV subsidy leading to flat growth

2 / UNITED STATES OF AMERICA

The USA is relatively lagging vis-à-vis the global transition to EVs

The USA was the earliest adopter of EVs. However, the pace of growth has been relatively slower in the USA and it is still lagging behind Europe and China in terms of pace of adoption. In 2019, a total of 359,000 BEVs and PHEVs were sold in the USA vs 590,000 in Europe and 1.2 million in China.

EV SALES (in 000s)



INFRASTRUCTURE

55,000 +
EV Chargers

50 + GW
Battery Capacity

2.0% 2019 EV Penetration

Some of the reasons for slower growth include

A /

The USA has lower fuel costs compared to China and European countries. Gasoline prices per gallon are about USD 0.8 cheaper compared to China and about USD 0.5 compared to several European countries.

B /

Several environmental norms set during the President Obama regime which were introduced to reduce the vehicular emmissions are being rolled back. The USA is also revoking the authority of California to set stricter environmental norms, which was one of the reasons for higher EV penetration in that area.

C /

The passenger car market in the USA has a relatively higher proportion of large cars like trucks, SUVs, etc. There are very few options for EVs in these segments. Additionally, it is more difficult to achieve TCO parity in these segment.

However, due to efforts by a few specific state governments, the USA market has higher adoption of electric vehicles in a few places like Seattle, Portland, San Jose, etc. There is a direct correlation between incentives and EV penetration in the USA states. The incentive across states is not equal, which can be seen in the varying EV penetration across states. California is the largest EV market in the USA. Apart from providing highest incentives which range from USD 2,500 to USD 7,000, it has taken several other steps like access to the HOV (High-occupancy vehicle lane) and discounts on recharging. The USA also have a federal program which offers tax credit up to USD 7,500 on the purchase of PEVs (but limited to 200,000 units per OEM)

The price of top selling EV models in the USA range from USD 33,000 to 90,000. In that context, it is a very different market as compared to China or India.

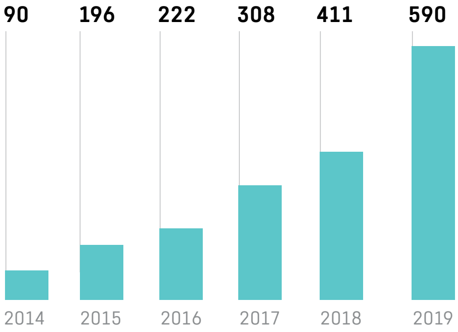
3 / EUROPE

The European Electric Vehicle market is amped up and on the rise

Sales of new electric road vehicles have been growing significantly in recent years, largely driven by the mass expansion of this mode of transport. Despite its rapid growth, the EU market for such vehicles is still small and largely dependent on support policies. Most electric road vehicles are concentrated in a few northern and western EU member states, although southern and eastern ones have recently recorded the highest sales growth.

Europe hosts the countries with the largest penetration of electric car sales. Norway approached 56% in 2019, more than 2x the next highest country, Iceland (25%) and 3x the Netherlands, which has the third-highest (14%). In terms of sales volumes, Norway is followed by Germany, the United Kingdom, France, Denmark and the Netherlands.

EV SALES (in 000)



INFRASTRUCTURE

125,000 +
EV Chargers

20 + GW
Battery Capacity

3.6 % 2019 EV Penetration

Over the years, the European countries have taken various policy measures and have provided incentives to push adoption of EVs.

A /

Additional taxes on conventional vehicles

In several countries, the governments have provided large scale incentives and subsidies to EV purchasers, at the expense of ICE vehicle owners in the form of higher taxes, fees, tolls and parking fees to bring the ownership cost lower than ICE vehicles.

To put things into perspective, a Volkswagen Golf costs EUR 31,000 (which includes EUR 11,000 in taxes) vs e-Golf which costs EUR 27,000.

B /

Policies to ban diesel vehicles implemented by various countries

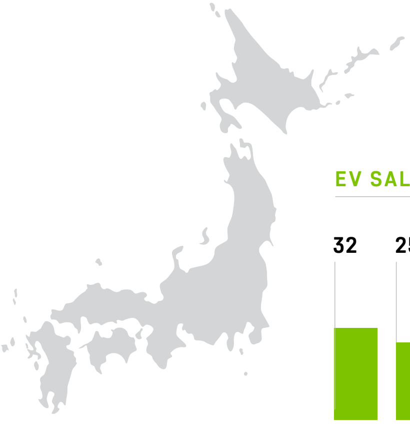
Most countries in Europe like Norway, the UK, France, the Netherlands and a few others have set dates (in the next two decades) to ban conventional ICE vehicles. Germany has already given permissions to individual cities to ban diesel vehicles.

These steps are leading to higher deliberation by people during car purchases and higher EV adoption.

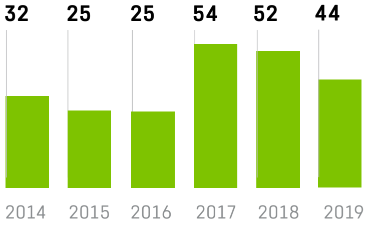
4 / JAPAN

The earliest adopter of technology, switching from Hybrid to Pure EV

Japan was one of the earliest adopters of EVs. Due to the dearth of oil, Japan took early steps in incentivising the plug-in vehicle. The Japanese dominated the electric hybrid car market with Toyota Prius, the highest selling low-emission car till today. Nissan Leaf has now taken the baton and dominates the domestic EV market.



EV SALES (in 000)



INFRASTRUCTURE

30,000 +
EV Chargers

25 + GW
Battery Capacity

0.8 % 2019 EV Penetration

A /

Strong focus on Hydrogen economy

Japan is promoting Hydrogen economy in a big way. Availability of non-fossil electricity makes the proposition very attractive for Japan. Toyota Mirai is the top selling fuel cell car in the world. Toyota launched the Mirai sedan at the end of 2014 but has only sold around 10,000 units globally. High costs of vehicles and high capital investments required for setting up refuelling stations are major deterrents in the adoption of fuel cell vehicles. However, the picture might change rapidly once the technology reaches maturity in fuel cell design.

B /

TCO gap has been a huge barrier for growth

Consumers in Japan are driven by economics and the TCO gap has prevented them from mass adoption of electric vehicles. However, smaller and compact EVs with lower TCO gap are trending in Japan and the market leader, Nissan, is also ready to launch a smaller electric vehicle called the Nissan IMk in the near future.

C /

The best charging ecosystem compared to any other country

Japan's network of EV-charging infrastructure is far superior to other EV markets — there are more battery recharge points than petrol stations across the country, with further plans to install fast chargers every 15 km along the highway or within every 30 km radius.

D /

Continuous policy support by the government

The government's continuous support in policymaking has spurred the growth of the country's EV market share. Currently, the government grants one-time subsidy at the rate of USD 100/ KWh of the battery size of the vehicle. Japan has also pledged to switch to emission-free vehicles completely by 2050.

Global Battery Industry

The rise of electric vehicles has caused upheaval in the Lithium ion battery industry. As of 2018, the global Li-ion battery manufacturing capacity was about 330 GWh per annum. A large part of this capacity is currently concentrated in China.

The Li-ion battery industry is dominated by five companies – Panasonic, CATL, LG Chem, Samsung and BYD. Battery mega factories are coming up at a phenomenal rate. There are now close to 115 announced mega factories in the pipeline, with over 2,000 GWh per annum of capacity in the industry's pipeline for 2028.

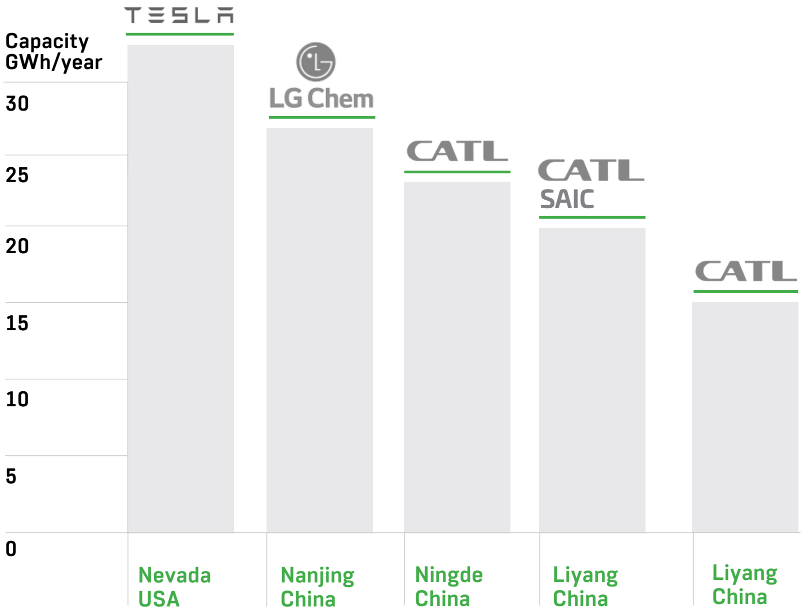
While the underlying cell technology itself requires massive capital and time commitment from companies, two other critical factors for battery companies are —

A / Scale

B / Raw Material Supply Security

EXHIBIT 28 ↘

Top 5 Li-ion battery gigafactores by capacity



Top countries/regions (by installed capacity)

CHINA	220 GWh
UNITED STATES	50 GWh
JAPAN / S KOREA	40 GWh
EUROPE	20 GWh

Top manufacturers (market share)

PANASONIC	22 %
CATL	14 %
LG CHEM	14 %
SAMSUNG	10%

A /

Scale — Go big or go home

The scale of operations plays an important rolein battery manufacturing economics. A large gigafactory can offer 20% of material cost benefits as compared to a small sub-gigawatt battery manufacturing set-up.

Currently, a large scale battery manufacturing plant takes anywhere between USD 60-100 mn/GWh of capital expenditure. The exact expenditure varies depending on choices related to machinery and other process decisions.

Over the years, the battery industry has witnessed improved capital expenditure efficiencies. This has led to

A / Technological developments in cell chemistries and manufacturing process

B / Higher automation in manufacturing as the scale has built up

The capital expenditure efficiency is expected to further improve and reach sub USD 50 mn/GWh by FY25.

B /

Raw Material Supply — Long term partnerships for security and economics

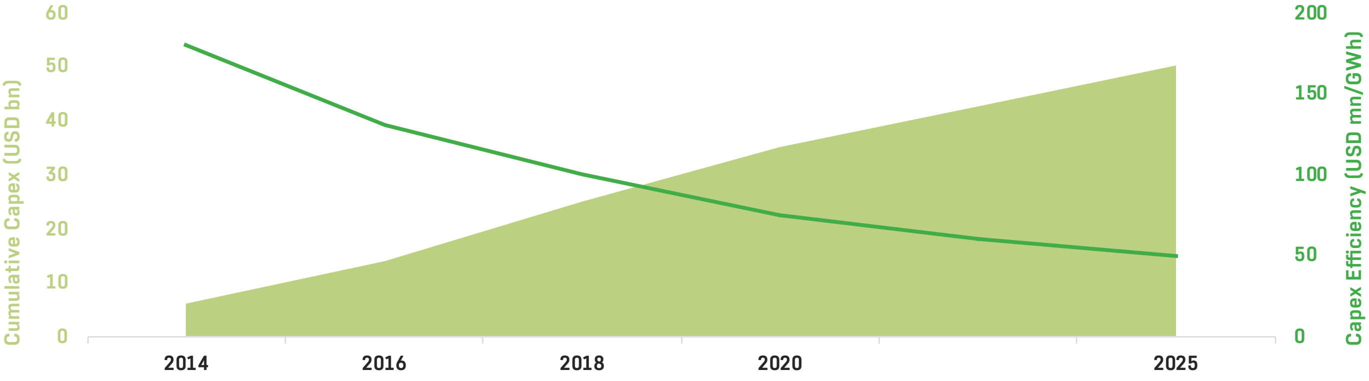
Raw materials, especially Lithium and Cobalt are scarce, concentrated in a few countries and controlled by a few companies. The supply-demand equilibrium is relatively unstable and prices can move quickly. Hence, it is critical for battery manufacturers to establish a strong supply chain, preferably through long term partnerships.

A classic example of long term partnerships in the battery space is that of Tesla and Panasonic. This partnership uses the core competencies of both companies to produce some of the best batteries in the world at costs that are amongst the lowest in the industry. Through strategic sourcing, Tesla has managed to create 10% cost benefits vis-à-vis other competitors.

One of the key reasons behind China’s thriving battery industry is its access to Lithium and Cobalt, which has been achieved not only through domestic production but also through partnerships with various countries and companies.

EXHIBIT 29 ↘

Capex trend in Li-ion battery industry



Batteries – Insourcing vs Outsourcing by OEMs

The battery constitutes 40% of the vehicle cost, making it the single largest cost component in an EV. For an OEM, the battery sourcing strategy is an extremely critical decision. Apart from being the single largest cost component, batteries are critical for performance – Range, Power, Life, Safety, and Charging Time. Hence, a tight control over battery sourcing is important. The importance of the battery is so high in an EV that it makes one believe that car manufacturers will have to insource the battery manufacturing in order to stay relevant in the market.

However, a large part of the market prefers to outsource the batteries. This is mainly because of two reasons —

A / Most OEMs do not have the scale that economical battery production demands

B / Cell technology development is cost intensive and evolving rapidly. Hence getting into cell manufacturing does not fit into the risk profile that aligns with the business model of OEMs

The outsourcing models have been different but a majority of the market has opted for it in some way or the other.

Battery manufacturer, BYD forward integrated into making vehicles and is now the #2 electric car manufacturer by volumes.

Tesla got into a JV with Panasonic to produce batteries. In the future, more such completely insourced business models could come up but the likelihood of traditional OEMs getting into battery pack manufacturing including cells, is low.

EXHIBIT 30

5 key battery sourcing strategies adopted by OEMs

1 / BYD AUTO

Captive end-to-end production by OEMs

OEMs manufacture batteries in-house including cells

2 / MAHINDRA

Captive pack production by OEMs

OEMs procure cells and manufacture battery packs in-house

3 / NISSAN

Supply by cell companies

Cell companies forward integrating into battery pack and supplying to OEMs

4 / TESLA

Co-developed between cell companies and OEMs

OEMs strategically tie-up with cell companies to manufacture batteries

5 / DAIMLER

Supply by battery pack manufacturing companies

Pack manufacturers procure cells from cell vendors and assemble battery packs with BMS to meet OEM requirements

EXHIBIT 31

Key battery suppliers for top OEMs

GLOBAL BATTERY COMPANIES	SDI	LGC	SKI	PANASONIC	AESC	CATL	BYD
Non-Chinese OEMS							
TESLA				^			
VW	^	^				^	
GM		^					
BMW	^					^	
AUDI	^	^					
NISSAN		^			^		
FORD		^					
DAIMLER		^		^		^	
VOLVO		^					
RENAULT		^			^		
HMC/KIA	^		^				
FIAT/CHRYSLER	^						
Chinese OEMS							
BYD							^
BAIC			^			^	
GEELY						^	
BAIC BJEV						^	

04

Where does India stand amidst the electric disruption of automotive industry?

Where does India stand amidst the electric disruption of automotive industry ?

India’s EV ambitions started taking shape with the introduction of the National Electric Mobility Mission Plan (NEMMP) in 2013. The plan underlined an ambition to have 6-7 million EVs on the road by 2020. Today, in 2020, while the number of EVs on the road are far lesser than what the policy envisaged, the enthusiasm created by electric vehicles in India is significant.

A large number of start-ups have come up in this space in various parts of the ecosystem – OEMs, component manufacturers, charge point operators and other service providers. Established players have laid down their EV strategies and large investments have been committed. Policy makers are looking at EVs as a potential solution to India’s pollution problem. After spending INR 5.3 billion through FAME-I, the government has announced FAME-II with a total outlay of INR 100 billion. Consumers are increasingly becoming educated towards EVs and TCO logic. They are willing to go electric for a good product, even if it is at a slightly higher price.

EV adoption, in India, was largely restricted to 2W/ 3W so far. Despite challenging economics, the 4W segment has started showing an uptick in adoption. Two premium EV variants were launched in 2019 – Kona (Hyundai) and ZS (MG Motor). ZS received close to 3,000 bookings in its first month of launch - more than the total electric cars sold in India in nine months prior to that. Tata Motors' electric Nexon comes with an attractive combination of performance and mid-range pricing. The light commercial vehicle segment is also being explored for electrification.

Investors are actively looking at the EV space as the next big opportunity to create value. Close to USD 700 million of capital has been raised in this space in India. A number of businesses are trying to leverage electric mobility to create value. Electric shared mobility is one such example.

With falling battery prices, the economic argument against EVs is rapidly weakening. The policy support is strong. OEMs have started taking bets on the EV space. Domestic ancillary industry, especially the battery pack manufacturing industry, has started taking shape. With all these fast-evolving changes, India stands at an inflection point of EV adoption.

EV policy makers in India have taken a clear direction but implementation lacks momentum

Policy directive is central to how fast and sustainable the electrification of vehicles in India shall be. Almost a decade after MNRE EV subsidies, policy makers in India have set a clear direction for the EV ambitions of the country through FAME-II. Seeds of FAME were sown in the form of National Electric Mobility Mission Plan 2020 which was set out in 2013. FAME-I which was launched in 2015 created momentum in the market and now there is a tangible ecosystem established in India. FAME-II has taken bolder steps and clearly highlights the governments intent for promoting EVs.

MNRE
2010

A portion of Ministry of New and Renewable Energy's subsidy was extended to electric vehicles

NEMMP 2020
2013

INR 200 billion investment to deploy 6-7 million electric vehicles in India

FAME - I
2015

Launched to fast track the goals of NEMMP 2020; INR 8,950 million planned outlay mainly through subsidies

FAME - II
2019

Extension of FAME - I; INR 100 billion investments planned over FY20 - 22

FAME - I

FAME – Faster Adoption and Manufacturing of Electric (and hybrid) Vehicles was launched as part of NEMMP in 2015. It was initially launched with a total outlay of INR 8.0 billion over a period of 2 years. Eventually, the scheme was extended till 2019 and the total outlay was increased to INR 9.0 billion. However, the total fund utilization was only INR 5.3 billion out of which INR 3.4 billion was towards vehicle subsidies.

In addition to the direct subsidies, grants were sanctioned for specific projects under pilot projects, R&D/technology development and public charging infrastructure components under the scheme. 465 buses were sanctioned to various cities/states under this scheme. A total of 0.3 million vehicles were supported with subsidy as part of FAME-I.

The impact of FAME-I went beyond the actual numbers and it managed to create a significant buzz in the industry. During this scheme, the awareness about EVs increased significantly - both amongst customers and the industry players. The early foundation of India's EV ecosystem was built during this period and FAME-II, which was announced in March 2019, aims to leverage this foundation to create a platform for the EV industry to truly take off.

EXHIBIT 32↘

FAME - I Summary

2015 - 2019

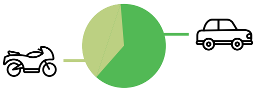
OEMS REGISTERED

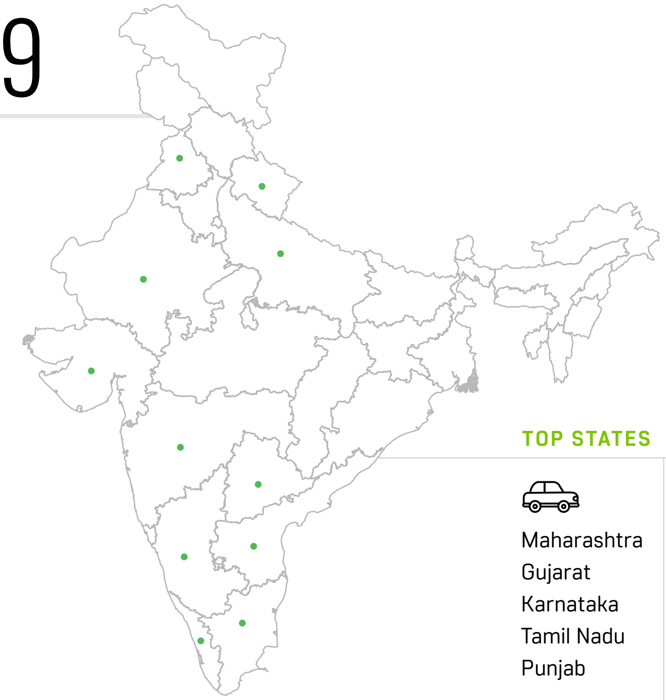
7 🚗	18 🏍	4 🛺

OUTLAY
INR **9.0** bn

UTILIZATION
INR **5.3** bn

SUBSIDY UTILIZATION BY VEHICLE TYPE
INR **3.4** bn





TOP STATES

🚗	🏍
Maharashtra	Rajasthan
Gujarat	Haryana
Karnataka	Uttar Pradesh
Tamil Nadu	Maharashtra
Punjab	Gujarat
	Uttarakhand

FAME - II

FAME-II clearly underlines the fact that the policy is directed towards rapid EV adoption. The scale of the program, even though small in context of the overall automobile industry, is encouraging. Good implementation with maximum fund utilization would help the EV industry cross the inflection point and register disruptive growth from FY22 onwards.

Break - up of demand incentives under FAME - II

INR
15 Billion / FY20

INR
50 Billion / FY21

INR
35 Billion / FY22

Planned Outlay of INR 100 Billion

1 /
DEMAND INCENTIVE

An upfront reduction in purchase price of the eligible vehicle, which will be a compensated to OEMs by the government

Strong focus on promoting electric vehicles for public transport

2 /
CHARGING INFRASTRUCTURE

2,700 charging stations; One charging station every 3km in select cities

Government to provide support to set up charging infrastructure

One slow charger for every e-bus purchased and one fast charger for every 10 e-buses purchased

Demand Incentives —

A large portion of the FAME-II scheme is to promote EV adoption through direct subsidies. The scheme is offering subsidy at around INR 10,000/kWh/vehicle for all vehicles except buses and trucks. For buses and trucks, the subsidy is around INR 20,000/kWh/vehicle.

FAME-II introduced a number of changes in the eligibility criteria to avail the subsidy. In FAME-II, subsidy is linked to the battery size rather than to the vehicle type. Minimum speed and range were introduced as criteria to encourage adoption of higher performance vehicles. While the policy's objective for promoting higher specification vehicles seems to be in the right direction from a long term perspective, it doesn't seem to be in sync with the current market demand. This is especially true for the 2W segment which

A / Constitutes the largest part of the market

B / Is the fastest growing segment in terms of adoption

Due to the range and speed criteria – subsidies are applicable only to high specifications e-2Ws which form a small part of the market. This mismatch between the market demand and the policy's vision is evident from the fact that only around 15,000 e-2Ws availed the FAME-II subsidy in FY20 while the total subsidy pool covers 1 million vehicles over a three year period. In general, the Indian ICE 2W market is dominated by low to mid-price vehicles; 90%+ of the ICE 2W market still buys products that are in the price range of INR 40K to 90K, which corresponds to the low/medium speed EV category – which is not eligible for the subsidies. For the policy objective of encouraging higher specification e-2W, the vehicle cost itself needs to come down. That will happen as the battery prices come down in the future. In the near term, extension of subsidies to lower specification e-2W can be beneficial for higher industry adoption.

EXHIBIT 33↘

Break - up of demand incentives under FAME - II

CATEGORY	PRICE CAP (INR)	NO. OF VEHICLES TO BE SUBSIDIZED	SUBSIDY (INR/kWh)
2W	0.15 mn	1,000,000	10,000
3W	0.5 mn	500,000	10,000
4W - BEVs	1.5 mn	35,000	10,000
4W - HYBRIDS	-	20,000	10,000
BUS	20 mn	7,090	20,000

Subsidies are capped at 40% of cost for buses and 20% of the cost for others

Subsidies are limited to EVs using advanced Li-battery and newer technologies only

Charging Infrastructure —

FAME-II also provides for setting up public charging infrastructure. The broader objective is to set up 2,700 charging stations in metros, cities with a million plus population and highways. In addition, there is a provision for one slow charger to be provided to a buyer for every e-bus purchased and one fast charger for every 10 e-buses purchased.

1 / PHASED MANUFACTURING PROGRAM

Along with FAME-II, the policy has also taken concrete steps that further highlight the strong intentions to facilitate rapid EV adoption in India. In order to promote localization of the EV supply chain, the government has put in place the Phased Manufacturing Program (PMP). At an initial stage, the program has specified the basic customs duty structure to encourage domestic manufacturing of EV related components. The table below summarizes basic customs duty changes for various components.

EXHIBIT 34↘

Proposed custom duty structure under PMP

DESCRIPTION	VEHICLE TYPE	CURRENT BCD	PROPOSED BCD	PROPOSED DATE OF PMP
CBU	Bus & Trucks	25%	50%	
SKD	PV & 3W	15%	30%	April 2020 onwards
	2W		25%	
	BUS		25%	
	Trucks		25%	
CKD	Bus	10%	15%	
	PV			
	2W			
	3W & Trucks			
Lithium ion cells for use in manufacture of Lithium ion accumulator for EVs		5%	10%	April 2021 onwards
Battery packs for use in the manufacture of EVs		5%	15%	
Parts used in the manufacture of EVs like AMC charger, AC/DC motor, AC/DC motor controller. Power Control Unit (Inverter, AC/DC Converter, Condenser), Energy monitor, Contactor, Brake system for recovering, Electric compressor		0%	15%	April 2021 onwards

In a revision to the original PMP, the policy has further specified the requirements of component indigenization in order to take benefit of FAME-II. The table summarizes key components and target dates for domestic sourcing for different vehicle categories.

EXHIBIT 35 ↘

Localization timelines under PMP for key components

KEY COMPONENTS	2W/3W	4W/BUSES
CHASSIS	July 19	April 19
MOTOR CONTROLLERS	April 20	April 21
EV MOTOR	April 20	April 21
ON-BOARD CHARGER	April 20	April 20
BATTERY PACK (ASSEMBLY)	April 19	April 19
AC TYPE 2 CHARGING INLET	NA	April 20
DC CHARGING INLET (CCS2/CHAdeMO)	NA	October 20

2 /

E-BUS PROCUREMENT

In June 2019, the government invited EOIs from STUs, municipal corporations and other public transport entities with an objective of deploying 5,000 e-buses. The key objective of the scheme was to reduce vehicular pollution in cities and hence, it was limited to large cities with population of over 1 million, smart cities, satellite towns connected to metros, etc. The structure of the scheme is very interesting.

Under the program, private operators (currently, mostly comprising of OEMs) have to operate the buses on a gross cost contract (GCC) basis. The operators will provide buses, run them and create supporting charging infrastructure. The STUs will provide a minimum operational distance per bus over the contract period. STUs had to submit proposals to DHI for operating e-buses. 86 proposals for 14,988 buses were received from which 64 cities have been sanctioned 5,595 e-buses.

The selection took into account various parameters like road tax structures, EV policies, pollution levels, charging infrastructure, vehicle density, etc. Final allotment of e-buses was done by ranking the qualified cities by the weighted average of total assured km per bus during the entire period of contract.

The STUs are now in process of tendering and operator selection is ongoing. As per the update in January, 2020, 30 cities have awarded 2,000 e-buses to operators and bidding is underway in 20 cities for 1,900 buses. PMI Foton and Olectra BYD have bagged the largest orders so far with 750 and 600 buses respectively. The GCC contracts depending on specific use cases are being bid in the range of 55-85 INR/Km. The FAME-II subsidy covers 10-15 INR/Km.

3 /

GST BENEFITS & TAX INCENTIVES

Through the 2019 fiscal budget, the government has launched new incentives to promote EV adoption. The GST on Electric Vehicles has been reduced to 5% from 12%, while GST on ICE vehicles continues to be 28%. INR 150,000 tax benefit is available on the interest paid towards a vehicle loan for an EV.

State Policies — States with draft or adopted EV policies

1 / ANDHRA PRADESH

Focus on promoting gigafactory establishments (10 GWh+)

100% electrification of APSRTC bus fleet in 4 cities by 2025 and whole state by 2029

2 / BIHAR

100% electrification of paddling rickshaws by 2022

Fast charging station every 50 Km on highways

3 / DELHI

25% of new vehicles registered from the year 2023 to be EVs

Target of running 50% e-buses in Delhi by 2023

4 / KERALA

1 mn EVs by 2022 and 6,000 e-buses by 2025

Provision of viability gap funding for e-buses and government fleets

5 / KARNATAKA

Interest-free loans on the net SGST for EV manufacturing enterprises

Investment subsidy for setting up the first 100 charging stations

6 / MADHYA PRADESH

25% of new vehicle registrations in public transport to be EVs by 2026

7 / MAHARASHTRA

Increase the number of EVs to 0.5 mn and attract an investment of INR 250 bn in EV manufacturing and component manufacturing

Subsidies for e-buses and retail 4W customers

8 / PUNJAB

25% of annual registrations to be EVs in 5 years

9 / TAMIL NADU

Reimbursement of SGST, 15% capital subsidy on intermediate products, electricity tax exemption

100% stamp duty exemption for transactions related to EV manufacturing, 15% land subsidy (50% in select districts)

10 / TELANGANA

25% electrification of buses by 2022, 50% by 2025 and 100% by 2030

Focus on attracting investments especially, in Li-ion cell manufacturing

11 / UTTARAKHAND

100% electrification of public transport, shared mobility and goods transport in five priority cities by 2030

12 / UTTAR PRADESH

200K charging stations by 2024 and 1 mn EVs on the road in all categories and 70% electric vehicles in public transport by 2030

Subsidies to promote capex, exemption from stamp duty and electricity duty, SGST reimbursement

SOURCE

State Policy Drafts, TransportPolicy.net, EV-Ready India - White Paper by Ola

OEMs are gathering momentum

FAME-I was instrumental in creating early interest within OEMs. With FAME-II coming into action and the heightened buzz in the market, OEM interest in the EV space has rapidly increased.

The 2W category has seen the largest activity with more than 15 e-2W manufacturers currently operating in the country.

EXHIBIT 36↘

2W	KEY MODELS	PRICE (000 INR^)	BATTERY	RANGE (Km *)	TOP SPEED (Km/hr)	KEY HIGHLIGHTS
HERO ELECTRIC	Flash E2	50	Li	65	25	Sales of 50K in FY20; #1 player in India
	Optima E2	57	Li	60	45	Invested by OAKS (Formerly Alpha Capital)
	Nyx ER	70	Li	100	42	Pan-India dealer network of 500 dealers
AMPERE	Zeal	70	Li	70	50	Sales of ~19K in FY20
	Reo -Li	45	Li	55	25	Invested by Greaves Cotton
	V-48	37	Li	55	25	
OKINAWA	I-Praise+	109	Li	160	60	Sales of 1,440 mn in FY19
	Lite	60	Li	50	25	300+ Dealerships
	Ridge+	73	Li	100	55	
ATHER	Ather 450X	149	Li	85	80	Invested by Hero MotoCorp, Sachin Bansal, Tiger Global
REVOLT	RE300	118	Li	80	65	No.1 player in e-motorcycles segment
	RE400	138	Li	85	80	
BAJAJ	Chetak	115	Li	95	80	Bajaj created an EV division - Urbanite
TVS	iQube	115	Li	75	78	Launched in Bengaluru, to be expanded in phases

3W

In the 3W category, the e-rick category has been a positive surprise, even while many of the large ICE auto OEMs are yet to launch their EV models. There are close to 0.7 million e-ricks annually sold in the country today with a large number of them being sold by the unorganized players. The majority of e-ricks are still based on Lead Acid batteries but that landscape is expected to evolve rapidly in favour of Li-ion batteries over the next 2-3 years.

EXHIBIT 37↘

OEM	KEY MODELS	PRICE (000 INR^)	BATTERY	RANGE (Km *)	TOP SPEED (Km/hr)	KEY HIGHLIGHTS
MAHINDRA ELECTRIC	Treo	270	Li	130	45	Mahindra & Mahindra susidiary
	Treo Yaari	170	Li	100	25	No. 1 player in electric 3W segment
KINETIC GREEN	Kinetic DX	140	Pb	60	25	Venture of Firodia Group
	Kinetic Safar Smart	190	Li	60	25	
	Kinetic Safar Shakti	150	Li	60	25	
LOHIA	Comfort DLX	140	Pb	100	25	Delhi based group with interest in diesel 3Ws, e-ricks and e-2Ws
	Hamrahi	130	Pb	75	25	
PIAGGIO	Ape E-City	200	Li	80	60	To invest INR 3,000 mn in next 3 years
BAJAJ / TVS						Under development, yet to launch

4W

4W OEMs have been modest in their EV ambitions and understandably so, given the high cost difference between an ICE and EV. The 4W market was limited to only 2 domestic OEMs – Tata and Mahindra, and they were primarily catering to government-initiated demand through EESL. Recently, OEMs like Hyundai and MG have taken a bet on premium electric cars, with Hyundai launching Kona and MG launching ZS in 2019. Tata's electric Nexon comes at an attractive price point and can potentially attract a larger portion of the retail market.

EXHIBIT 38 ↘

OEM	KEY MODELS	PRICE (INR mn^)	BATTERY	RANGE (Km *)	TOP SPEED (Km/hr)	KEY HIGHLIGHTS
TATA MOTORS	Tigor EV	1.1	Li	140	80	Launched Tigor for retail buyers in Oct 2019
	Nexon EV	1.5	Li	300	120	Nexon EV launched in Jan 2020 was the highest selling electric car in the month of March 2020 ahead of MG ZS
MAHINDRA ELECTRIC	E-Verito	1.2	Li	140	86	Oldest EV player in India, having started its EV journey with Reva in 2001 Planning to launch e-KUV100
HYUNDAI	Kona	2.4	Li	450	155	Launched Kona in Aug 2019
MG MOTOR	ZS EV	2.1	Li	340	140	MG received ~3,000 bookings for ZS in the first month of launch - more than cumulative electric car sales in 9 months prior to that
MARUTI SUZUKI	WagonR EV					Planned to launch in FY20; Now deferred

^ **PRICE**
Ex-Showroom Price

* **RANGE**
As reported on companies' websites. Some companies report ARAI range while some companies report range under ideal operating conditions. The practical range however is lower than ARAI and lower than ideal range depending upon usage patterns

Bus

Bus demand is completely driven by the government and the recent 5,000 bus tender has kindled a lot of activity in this space. There are only a handful of OEMs active in this space with Olectra leading the way.

EXHIBIT 39↘

OEM	MODEL	RANGE * (Km/Charge)	LENGTH (Meters)	KEY HIGHLIGHTS
OLECTRA	K6	200	7	Olectra is owned by Megha Engineering. It has collaborated with BYD for e-buses First company to deploy 100 electric buses in India Has 160+ buses deployed in India and has won a tender for 600 more buses under FAME-II
	K7	200	9	
	K9	300	12	
TATA MOTORS	Star Bus Ultra Electric 6/9	215	9	60% market share in FAME-I bus deployment. Has won order for 300 e-buses from Ahemdabad Janmarg Limited and 220 bus contract under FAME-II
	Star Bus Ultra Electric 9/12	151	12	
ASHOK LEYLAND	Circuit - S	50	12	First battery swapping bus project in collaboration with Sun Mobility in Ahmedabad
JBM SOLARIS	Ecolife Electric	150	9/12	JV with Polish bus maker Solaris
FOTON PMI	Urban	144	12	JV between PMI Electro Mobility and Beiqi Foton Motor (China) Won contract for 760 buses under FAME-II
	Regio	168	9	
	Lito	NA	7	

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* RANGE

As reported on companies' websites. Some companies report ARAI range while some companies report range under ideal operating conditions. The practical range however is lower than ARAI and lower than ideal range depending upon usage patterns

The battery industry has started shaping up

India has a limited role to play in the electric vehicle battery value chain in the medium-term. In the next 3-5 years, the Indian EV battery industry is largely expected to remain limited to battery pack manufacturing wherein the cells will continue to be imported. Several companies have announced plans to set up cell manufacturing units in India. However, the industry needs to achieve a certain scale for cell manufacturing to be cost competitive with the global market. Critical factors that will define India's role in the battery value chain are cell technology, access to key raw materials and scale of industry.

1 /

CELL TECHNOLOGY

India has not developed an indigenous cell technology. Globally, cell manufacturing is consolidated amongst 5 players, each of them putting in billions of dollars in cell R&D to develop more cost efficient and scalable cell technologies. Given the competitive landscape and the high entry barriers, both in terms of technology as well as capital, the likelihood of companies investing in existing Li-ion cell technologies is very minimal.

Domestic manufacturers, as and when they foray into cell manufacturing, would prefer to enter into technology partnerships with global battery players (rather than investing in technology).

2 /

ACCESS TO RAW MATERIALS

India barely has any reserves of Lithium and Cobalt, two of the most critical elements of a Li-ion cell and would be almost completely dependent on imports for manufacturing Li-ion batteries.

The global supply chain for these materials is still not well established and is volatile. All key global battery companies have strategic partnerships to ensure a stable supply. China, in addition to domestic Lithium production, has managed to establish strong control over the global supply chain for these materials and that is one of the primary reasons behind their flourishing battery industry. India will need policy level efforts to ensure stable access to raw materials in order to support domestic cell manufacturing.

3 /

SCALE OF INDUSTRY

India is largely a light electric vehicle market. Over the next 5 years, a large part of the Indian market will comprise of sub 10 kWh batteries. So, even with the most optimistic penetration scenarios, the battery industry in India would be around 30 GWh by FY25.

This is a too small a market for large scale cell manufacturing to be feasible in India. For demand scale in the battery industry to pick up, large scale adoption in passenger vehicles is critical but that is a remote possibility till FY25.

The first two bottlenecks are less critical if the possibilities of global battery companies setting up manufacturing in India or joint ventures between domestic and global companies are considered. However, the small scale of industry is still a major impediment for the emergence of the battery manufacturing industry in India. In addition to the small scale, the fact that this scale is distributed over a large number of small battery packs that go into the price sensitive 2W and 3W industry, makes a business case in India less attractive for large global battery companies.

It is likely that in the foreseeable future, only ventures that have large underwritten or captive demand will get into cell manufacturing in India. This has already been exemplified through the announced JV between Suzuki, Denso and Toshiba – AEPPL (Automotive Electronics Power Private Ltd.) for battery manufacturing in India.

Even AEPPL is planning to first set up a battery pack assembly plant and then later, by FY25, move into cell manufacturing.

The government has started pushing for localization of cell manufacturing in India. The aim is to set up gigafactories, each having a capacity of 10 GWh. Initial steps are also being taken to gain control over critical minerals such as the formation of Khanji Bidesh – A JV between NalCo, HCL and MECL to acquire Lithium and Cobalt mines abroad.

While cell manufacturing will have to get localized in India as the market gains scale in the long term (>5 years), in the near to medium term (3-5 years), India has a limited role to play in the battery value chain and the same would be restricted to the assembly of battery packs.

The battery industry in India is going through a formative phase

Till date, a large portion of electric 2W and 3W sold in India are based on Lead Acid batteries. With FAME-II coming into the picture and increased OEM focus towards higher performance vehicles, the shift towards Li-ion batteries is expected to be much faster. 2Ws are expected to shift to Li-ion batteries quickly while 3W e-ricks might take 2-3 years for a complete shift. The shift to Li-ion batteries has started shaping up the domestic Li-ion battery industry.

A large part of the Indian Li-ion battery supply is still made up of batteries imported from China. The need for high-quality reliable batteries and the government's push for localization has led to several domestic companies entering battery pack manufacturing.

Exicom, Bosch, Tata Autocomponents, Phylion, Exide-Leclanche, Greenfuel, Okaya are some of the leading battery pack suppliers in India today. There are several start-ups doing battery pack assembly at a small scale in various regions in India. These include the likes of ChargeDock, Euclion, Octillion, etc. A number of large companies have also indicated potential interest in getting into battery cell manufacturing. RIL, Adani, BHEL, IOCL, Panasonic and Tata Chemicals, have announced plans to enter cell manufacturing but no on-ground action has taken place till now.

EXHIBIT 40

Automotive Li-ion battery landscape in India

MANUFACTURERS

Total installed capacity = ~2 GWh

DOMESTIC COMPANIES

EXICOM POWER SOLUTIONS
AMARA RAJA Gotta be a better way
BOSCH
SUN MOBILITY
GREENFUEL
EXIDE
TATA AUTOCOMP SYSTEMS LIMITED
OKAYA NEVER STOP INDIA

GLOBAL COMPANIES

LG Chem
国轩高科 GUOXUAN HIGH-TECH
PHYLION

OEMs

Mahindra
ATHER
BYD

Differentiators for domestic battery industry

With the role of the battery industry in India being limited to pack manufacturing, the race for differentiation is intense amongst the players.

There are three key sources of differentiation – scale, sourcing, and R&D/technology.

1 /

SCALE

Scale enables benefit in cell procurement costs. Scale also enables more automated factories that are cost efficient. Large cell manufacturers are less inclined to work with smaller volume battery pack companies.

2 /

SOURCING

The ability to secure high quality cells from global manufacturers is critical. At a lower scale, the only viable option for a battery pack company is to source cells from Chinese manufacturers. However, to do so effectively, an understanding of cells and the ability to test and validate quality is critical.

3 /

R & D

Strong R&D is essential for pack companies to drive the cell-pack efficiency via good design, thermal management and a advanced battery management system. A good BMS can create significant differentiation for a battery pack manufacturer.

Charging Infrastructure is currently lacking, but new business models are coming up to plug the gap

While a lot of initiatives have been taken to encourage the adoption of EVs in India, little has been done to develop public charging infrastructure. Although regular at-home charging remains as one of the great advantages of electric-drive technology, it does not fulfil every charging need. A mix of workplace charging, public charging and fast charging is needed to extend range and increase charging access to those customers with no home charging.

The EV adoption and charging infrastructure is a bit of a chicken and egg problem. On one hand, without good infrastructure, owning and operating an EV is not convenient for users, hence, they would want to wait till such infrastructure is available. On the other hand, low adoption of EVs drastically impacts the economic viability of any public charging infrastructure project. A majority of existing charging stations are catering to either captive demand or large commercial fleets like e-ricks.

Current DC charging points

700

Current AC charging points

1,500

2,600 **Charging station projects announced as of January, 2020**

While the commercial business models are struggling on account of demand, the government is trying to deploy infrastructure through bodies like EESL. In Jan 2020, the government approved 2,600 charging stations to be set up under FAME-II.

Players like Lithium Urban – India's largest 4W EV fleet, have been able to successfully develop infrastructure leveraging their captive demand. Currently, all players developing infrastructure for captive usage are also treating it as a business differentiator and not sharing it for public use.

Another key problem with creating fast charging infrastructure is that there are almost no vehicles on the road at the moment that can handle high-power DC charging like 120 kW. For DC fast charging to become feasible, vehicles need to be equipped with batteries that can handle rapid charging.

EXHIBIT 41

Key players in the EV charging market

EVM EV MOTORS INDIA PVT. LTD

एनटीपीसी NTPC

Fortum

TATA POWER

बी एच ई एल BHEL

CHARGE+ZONE™ AN EV CHARGING COMPANY

Li Lithium

REIL

magentapower Green Energy Solutions

EESL

Battery Swapping

3W is by far the largest adopter of EVs in India at the moment. The number of 3W EVs in India make a good case for developing charging infrastructure. One of the key business models that has emerged for charging EVs is battery swapping.

Battery swapping enables e-rick drivers to avoid 3-4 hours of down time thus, increasing their earning potential. It also enables a business model wherein the battery cost is delinked from the vehicle, reducing the upfront cost pressure on a vehicle owner and they can use the battery as a service from the charging station operators.

EXHIBIT 39

Battery swap station at an Ola charging station

EXHIBIT 42

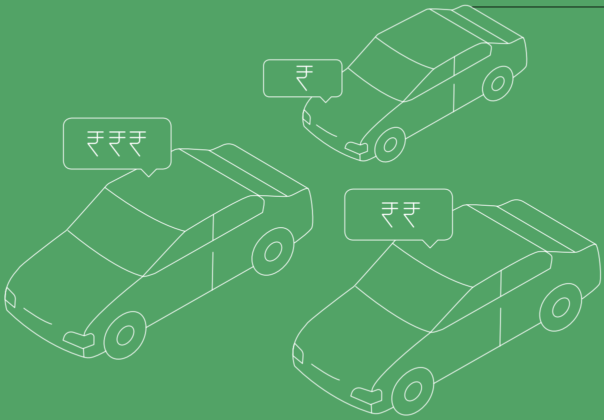
Key EV charger manufacturers in India

The need for charging infrastructure is an opportunity for charger manufacturers themselves. Many of these are companies that have significant experience in power electronic products. Exicom is currently leading the EV battery charger market, followed by Delta in India.

SIEMENS
EXICOM POWER SOLUTIONS
DELTA
Raychem®
ABB
MASS-TECH CONTROLS PRIVATE LIMITED

05

TCO Equation in India



Different segments lie on different parts of the TCO spectrum

Electric vehicles have a significantly higher upfront cost, as compared to ICE vehicles, largely on account of battery costs. On the other hand, the operating costs for an EV are much lower. Thus, Total Cost of Ownership (TCO) is an important and more correct assessment of economic comparison between ICE vehicles and EVs.

A TCO comparison across different vehicle categories and use cases within them has been presented below. The TCO analysis has been done for a 5 year period and takes into account maintenance cost, salvage value, new battery cost, if needed, and inflation. Details of TCO assumptions are presented at the end of this section.

1 / ELECTRIC - 2W

At parity for retail and a no-brainer for commercial use

Electric 2W are at TCO parity with ICE 2W for multiple scenarios. Depending upon the vehicle specification, TCO parity is achieved at different usage levels. Low/medium speed e-2W would achieve TCO parity at less than 10Km of daily usage.

The TCO for high speed 2Ws is not yet attractive and TCO parity is achieved at 40+ Km daily usage. While the upfront cost (without subsidy) in the case of a medium–high performance electric 2W is 50-75% higher than the ICE equivalent, the operational cost per Km is almost 1/6th that of an ICE 2W.

A comparison of Hero Electric Optima E2 (Low Speed e-2W) and Ampere Zeal (Medium Speed e-2W) with TVS XL-100 (Moped) and TVS Pep indicates a ~25% lower TCO. Ather 450x TCO is about 20% higher than Activa BS VI. Commercial use for electric 2W seems highly favourable with 33% TCO advantage.

EXHIBIT 43

TCO Analysis

ELECTRIC VEHICLES
Capex Opex

ICE VEHICLES
Capex Opex

*TCO with subsidy benefit

2W

Low Speed 2W - Retail

HERO OPTIMA E2
INR 93,724
55% 45%

TVS XL-100
INR 120,982
34% 66%

Medium Speed 2W - Retail

AMPERE ZEAL
INR 116,456
70% 30%
*INR 94,557

TVS PEP
INR 126,223
40% 60%

High Speed 2W - Retail

ATHER 450X
INR 219,974
72% 28%
*INR 187,124

HONDA ACTIVA BSVI
INR 156,353
60% 40%

Medium Speed 2W - Commercial

HERO OPTIMA ER
INR 212,425
38% 62%
*INR 190,526

HONDA ACTIVA BSVI
INR 290,824
23% 77%

3W

E-Rickshaw (Li-ion)

KINETIC SAFAR SAMRT
INR 501,241
42% 58%
*INR 456,225

E-Rickshaw (Lead Acid)

KINETIC DX
INR 500,415
27% 73%

Auto Rickshaw

MAHINDRA TREO
INR 561,081
54% 46%
*INR 479,502

BAJAJ COMPACT
INR 580,361
39% 61%

4W

Car- Retail Medium

TATA NEXON EV
INR 1,800,049
70% 30%

TATA NEXON PETROL
INR 1,757,940
58% 42%

Car- Retail Premium

HYUNDAI KONA
INR 2,763,033
70% 30%

HYUNDAI CRETA
INR 2,548,536
62% 38%

Car- Commercial

MAHINDRA E-VERITO D6
INR 2,162,449
53% 47%
*INR 1,871,201

MAHINDRA VERITO D6
INR 2,126,378
45% 55%

CV

Light Commercial Vehicle

CONCEPT LCV
INR 2,195,770
38% 62%
*INR 1,852,316

TATA ACE
INR 1,855,196
31% 69%

Bus

E-BUS
INR 22,609,090
62% 38%
*INR 15,740,026

ICE CITY BUS
INR 16,105,243
42% 58%

2 / ELECTRIC - 3W

At parity – must go electric

The TCO comparison between Lead Acid battery-based e-rick (Kinetic DX) and Li-ion battery-based e-rick (Kinetic Safar Smart) indicates that Li-ion is at TCO parity with Lead Acid. The Li-ion e-ricks have a lower total cost of ownership without considering subsidy benefits, if daily running is more than 120 km. The benefit of lower charging time with Li-ion, which is a reduction in the down time for drivers during the day, has not been considered for this analysis and if considered, would further improve the TCO for Li-ion.

A comparison in the 3W-Auto category between Mahindra Treo and Bajaj Compact indicates lower TCO for Mahindra Treo.

For an average daily usage case of 100 km, the TCO of Mahindra Treo is 16% lower than Bajaj Compact. Even in absence of subsidy benefit on Treo the electric variant breaks even with CNG variant.

3 / ELECTRIC - 4W

TCO parity for personal use is still distant; fleet applications are very close

A retail use case comparison in the premium 4W category between Hyundai Kona and Hyundai Creta highlights that there is a wide gap between the TCO of an electric car and an ICE car. Kona is not only 33% more expensive in terms of upfront cost but on a TCO basis, Kona is about 8% more expensive than Creta.

A comparison between Tata Nexon EV and Nexon ICE in the mid-price segment indicates 2% higher TCO for electric variants.

The commercial use case, however, comes much closer to TCO parity. A comparison between Mahindra e-Verito and ICE Verito for fleet operators indicates a 12% lower TCO for EV when compared to Diesel car and 2% lower TCO when compared to CNG car. Even without the subsidies, which are available on commercial e-4W applications, electric cars are close to TCO parity for a commercial use case. The threshold km/day for a cost parity is about 120 km.

4 / ELECTRIC - BUSES

TCO parity is distant but government driven demand + subsidies delink the adoption from the TCO equation

Buses have a very high upfront cost differential (>100%) due to the large size of the battery. In terms of the TCO, the gap is very wide and electric buses are about 40% more expensive at a daily use case of 200 km. However, it is expected that the adoption in buses would be based on government push and not on TCO parity.

EXHIBIT 44

Detailed working for TCO estimation

🟩 ELECTRIC VEHICLES

🟦 ICE VEHICLES

All numbers are in **thousand INR** unless otherwise stated

* Range **per charge** or **per liter fuel**

2W

		2W-LOW SPEED		2W-MEDIUM SPEED	
		HERO OPTIMA E2	TVS XL-100	AMPERE ZEAL	TVS PEP
Vehicle Ex-Showroom Price		58	45	69	56
Interest Cost On Loan		-	-	-	-
Additional Battery Cost		17	-	-	-
Total Fuel Cost		7	56	8	51
Total Maintenance Cost		11	22	11	22
Salvage Value		12	11	8	14
Total Cost Of Ownership With Subsidy		94	121	95	126
Total Cost Of Ownership w/o Subsidy		94	121	116	126
Average Running/Day	(Km)	20	20	20	20
Battery Pack Size	(kWh)	1.3	-	1.8	-
Range*	(Km)	50	50	65	55
Charging Cycles	(#)	650	-	650	-
Subsidy Available		-	-	18	-
Additional Battery	(#)	1	-	-	-

		2W-HIGH SPEED		2W-COMMERCIAL USE	
		ATHER 450X	HONDA ACTIVA BSVI	HERO OPTIMA ER	HONDA ACTIVA BSVI
Vehicle Ex-Showroom Price		148	70	69	70
Interest Cost On Loan		-	-	-	-
Additional Battery Cost		-	-	73	-
Total Fuel Cost		13	63	30	188
Total Maintenance Cost		17	28	22	33
Salvage Value		23	18	18	14
Total Cost Of Ownership With Subsidy		187	156	191	291
Total Cost Of Ownership w/o Subsidy		220	156	212	291
Average Running/Day	(Km)	20	20	60	60
Battery Pack Size	(kWh)	2.9	-	2.7	-
Range*	(Km)	65	45	75	45
Charging Cycles	(#)	1,000	-	650	-
Subsidy Available		27	-	18	-
Additional Battery	(#)	-	-	2	-

3W

		E-RICKSHAW		3W-AUTO	
		KINETIC SAFAR SMART	KINETIC DX	MAHINDRA TREO	BAJAJ COMPACT
Vehicle Ex-Showroom Price		191	144	270	240
Interest Cost On Loan		-	-	-	-
Additional Battery Cost		154	199	96	-
Total Fuel Cost		89	135	104	302
Total Maintenance Cost		17	17	17	28
Salvage Value		36	26	66	36
Total Cost Of Ownership With Subsidy		456	500	480	580
Total Cost Of Ownership w/o Subsidy		501	500	561	580
Average Running/Day	(Km)	100	100	100	100
Battery Pack Size	(kWh)	3.8	6.7	7.4	-
Range*	(Km)	60	70	100	30
Charging Cycles	(#)	1,000	250	1.500	-
Subsidy Available		37	-	67	-
Additional Battery	(#)	3	10	1	-

LCV and Bus

		LIGHT COMMERCIAL VEHICLE		CITY BUS	
		CONCEPT LCV	TATA ACE	E-BUS	ICE-BUS
Vehicle Ex-Showroom Price		625	600	10,000	7,000
Interest Cost On Loan		153	147	2,455	1,719
Additional Battery Cost		328	-	-	-
Total Fuel Cost		706	1,008	3,528	6,912
Total Maintenance Cost		55	83	166	276
Salvage Value		95	60	1,629	700
Total Cost Of Ownership With Subsidy		1,852	1,855	15,740	16,105
Total Cost Of Ownership w/o Subsidy		2,196	1,855	22,609	16,105
Average Running/Day	(Km)	150	150	200	200
Battery Pack Size	(kWh)	25	-	250	-
Range*	(Km)	75	18	200	3.5
Charging Cycles	(#)	2,000	-	2,500	-
Subsidy Available		250	-	5,000	-
Additional Battery	(#)	1	-	-	-

4W

		4W-MID SEGMENT		4W-PREMIUM SEGMENT		4W-COMMERCIAL USE	
		TATA NEXON EV	TATA NEXON PETROL	HYUNDAI KONA	HYUNDAI CRETA	MAHINDRA E-VERITO D6	MAHINDRA VERITO D6
Vehicle Ex-Showroom Price		1,550	1,150	2,388	1,800	1,005	1,000
Interest Cost On Loan		381	282	586	442	247	246
Additional Battery Cost		-	-	-	-	273	-
Total Fuel Cost		64	353	75	353	323	786
Total Maintenance Cost		33	55	55	83	39	66
Salvage Value		426	230	648	360	144	100
Total Cost Of Ownership With Subsidy		1,800	1,758	2,763	2,549	1,871	2,126
Total Cost Of Ownership w/o Subsidy		1,800	1,758	2,763	2,549	2,162	2,126
Average Running/Day	(Km)	30	30	30	30	130	130
Battery Pack Size	(kWh)	30	-	39	-	21	-
Range*	(Km)	200	12	220	12	120	20
Charging Cycles	(#)	1,500	-	2,000	-	1,200	-
Subsidy Available		-	-	-	-	212	-
Additional Battery	(#)	-	-	-	-	1	-

---

1 / TCO analysis is done basis ex-showroom price as the registration costs vary from state to state with several states having favourable policies towards EVs

2 / Only 4Ws and higher vehicles have been assumed to be purchased through vehicle financing

3 / Cost of additional batteries is assumed at a 20% discount considering exchange benefit and decrease in their price in market

4 / Fuel cost has been estimated basis efficiency assumptions as specified and fuel rate of INR 70/litre for petrol, INR 60/litre for diesel, INR 45/Kg for CNG and INR 7/kWh for Electricity

5 / Maintenance cost has been estimated considering the total utilization of vehicle in Km

6 / Salvage value for ICE and ex-battery EV are considered as a % of upfront cost. The salvage value for battery has been estimated basis the life remaining in battery

7 / Inflation @4% has been assumed for all costs

8 / Subsidy available is taken as per FAME-II portal or as per the criteria specified under FAME-II guidelines

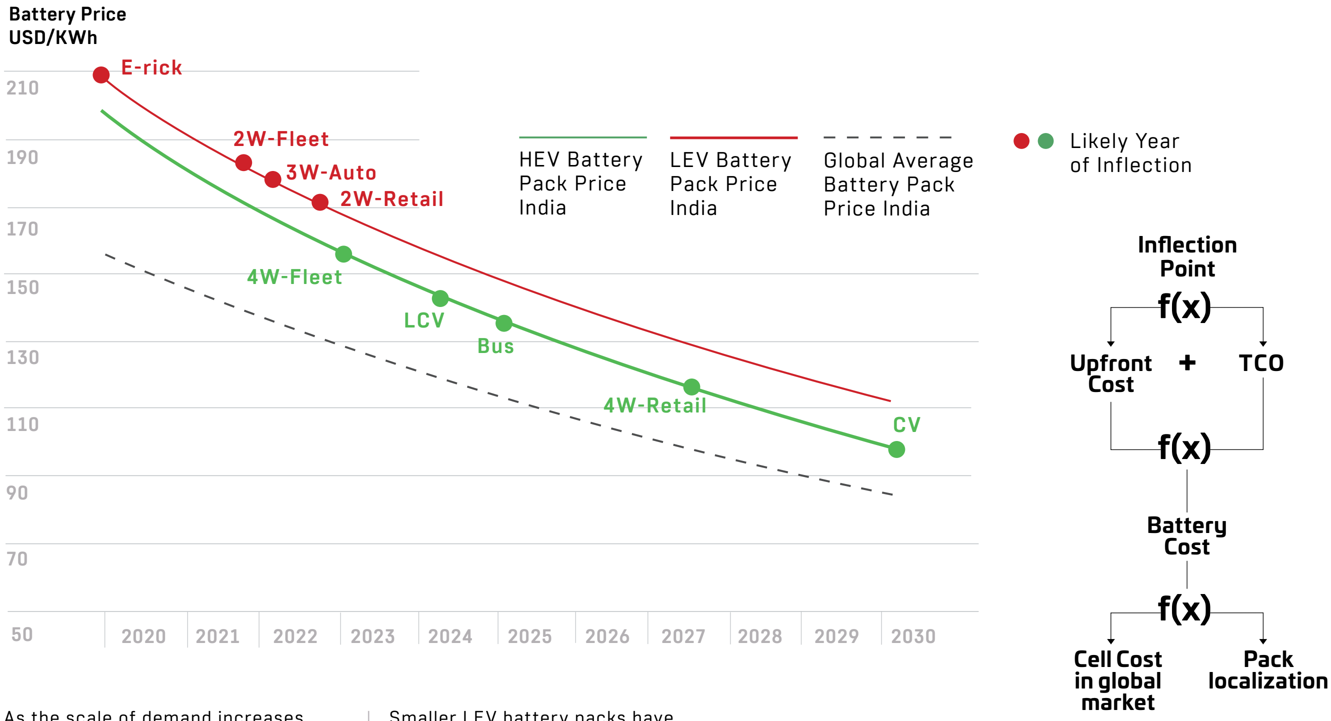
TCO implications for large scale adoption

While the policy incentives and a general buzz in the market can create momentum for EV adoption, the eventual large-scale adoption will only happen when EVs make economic sense to the end-user. The inflection point for EV adoption in India will be contingent not only on the TCO, but also on the upfront cost. Retail users and individual buyers are especially sensitive to the upfront cost.

The largest driver for the upfront cost and hence the TCO, is the cost of the battery. As the cost of battery reduces, the TCO of the EVs would become lesser than the ICE equivalent models and that would determine the inflection point for rapid adoption of EVs. Higher capital expenditure but lower operating expenses for EVs also makes the asset utilization a critical factor. Commercial applications – where vehicles run for larger distances over their lifetimes are already at or are very close to parity (considering the benefit of subsidies in the case of buses).

EXHIBIT 45

EV adoption inflection point for different vehicle segments



As the scale of demand increases and pack manufacturing gets localized, cost differential vs global pack prices will reduce

Smaller LEV battery packs have higher per pack cost as non-cell components do not decrease linearly with pack size

Early adopters and laggards

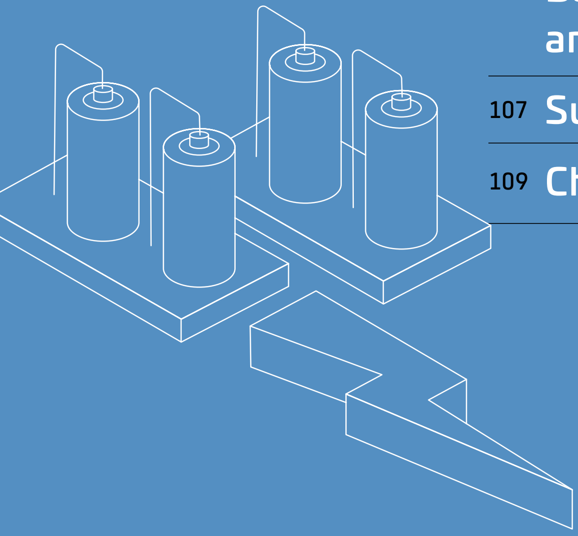
Fleet operators understand the logic of TCO and going electric is an inevitable shift for them to stay competitive. They also benefit from a tighter control over the ecosystem and hence, are better positioned to create captive charging infrastructure. They understand the importance of a good battery and are trying to keep closer control over its sourcing by dictating the battery procurement process to OEMs. 2W and 3W fleets must go electric and most of them are already working towards it. 4W fleets face bigger challenges due to charging infrastructure needs and non-availability of good quality entry segment electric cars and so, a transition there will take longer.

The 3W-auto market has been a laggard in going electric. The primary reason is that the owners of 3W autos are largely individuals and so the demand side drivers are weak. Also, key manufacturers like Bajaj and Piaggio have not yet gone big on electric variants. Both companies are expected to launch their EVs soon and that will create a shift in this segment.

Light commercial vehicle use cases, especially the ones running on a fixed route or with a fixed schedule, are extremely amenable to electrification – e.g. LPG cylinder delivery, e-commerce last mile delivery, etc. While some pilot tests have come up in that segment, it has not seen participation from any meaningful player. The key bottleneck here is a lack of electric LCVs in the market. Key OEMs like Tata and Mahindra as well as a few interesting start-ups are working on electric LCV platforms that should create a positive impact in this segment.

06

Factors that will determine EV adoption in India



Key Drivers of EV Adoption in India

The rate and degree of EV penetration in India is not an easy question to answer. However, the drivers of this adoption are clear.

There are four critical factors that will drive this in India over the next decade – policy, battery cost, charging infrastructure and supply chain localization.

The first two factors are the most critical ones and the next two are essential conditions to support large scale adoption.

As part of the analysis, the impact of these factors on the overall adoption has been considered in order to arrive at a reasonable range for EV adoption by FY25.

---

1 /

Policy

+ **Mandate** – **Support**

A / Policy support through subsidies alone might not be the most effective tool for large scale adoption

B / A mandated policy guideline, that is in sync with projected EV economic parity can fast-track the adoption significantly

---

2 /

Battery Cost

In global market

+ **USD <100/kWh** FY25

– **USD 130+/kWh** FY25

A / Battery cost is the single largest constraint for EV economic parity, thus, preventing large scale adoption

B / The decline in battery prices is fairly certain, but slower decline will affect adoption, especially, in the 4W category

---

3 /

Charging Infrastructure

+ **1 Fast Charger** for every 20 EVs

– **1 Fast Charger** for every 100 EVs

A / Good public charging infrastructure is essential for retail adoption of EVs especially 4W

B / The chicken and egg situation in charging infrastructure and EV adoption requires an initial push from the government

---

4 /

Supply Chain Localization

+ **80%** – **50%**

A / Currently high import dependency for key components

B / Battery packs, motors, controllers, key electronics need to get localized in the country to augment the growth of local players in the EV supply chain

Policy push vs policy support

India's EV policy ambitions are directionally clear and policy makers have extended reasonable amount of support to the ecosystem. Yet, the penetration of EVs has not reached the level that one would have expected. One of the key reasons behind the lower EV adoption is the economic parity. EVs are significantly more expensive than ICE vehicles in terms of the upfront cost and the TCO argument is slightly difficult to appreciate for a retail customer. Hence, the primary route that the policy has adopted to promote EVs is to subsidize the vehicles.

1 /

Policy intent is good but execution can be better

The idea behind subsidizing EVs makes sense as the objective is to create momentum in the market. FAME-I was a success in that aspect and FAME-II will hopefully take the industry to a scale where sustainable EV adoption can happen. However, subsidies can't be the driver for large scale adoption – that will happen only when economic parity is considerably in favour of EVs. The FAME-II pool of benefits for 2W is equivalent to 1.3% of the 2W market in India, which clearly underlines the limitations of subsidy driven adoption.

The localization of the supply chain is being promoted through the Phased Manufacturing Program (PMP). The early deadlines for localization have already passed and some of the critical deadlines (e.g. battery, motor) were set for April 2020.

Yet the extent of localization achieved is very low. A strict implementation of such a program is essential but the existing industry traction should also not be derailed in the quest for localization. This is a delicate challenge for the policy to address.

Tax incentives, GST benefits and other measures at the central government level to drive consumer interest are a welcome sign. The state EV policies can complement this effort better. Policy makers are also trying to address some difficult aspects of the EV industry like the reliable supply of key battery raw materials, establishing public charging infrastructure, setting up battery gigafactories in India.

In short, there is basic policy support offered through subsidies with the hope that EV adoption picks up and there are a host of measures to make this adoption sustainable. Making EVs sustainable through localization, supply chain security, etc. can only succeed if adoption picks up. To understand this let us take the example of supply chain. For the battery cell industry to get localized in India, the industry needs to reach a scale where the demand for batteries is at least a 100 gigawatts a year. For domestically manufactured components like motors to be cost competitive, there needs to be a large volume of demand.

The current policy measures have significant limitations. A few bolder steps by the government can do a lot of good for the EV industry in India.

2 /

The Industry needs policy push and not just policy support

While large scale subsidy driven EV adoption is not feasible, the slow adoption of EVs (once the economic parity is favourable) is also not ideal for the industry. There is reasonable visibility on battery prices and correspondingly on the EV economics vs ICE vehicles. For certain categories, the parity is already achieved and for others it will come as the battery prices decline. One of the key objectives that the policy should drive is to push EV adoption in line with economic feasibility, ensuring that the industry does not lag behind in the EV transition vis-à-vis the rest of the world.

A clearly mandated adoption target is a must for the Indian industry. The scope, nature and timelines for the mandate can be debated with the industry participants and set accordingly, keeping in mind the best interests of the ecosystem as a whole. Mandating EVs has been considered at the policy level and the recent rumours around 100% electrification of 2W/3W attracted fierce criticism from the industry, especially from the ICE OEMs. Before debating the kind of mandate that should come, it is important to understand why a mandated target provide significant impetus to the industry.

A clear mandate achieves three objectives –

A / It removes uncertainty over whether the industry will grow or not

B / Gives a timebound roadmap for stakeholders to prepare themselves for an EV shift

C / Creates confidence within the ecosystem and encourages investments in supporting infrastructure which are essential for large scale EV adoption

The objective of the mandate should be less about expediting the EV adoption and more about streamlining the transition. A large target adoption has massive ramifications for the industry. The 100% 2W/3W mandate which was in the news is extremely difficult to implement and is a potential threat to the overall auto industry.

Huge capital investments would need to be incurred by OEMs; the battery industry would need at least an INR 100 billion of investments towards local manufacturing of batteries. Key new components like motors and controllers would not only need large investments but a hasty mandate could mean that the industry could become over reliant on the global industry for technology.

At the end of this, the important question is whether the customer would prefer to buy an electric vehicle that is either high in cost or low on performance. If not, then there would be massive repercussions on the established auto industry. Some important considerations while mandating EVs are –

I / The extent of the mandate needs to be in sync with the level of demand that makes economic sense for EVs. Otherwise, OEMs will find it difficult to meet their targets.

II / The timing of the mandate must consider the economic parity of EVs vs ICE vehicles. The objective of mandating adoption is not to sell EVs when they are not economically viable but to ensure that as soon as economic parity is achieved the adoption picks up rapidly.

III / Supply chain is virtually non-existent today in India, mandated adoption should not come by relying on imports. Enough time must be given for the domestic industry to prepare itself for supporting EV production.

Fleets are one of the first segments where a mandate could come in effect. Fleets have favourable economics for EV adoption and they can appreciate the higher capital expenditure for lower operational expenses. Such a mandate would also need minimal subsidization from the government as EVs are at or close to economic parity already for fleet usage. Such a mandate could act as a pilot experiment for a larger, more long-term mandate for OEMs. For larger mandates, flexibility can be built into the method of implementation. China is good example in this context. Starting from 2019, China introduced EV credit policy by which automakers have to earn credit points from NEVs equivalent to a certain percentage of the total vehicles produced. The credit points required increase every following year starting at 10% in 2019 and there are penalties for not completing the credit requirements.

To conclude, the mandated EV adoption target must be set in India. Policy support keeps the onus of implementation on the government, while a mandated target shifts the onus of implementation on the stakeholders in the ecosystem. The latter is a more rational and practical approach, assuming that the nature of the mandate is carefully drafted.

Battery cost reduction a key enabler

Battery cost reduction is an important driver for EV adoption as it significantly impacts the upfront cost and TCO parity of the EVs. How battery costs pan out over the next five years is perhaps the biggest determinant of EV adoption in India.

Battery costs have fallen by around 85% in the last decade. The prices are further expected to decline rapidly. The elements driving the price decline are as follows –

1 /

Changes in cell chemistries

New cell chemistries are being aimed at reducing consumption of expensive raw materials and offering higher performance in terms of energy density.

E.g.

NCM 811 chemistry uses 50% less Cobalt and Manganese than NCM 622. Chemistry upgrade of the electrodes is the key to a high energy battery but the trade-off with structural stability must be managed.

2 /

Scale of operation

Large capacity creation in cell and battery manufacturing is enabling economies of scale. In addition, production lines are running at higher speeds.

E.g.

One of SDI's lines increased from an original capacity of 300K cell / month to 500K cell / month. Surplus capacity in the market is also creating pricing pressure on manufacturers.

3 /

Developments in other components

Improvements in other critical cost components like electrolytes and separators are further reducing the cost of batteries.

E.g.

In 2016, a research group including Toyota discovered the conductor LiSiPSCl, which has ionic conductivity around 2.5x the performance of existing electrolytes.

Global price projections

Battery prices vary between chemistries. Different companies and OEMs have chosen different chemistries. NCM, NCA, LFP are the key chemistries in the market today. The price expectations for different battery chemistries are mapped in the chart below.

The mix of battery chemistries is also expected to change over a period of time. LFP and NCM 111 are expected to phase out slowly. Nickel rich NCM chemistries are expected to take a larger share of the market. Average battery prices are expected to demonstrate a falling trend till 2025. Overall, the prices are expected to fall to 110 - 120 USD/kWh by 2025.

EXHIBIT 46 ↘

Global average battery pack price projection

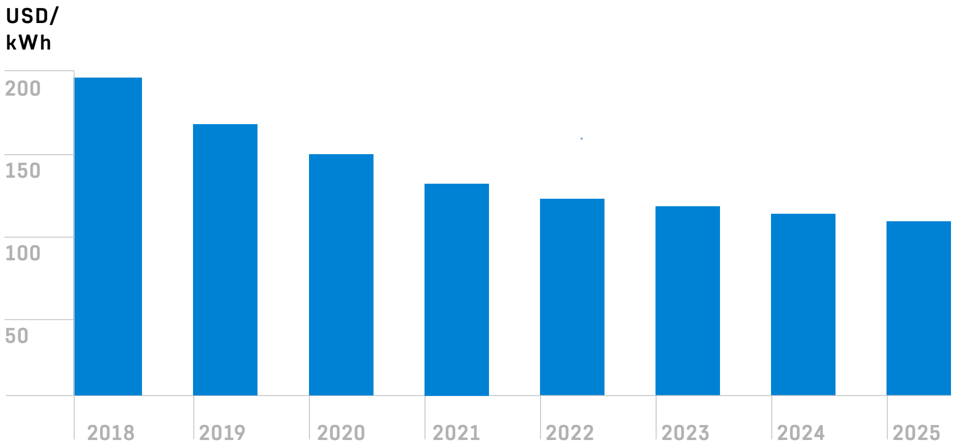
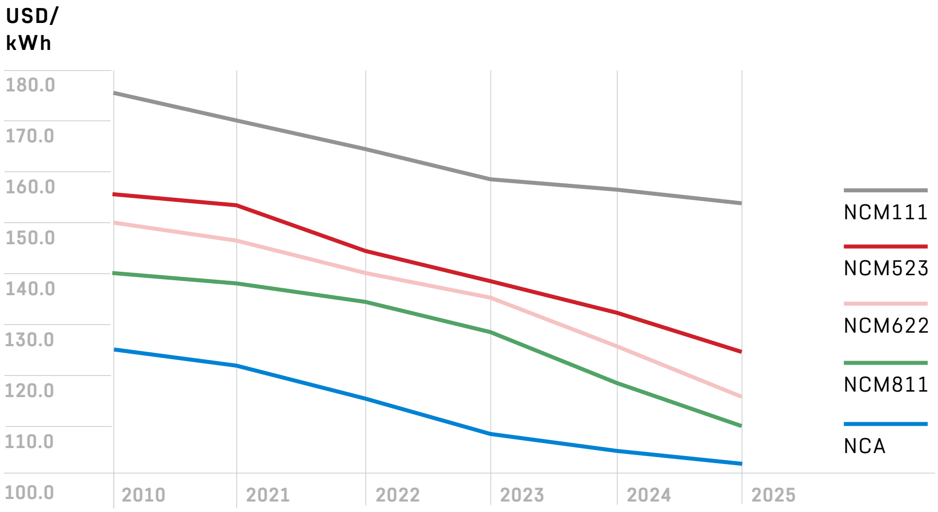


EXHIBIT 47 ↘

Average pack price expected by chemistry type



Battery price implications for the Indian market

Price points in the Indian battery market are significantly different when compared to the global market and a direct comparison with global price average does not portray the ground reality of the Indian market. A number of factors are responsible for such contrasting market dynamics in India.

I /

Lower bargaining power over cell manufacturers

The demand scale in India is minuscule at the moment. Thus, the cell prices that Indian battery pack manufacturers get are significantly higher than what a large global OEM with much higher volumes has to pay.

II /

Market composition

The Indian market is largely concentrated towards small batteries like 1-10 kWh. Currently, even the locally manufactured passenger vehicles operate with very small batteries of <30 kWh. The ex-cell cost of a battery pack does not move linearly with the pack size. The global data represents an average battery pack size of 60 kWh. Smaller batteries have higher per kWh price on account of increased costs in terms of balance of pack.

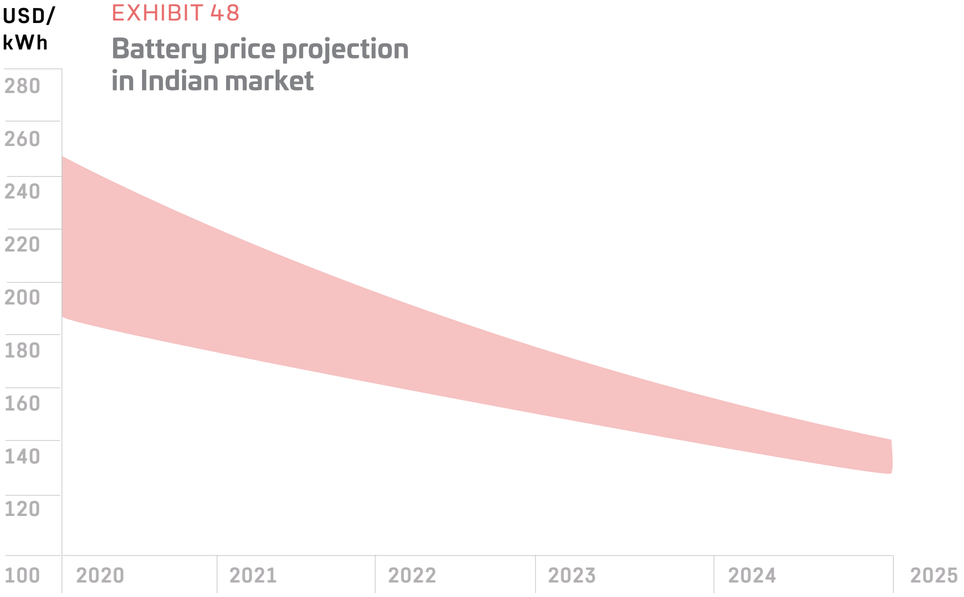
III /

Chemistry choice

India is largely using LFP and NCM 1:1:1 at the moment. Going forward, most Indian players are expected to rely on NCM chemistry with a gradual shift towards Nickel rich variants. NCM 6:2:2 and NCM 7:4:3 are already being used by 4W and bus OEMs in the domestic market.

EXHIBIT 48

Battery price projection in Indian market



Taking into consideration the decrease in battery prices at a global level and the increasing scale of the Indian market, battery prices are expected to fall to USD 130-150 /kWh by FY25.

Supply chain reinvention and its localization

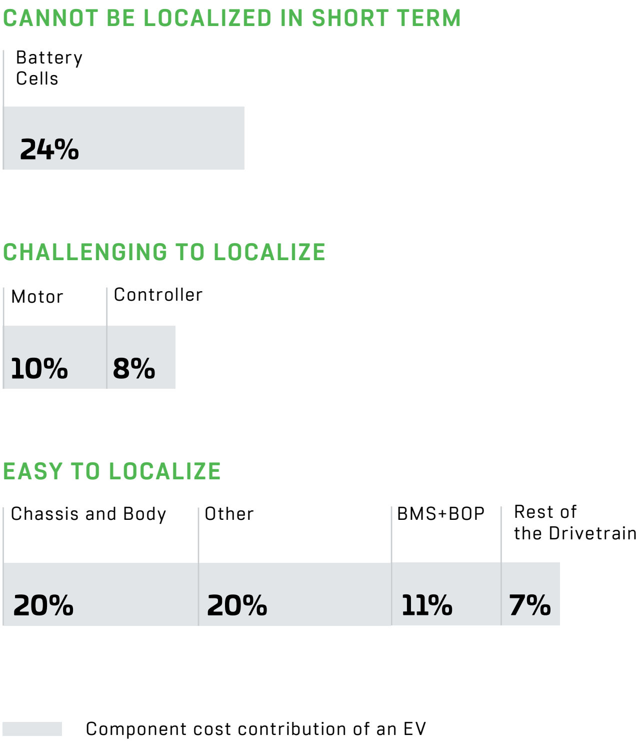
EV manufacturing in India, currently, is largely supported by imported components. While the small scale doesn't justify the localization of critical components, a roadmap to do so as the industry gains scale, would be imperative. Electric vehicle components present an INR 200 bn market opportunity by FY25 in India. As a country, India has been historically very good at cost engineering in manufacturing set ups. However, a large portion of EV components need deep technological capabilities.

Time, effort and large amounts of capital is needed to make sure that when the EV dream is actually realized in India, it is supported by a vibrant domestic supply chain rather than an import dependent supply chain.

Localization of the supply chain is also critical from the perspective of bridging the cost differential between EVs and ICE vehicles. A well-established local supply chain can help reduce the cost of electric vehicles.

EXHIBIT 49

Ease of localization for different components



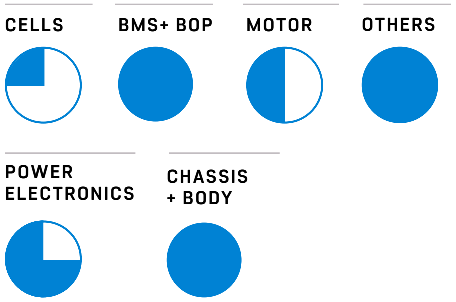
There are two key stakeholders that influence the supply chain localization in India – the first is the government and the second are the incumbent auto component companies. The government has taken policy measures to support component localization in India. Phased Manufacturing Program is an important step in this direction. Incumbent auto component companies have vast experience in the automobile industry in India. They are excellent at cost engineering and have the muscle to deploy capital for new components for EVs.

While a well established supply chain is not a direct determinant of EV adoption, whether or not the supply chain can get localized is an important question that needs to be addressed.

This localization has its own challenges, and it will take time, but the country needs to invest in it, starting from now.

EXHIBIT 50

Potential for localization



Key challenges in localization

Cells, which are the largest cost component in EVs, are also the most difficult to indigenize. Even in the best case, a large majority of cells are expected to be imported into India.

BMS and BOP technology, on the other hand, are relatively easier to master. Field experience is critical for fine-tuning BMSs and that will only come with a learning curve of the Indian market.

A lack of availability of rare earth magnets is a key bottleneck for the domestic motor industry. Small motors for light electric vehicles should be easier to manufacture locally. Large motors need sophisticated technology and could take a longer time to be localized in India. The market for larger motors is also expected to be limited as adoption in the PV and CV segments will be low until FY25.

Controllers are technologically intensive and can be developed locally if investments are made in technology. There are already companies that are focussing on EV controllers, specially, for the 2W and 3W markets, where there is a large void, as global players are more focussed on PV and CV segments.

Other components and bodies are closer to the core strength of Indian manufacturers and there is a high likelihood that their manufacturing will get localized rather quickly.

EXHIBIT 51

Localization opportunity for EV components

COMPONENT	CELLS	BMS+BOP	MOTOR	POWER ELECTRONICS	CHASSIS & BODY	OTHERS
FY25 MARKET SIZE (INR bn)	80	35	25	35	75	
CURRENT LOCALIZATION	None	Low	Very Low	Very Low	High	Low
OPTIMISTIC CASE	30%	100%	70%	100%	100%	75%
PESSIMISTIC CASE	<5%	40%	30%	50%	80%	50%

Charging infrastructure for India's unique needs

The Indian EV market has multiple unique requirements. 2W and 3W make up for over 80% of the overall market and are likely to be the first adopters of electric vehicles.

Low and medium speed 2Ws can be easily charged at home and most of them run less km/day than what the battery capacity allows, making range anxiety a lesser of a problem. A large portion of the urban population lives in high-rise buildings, where parking facilities are either poor or non-existent.

3W typically require an additional charge during the day given that they run for longer distances. This additional charging has critical implications for the driver as the time it takes is the opportunity cost for not running the vehicle.

In passenger cars globally, 70% of the charging is done at home on slow AC chargers and the rest is supported by the public charging infrastructure. Home charging in India, especially, in urban areas is tricky due to the lack of proper parking arrangements. Also, the miniscule levels of 4W EV uptake is not encouraging the development of public charging infrastructure.

Buses have very large batteries that need DC fast chargers to charge them in 5-6 hours during the night. While depots are perfect places to charge these buses at night, each depot has hundreds of buses and if a significant number of them need to be charged together, the capability of the grid is an important aspect to be considered.

EXHIBIT 52

EV charging requirements

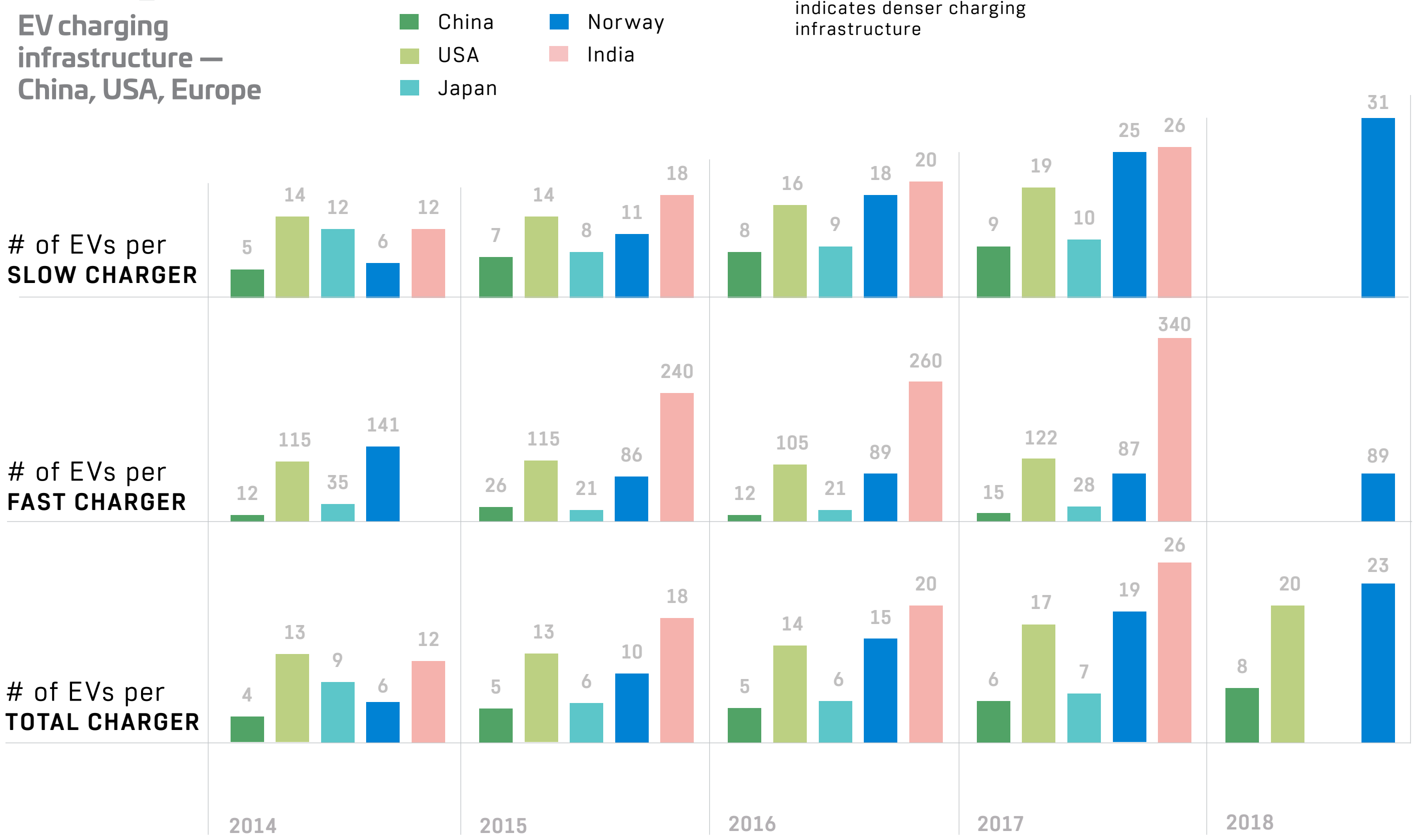
	2W	3W	PV	BUS
TYPICAL BATTERY	2 kWh	4-8 kWh	40 kWh	200 kWh
CHARGING TIME	AC – 3-4 hrs	AC - 4/5 hours DC - 30 mins	AC - 7/8 hours DC - 1 hour	DC – 3-4 hrs
MOST SUITABLE PLACE	Home	Home/Station	Home/Station	Depot
POTENTIAL SOLUTIONS	Infrastructure development at residential complexes Business models to charge 2W through regular plug points at various commercials places	Battery swapping Infrastructure development by fleets	Infrastructure development by/ or for fleets Public charging stations with business models that attract customers	Distributed pantograph charging

Public charging infrastructure has not been conducive for initial adoption in the Indian market. The country is witnessing almost non-existent infrastructure, despite all the buzz around EVs in the market today. While the initial EV adoption was not aided by public charging infrastructure, creation of the same is a necessary condition for large scale adoption in the country. Both EV adoption and charging infrastructure will need to be developed simultaneously. Development of residential/private/commercial infrastructure will need creation of awareness, municipal level policy support and some innovative business models.

Globally, EV adoption has been supported by extensive charging infrastructure development. China invested huge amounts of money in creation of charging infrastructure. Today, China has close to 50% of the global infrastructure and also has 50% of the global EV market.

EXHIBIT 53

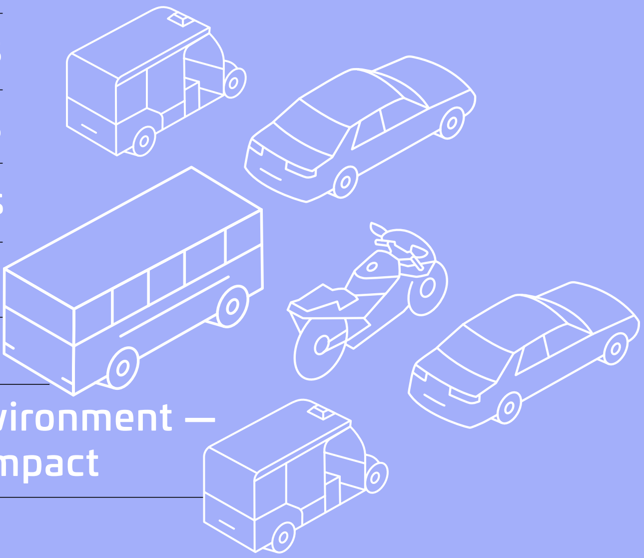
EV charging infrastructure — China, USA, Europe



A lower EV/Charger ratio indicates denser charging infrastructure

07

EV Penetration in India



Scenarios over the next 5 years

Battery price reduction is the most important driver for mass scale adoption of EVs. As prices fall, the role of policy would be critical in ensuring that India doesn't lag in EV adoption. Policy and battery cost are the two main drivers that will decide how adoption takes place in India over the next 5 years. Development of local supply chain and public charging infrastructure are two supporting conditions that will have a further impact on the extent of EV adoption in the country.

3W, 2W Fleet, 2W Retail, Buses, 4W Fleet, 4W Retail would be the pecking order of electrification in India. 2W/3W present an attractive TCO argument. A controlled mandated adoption target could make a significant difference to the growth in this category. E-bus adoption is driven by the government and will continue to be the case given the lack of TCO parity. 4W adoption is largely expected to be restricted to 4W fleets, with retail penetration being driven by the OEMs, push to launch new variants in the market and the development of public charging infrastructure.

EXHIBIT 54

Rate of EV adoption

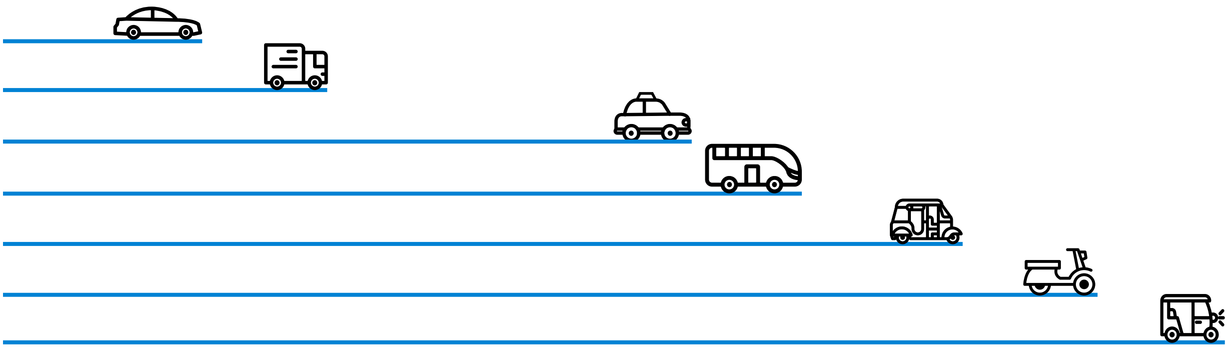
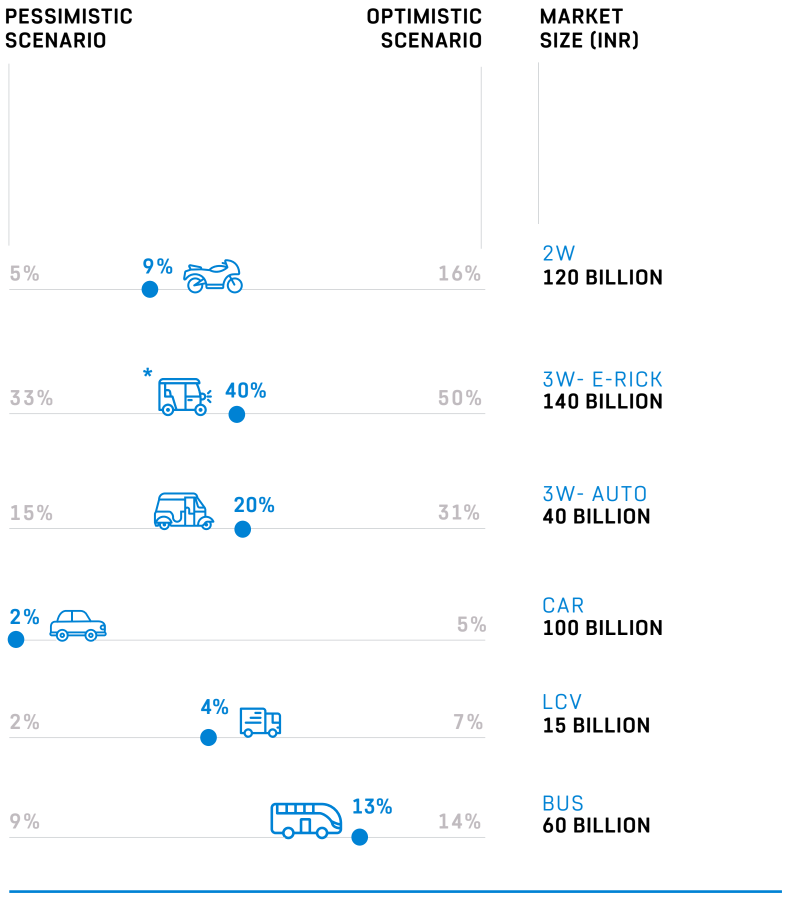


EXHIBIT 55

Electric Vehicle adoption in India

DRIVERS FOR ADOPTION	**POLICY**	+ **BATTERY PRICE**	+ **CHARGING INFRASTRUCTURE**	+ **SUPPLY CHAIN EVOLUTION**
SCENARIOS	+ Mandated adoption target	+ USD 120-130/kWh by FY25	+ Easy access to high voltage DC fast charging	+ 80%+ components localized
	- Clear policy framework and support through incentives	- USD 140-150/kWh by FY25	- Poor public charging infrastructure	- <50% components localized

= FY25 EV adoption scenarios



● AVENDUS ESTIMATE

= 475 BILLION

* Penetration represents the adoption of Li-ion batteries in this segment. Market Opportunity represents the total market size

2W —
Upfront cost expected to be a major dampener, despite favourable TCO

The total cost of ownership of low to medium specification electric 2W is lower than ICE vehicle equivalents. The operating costs which are almost 1/6th in case of electric vehicles, is the major driver for TCO parity despite the upfront cost being high. 2W is largely a retail market and is highly sensitive to pricing. Thus, in addition to favorable TCO, lower upfront cost is essential for mass adoption of e-2Ws.

However, as the battery prices reduce, it is expected that a reduction in upfront cost will drive interest among retail customers. The point of inflection for mass adoption of electric 2W is expected to be reached by around FY23 with battery prices falling to USD 160-170/kWh. By that time, a successful implementation of FAME-II would put 1 million electric 2W on road, giving a vital learning curve for the whole ecosystem.

Customers need access to good financing options to buy EVs, availability of which is limited currently. General awareness around EVs could attract the higher usage customers to shift to EVs. Customers also need better purchase options in the market. EVs are easy to make and customize. If OEMs were focused on scale and cost for ICE vehicles, they need to focus on customization and the value proposition for EVs. A typical large ICE vehicle 2W OEM has 5-6 models in its portfolio whereas a typical large OEM of the future would have 15-20 EV models offering a wide choice of specifications for the customer.

The role that top incumbent 2W ICE vehicle companies in India assume during this transition would define not only how the industry transforms but also how these companies endure the EV shift. One of the key impacts that EVs are likely to have on the 2W OEM industry is that it will become more fragmented than what the current ICE market is. It is more likely that the industry will have 6-8 large players accounting for the majority of the market along with a number of small players operating in niche market segments.

2W fleets are likely to shift to EVs much more rapidly. Dock-less ride sharing companies, delivery fleets like Swiggy or Domino's are already charting out plans to go electric. For fleets, considering massively low operating costs, not going electric would be a costly mistake.

3W —

E-ricks to rapidly shift to Li-ion, and Autos to benefit from a strong TCO rationale

E-ricks has been a surprise category and has grown rapidly in the last 5 years. Currently, a majority of the market is based on Lead Acid batteries. The e-rick market is around 0.7 million units a year. Close to 50% of this market is completely unorganized and unregulated. The cost of an e-rick from an unorganized-unregulated market to a fully organized-regulated market changes from INR 80K to about INR 130K.

Li-ion is a superior battery choice as compared to Lead Acid. Li-ion batteries have a longer life, higher depth of discharge, do not result in massive deterioration in range over the life of the battery, and can be charged quickly as compared to Lead Acid batteries. A shift from Lead Acid to Lithium makes complete sense right now. Fleet based 3W operations have already started to use Li-ion. However, the problem of higher upfront costs is dampening Li-ion adoption in the e-rick market at a larger scale. The good quality, regulation compliant e-ricks with Lead Acid batteries cost around INR 130K. The same would cost around INR 190K with Li-ion batteries.

Li-ion based e-ricks are expected to get up to 25% market share by FY23 and after that, the shift could become very rapid. The market is expected to shift away from unorganized-unregulated to at least semi-organized and regulated.

The auto market is concentrated between 3 OEMs and is almost entirely retail in nature. So far, there has been no push from OEMs nor any pull from the demand side. However, several factors are prompting auto makers to shift to electric. With e-ricks growing, the traditional auto market has the pressure of staying relevant. Even though e-ricks and autos operate in mutually exclusive segments right now, the line between these two categories is thin and might vanish in the future as bigger batteries become cheaper. On a TCO argument, e-autos make sense even against CNG 3W vehicles. This, along with additional benefits like no permit cost, will drive the adoption of electric autos in the near term. Key OEMs are in the final phase of their product development. Bajaj and Piaggio are expected to come out with e-autos soon.

A 20% penetration in the 3W-auto category is expected by FY25.

4W—

Adoption to largely remain restricted to fleets. OEMs will be key in driving retail penetration

India is a relatively difficult market for electric cars. 78% of Indian car sales are at price points of sub INR 1 million. An electric car with the same price tag cannot match the performance of an ICE car. ICE equivalent cars have a much bigger battery. While the Indian market is less likely to go for super big battery packs like the 100 kWh used in Tesla, even a 40 kWh battery pack creates a huge difference in the upfront cost for cars. Plus, retail use case of cars have lower running over their lifetime and so, the TCO argument does not hold true for retail customers. A good electric car, however, provides a driving experience that cannot even remotely be matched by an ICE vehicle. That has to be the key retail sales pitch for electric cars.

Electric cars in the retail category are expected to make up 2% of the market by FY25. The tipping point for electric cars is expected to come around FY27 at battery prices of around USD 120/kWh.

Fleet operators on the other hand are incentivized to go electric. On a TCO basis, electric cars are cheaper for average daily running in excess of 120 km. Fleets also benefit from the fact that they can set up their own captive charging infrastructure to manage the charging demand. They also have a complete understanding of the pattern of demand for charging, usage of battery, etc. and can create a more economical fleet ecosystem as compared to ICE. Several successful cases have been seen in India. Lithium Urban is operating a 1,000+ strong fleet of electric cars. An electric car is a high capital investment and any use case that can assure a high asset utilization is fully incentivized to go electric.

20% of the 4W fleet market in India is expected to shift to electric by FY25.

Bus — Will continue to be driven by public transport demand, led by the government

The electrification of buses in India is primarily being driven by the objective of reducing pollution in cities. In that context, the factors that were identified as critical for electrification have lesser impact on bus electrification. DHI is in the process of deploying 5,000+ buses under FAME-II. Various state governments have laid down plans for pubic transport bus electrification.

At current battery prices, the cost differential between an electric bus and diesel/CNG bus is huge and even on a TCO basis, electric buses are significantly more expensive. Thus, without subsidies, bus sales are not expected to happen. FAME-II covers for 7,090 buses by FY22; there are additional efforts by the state governments to promote electric buses.

Electric buses are expected to come at TCO parity with ICE equivalents at batteries prices of USD <100/kWh. By FY25, electric buses will contribute to about 13% of total sales.

Interesting opportunities in the LCV space and freight applications

High capital expenditure, low operating expense – that summarizes the EV economic viability decision. Hence, any business model that can ensure high utilization of vehicles has an advantage in going electric. In that perspective, light commercial vehicles segment is an interesting opportunity for EVs. For both goods carriers as well as last mile public transport, electric LCVs make economic sense. Key CV OEMs – Tata Motors, M&M and Ashok Leyland are working on e-LCV models.

Trucks suffer from the same capital cost dilemma as buses. However, freight operations can offer very high asset utilization levels and have the potential to go electric. Electric mobility as a service for freight operators, is a business model that is being closely evaluated by OEMs and investors, and is likely to come to fruition soon.

EVs are likely to penetrate up to 4% in the LCV segment. Penetration in the truck segment is not likely to pick up outside mobility-as-a-service business models.

Current Environment

Current Environment — COVID-19 Impact

Expect a relatively rapid revival of the EV industry in India

COVID-19 has hit the Indian auto industry at a time when it was already grappling with the dual challenge of slower demand and recent BS-VI transition. In FY20, ICE auto sales declined by 18%. Given the COVID-19 situation, Q1FY21 is expected to be a washout for most OEMs even though most of them are resuming production at some scale. FY21 is expected to be a tough year for the auto industry and sales are expected to show a double digit decline across vehicle categories.

EV sales increased by 20% in FY20 – a slower than expected growth as there was a FAME-II transition impact on the e-2W market (as discussed earlier in the report). A significant portion of the EV industry in India is represented by SMEs and start-ups. The COVID-19 lockdown is expected to affect this part of the industry the most. EV plans for most ICE OEMs are likely to be on the backburner as these companies will be busy restoring their "bread-and-butter" ICE products. The EV industry, in the short term, will have to fight for survival given that most of the EV players have been focussed on growth and and have been generating limited cash.

COVID-19 is expected to be a part of our lives for the next 12-18 months. The auto sector, in general, might be on a slow revival trajectory post COVID-19 but the revival of the EV industry is expected to be faster. The EV consumer of today is significantly different as compared to an ICE vehicle consumer. EV purchase decision is influenced more by the value proposition rather than only on comfort or leisure. To that extent, the impact of reduction in discretionary consumer expenditure is less likely to affect EVs than ICE vehicles.

97% of EV sales in India are in the 2W segment and within 2Ws, 90%+ sales are in the low-medium speed segment. The low-medium speed e-2Ws are marginally cheaper than ICE vehicles in terms of upfront cost and significantly cheaper in terms of TCO. Hence, while the overall 2W market will degrow in FY21, EVs as a percentage of 2W sales could very well increase. The need for affordable personal mobility will increase in a COVID-19 world. E-2Ws make a strong case for such mobility demand.

In other segments, the COVID-19 impact could be more significant. e-auto launches by major auto OEMs are likely to get deferred. The growth of e-ricks will slow down as the use of public transport by people reduces. Shared mobility presented a compelling use case for e-4W but that segment will now be dented significantly in the near term. The retail demand for e-4W can get heavily impacted as the value-for-money proposition here is not as strong as e-2W and e-3Ws. Buses are relatively neutral and the electric bus market is expected to show strong growth on account of e-bus deployment project under FAME-II.

In summary, while the short-term negative impact on EV growth is certain, the EV industry is likely to revive faster and penetrate deeper into the overall auto sales in India.

While it is too early to draw parallels, the trends in the global EV market indicate a lower impact of COVID-19 on EVs. Sales in worse affected countries in Europe and China were impacted lesser than ICE vehicles in the months of February and March 2020. The revival of EV sales has been rather encouraging in China. Electric car sales in China grew more than 3X in March-20 as compared to February-20, ending up with a 5.7% penetration for the month – higher than the 2019 number.

COVID-19 to expedite the ICE-EV shift in the long term

In the longer term, COVID-19 is expected to accelerate the ICE-EV shift at a global scale.

Multiple structural changes are expected to take shape in the post COVID-19 world —

- **Aspiration for clean mobility**
- **Need for affordable personal mobility**
- **Growth of online delivery**
- **Value driven purchase**

The aspiration for shifting to a cleaner mobility will get fresh impetus at a policy level as well as at a personal level. The otherwise price sensitive Indian customer is much more likely to appreciate the value of cleaner mobility – a shift that in the normal course of life would have been difficult. The policy's focus on EVs will get slightly distracted in the short term but is likely to become firmer in the long term.

The demand for affordable personal mobility will go up. Auto sales in China, post SARS-2002, went up due to an increased demand for personal mobility. The poor state of public transport in India means that the need for affordable personal mobility can increase even faster in a post COVID-19 India. The e-2Ws are most likely to cater to this mobility need, as the e-4Ws still do not make an equally meritorious case for retail use.

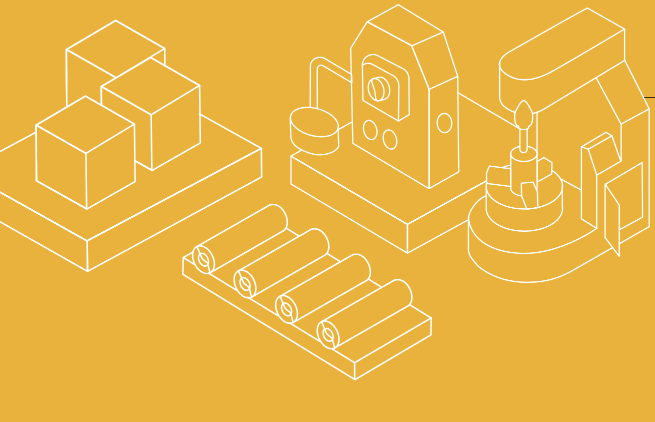
The online delivery market is expected to grow faster post COVID-19. These companies are highly incentivized to go electric due to a lower TCO.

Consumer purchase decisions are expected to be more value driven rather than leisure, feature or performance driven. The shift from ICE 2W to e-2W would be much faster in such purchase decisions. The shift from ICE to EV in commercial (especially fleets) use cases in 3Ws, 4Ws and LCVs will become faster in the long term.

FY22 was expected to be the inflection year for the Indian EV industry. In the context of COVID-19, the inflection point is likely to get delayed by a year. But the EV transition post the inflection point will be faster and the industry is expected to stay on track to achieve the FY25 penetration levels that it would have achieved in the absence of COVID-19.

08

Impact on the other parts of the automotive and energy ecosystem



Impact on the auto component industry

Over the years, India has successfully developed a thriving auto component industry. Today, this industry is about USD 50 billion in size and contributes to 2.3% of the country's GDP. Close to 3 million people are employed by this industry. It is also one of the most cost-efficient industries that has enabled the rapid growth of the automobile sector in India.

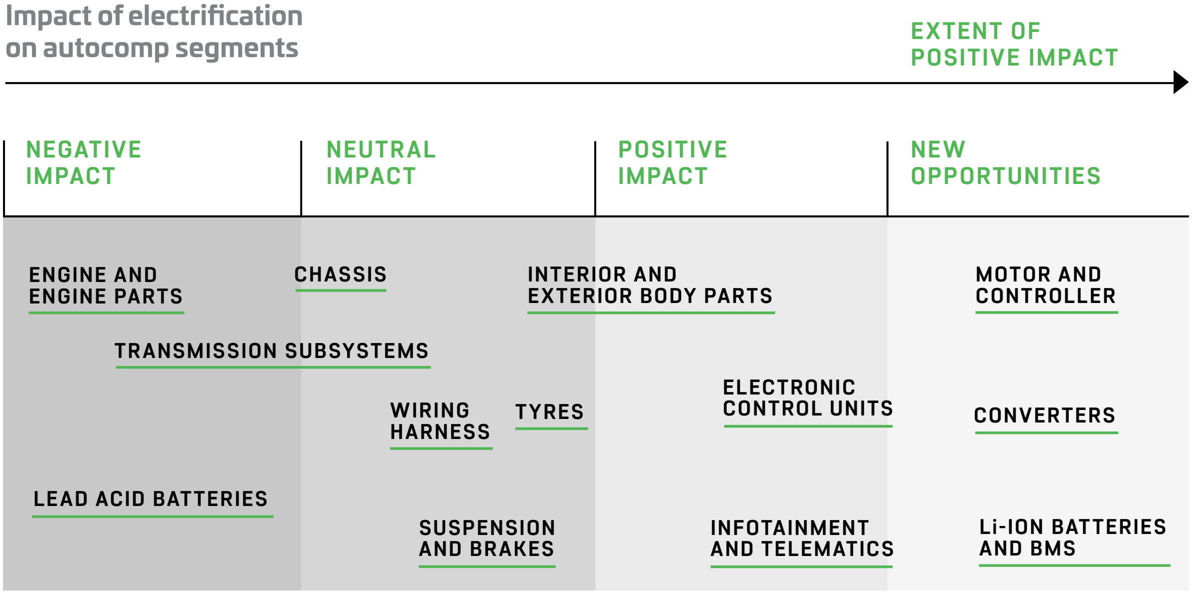
Electric vehicles will change the structure of the auto component industry. Many components used in ICE vehicles will disappear from EVs. The most impacted category would be engine and related components as it will be completely phased out with EV adoption. Drivetrain components would get impacted next as content/vehicle would drastically come down (except for steering related components) considering a much simpler drivetrain design in EVs. Batteries would completely change and as mentioned earlier, this is an open field for new players. Suspensions and braking systems would face a neutral impact, while mechanical designs and technologies might change/improve overall. From the component manufacturers point of view, the impact would be neutral.

Body parts, both internal and external, are also expected to remain neutral. Impact on electrical components would be neutral to negative as the electrical design of an EV would be vastly different when compared to an ICE and would therefore need a considerable shift in technology. Electronic components would have a positive impact as an electric vehicle will need sophisticated control solutions for motors and battery. Also, the larger adoption of infotainment and telematics would result in increased content/ vehicle.

EVs open a huge opportunity for certain new components. The three key components are battery, motor and controller. Today, India has little infrastructure or technology for manufacturing these domestically. These three component categories present a market opportunity of INR 150 bn by FY25. Other new components that EVs would bring into the picture are AC-DC/DC-DC converters, inverters, and e-axles.

EXHIBIT 56

Impact of electrification on autocomp segments



Grid composition and capability

1 / GRID COMPOSITION

EVs are better than ICEs, even with the current coal-heavy grid mix

India has a coal heavy grid mix. 75% of the electricity in India comes from coal and only 16% comes from renewable energy sources. Coal based electricity has a very high carbon footprint. Thus, a question that is often raised is – Is the source of pollution being shifted from cities to power plants? Li-ion batteries have a higher carbon footprint as well, through their life cycle.

So, the other important question is – Do electric vehicles have a negative carbon footprint impact over their complete life cycle?

Firstly, it is important to understand the carbon emissions of an EV vs an ICE vehicle. The data used is from the Alternative Energy Data Center of the US Department of Energy. It provides state wise car emissions average for EVs and ICE cars. Each state has a different grid mix. A regression analysis was done and the USA state wise grid mix vs EV emissions data was used to arrive at a typical EV emission for an India equivalent grid mix. An average gasoline car in the USA emits around 5.2 MT/year of CO_2. An electric car with an India equivalent grid mix emits around 3.8 MT/year of CO_2.

To draw parallels for the Indian market based on the USA data has fallacies. Indian ICE vehicles are likely to have higher emissions considering the poor road and traffic conditions. At the same time, Indian power plants are likely to have far higher emissions than similar plants in the USA. Given the difficulty in quantifying these differences, they have not been incorporated in the analysis. While the exact numbers could vary slightly, the broad inference is that even for the Indian grid which is heavily coal dependent, EVs have a significantly lower carbon footprint than ICE.

Now, to the second question around life cycle emissions of an ICE vehicle vs an EV. Again, the quantification of carbon emissions over the entire life cycle of an ICE vehicle and an EV is tough.

Except for the Li-ion battery, the rest of the EV is similar to an ICE vehicle and hence, a simplistic assumption is being made that an ex-battery EV has the same carbon footprint as that of an ICE. That's a very conservative assumption given that an ICE has far higher number of components and is certainly likely to have a higher carbon footprint as compared to an ex-battery EV.

The CO_2 emissions over the battery life cycle are again difficult to estimate. At the higher end of the reported numbers, studies indicate that a 30 kWh Li-ion battery contributed to 5MT CO_2 through its entire life cycle. An EV in India would thus, take about 3.5 years to net off this additional CO_2.

Without over-emphasising on how good EVs are, the broad message is that EVs are more carbon efficient when compared to ICE vehicles in India.

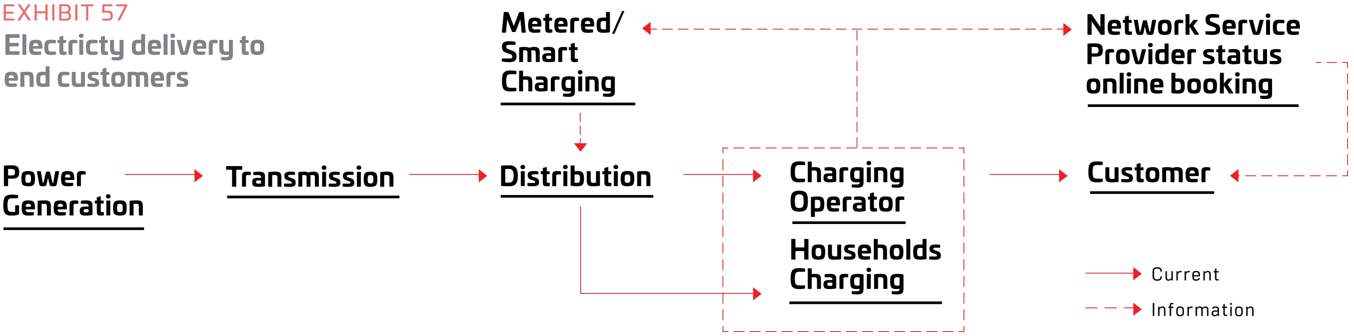
2 / GRID COMPOSITION

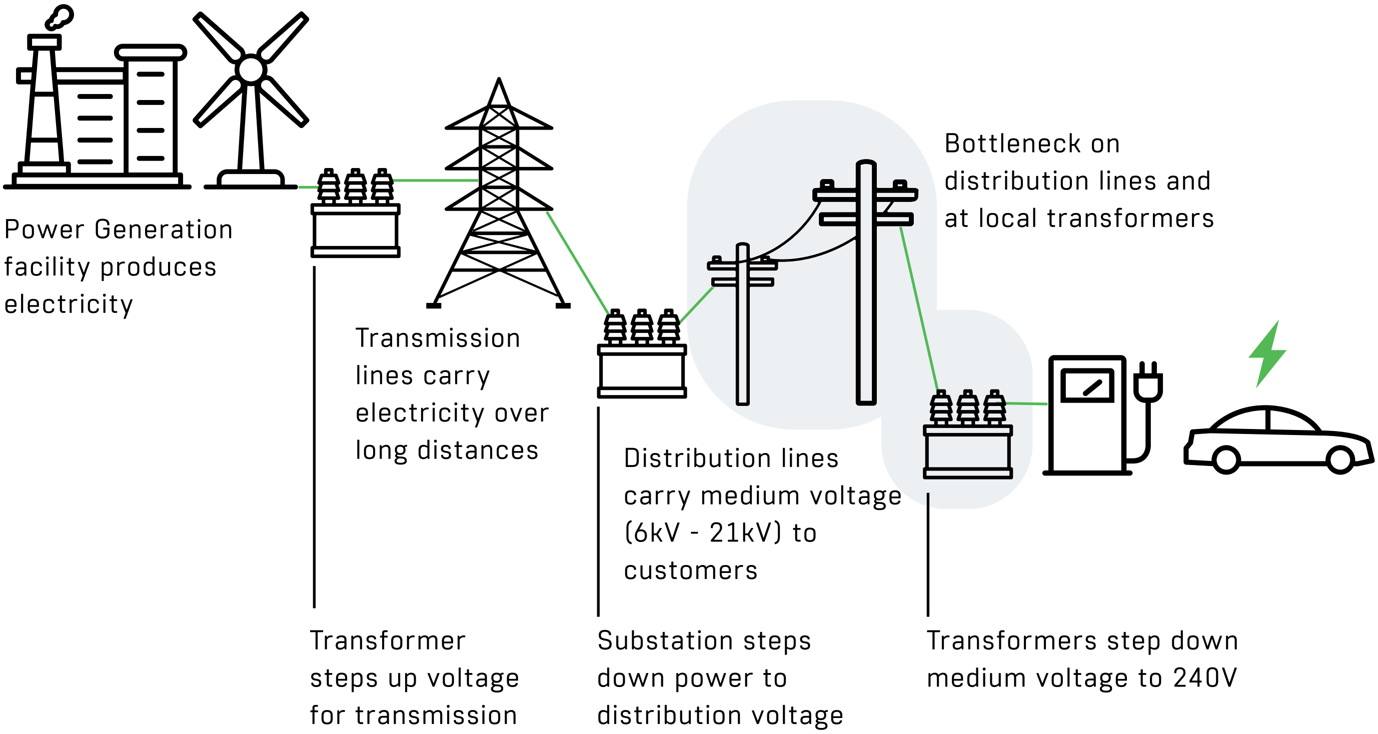
EVs are better than ICEs even with the current coal-heavy grid mix; A shift away from coal, however, is a must to truly address the pollution problem

EVs are an enabling mechanism to address the pollution problem. To truly address this, the Indian grid will have to become more carbon efficient. A reduction is needed on the reliance of coal fired power plants and an increased contribution from solar and wind energy into the grid. The larger policy vision seems to be aligned with this objective as well. If India reduces coal-based electricity to 30% of the grid, then an electric car in India would have 1.5 MT/year CO_2 emissions. This means means an EV would break-even with an ICE within 1.5 years in terms of the CO_2 footprint.

EXHIBIT 57

Electricty delivery to end customers





3 / GRID CAPABILITY

A sustainable and efficient grid is needed to develop customer's trust in electric vehicles

Adoption of vehicles will not just depend on the automobile industry. It requires significant support from power and technology sectors to create a charging ecosystem that can reduce the stress of EV charging for the people.

The diagram represents how electricity is delivered to the end customers. Power plants generate electricity and increase the voltage as power is transmitted to the transmission lines. The transmission lines bring power to a substation near a population centre to step down the voltage. From the substation, the power is delivered at a medium voltage of (2.2kV – 33kV) to smaller transformers, which step down to the appropriate voltage for connecting EV chargers. This AC is then converted to DC in the fast charger to match the battery voltage of the vehicle.

4 / GRID CAPABILITY

Power generation and transmission needs upgradation and at a faster pace

As EV penetration is currently low, there should not be a major impact on transmission and power generation infrastructure. But it is estimated that EVs alone would consume about 1.2-1.5 GW of power in Delhi. This is expected to form about 25-30% of the city's current requirement. This would require upgradation of lines and development of infrastructure in the coming years.

India has taken initiatives which help in reducing this issue. The country has also been upgrading to high power distribution lines in order to upgrade to efficient transmission systems.

EV charging can be a boon to solar based electricity generation in India, if managed well. EV charging during the day can act as mass storage systems that can utilize significant solar power, balancing the load. This will improve performance and lead to the efficient use of this renewable source.

5 / GRID CAPABILITY

Distribution would be impacted significantly by concentrated EV adoption

Adoption of EVs will grow in concentrated groups, as consumers tend to get influenced by EV purchases in their vicinity. If 10% of households in a block switch to EVs with a Level 1 charger in their homes, it is estimated that it would add around 20% of peak additional load. This would require significant upgradation to the present distribution system. Utility providers in other countries are providing discounted pricing for charging during non-peak hours to reduce the impact on the grid. That is not the case in India. In China, a study of 27 residential communities was carried out. It revealed that when EV penetration had reached 20% in 21 communities, the local grid required an upgradation.

In India, a majority of transformers are of <100 kVA capacity. Adding even one Level 2 wall mounted charger (3kW -22kW) along with the current usage would add significant stress on the transformer. Hence, a major upgradation is required in areas of higher adoption to meet the demand of EVs.

For higher level chargers, separate transformers are required to be installed. This would add to the expenditure of setting up EV infrastructure in India.

The upgradation of distribution systems also has positives. The low capacity transformers, which form the majority of transformers used today, are manufactured with conventional materials which results in very high power loses of around 16% (compared to global average of 1-2%). The higher capacity transformers will help reduce these losses and thus, reduce the electricity charges going forward.

6 / GRID CAPABILITY

New business opportunities for management of EV charging supply-demand dynamics

An EV charging operator would also require engaging with a Network Service Provider (NSP) to interact with customers. As EV charging (unlike refilling fuel in combustion vehicles) takes significant amount of time, it requires proper communication with customers to avoid demand-supply issues. There have already been a few instances where there were huge queues of vehicles outside stations causing traffic jams and problems to the surrounding neighbourhood. An EV charging operator should be able to show the current and future status of chargers, provide a facility to book slots remotely, provide invoicing, etc. This would create significant opportunities for start-ups to establish platforms for the EV charging management.

7 / GRID CAPABILITY

Smart/metered charging will be the future

In metered charging there is communication from the grid, depending on its load, which influences the behaviour of charging by using variable tariffs, charging limitations, etc. In more advanced systems, it can directly communicate with the vehicle during charging. It tries to balance the load on the grid and reduces the peak requirement by using the EV as energy storage systems. This is mainly at ideation stage and requires high level development in EV infrastructure and communication. There are pilot facilities in developed countries adopting this at a smaller scale. Tesla also has a system where the charging rate is reduced when many cars are simultaneously connected, to avoid exceeding limitations of the transformers and other equipment.

Another advanced application in this field is Vehicle to Grid (V2G) charging. In this technology, the vehicles act as energy storage devices. Batteries in vehicles can transfer the current back into the grid when the grid demand is high and gets charged when the grid demand is low. This reduces the energy charges for batteries and balances the grid. However, this requires a high level of communication between the grid and the vehicles, and, compatibility of transferring current back to the grid.

Battery Recycling

1 /

First step — second life

End-of-life EV batteries have large potential applications in stationary storage systems. Second life batteries find applications in a variety of services including frequency response, backup power, demand side response and auxiliary capacity. Batteries are also being used for energy storage coupled with EV charging, in order to reduce stress on the grid and to decrease the demand during peaks. The concept is rapidly picking up in the USA and China where second life battery availability is increasing.

In China, new regulations call for battery and vehicle companies to arrange for both recycling and assessment of second life potential. The Li-ion adoption and awareness in the Indian ESS market is gradually picking up. Li-ion is expected to replace Lead Acid for commercial UPS, renewable integration and Telecom ESS applications. Second life Li-ion batteries could make an interesting case for the cost sensitive home UPS market as well, where Li-ion ESS would otherwise find it tough to penetrate.

2 /

Circular energy – key to India's self sufficiency

India has virtually no reserves of key battery materials like Lithium and Cobalt. The industry in India will depend upon the import of these materials in the early phase of its growth. With EV adoption picking up pace by FY25, the end-of-life Li-ion battery market is expected to grow to ~100,000 tonnes by FY30. Recycling of these batteries is critical for India to keep the import dependency at a minimum.

Not all end-of-life batteries are expected to reach the recycling stage, as a large portion of them are hoarded or just disposed off. Non-availability of a sophisticated supply chain is partially a reason for that as well. Even if one considers a 50% recycling of end-of-life batteries, that represents a market opportunity of USD 0.8 billion by FY30.

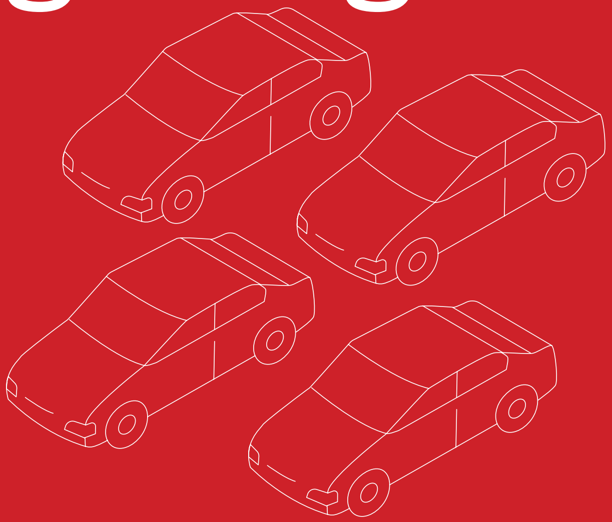
EXHIBIT 58

Recyclable material in Li-ion batteries

MATERIAL	USD/Kg	% CONTENT IN A CYLINDRICAL CELL (18650)							
		NCM111	NCM523	NCM622	NCM811	NCA	LFP	LMO	LCO
CASING									
STEEL	0.3	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
ALUMINUM	1.8	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
CURRENT COLLECTORS									
ALUMINUM	1.8	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
COPPER	6.0	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%
ANODE MATERIAL									
GRAPHITE	1.2	18.1%	18.1%	18.1%	18.1%	18.1%	18.1%	18.1%	18.1%
CATHODE MATERIAL									
MANGANESE	2.4	6.1%	5.5%	3.6%	1.8%			19.4%	
LITHIUM	70.0	2.3%	2.3%	2.3%	1.9%	2.3%	1.4%	1.2%	2.3%
COBALT	30.0	6.5%	3.9%	3.9%	1.9%	2.9%			19.3%
NICKEL	12.0	6.5%	9.7%	11.6%	15.4%	15.4%			
ALUMINUM	1.8					0.4%			
IRON	0.4						11.3%		
TOTAL VALUE (USD/KG)		**5.4**	**5.0**	**5.2**	**4.8**	**5.3**	**2.0**	**2.3**	**8.3**

09

A New Beginning



The dawn of clean energy disruption

While concluding this whitepaper on electric vehicles, it would be apt to put the EV transformation in context with the larger picture of clean energy disruption. Today, solar energy has become more economical than thermal power plants, something that was unimaginable 10 years ago. General Electric Company (GE) exemplifies how an inability to keep up pace with rapid industry transitions can erode value. GE destroyed an unprecedented USD 193 billion or 74% of its market capitalization between 2016 and 2018. This value destruction was driven in large measure by the collapse of the new thermal power construction market globally, and GE's inability to adapt to the new energy regime. This is also a reflection of how fast disruptive changes can alter industry structures.

In the future with rooftop solar, there will be no centralized energy generation and distribution. The grid would become decentralized. When this clean energy powers electric vehicles, the transportation industry would truly become clean. The next areas of this disruption are shared mobility and autonomous driving. Unlike today, where everyone owns a car, which ends up being parked for a majority of time, mobility, in the future, will be shared and available on demand, powered by electric vehicles and in the long term, be autonomous.

Electric vehicles are not just about disrupting the ICE automobile. They are part of the larger disruption in energy and transportation. The way of living is going to transform and EVs will be an essential part of the new way of life.

EVs are undeniably superior products and a technological disruption to the ICE vehicles. In a span of less than 15 years, at the start of the last century, the USA went from nearly 100% horse carts to almost 100% gasoline cars. When the first call was made over a mobile phone in India in 1995, it seemed like a niche product that wasn't meant for the masses. It took the government 8 years to weed out all the inefficiencies in the country's telecom policy. In 2003, there were a mere 13 million mobile phone subscribers and 97% of the market share was controlled by 2 companies. Today in 2020, India has 1.2 billion mobile phone subscribers and those two companies hold less than 10% of the market share.

The world has witnessed disruptions time and again, yet every new disruptive innovation is met with a lot of cynicism in the initial stages. Like the beginning of every disruption, electric vehicles are also surrounded by uncertainty. At what pace EVs will be adopted is a question that has bewildered everyone and despite all the views in the market today, including ones in this whitepaper, it is hard to accurately predict the same. Notwithstanding the challenges around estimating the pace of adoption, what one needs to appreciate is the inevitable reality that in the near future, EVs are going to define the new regime of mobility.

GLOSSARY

2W	2-Wheeler
3W	3-Wheeler
4W	4-Wheeler
AC	Alternating Current
B2B	Business to Business
B2C	Business to Consumer
BEV	Battery Electric Vehicle
BCD	Basic Custom Duty
BLDC	Brushless DC Motor
BMS	Battery Management System
BOP	Balance of Pack
BS-VI	Bharat Stage VI
CAFE	Corporate Average Fuel Economy
CBU	Completely Built Up
CKD	Completely Knocked Down
COVID-19	Coronavirus Disease 2019
CPO	Charge Point Operator
DC	Direct Current
DHI	Department of Heavy Industry
E-2W	Electric 2-Wheeler
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FAME	Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles
FCEV	Fuel Cell Electric Vehicle
FOC	Field Oriented Control
GCC	Gross Commercial Contract
GST	Goods and Services Tax
GWh	Gigawatt-Hour
ICE	Internal Combustion Engine
kWh	Kilowatt-Hour
LFP	Lithium Iron Phosphate
Li-ion	Lithium ion
LMO	Lithium Manganese Oxide
LTO	Lithium Titanate Oxide
MNRE	Ministry of New and Renewable Energy
MT	Metric Ton
MWh	Megawatt-Hour
NCA	Lithium Nickel Cobalt Aluminum Oxide
NCM	Lithium Nickel Cobalt Manganese Oxide
NEMMP	National Electric Mobility Mission Plan
OEM	Original Equipment Manufacturers
PHEV	Plug-in Hybrid Electric Vehicle
PMP	Phased Manufacturing Programme
PMPM	Permananet Magnet Synchronous Motor
SKD	Semi Knocked Down
SMEV	Society of Manufacturers of Electric Vehicle
SoC	State of Charge
SoH	State of Health
STU	State Transport Units
TCO	Total Cost of Ownership
W	Watt
Wh	Watt-Hour

SOURCES

EXHIBIT 1
Alternative Fuels Data Center of US Department of Energy,
ACMA, Rolland Berger, Factor Daily

EXHIBIT 2
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EXHIBIT 5
Analyst Reports, Avendus Research

EXHIBIT 6
Post and Beyond Lithium-Ion Materials and Cells for Electrochemical Energy Storage – Google talk by Andreas Hintennach (Daimler)

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EXHIBIT 9
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EXHIBIT 12
Post and Beyond Lithium-Ion Materials and Cells for Electrochemical Energy Storage – Google talk by Andreas Hintennach (Daimler)

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EXHIBIT 14
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EXHIBIT 47
Analyst Reports, Avendus Research

EXHIBIT 53
Statista, IEA, Norsk Elbilforening, News Articles

EXHIBIT 58
Circular Energy Storage

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