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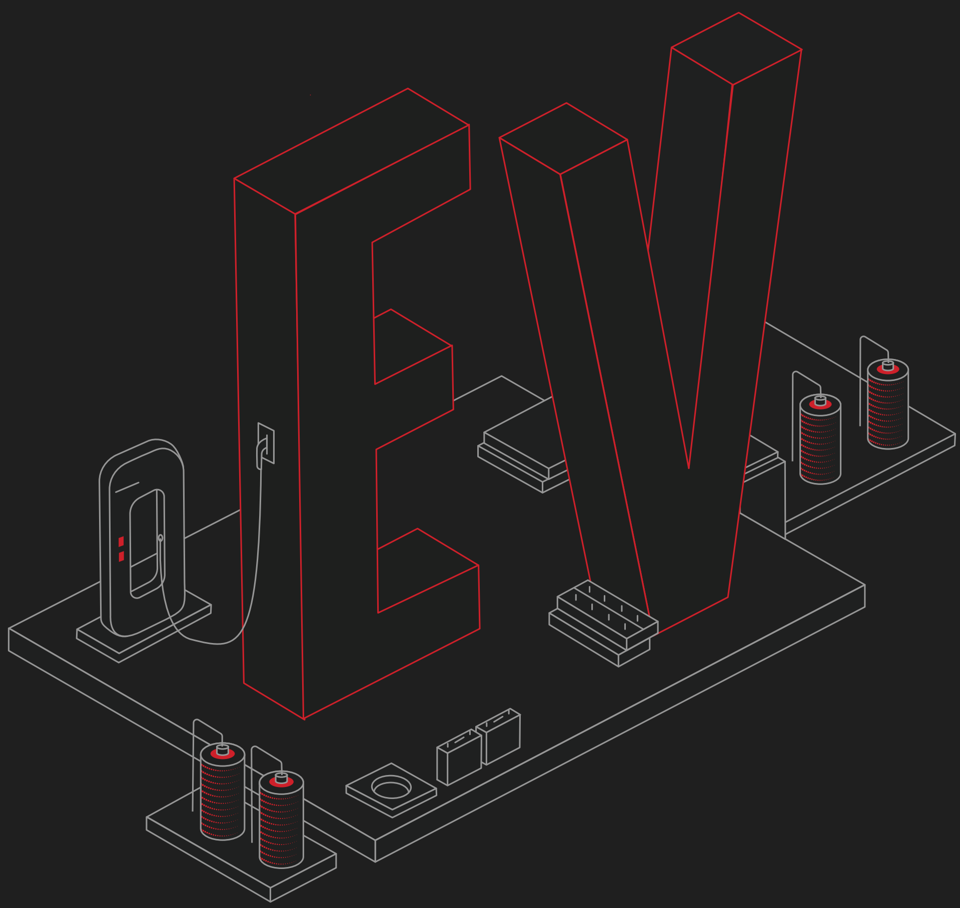
Next is the only level

Electric Vehicles

Charging towards a bright future



July 2020

INDEX

Message from the authors 6

Electric Vehicles – A futu… to em… 8

Electric Vehicles Ecosystem – An interplay demanding coherent development 13

This is an interactive PDF, click on the Index to jump to different chapters/sections

Sources are linked as well

EXHIBIT 6

Advanced technologies in different stages of the development cycle

INDEX

Message from the authors 6

Electric Vehicles – A future we need to embrace! 8

Electric Vehicles Ecosystem – An interplay demanding coherent development 13

Electric Vehicles - 101

- **Types of EVs** 18
- **Electric powertrain – simpler, smarter and more powerful** 20
- **Key components of EV** 22
- **EV battery – 101** 23
  - Li-ion is the future of EVs 23
  - Li-ion – The race within 26
  - Battery – Cell to pack 28
  - Battery economics 34
  - Battery chemistries of the future 37
  - Fuel cell – Too far to be a threat for batteries 41
- **Introduction to other key components/ systems** 44
- **EV charging** 48
  - Charging basics 48
  - India’s stance on EV charging 52

INDEX

Global EV Industry

EV – A common dream across the world 54

Evolution of key markets 57

China – Winning the Electric Vehicles race 57

USA – Lagging in the global transition to EVs 60

Europe – EV market is amped up and on the rise 62

Japan – Earliest adopter of technology, switching from Hybrid to Pure EV 64

Global battery industry 66

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

EV policy in India has taken a clear direction, but implementation lacks momentum 72

OEM traction has started to pick up 79

Battery industry has started shaping up 83

Charging infrastructure lacking but new business models are coming up to plug the gap 87

TCO Equation in India

TCO implications for large scale adoption 91

Factors that will determine EV adoption in India

Policy push vs policy support 101

Battery cost reduction to enable TCO parity and bridge capex gap 104

Global price projections 105

Battery price implications for Indian market 106

Supply chain reinvention and its localization 107

Charging infrastructure for India's unique needs 109

INDEX

EV penetration in India — Scenarios over next 5 years

2W – Upfront cost expected to be a major dampener despite positive TCO parity **114**

3W – E-ricks to rapidly shift to Li-ion and Autos to benefit due to a strong TCO rationale **115**

4W – Adoption to largely remain restricted to fleets; OEMs key in driving retail penetration **116**

Bus – Will continue to be driven by public transport demand led by the government **117**

Other – Interesting opportunities in LCV space and freight applications **117**

Current Environment – COVID-19 Impact **118**

Impact on the other parts of the automotive and energy ecosystem

Impact on the autocomponent industry **122**

Grid composition and capability **123**

Battery recycling **128**

A New Beginning **130**

Glossary **132**

Sources **133**

Disclaimer **134**

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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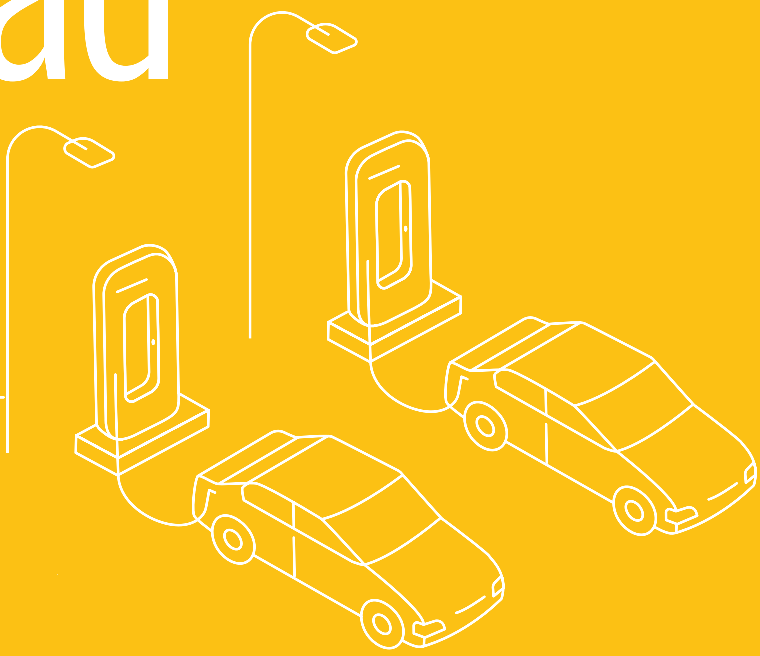
JULY 2020

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.

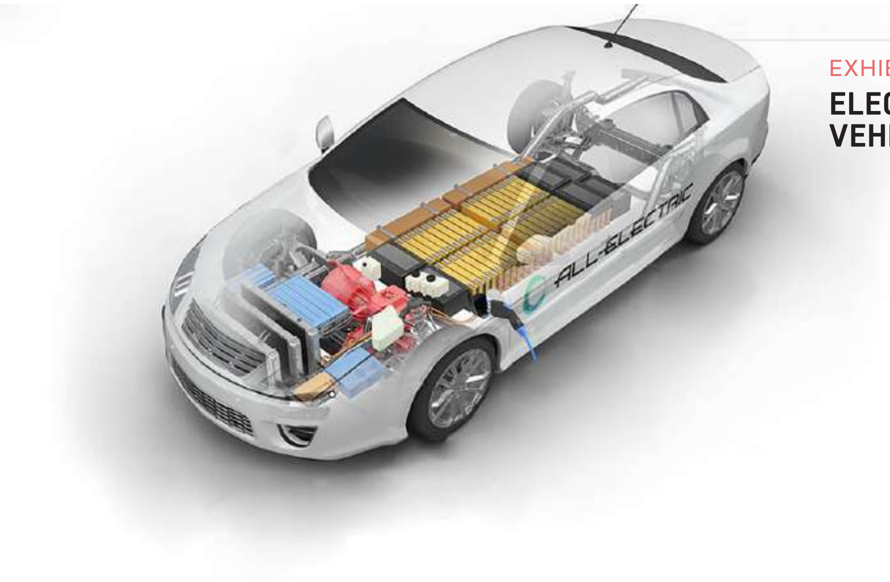


EXHIBIT 1 ↘

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.

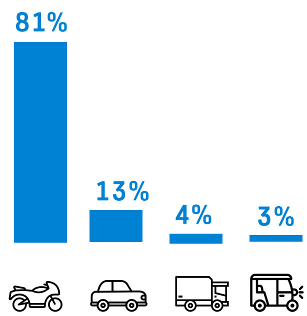
There are several short-term hurdles in the path of mass EV adoption in India. The industry players and policy makers need to invest time and money for the EV ecosystem to truly flourish.

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

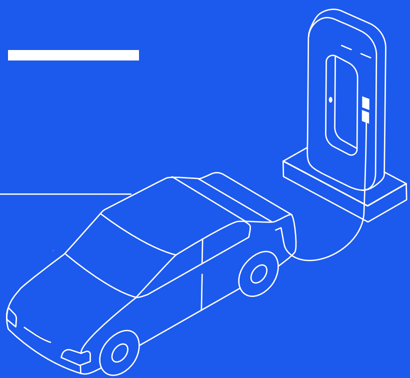
14 / 20 of the world's most polluted cities are in India

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.

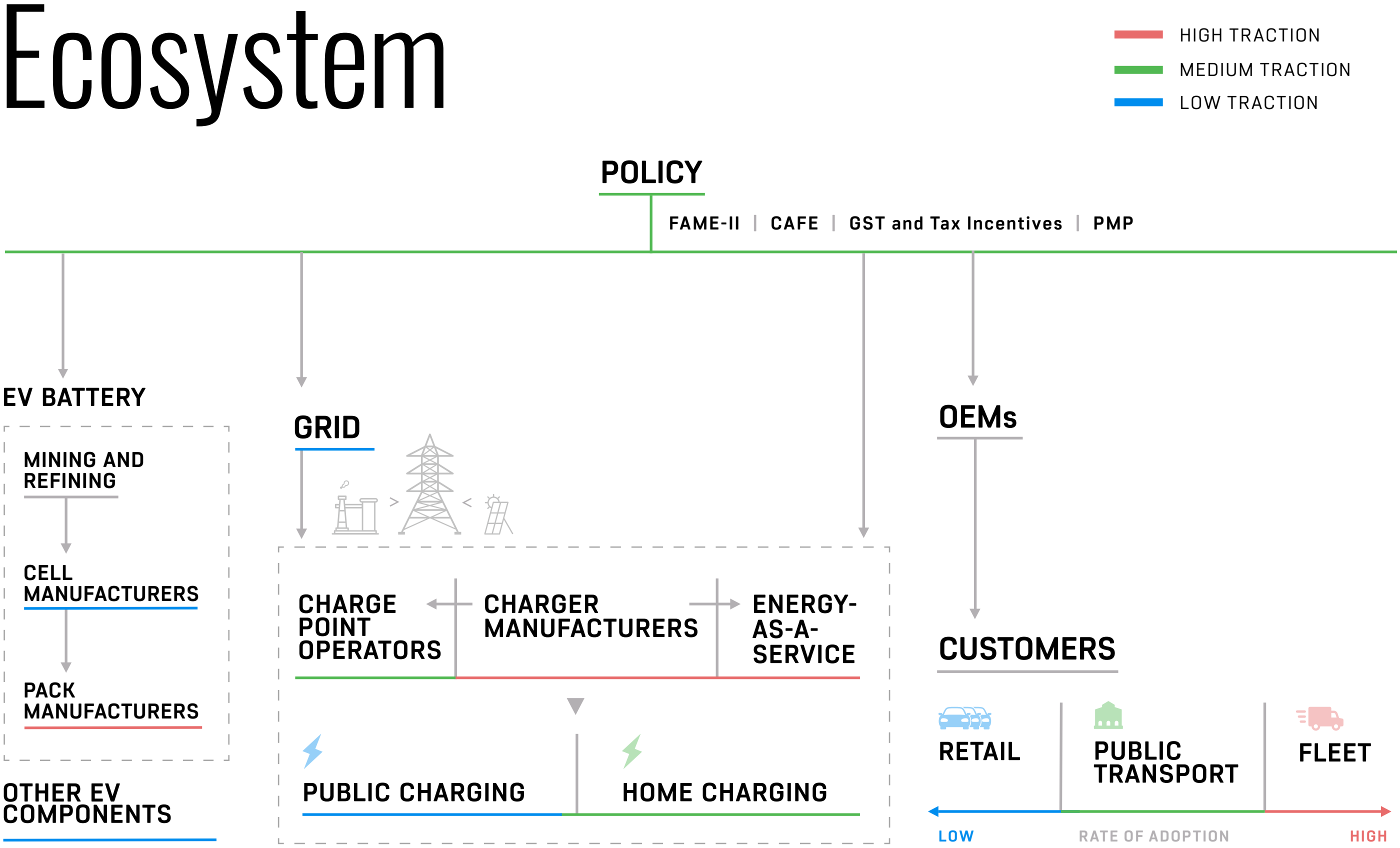
6 /

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



Key OEMs

02

Electric Vehicles — 101

18 Types of EVs

20 Electric powertrain — simpler, smarter and more powerful

22 Key components of EV

23 EV battery 101

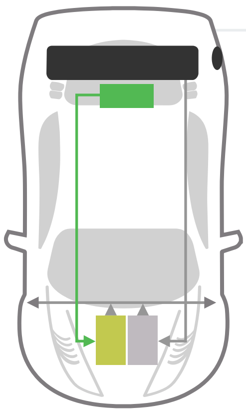
44 Introduction to other key components

48 EV charging

EXHIBIT 4

Types of EVs

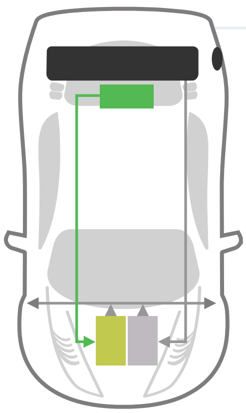
The transition from ICE to EVs is happening in multiple phases - from mild hybrids to full hybrids to plug-in hybrids (PHEVs) to battery electric vehicles (BEVs) to fuel cell electric vehicles (FCEVs). Hybrids is an interim stage of this transition, with the shift eventually being driven by BEVs in the 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**

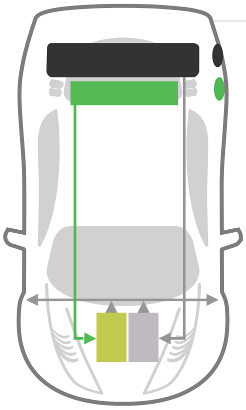


Full Hybrid

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**

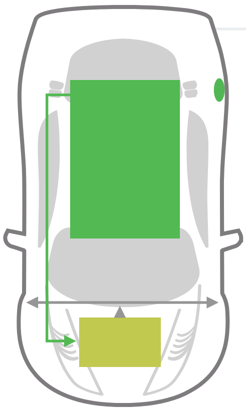
BATTERY PACK | ELECTRIC MOTOR | ICE ENGINE | ICE FUEL TANK | FUEL FILLER | CHARGE PORT | HYDROGEN FUEL TANK | FUEL CELL STACK



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.

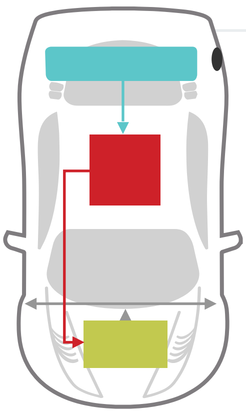
e.g. **MITSUBISHI OUTLANDER; VOLVO XC90**



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.