Study on xEV market and opportunities for xEV component suppliers

Delhi, 2018

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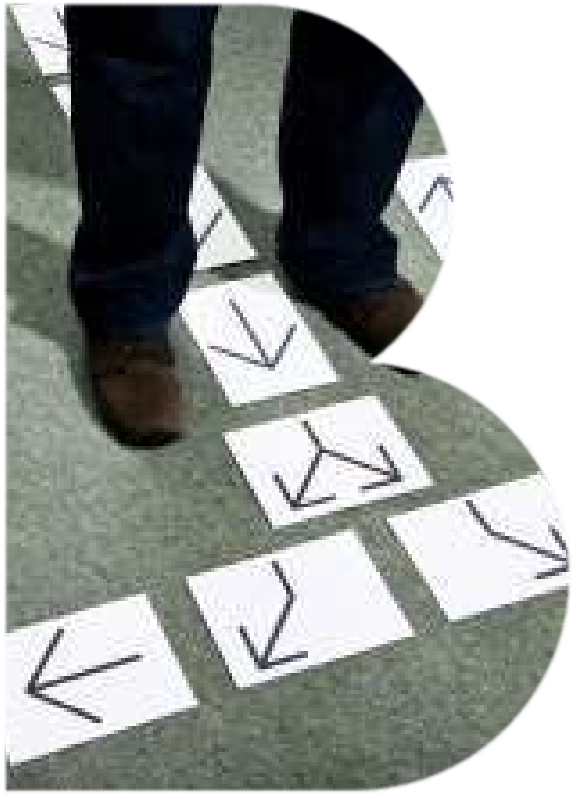
Executive Summary

1. Government incentives, preferential access to EVs & charging infra development are key growth drivers for EVs in the major markets
2. Core xEV components are expected to account for >50% of the auto components markets in 2025
3. Significant cost reductions of 30-35% are expected in batteries by 2025
4. Most global OEMs are either well integrated or have formed a well-established supply network
5. Global suppliers are also technology owners with a strong patent portfolio
6. Massive govt. push combined with improving TCO has widened the corridor of possibilities for India
7. But OEMs are working in silos and suppliers are far behind in technology, posing significant risks to their exports and local market
8. Traditional powertrain component suppliers must act now, or else risk losing the opportunity to Chinese OEMs and component manufacturers
9. Potential EV opportunities for local suppliers lie in parts & assemblies of e-motors, and thermal management, connectors and power electronics (excl. power distribution modules)
10. Suppliers need to acquire technology inorganically, reach to global markets swiftly and demonstrate capabilities to global & local OEMs; ACMA to play a supportive role for the same
11. The government needs to define xEV targets & plans which are long term, consistent & coherent across ministries, define standards & provide support to the industry

Source: Roland Berger

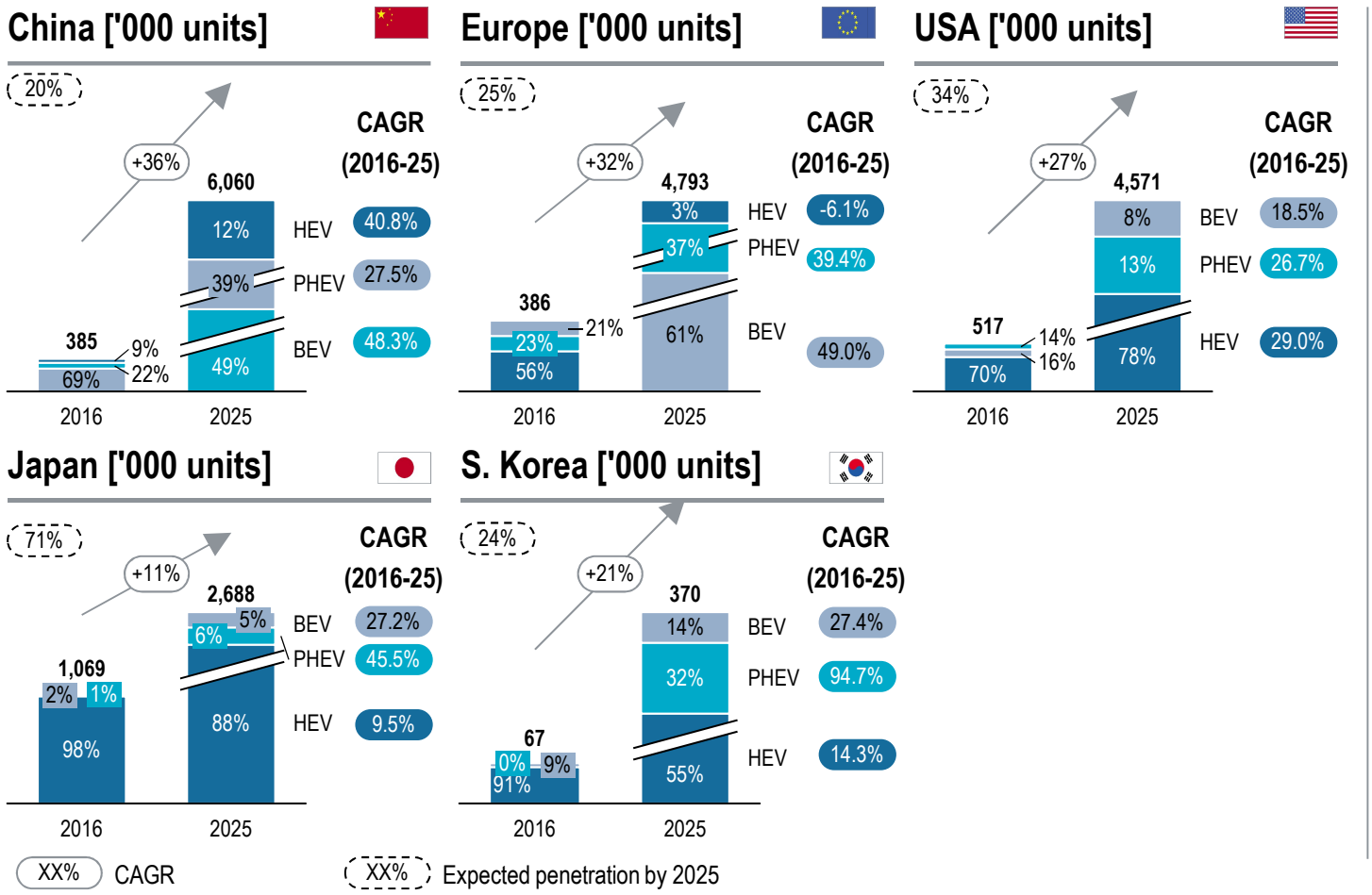
A. xEV market size and growth forecast



A.1 Electric and hybrid vehicles (xEV)

Strong growth is expected across all regions in xEV sales by 2025 – China would remain the largest market globally in 2025 as well (1/2)

4W xEV sales forecast for major xEV markets excluding India, 2016-2025

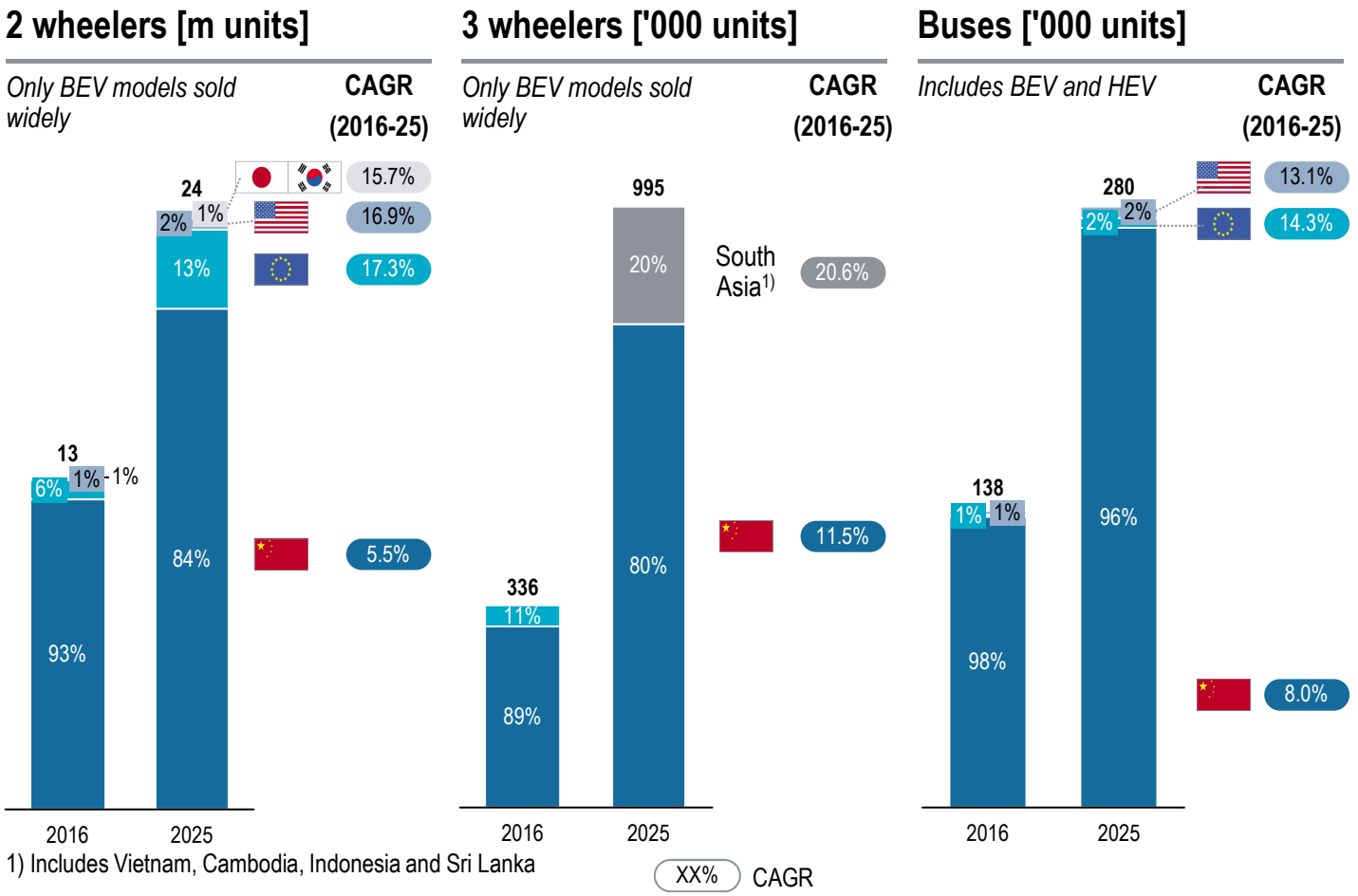


- China is expected to remain the leader in xEV sales globally by 2025 as well
- Strong growth is expected in all geographies for xEVs, aim for sustainable transportation and reducing the emissions would be the key push in all geographies for xEVs
- Declining costs of Li-ion batteries would increase the attractiveness of xEV for customers
- However, development of charging infrastructure would be necessary to sustain demand in the market

Source: Expert Interviews, Roland Berger

Strong growth is expected across all regions in xEV sales by 2025 – China would remain the largest market globally in 2025 as well (2/2)

xEV sales forecast for major xEV markets excluding India, 2016-2025



1) Includes Vietnam, Cambodia, Indonesia and Sri Lanka

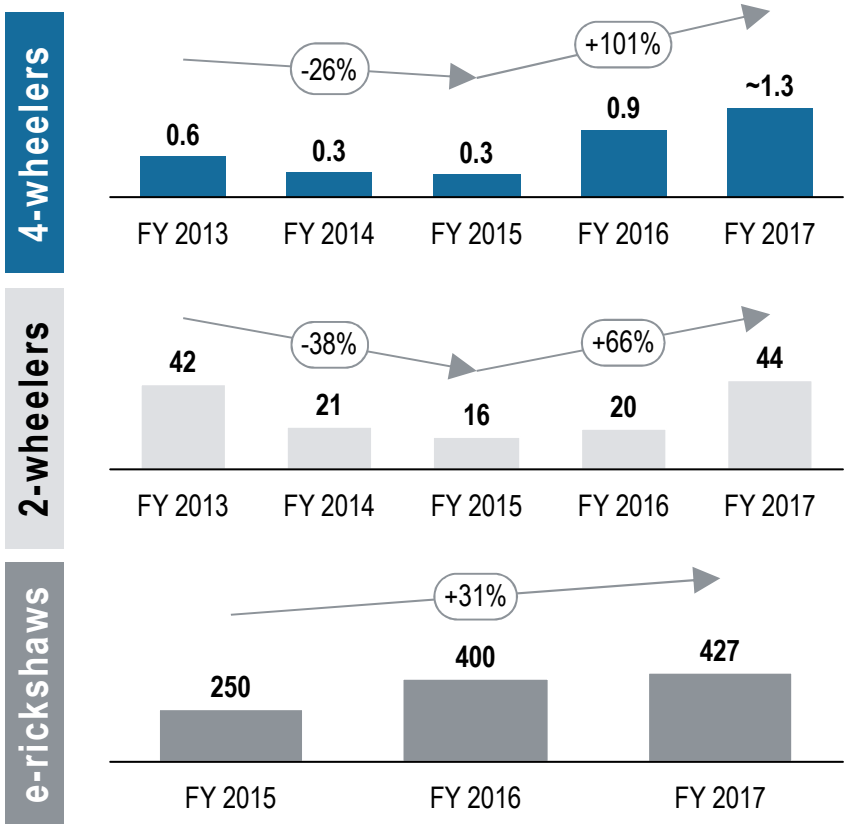
- 2 wheeler sales would mainly be driven by intra-city restrictions and no emission zones within cities such as London, Paris, New York, etc.
- Developing economies in South Asia and rural regions in China would have high demand for E3W mainly due to development of economic activities
- Need for clean public transportation and government initiatives to curb pollution would be key driver in buses segment

Source: Expert Interviews, Roland Berger

The Indian xEV market has so far been insignificant and largely dependent on demand incentives

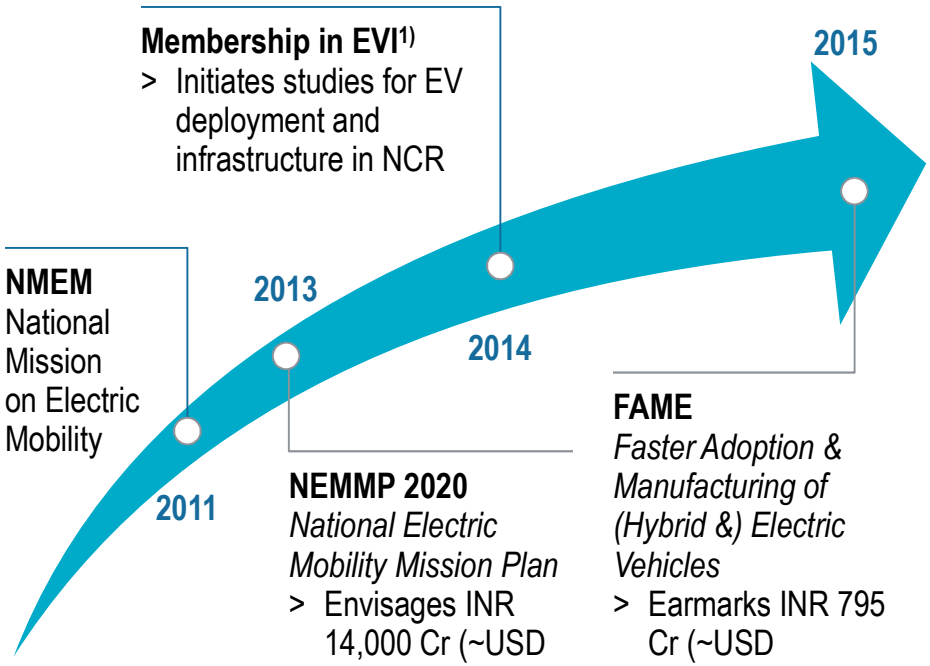
Historical growth of EVs in India driven by key government policy inputs

xEV market volumes ['000 units]



1) Electric Vehicle Initiative; 2) 1 USD = 65.27 INR

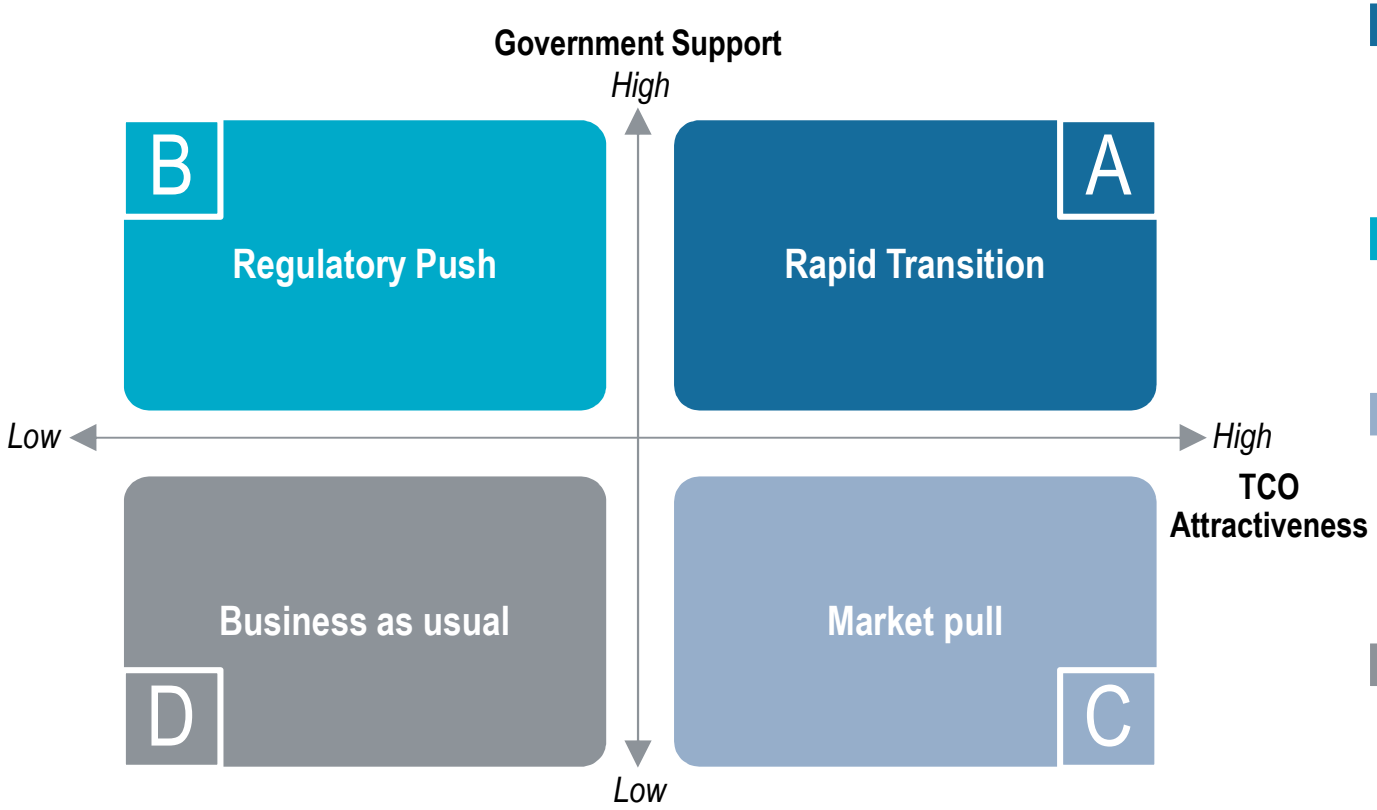
Policy Evolution



Source: News Reports, Department of Heavy Industries, Roland Berger

Based on EVs' TCO attractiveness for customers & push/support from government, 4 possible scenarios can be identified for the future

Possible EV scenarios for India



A Rapid Transition

This would be an ideal scenario where there is pull from the customer due to favorable TCO and there is infrastructure support from the government

B Regulatory Push

> Due to push from government and mobility restrictions within major cities, customers would be compelled to purchase EVs

C Market pull

> There is sufficient demand from the customers due to favorable TCO, however there is lack of government support for setting up charging and other supporting infrastructure

D Business as usual

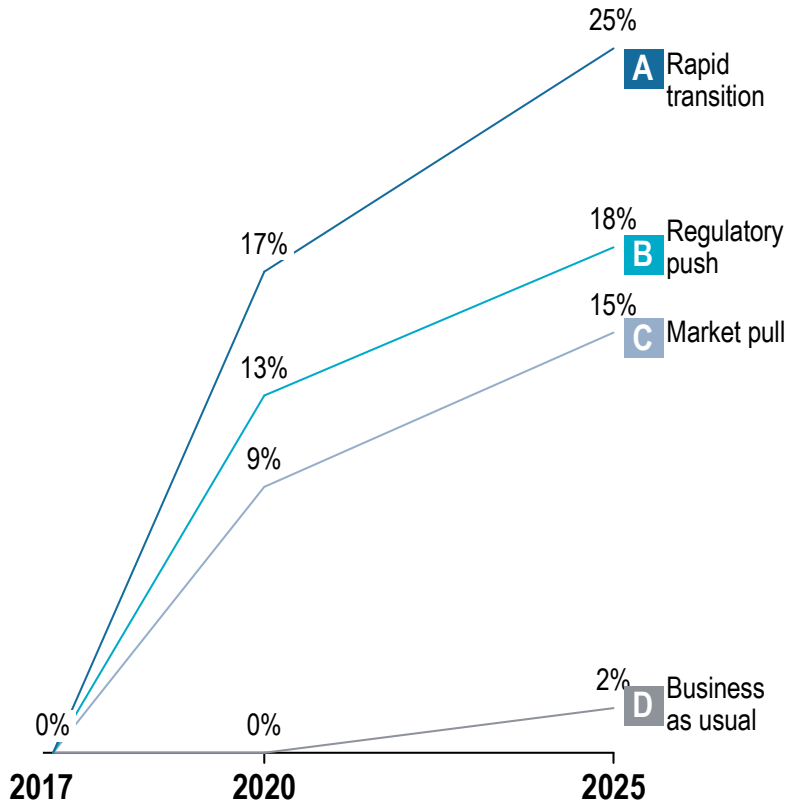
> With an unfavorable TCO for EVs and lack of push from government's would lead to minimal growth in EV penetration across segments

Source: Roland Berger

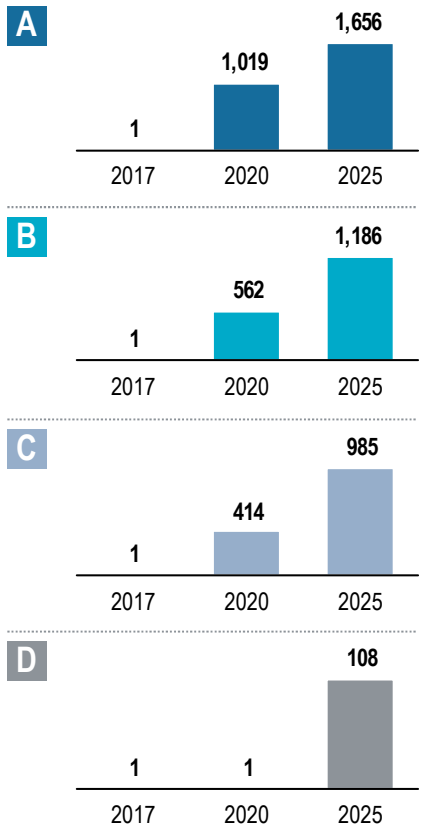
Massive government push combined with improving TCO has widened the corridor of possibilities for India in 4 wheelers

India: xEV market forecast – 4 wheelers ['000 units]

Potential xEV scenarios for India



xEV volumes ['000 units]



Key assumptions

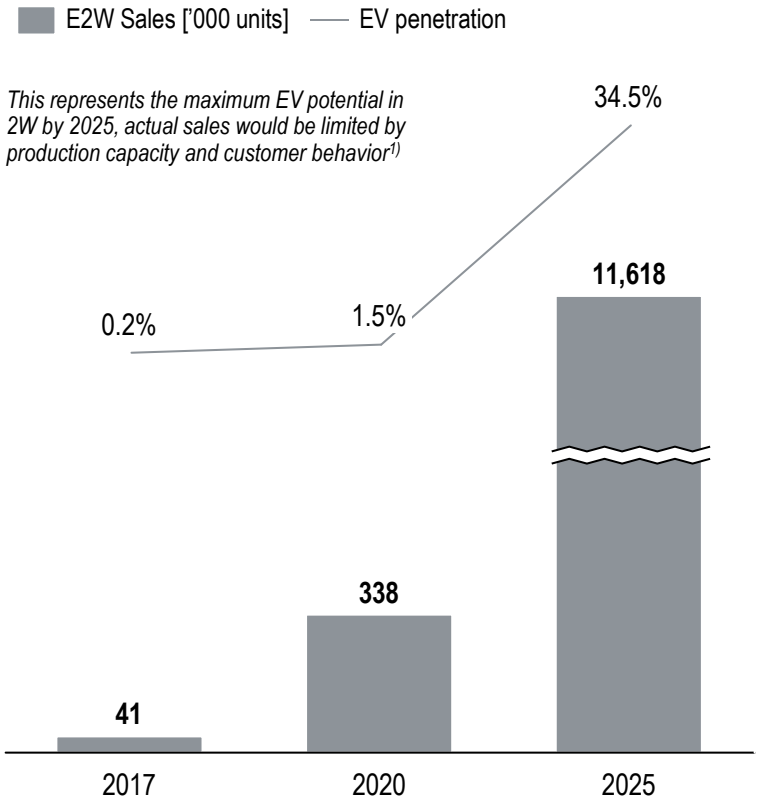
- Government push and TCO have been considered to develop 4 different scenarios for EVs
- Following key areas of government push have been assumed:
  - FAME incentives
  - Intra-city restrictions
  - Charging infrastructure setup
  - Reduced electricity tariffs for EV charging
- By 2025, a decline of ~30% is expected in EV costs, leading to a positive TCO for customers
- Once TCO parity is achieved, charging infrastructure would drive penetration
- Battery swapping model is assumed to be implemented for taxi segment in 4 wheelers

Source: Roland Berger

EV in 2W segment can potentially target 34.5% of total 2W market – actual penetration would be limited by production capacity constraints

India: xEV market forecast – 2 wheelers ['000 units]

Potential EV penetration and volumes for 2W in India



Production capacity of EV players (2017)

OEM	Capacity
Ather Energy	15k
Tork Motorcycles	50k
Hero Electric	65k
Lohia Auto	100k
Electrotherm	250k
Morello Yamasaki	60k
Ampere Vehicles2)	10k
Total	550k

> At present only Ather and Tork's products can match the performance of ICE type 2W (products not yet in market for sale)

> However, other OEMs are working on Li-ion products and by 2025, it is expected that they would have higher power vehicles in their portfolio

Future EV plans of ICE OEMs

Hero MotoCorp	Developing E2W at its center in Jaipur. Plans to launch E2W on Duet platform
Bajaj Auto	Plans to launch a new brand, Urbanite, for EVs by 2020
TVS Motors	Developing an e-scooter (codename U218), launch expected by 2018
Honda	In discussions with stakeholders to bring down costs & ensure infrastructure availability to launch products in India

- Announced and existing EV models in India can compete with vehicles in less than 125cc segment only
- 99.5% scooters are in <125cc segment, therefore they can have 100% penetration in urban India
- Customer affinity towards 125-250cc segment is increasing in motorcycles, therefore it is expected that by 2025 only 49% of motorcycle segment would be <125cc
- Rural market which accounts for 50% 2W sales in India, would not be impacted by EV
- Total urban sales that can potentially be impacted by 2025 is ~11.6m units (34.5% of total 2W volumes in 2025)
- Production capacity would be the major limiting factor for EV penetration in 2W segment

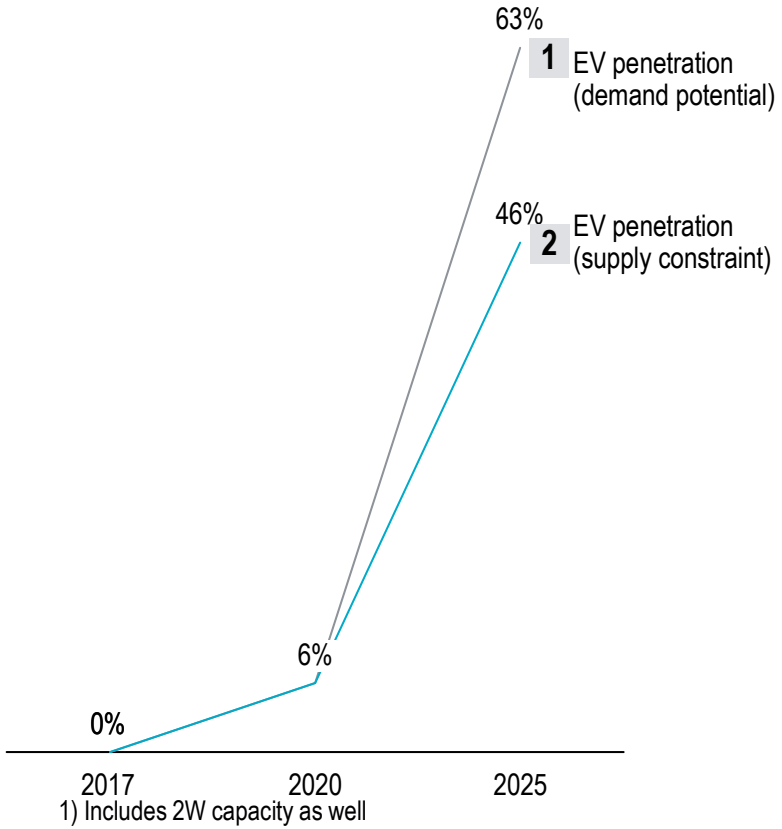
1) EV 2W offers better TCO and the price difference by 2025 is expected to be ~INR 10k, ideally customers should be attracted towards EV purchase, however there might be skepticism in customer mind and full acceptance depends on customer mindset; 2) Includes e-rickshaws capacity also

Source: Press reports, Primary interviews, Roland Berger

L5 category 3W have a potential of 63% BEV penetration by 2025, but it is expected to be limited to 46% due to capacity constraints

India: xEV market forecast – 3 wheelers ['000 units]

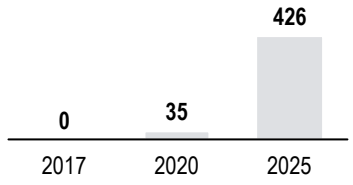
Potential EV penetration for L5 category 3W in India



1) Includes 2W capacity as well

EV volumes (L5) ['000 units]

1



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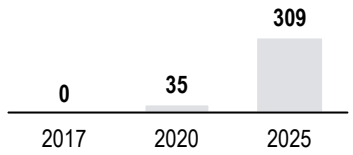


E3W capacity in India (2017)

OEM	Capacity [units]	L5 product
Lohia Auto	40k	No
Ampere Vehicles[1)]	10k	No
Kinetic Green	48k	Yes
Clean Motion	10k	Yes

> Mahindra has set up E3W manufacturing in Haridwar plant with capacity of 12k units annually

Assumptions and comments

> L5 category 3W can potentially match the power performance of ICE 3W by 2025

> Only passenger segment is expected to have EV penetration as performance of EV in cargo segment would be poor due to frequent overloading and thus would not attract customers

> Within passenger segment also only vehicles with driver +3 seat configuration in urban areas will be impacted. This segment is 63% of total 3W market

> Further production constraints would play a key role. Amongst traditional ICE 3W players only Mahindra has launched it E3W, Bajaj is expected to launch its E3W in 2018 and Piaggio does not have any E3W plans for India

– The transition of ICE production line to EV production line would be slower in Bajaj as compared to Mahindra due to in-house engine production. By 2025, it is assumed that Bajaj has 30% and Mahindra has 60% of current capacity converted for EV production

– Existing L5 EV 3W players are assumed to increase their capacity by 50% by 2025

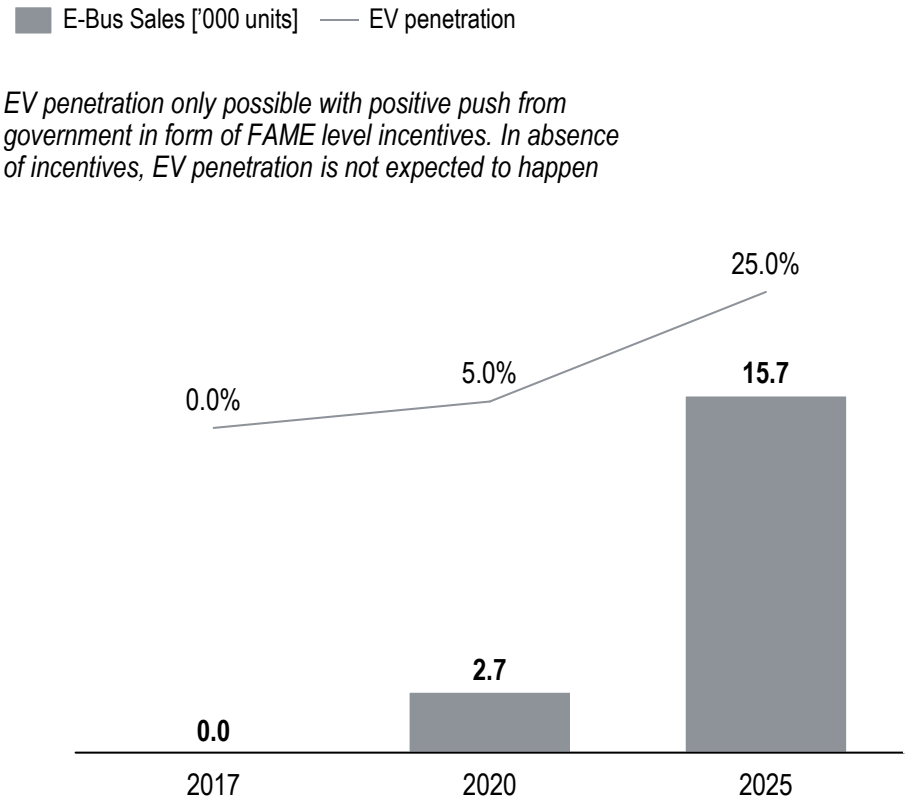
– Overall E3W L5 capacity would become 309k units annually (~46% of total L5 3W market)

Source: Press reports, Primary interviews, Roland Berger

EV penetration in buses is only possible through incentives & 12 years battery warranty – localization and range reduction offer favorable TCO

India: xEV market forecast – Buses ['000 units]

Potential EV penetration and volumes for Buses in India



Assumptions

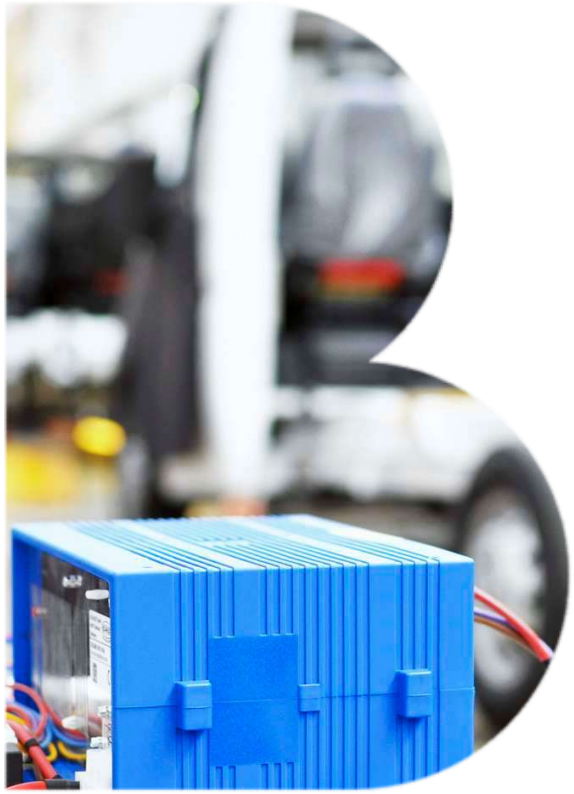
- Battery swapping model is in place, investment for infrastructure setup is made by both private players and OEMs
  - In rapid transition scenario all tier 1 and 2 cities are expected to have adequate infrastructure for battery swapping
  - In government push and market pull scenarios, top 10 cities would have infrastructure
  - In BAU scenario, only tier 1 cities would have infrastructure
- Global OEM level battery warranties of 12 years are present for buses in India
- In addition to existing EV bus models, 2 hypothetical cases have been considered: Partially localized models from Indian OEMs with reduced range and fully localized models from global OEMs
- Tier 1 and 2 cities assumed to account for ~90% of intra-city buses volumes annually on account of higher requirement of intra-city transportation

EV penetration: key highlights

- Bus models which offer favorable TCO to customers in presence of FAME incentives and 12 year battery warranty are: Partially localized models from Indian OEMs with reduced range and fully localized models from global OEMs
- Penetration would be zero in inter-city buses as the range and infrastructure would not support long distance commutes, only intra-city buses would have EV penetration

Source: Press reports, Primary interviews, Roland Berger

A.2 xEV components

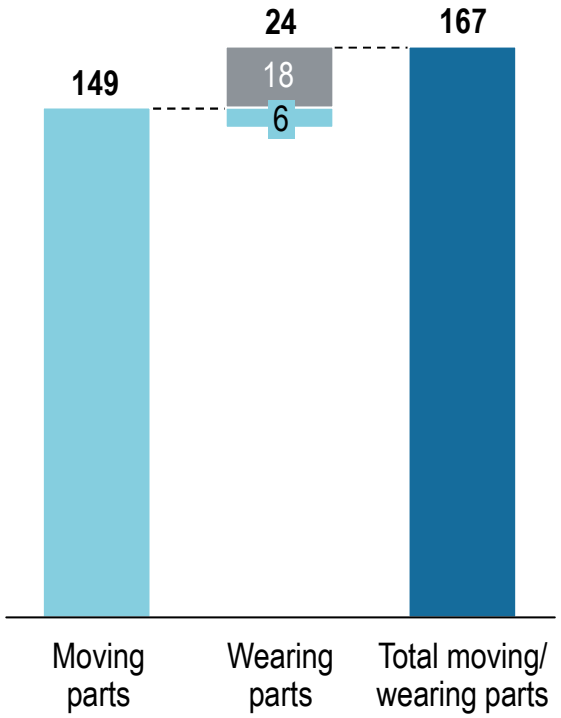


With 80% fewer moving parts vs. ICE, xEVs component undergo less wear and tear thus negatively impacting aftersales business

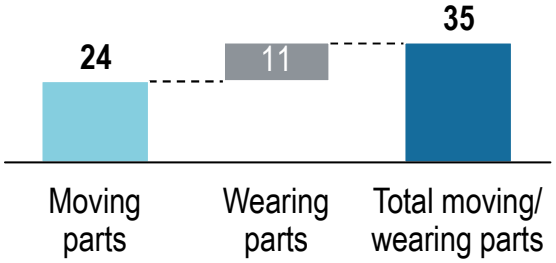
Number of moving components, ICE vs. xEV

Moving parts in powertrain

ICE vehicle



Battery vehicle



> Mechanical complexity is much lower in a battery vehicle as the number of moving parts is significantly lower than those in an ICE vehicle

> Lesser moving and wearing parts lead to lower maintenance costs for vehicles over their lifetime

- ICE vehicle gearbox and clutch has high maintenance requirements after 150k kms. BEV gearbox is much simpler and maintenance requirements are lower
- Spark plugs and engine oil need to be regularly changed for ICE vehicles. These components are absent in BEVs
- After treatment components, i.e., particulate filters, mufflers, turbochargers etc. wear down with usage. These components are not needed in BEVs

> However, the electronics complexity is much higher in a battery vehicle. The semiconductor powertrain content in BEV is 6-10 times more than that in an ICE vehicle

Source: UBS, Secondary Research, Roland Berger

Engine & exhaust system components would become obsolete, and transmission would undergo significant changes

Comparison of ICE and BEV components

Key changes in components

> Comparison of an ICE car and electric car highlights the key component changes in powertrain

> **Obsolete components:**
- All combustion engine and exhaust system related components such as pistons, spark plugs, turbochargers, etc. would become obsolete in BEVs
- Vehicle transmission system would have significant changes
  - There would be no requirement of clutch/ torque control systems as e-motor has a wide usable torque range
  - Other sub-components such as a starter generator, a start-stop system would become redundant for BEVs

> **Changed components:**
- Gearbox would become an optional component, would be highly simplified and would typically be a single speed type

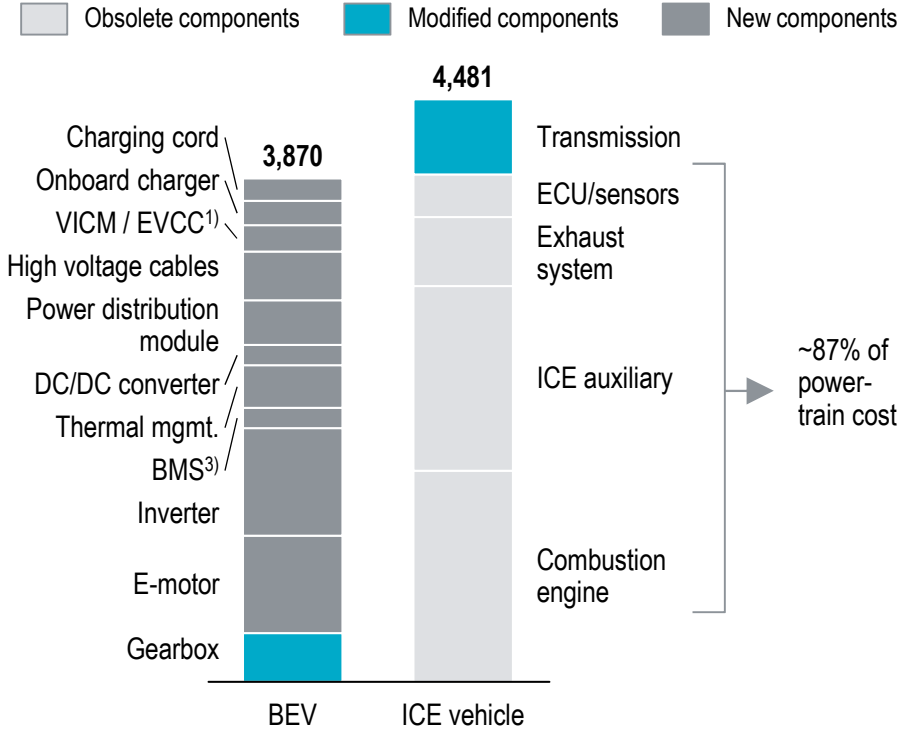
> **Unchanged components:**
- Vehicle exterior and interior components would not have significant changes when shifting from an ICE vehicle to BEV

> **New components:**
- Electric motor would replace the functionality of combustion engine in an electric vehicle
- Semiconductor content would increase in BEVs due to inclusion of new components – DC/DC converter, inverter, power distribution module, onboard charger, BMS[2], VICM[1] and EVCC[1]

Powertrain components[2] – BEV vs. ICE (USD)

ICE representative vehicle – Volkswagen Golf

BEV representative vehicle – Chevrolet Bolt

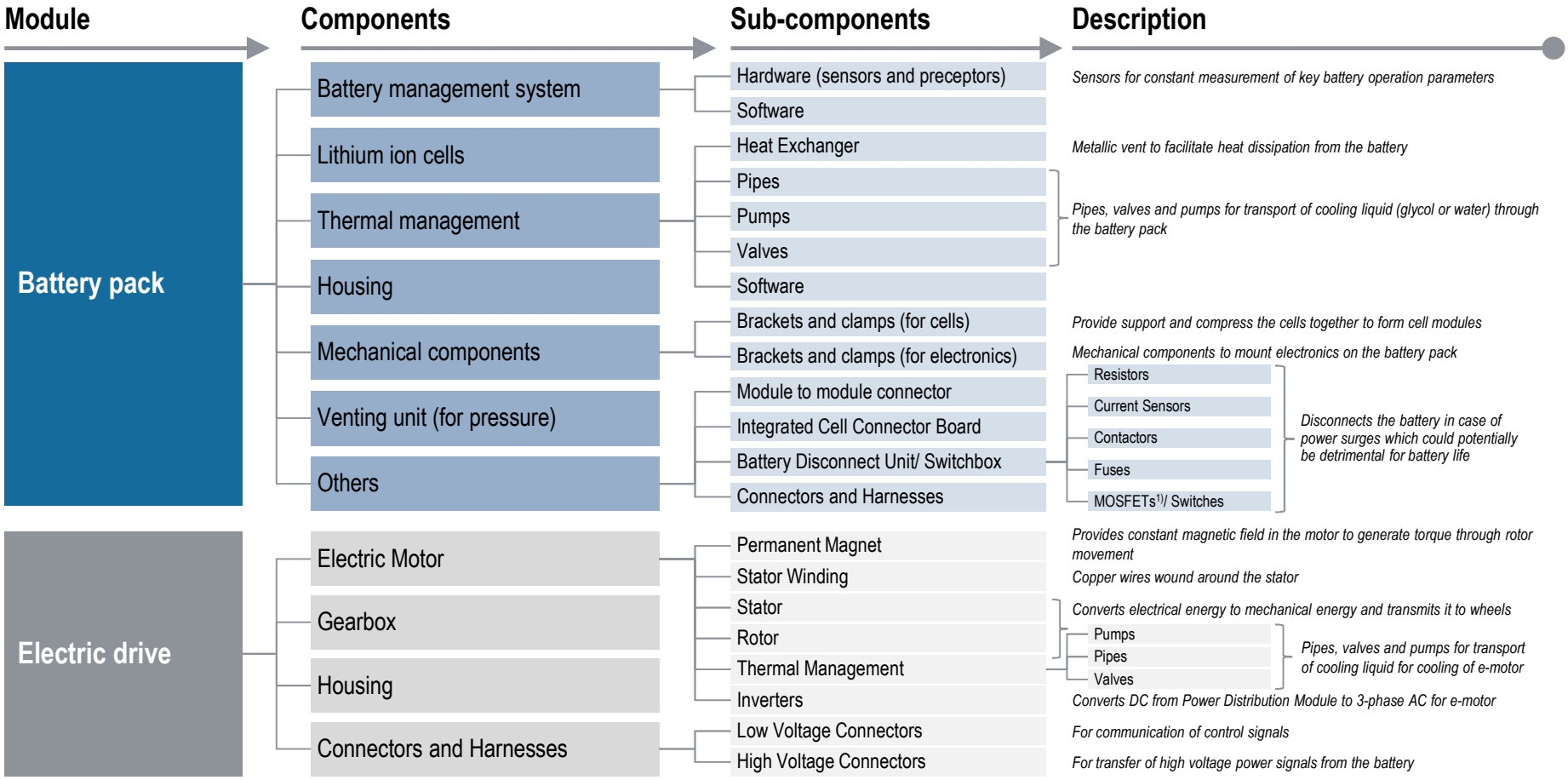


1) Vehicle interface control module / Electric vehicle communication controller; 2) Excludes battery costs; 3) Battery management system

Source: UBS, Roland Berger

xEV powertrain comprises of modules different from ICE: battery pack, electric drive, power electronics & vehicle interface control (1/2)

xEV sub-component breakdown (1/2)

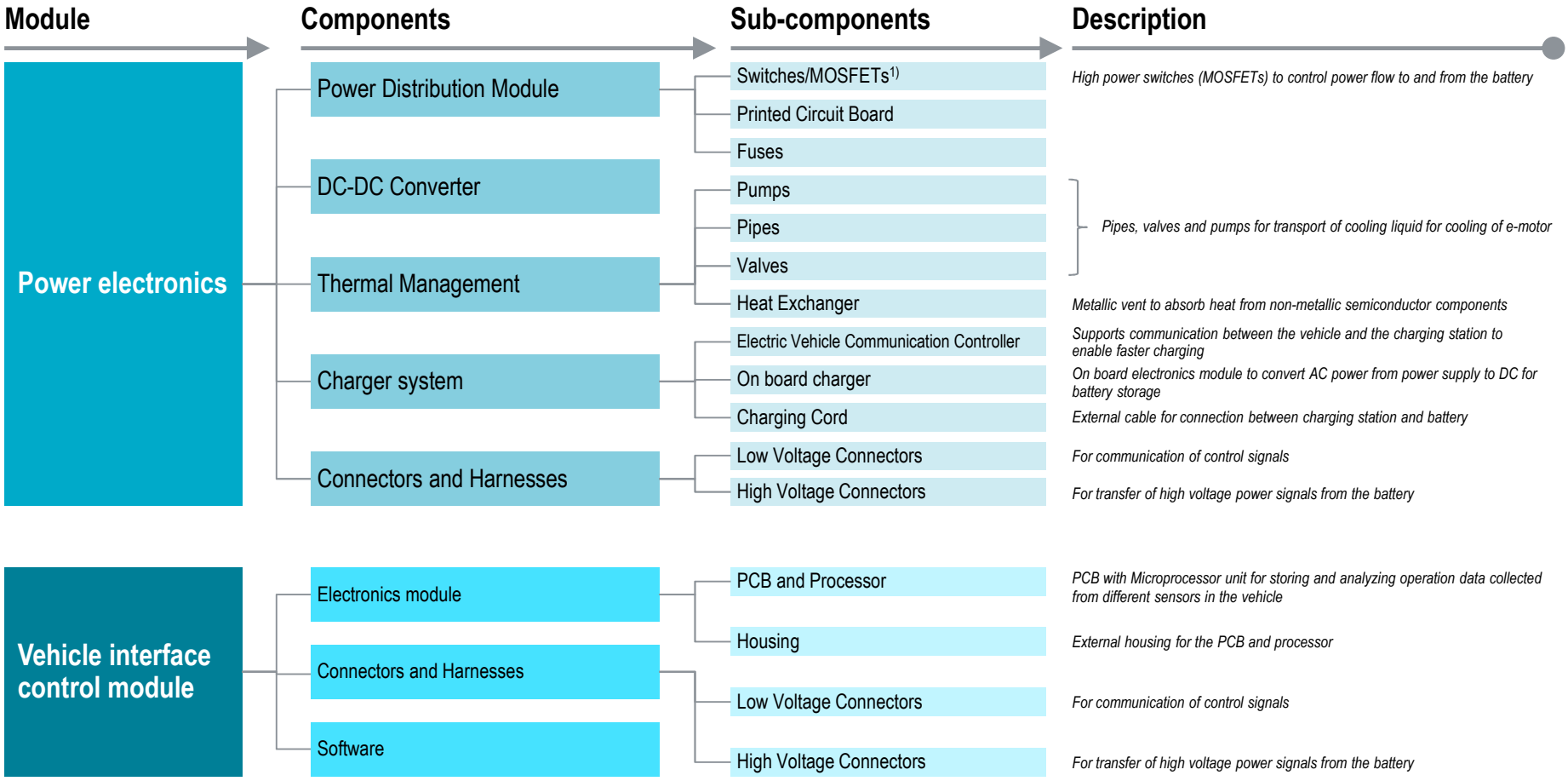


1) Metal oxide semiconductor field effect transistor

Source: Expert Interviews, Roland Berger

xEV powertrain comprises of modules different from ICE: battery pack, electric drive, power electronics & vehicle interface control (2/2)

xEV sub-component breakdown (2/2)

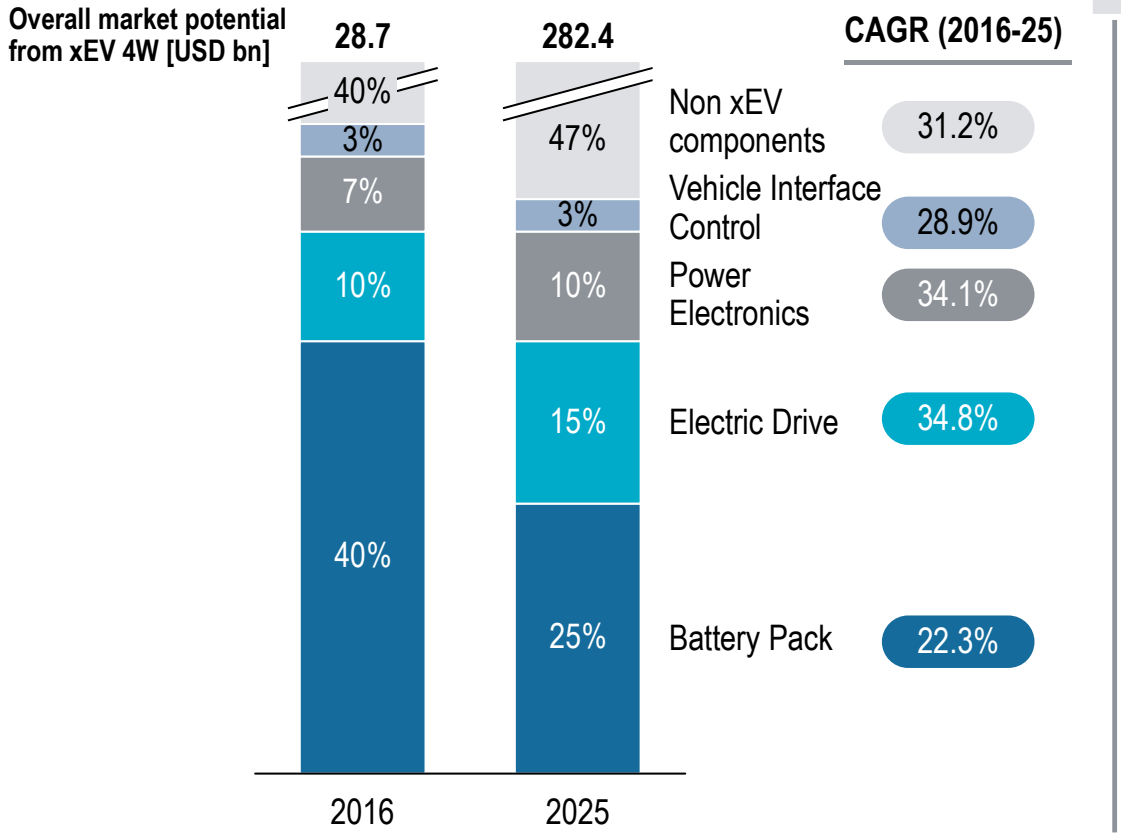


1) Metal oxide semiconductor field effect transistor

Source: Expert Interviews, Roland Berger

xEV components account for ~ 60% of overall electric vehicle cost at present, it is expected to remain more than 50% in 2025

xEV components' contribution to global auto-component market for xEV 4W (excl. India)



> xEV components currently account for ~60% of overall vehicle cost, amounting to USD ~150 bn globally

> Share of xEV components of the total vehicle cost is expected to go down to ~53% by 2025 on account of technology development in battery cells and scale advantage in other e-components

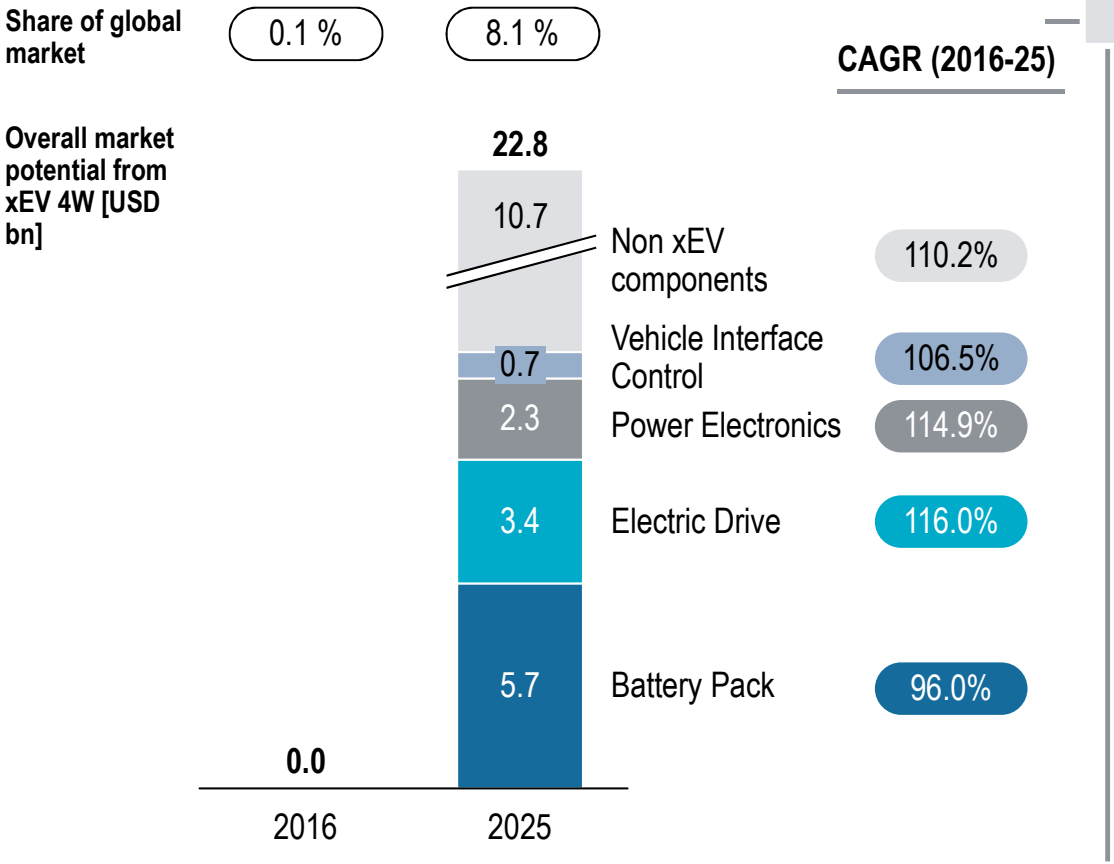
> xEV components within a battery electric vehicle can be split into following modules:

- Battery Pack – Power storing unit of the vehicle, includes lithium ion cells, battery management system, thermal management for battery pack, housing, and other electronic and mechanical components
- Electric drive module – Electrical components of the drivetrain such as the e-motor
- Power electronics – Semiconductor modules of vehicle
- Vehicle Interface Control Module – Diagnostic module for electric propulsion system

Source: Expert Interviews, Roland Berger

Indian market is expected to be ~8% of global xEV 4W component market in most likely EV scenario with 18% BEV penetration in India

BEV components' contribution to Indian auto-component market for BEV 4W



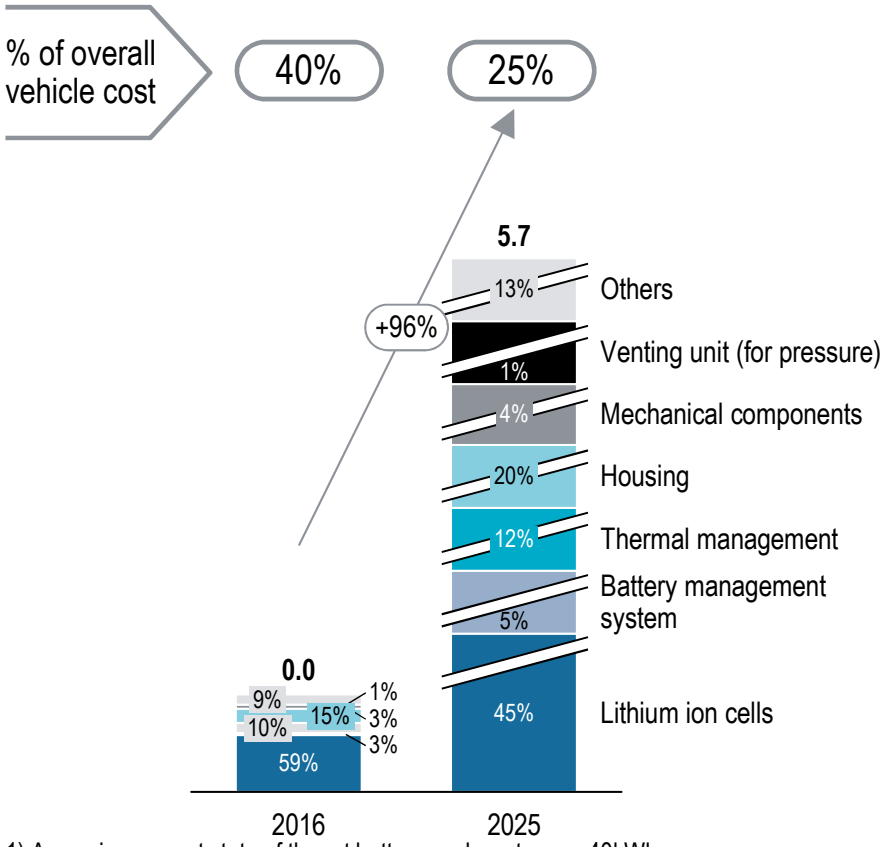
- xEV components are expected to grow to USD ~12 bn in India by 2025
- The major driver for the components market growth will be the increasing penetration of xEVs
- For Indian context high value components such as e-motor permanent magnet and lithium ion cells are expected to be imported
- Non xEV components include vehicle interior, exterior, chassis and infotainment systems
  - Increase in non-xEV components would mainly be due to advanced safety systems, telematics and other infotainment systems

Source: Expert Interviews, Roland Berger

Contribution of battery pack to overall vehicle cost is expected to go down mainly due to decline in cost of lithium ion cells

Sub-components within a battery pack – India

Battery pack market value [USD bn]



1) Assuming current state of the art battery pack system as 40kWh

Comments

> The overall market value for **battery pack** in India is expected to reach USD ~6 bn by 2025

> **Lithium ion cells** form the largest cost component for battery pack, accounting for ~60% of total battery pack cost

– The overall cost decline in battery pack would be mainly due to decline in cost of Lithium ion cells

– Going forward the cost of cells is expected to go down by 25-30% from USD ~145/kWh to ~105/kWh

> **BMS** is a critical component for safety operations of the battery, the overall complexity of BMS is expected to increase due to expected increase in battery power for vehicles

> **Thermal management** system for the battery pack includes pumps, pipes, valves and heat exchanger

– High amount of heat is generated in the battery during charging and vehicle operation, heat exchanger accounts for ~60% of the thermal management system costs. Pumps account for ~30% of the cost, and pipes and valves account for ~5% each

> Battery **housing** is made up of plastics and composite materials to provide shock proofing and insulation to battery from external environment

– Going forward it is expected that vents for heat exchange and clamps & brackets for electronic mounting would also be integrated within the housing system

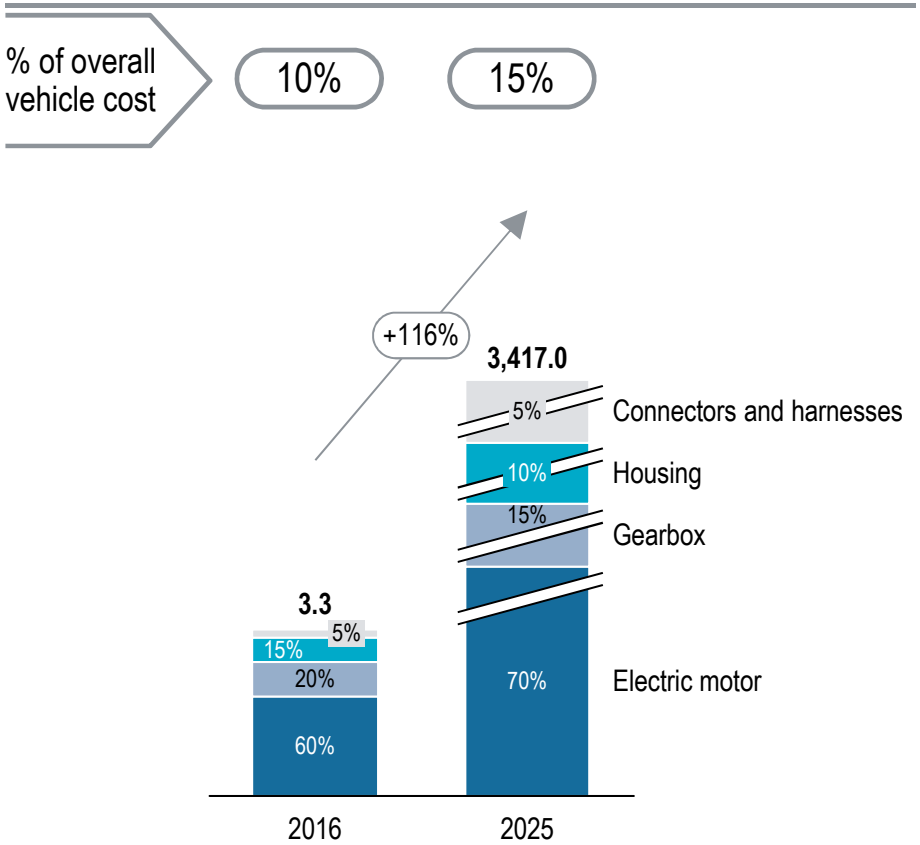
– The integration is expected to drive up the costs for battery housing and thereby an increased contribution to overall costs is expected

Source: Expert Interviews, Roland Berger

Electric motor forms the largest cost contributor to the electric drive module for electric vehicles; gearbox is an optional component

Sub-components within electric drive module – India

Electric drive module market value [USD m]



Comments

- The **electric drive module** consisting of e-motor, gearbox, housing and connectors is expected to grow with a CAGR of 35% over 2016-25
- With cost contribution from battery pack declining, the contribution from electric drive module would increase
- **E-motor** is the most critical component for an electric drive module and currently accounts for ~60% of the total module cost[1)]
- **Gearbox**[2)] is an optional sub-component for pure electric vehicles, it is mostly equipped in premium segment vehicles
  - The gearbox for electric vehicles has lower complexity than a conventional gearbox for ICE vehicle
  - Using a gearbox offers better acceleration and smoother drive
  - It accounts for 20% of electric drive module cost and is expected to decrease to 15% by 2025, mainly due to increase in e-motor's contribution
- **Housing** for e-motor and gearbox is currently separate and accounts for 15% of the electric drive module cost
  - Going forward, integration of the housing for e-motor and gearbox is expected; increased integration along with scale advantages is expected to decrease the absolute cost of housing
- **Connectors and harnesses** for the electric drive module includes both low voltage and high voltage systems for control signals and power transfer respectively

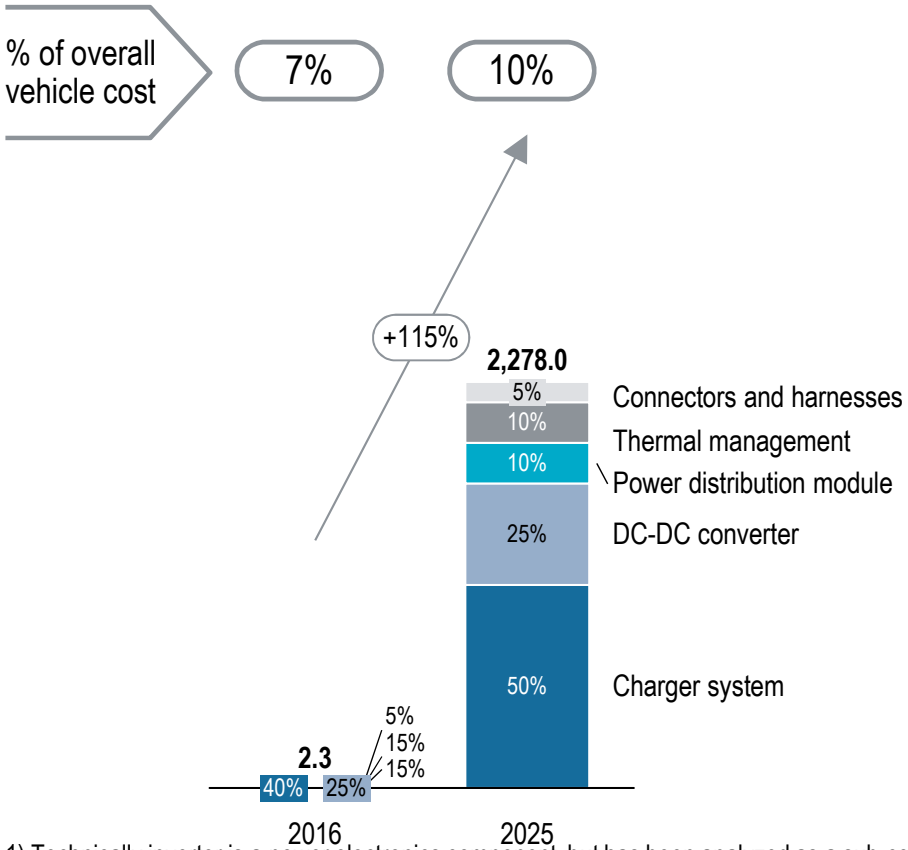
1) Detailed analysis of sub-components for e-motor discussed on the next slide; 2) Usually electric vehicles which have gearbox, use a 2 speed gearbox in contrast to a multi-speed gearbox in ICE vehicles

Source: Expert Interviews, Roland Berger

Power electronic components act as interfaces for power flow in EVs, inclination towards higher power would drive up the costs

Sub-components within power electronics module – India

Power electronics market value [USD m]



Comments

> The overall semiconductor content in vehicles is expected to go up with electrification of vehicle drivetrain

> Key **power electronics components** in an electric vehicle include DC-DC converter, inverter[1)], power distribution module, and charger system
  – Connectors & harnesses, and thermal management modules associated with power electronics are also discussed here

> **Charger system** *(discussed in detail on next slide)* constitutes ~40% of the cost with share expected to increase driven by need for faster charging

> **DC-DC converter** is used to step down the high voltages from the battery to low voltages for control signals to electronic components
  – Minor scale advantages can be observed in this sub-component

> **Power distribution module (PDM)** controls the distribution of power from battery to various components within the vehicle drivetrain
  – It consists of high power switches (MOSFETs), PCB and fuses. The MOSFETs account for ~90% of the PDM cost, fuses have negligible costs and the PCB accounts for the remaining ~10%

> **Thermal management system** for power electronics consists of pumps, pipes, valves and heat exchanger for non-metallic components
  – Pumps account for ~80% of thermal management module cost, pipes & valves account for ~5% each, and heat exchanger accounts for ~10%

> **Connectors and harnesses** are both of low voltage and high voltage type for control signals and power transfer from battery respectively

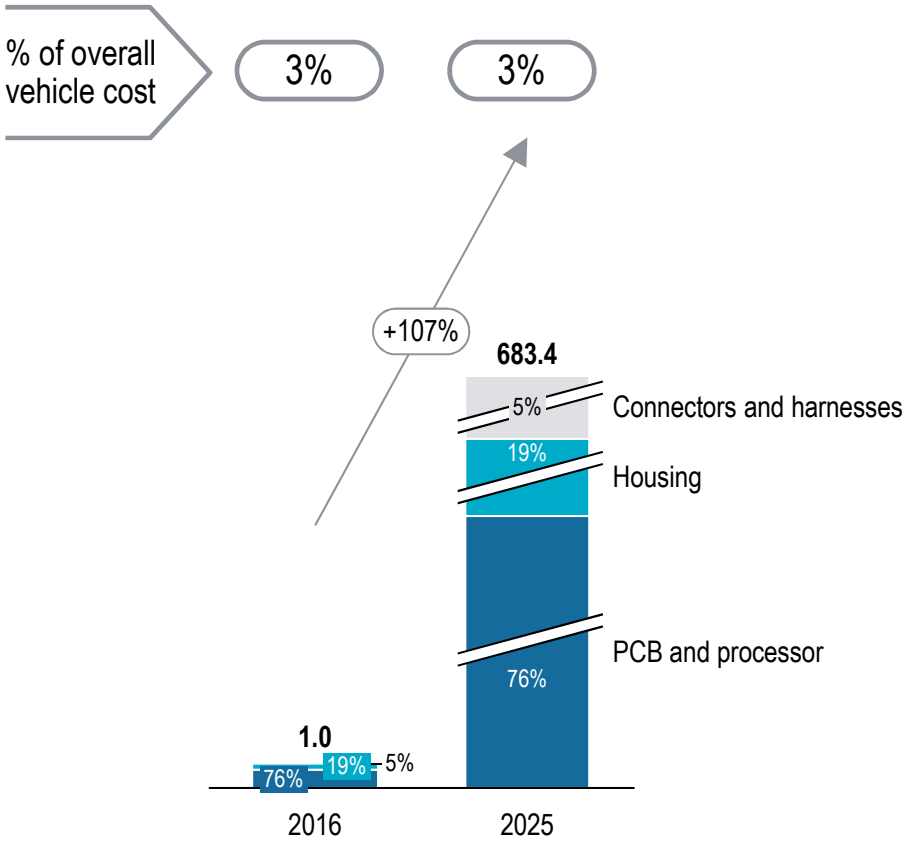
1) Technically inverter is a power electronics component, but has been analyzed as a sub-component of electric motor module because of high possibilities of integration within the e-motor module in future; Detailed discussion on charger system on the next slide

Source: Expert Interviews, Roland Berger

Microprocessor integrated in the vehicle interface control module (VICM) is the key contributor to the cost for this module

Sub-components within vehicle interface control module (VICM) – India

VICM market value [USD bn]



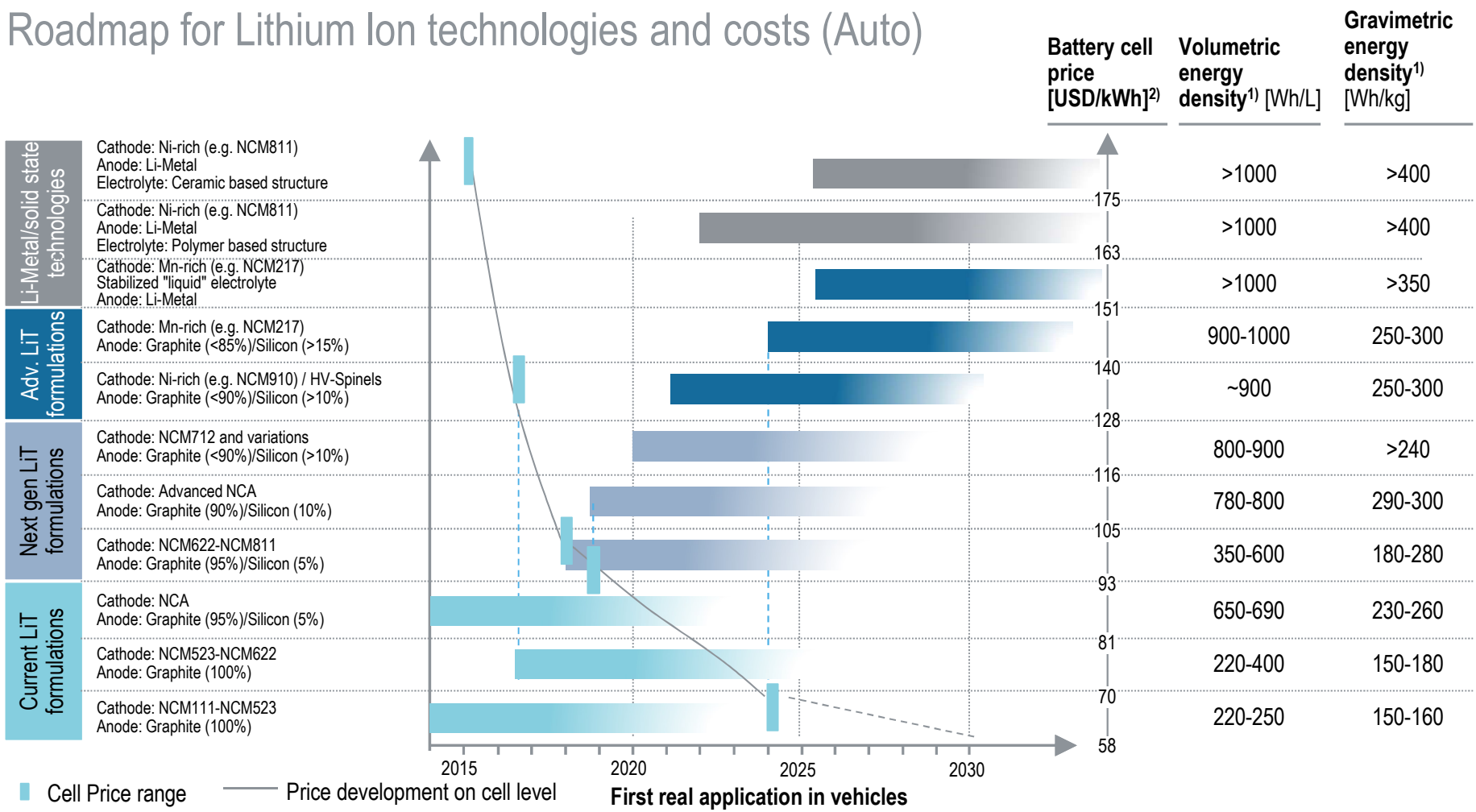
Comments

> The **VICM** functions like a data storage and distribution centre, controlling and monitoring operations between inter-reporting electronic modules
  – It maintains diagnostic information related to the electric propulsion system
> Key sub-components of the VICM include a PCB with an integrated microprocessor, housing and associated connectors & harnesses
> **PCB module** consists mainly of an integrated microprocessor chip which is programmed to perform diagnostics on data collected on vehicle operations
  – The microprocessor accounts is the largest cost component in the VICM accounting for ~80% the overall cost
  – Going forward significant changes in the hardware component cost of VICM is not expected, any cost advantage due to scale would be compensated by and increasing complexity of the module due to advanced electronic components
  – Advancement in software can be expected for this module
> The **housing** for VICM is typically made of plastics or composites and houses the PCB module of the VICM, it accounts for ~20% of the overall cost
> The **connectors and harnesses** for VICM are of both low voltage and high voltage types for control signals and power flow respectively

Source: Expert Interviews, Roland Berger

Rapid change in battery technology combined with scale effects is expected to reduce battery pack prices by 30-35% by 2025

Roadmap for Lithium Ion technologies and costs (Auto)



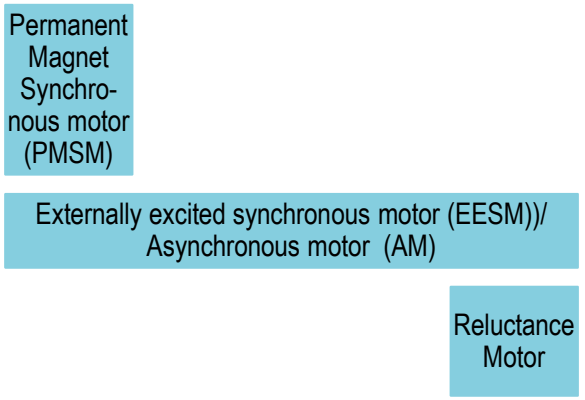
1) On cell level / *stacked electrodoes" only; 2) No inflation, current FX rates, EUR 1 = USD 1.164

Source: Interviews, Roland Berger

Likewise, technology of other critical components has also not yet stabilized

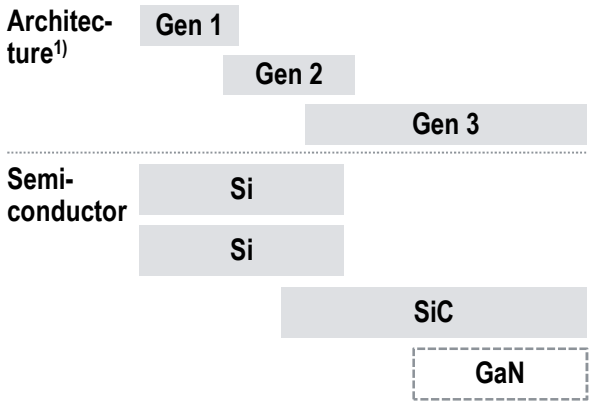
Technology trends in other key components for electric vehicles

Electric motor



- Focus on PMSM short-term despite higher cost in view of high energy density and efficiency requirements
- As battery cost come down greater focus on cost and gradual adoption of EESM and AM
- Adoption of externally excited and asynchronous motors due to higher emphasis on cost and lower packaging requirements

Power electronics



- Through 2023 gradual evolution at the module level, in terms of functional integration and part complexity reduction
- Gen 3 will introduce dedicated automotive IGBT and MOSFETs[2)]
- Gradual introduction of SiC over a relatively long overlap period in which Si and SiC co-exist due to high invest requirements

Charging infrastructure

	Supply power	Connector type	Cost
Level 1 AC charger	120V AC	J1722 port	~900
Level 2 AC charger	208/240V AC	J1722 port	~2,200-8,000
DC fast charging	208/480V AC	J1722 Combo CHAdemo Superchargers	~65,000

- There are no clear standards on which technology would be dominant going forward
- DC fast charging has slow adoption due to high initial costs
- However, standardizing a particular technology for a country can ease the infrastructure setup as scale benefits can be expected

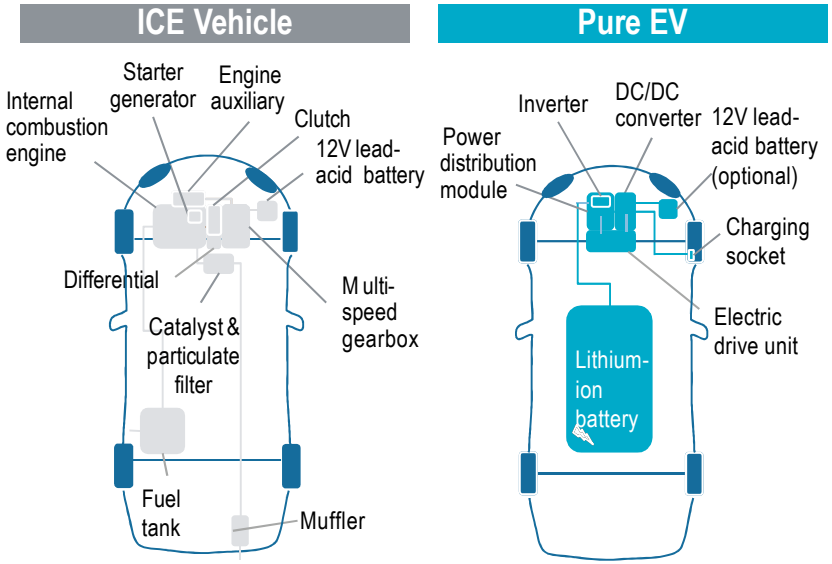
1) Architecture refers to the lithography technique used for chip fabrication. Gen1: Deep ultraviolet lithography, Gen 2: Deep ultraviolet lithography + Extreme ultraviolet lithography, Gen 3: Extreme ultraviolet lithography; 2) IGBT = Insulated gate bipolar transistor, MOSFET = Metal oxide semiconductor field effect transistor

Source: Secondary research, Roland Berger

The electrification of powertrain is inevitable - traditional powertrain component suppliers MUST ACT NOW …

Changes in 4W powertrain due to EV, Indian industry dependence on ICE components

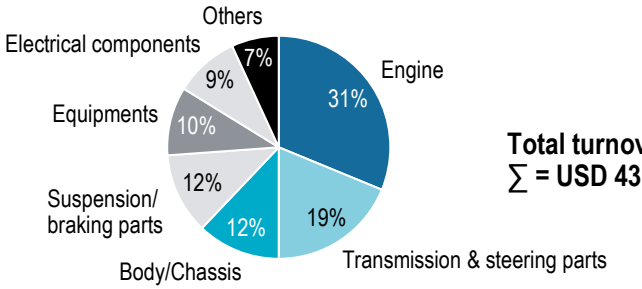
EVs are expected to account for ~18% of passenger car sales by 2025



2017	~100%	~0%
2025	82%	18% (most likely scenario)

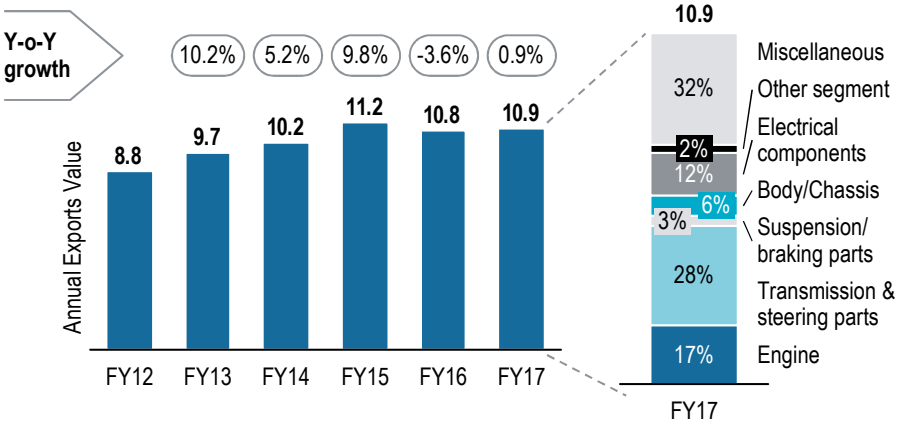
Market for traditional ICE components such as combustion engine, clutch, exhaust systems, etc. would be under threat from increasing penetration of EV

Traditional ICE components account for ~50% of Indian auto-component industry revenues



Total turnover 2016-17
∑ = USD 43.5 bn

Exports of auto components from India [USD bn]

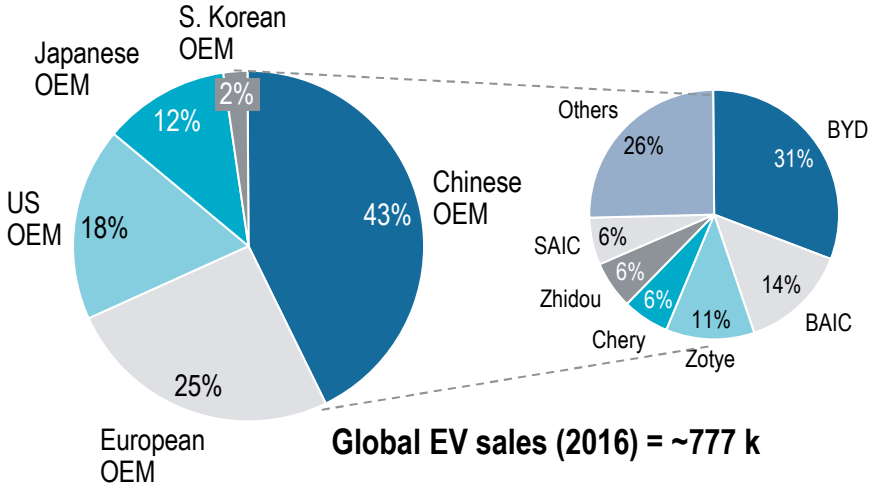


Source: UBS, ACMA annual repot and annual presentation, Roland Berger

… OR ELSE risk losing the EV opportunity to Chinese OEMs and component manufacturers

Dominance of Chinese players in EV domain

Distribution of EV[1] sales by origin of OEM [2016]



> Chinese OEMs account for ~43% of global PHEV and BEV sales

> BYD is the largest EV player globally with presence across both PV and CV segments. It has ~13% of market share globally in PV

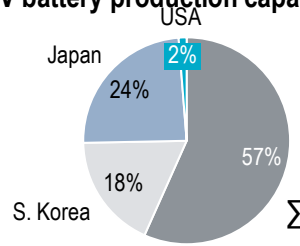
> BYD has plans underway for Indian market with its EV models, it has already partnered with Goldstone Infratech for bus segment

1) Includes PHEV and BEV

Chinese dominance in major xEV component space

Battery

xEV battery production capacity (2015)



∑ = 50 GWh

> Chinese players have 57% market share in battery market

> There are plans for additional factories with the capacity to pump out more than 120 GWh a year by 2021

E-motor

> Currently most OEMs are making e-motors in-house, but with scale build-up these are likely to be outsourced

> China has large number of high quality, cost-effective suppliers and major players such are BYD are already benefiting from these suppliers

> China's large rare-earth metal reserves give an edge to Chinese e-motor suppliers. China has 70% share in Neodymium magnets

Power electronics

> China is the leading producer of Silicon and has emerged as the favorite manufacturing destination for global xEV electronics suppliers

– The growing xEV market in China and the Chinese Govt. policies have attracted global suppliers to set up production facilities in China

– Global suppliers such as Infineon, Texas Instruments, TDK, etc. have set up manufacturing units in China

Source: EV Volumes, Roland Berger

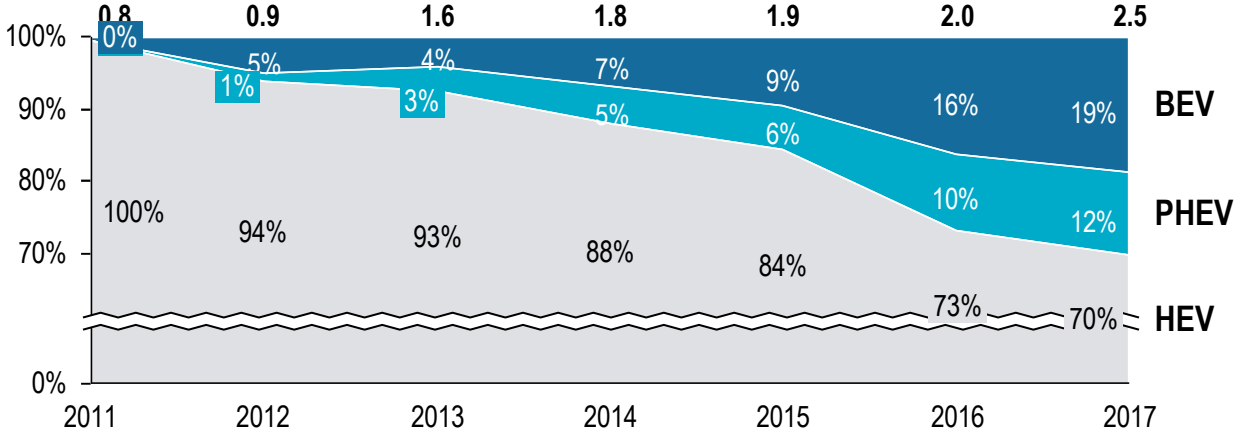
B. Need for support from the government

While most countries globally have transitioned to EV via hybrids, Indian govt. plans to leapfrog to EVs thus bypassing hybrids…

Role of hybrids in transitioning to BEV in global markets

Global evolution of xEV market[1)]

xEV sales (2011-16) [m units]



> Key xEV geographies globally have utilized hybrids as a stepping stone to shift to pure EVs

> The slow transition: ICEV > HEV > PHEV > BEV allowed gap time for development of charging infrastructure across the countries; OEMs also got time to make each stage commercially viable and make subsequent investments

> Indian government has plans to have a direct shift from ICEV to BEV

> The current FAME incentives cover strong Hybrids, PHEVs and BEVs. Under GST regime, Hybrids tax is lower than ICE but higher than BEVs

1) Includes key major xEV markets – China, USA, Europe, Japan and South Korea

"For India until charging infra comes – only way is plug in hybrid, as a short term solution, but it won't work in new GST structure"
Mahindra & Mahindra

"Hybrid is currently not being promoted and in fact there is a deliberate attempt to discourage it with 15 % cess. So hybrid is almost dead in India now."
JBM Automotive

"Most OEMs were planning around hybrids and would have transitioned to EVs in 2019-20. Even engineering teams at OEMs had hybrid mind-set and capabilities. Now, even new teams will be required"
Valeo

"With most ambitious estimates, BEVs may have 40% sales penetration in PVs. It still leaves an enormously large population of ICE vehicles. It makes lot of sense to at least partially electrify these into some form of Hybrids for further reduction of fuel consumption and CO2 emission. This will help in generating scale for localization of key components for HEV and EVs"
Maruti Suzuki

Source: Roland Berger

… and the government desires to do so with minimal incentives and by accelerating EV push in mass/public mobility applications

Indian government's recent EV initiatives

Indian government actions to accelerate EV push

- > Govt. released tender for 10k 4 wheelers through EESL[1] to replace govt. cars over a 3-4 year period, there are additional plans for tenders of 100k battery powered buses and auto-rickshaws
- > State transport units are also procuring e-buses for city transit – HRTC[2], BEST Mumbai and BMTC Bengaluru have given out tenders for fully electric buses
- > Incentives under FAME 1 have been extended to Mar'18 – but there is still uncertainty around launch of FAME phase 2
- > Push for smaller batteries along with battery swap, especially for 2/3 wheelers
- > NTPC and Power Grid Corp are planning to purchase batteries in bulk, which would be leased out to the govt.
- > India has a target of at least six million EVs on its roads by 2020
- > Government also plans to put around 1 million electric 3 wheelers and 10k electric city buses on Indian roads by mid-2019
- > Focus on slow charging infrastructure, as fast charging in Indian conditions expected to degrade battery faster
- > EESL has also floated tenders for 3,000 AC and 1,000 DC charging points

"Government policies have to be consistent, have a well-coordinated view and long standing. Clear policy and commitment of money/incentives is very important"
Maruti Suzuki

"Government incentives are very important at least for the first few years for EV penetration"
Rockman Industries

"We need low cost EVs and therefore policy should shamelessly support local players… Government will need to give incentives to local companies to innovate & invest in R&D"
Lucas TVS

"In India PHEV has not found any major demand/incentives – whatever little was there has been withdrawn. Government should do something in next GST council"
Mahindra & Mahindra

1) Energy Efficiency Services Ltd. is JV between power sector PSUs in India and is under the administrative control of Ministry of Power; 2) Himachal Road Transport Corporation

Source: Press Report, Primary Interviews, Roland Berger

However, supply side challenges exist in India with OEMs, suppliers and research institutes significantly behind their global peers

Key findings for OEMs, suppliers and research institutes

Indian OEMs

> OEMs are presently working in silos on EVs, which could majorly impact global competitiveness; need for collaborative pre-competitive research
> OEMs need to quickly commit to a defined but nimble powertrain strategy as the road ahead is long & uncertain and there is dependence on tech. owners
> Global OEMs are miles ahead in technology, understanding of EV customers, product & ecosystem experience; urgent need for knowledge & tech. transfer

Indian suppliers

> In the EV world, technology takes back priority over costs (which had become relevant for traditional ICE) as a value proposition. Together with the "electronification"[1] of global market, significant risks in-sight to exports market
> Global suppliers are already at the doorstep, with pilots & short term projects happening in India; threat of Indian suppliers missing the train even locally
> A proactive approach with pre-competitive joint research, inorganic technology acquisitions & an early global supply strategy could help Indian suppliers

Indian research inst.

> Barring a few pockets of excellence, Indian research institutes are ill equipped to help Indian suppliers with technology
> But Indian suppliers could collaborate with other good institutes to at least develop/acquire basic tech. capabilities in batteries, e-motors & charging
> Indian suppliers may need to explore global research institutes for advanced technology capabilities & for learning to work on industry-academia projects

"ACMA can link key suppliers, have bi-monthly open discussions on technical topics so that we can have a common understanding on what works for India…presently everyone is working in their own silos"
-Valeo

"We had suggested Indian players to collaborate & agree on a dimension for a "Bharat block" i.e. a modular approach to batteries just like in Nissan. But companies were not ready to invest and/or work together"
-DST

"Practical approach is missing in most universities, while analytical approach is missing in the industry"
-Mahle Behr India

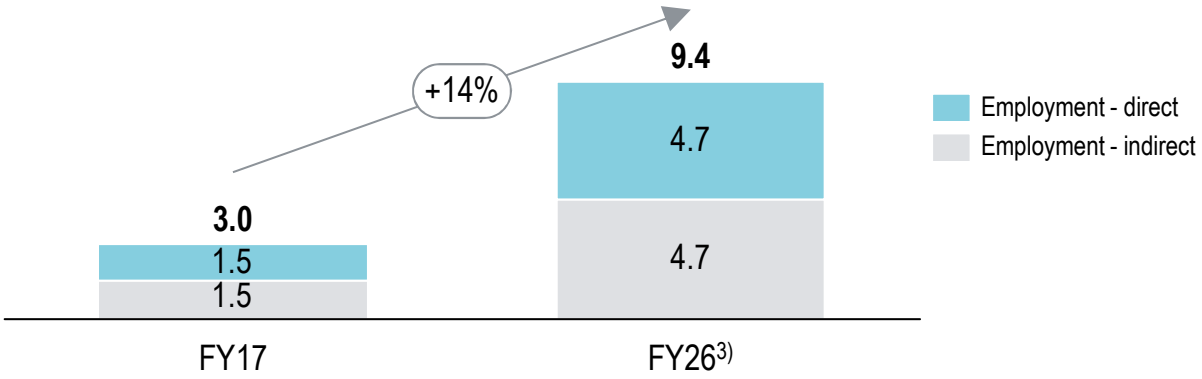
1) growth of autonomous driving, telematics/infotainment systems, IoT applications and V2X communication systems which require increasing electronic content per vehicle

Source: Expert interviews, Roland Berger

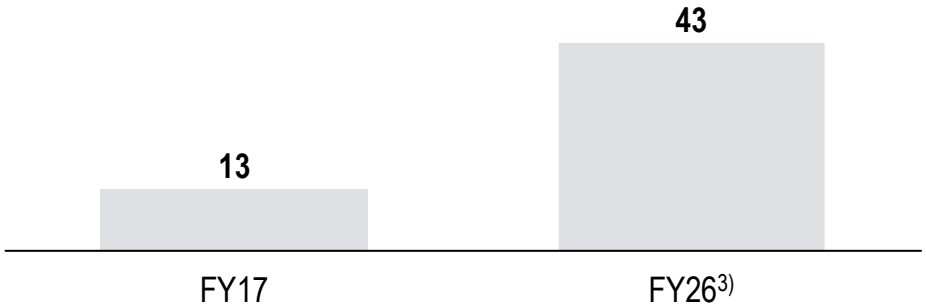
And with industry investments and jobs at stake, the country cannot afford to lose the domestic component industry in her quest for EVs

Employment and investments in the auto component sector in India (FY17, FY26)

Total employment in the auto component sector [m][1)]



Cumulative investments in the auto component sector [USD bn][2)]



- ICE powertrain contributes to over 60% of the employment generation in the auto component sector, thus potentially impacting up to 5.6 m in employment by FY2026 in a 100% EV scenario
- Significant investments will also be affected as ICE powertrain is the most technologically intense/advanced segment of the industry
  - These investments have a direct relation to the GCF and GDP growth of the country
- Therefore, the industry needs to be nurtured and guided on its path to electrification or else the country faces the risk of losing jobs and investments

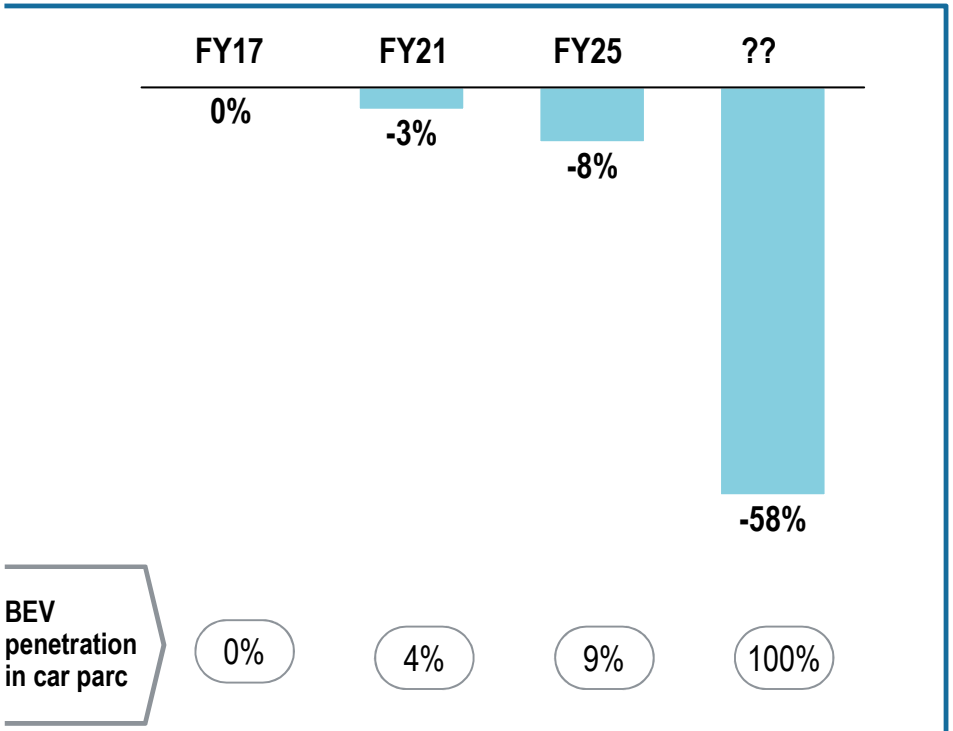
1) Indirect employment includes employment related to contract work, logistics and other support functions (canteen staff, etc.); 2) Gross block; 3) based on AMP targets

Source: ACMA, Roland Berger

EVs will also impact after-market revenues & consequently jobs, making the survival of domestic component industry even more critical

Impact on aftermarket

Impact on auto aftermarket revenue in India[1)]



- Lesser mechanical & moving components in a BEV in comparison to an ICE results in a substantial decrease in maintenance cost
  - On an annual basis, service costs to be trimmed by up to ~58% due to reduced need for replacement of parts & longer service intervals
- Effect on aftersales revenue pool is heavily dependent on BEV penetration in overall car parc
- As per the most likely scenario for India, impact on aftersales to be close to 8% by FY25
- Contraction in the aftermarket is also expected to result in considerable effect on jobs across the automotive aftermarket value chain
  - Aftermarket companies will need to invest in training, tools and equipment to carry out increasingly complex electrical repairs in BEVs
  - Dealerships which rely on sales of high-margin spare parts will need to find new avenues of growth
  - Unorganized players running garages & workshops will need to diversify into charging infrastructure installation & maintenance
- But there could be compensation from new jobs (not detailed)

1) As per most likely scenario

Source: SIAM, IHS, UBS, Roland Berger

C. OEMs' make-buy strategy

Low focus of global OEMs on India may reduce chances for Indian suppliers to enter global supply chain through local activities

Executive summary – Global OEMs in xEV space

OEM powertrain strategies

> Most global 4W & e-bus OEMs in the xEV space are focusing on mix of PHEV & BEV configuration in order to meet emission targets; very little focus on FCEV plans due to little/no Govt. incentives

> Focused all-electric powertrain strategy for 2W & 3W OEMs

Component sourcing strategy

> Battery management system emerges as the key technological capability - most OEMs are strengthening in-house competencies with the intention to package batteries[1)] in-house when xEV volumes increase

> Some 4W OEMs such as BYD, Tesla etc. are also integrated backwards and investing in Gigafactories to reduce the per kWh cost through scale economies and ensure a steady product supply

> Conversely, 2W, 3W, LCV and to a certain extent e-bus OEMs are outsourcing majority of the components to the external suppliers with the exception of BMS

> Other power electronics such as inverters, chargers in most cases are outsourced to external suppliers across vehicle segments

Future focus/ xEV targets

> Most OEMs are focusing on China as the key growth market – Strong commitments and plans made by traditional OEMs & startups towards China market entry/ expansion

Plans for India

> Most 4W OEMs do not have a focused India EV roadmap due to poor xEV supply chain & limited Government incentives and limited policy visibility

> 3W OEMs such as Terra Motors, Clean Motion are, however, inclined towards India xEV market to realize economies of scale

1) Cells/ modules will be outsourced to Tier 1 suppliers or produced through JVs/ subsidiaries

Implications for Indian suppliers

Opportunities

> Potential to tie-up with global suppliers to develop competencies in e-motor, power electronics etc.

Challenges

> Global OEMs do not have a EV roadmap for India entry in the near future; slow uptake of EVs in India may impede Indian suppliers' entry into the global xEV value chain

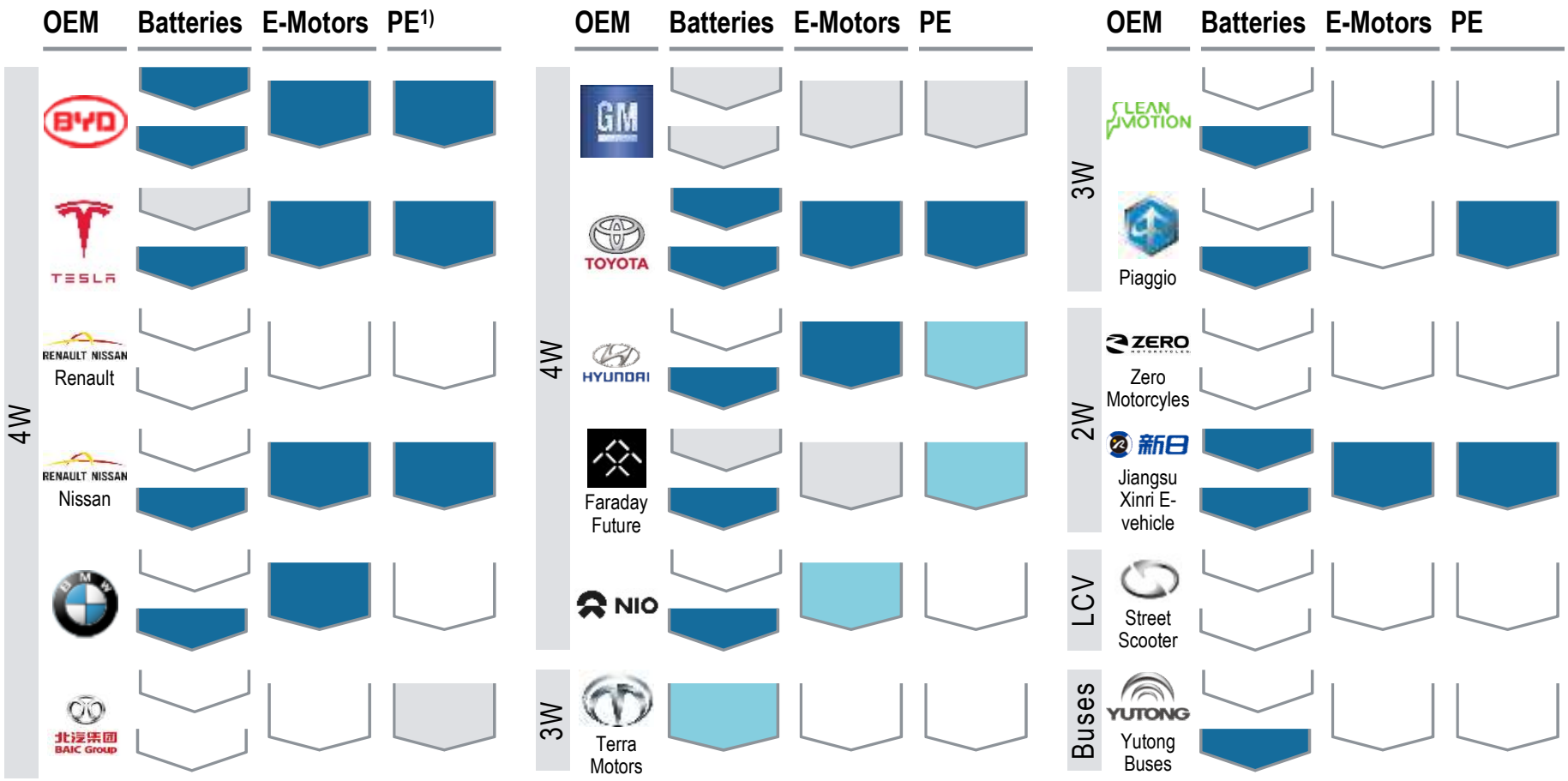
> Global OEMs, especially Chinese firms, may prefer to bring in their own suppliers and hinder Indian suppliers' xEV growth aspirations

> Indian component suppliers can develop competencies in e-motors & power electronics through tie-ups with global suppliers

> Lack of OEM driven EV market in India may hinder the growth of Indian suppliers in the global xEV value chain

Analysis of global xEV OEMs indicate that most players are either well integrated or have formed a well-established supply network

Fact-finding: Global xEV OEMs (positioning along EV value chain)



Source: Roland Berger

D. Recommendations

Govt. support is crucial to build a vibrant, globally competitive BEV ecosystem in India

Recommendations for Government

1 Policy support

1.1 Develop a **long term, consistent, phased & technology agnostic industrial policy for xEVs in India**, with alignment across ministries & distributed efforts across the levels of the administration

> Support a proportion of viability gap for each technology (BEV/hybrid)

1.2 **Address critical issues in detail upfront** (e.g. battery swapping related liabilities, recycling, etc.)

> Study what use cases lend to what technology (BEV/hybrids)

1.3 **Address issues of inverted duty structures for xEV components**, to ensure pick-up of local mfg.

2 Support for capability development

2.1 **Support localization and technology transfer** similar to **Chinese approach**

> Interest subvention for new capital equipment for electric mobility

> Support for collective buying of basic xEV technologies from outside the country

> Support for study missions for technology tie-ups with players in China & Europe

2.2 **Additional R&D support for electrification for the auto-components industry**, especially for MSMEs, startups and academia

3 Support for scale development

3.1 Support scale via **manufacturing (supply) related incentives**

> Priority lending for EV related projects through PSBs

> Concessions in electricity tariffs, property taxes and tax breaks for EV division until full production

> Priority allotment of land and services like water, electricity & speedy execution of administrative processes

3.2 Drive **standardization** and align with **global best practices to drive down cost and enable exports**

Source: Roland Berger

A long term consistent policy by the Indian govt. to create a volume certainty would help firm up e-mobility plans of the industry

Approach for development and monitoring of xEV policies

Define targets

> Constitute a high powered e-mobility team from across government departments and industry (incl. SIAM, ACMA & SMEV)
> Define targets with inputs from all the relevant stakeholders
  – Government ministries and departments – MNRE, Niti Aayog, DHI, Power ministry, Metro municipalities, etc.
  – OEMs and suppliers
  – Utilities
  – IT/ITES firms
  – Payment banks

Develop policies

> Localization policies: Enabling policies for parts that are easy to localize & with large expected market
> Export import policies: Low export duties for parts to be localized & low import duties for their child parts / raw materials
> Demand and supply incentives: Financial & non-financial incentives for consumers & OEMs/suppliers
> Public procurement policies: stimulate demand by large volume purchases of buses, 3W & government cars
> Policies for charging infra: enabling policies for tariffs, land acquisition & battery swap
> Skill development policies for new supply chain & ecosystem

Implement & co-ordinate policies

> Draw up timelines with inputs from the industry and various ministries
> Clearly distribute responsibilities of the various policy measures among the various departments and ministries
> Setup KPIs for monitoring like xEV penetrations, xEV related trade balance, charging infra density, etc.
> Communication to all the relevant ministries and departments for action
> Communication to the industry and general public

Monitor & tweak policies

> Annual review of targets vs achieved
> Assessment of bottlenecks, if any, in terms of policies and corrections in the policies
  – More frequent assessments in the beginning; reduced frequencies going forward post 2020

Source: Roland Berger

While Govts. can help create xEV demand through subsidies, infra & awareness, they can help mfrs. with tax benefits & other policy support

Demand and supply side supports recommended for Government

	Demand side support for consumers		Supply side support for manufacturers	
National level	> Subsidy for switching to xEVs > Tax refund on electricity used for charging	> Creating national level awareness on benefits of xEVs through advertisements	> Tax break for xEV div. until full prod.; import tax benefits for xEV T&M[2)] > Grants for R&D	> Long-term xEV policy roadmap to alleviate investment risks > Global tie-ups
State level	> Full exemption of Road tax for xEVs > Full or partial waiver of toll tax paid for SHs[1)]	> Support for setting up public charging infrastructure	> Provision of land at concessional rates for xEV facilities > Electricity supply at subsidized tariff	> Priority allotment of land and services like electricity, water, etc.
City level	> Concession in registration fee for xEVs	> Facilitation of fast paced registration > Development of designated parking space for xEVs	> Concession in municipality related taxes such as property tax	> Speedy execution of land allotment and other administrative processes

Financial support Non-financial support 1) State Highways 2) Tools and Machinery

Source: Roland Berger

GoI needs to provide differential R&D support for large firms, MSMEs, startups & academia for future sustenance of capabilities

Technology development support recommended for government for future sustenance

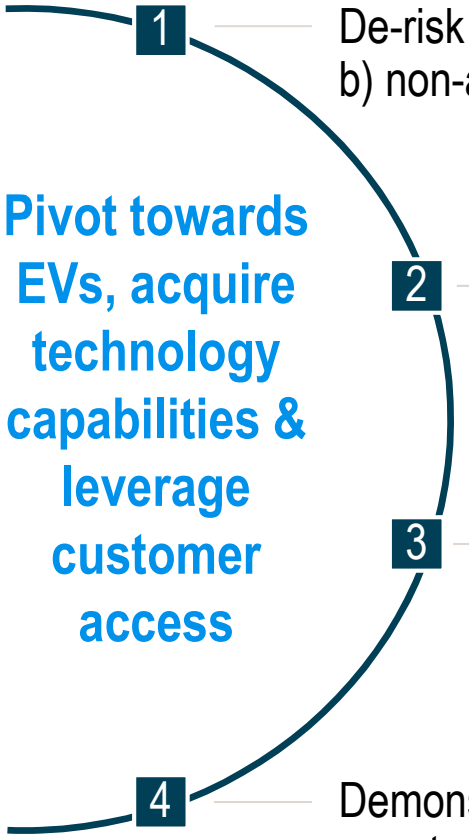
	R&D expenditure	Patenting	Collaborative R&D
Large firms	> Import duty exemptions on EV R&D equipment > 150% R&D tax deductions for EV research > 200% R&D tax deductions[2] for expenditure on R&D in EESM/AM[1] & Next gen Li battery chemistries[3]	> 1 year GST waiver on production value add for goods developed locally & patented in India & 2 countries in either Europe (one country), US or Japan > 10% corporate tax on global income of patents developed & registered locally	> 200% R&D tax deduction on research with National Labs /Universities/ IITs > 175% R&D tax deduction on sum paid to specified R&D institutes/Universities
MSMEs	> Import duty exemptions on EV R&D equipment > 200% R&D tax deductions for EV research > 300% R&D tax deductions[2] for expenditure on R&D in above mentioned topics	> 2 year GST waiver with similar conditions as above > 5% corporate tax on global income of patents developed & registered locally	> 250% R&D tax deduction on research with National Labs /Universities/ IITs > 225% R&D tax deduction on sum paid to specified R&D institutes/Universities
Startups	> Import duty exemptions on EV R&D equipment > 250% R&D tax deductions for EV research > 350% R&D tax deductions[2] for expenditure on R&D in above mentioned topics	> 3 year GST waiver with similar conditions as above > 0% corporate tax on global income of patents developed & registered locally	> 300% R&D tax deduction on research with National Labs /Universities/ IITs > 275% R&D tax deduction on sum paid to specified R&D institutes/Universities
Universities / research institutes	> Import duty exemptions on EV R&D equipment > Additional R&D grants[2] for projects on advanced Li & Li-Metal/solid state battery chemistries, GaN & SiC based semi-conductors	> Grants based on EV patenting activity > Financial & non-financial support in sale of licenses to Indian suppliers	> Preferential grants for collaborative projects > Support for match-making events

1) Externally excited synchronous motor / Asynchronous motor; 2) Incentives in case of R&D in future technologies; 3) Next gen Li battery chemistries include NCM622-811, advanced NCA, NCM712 and variations; advanced Li battery chemistries include Mn-rich (e.g. NCM217) and Ni-rich (e.g. NCM910) / HV-Spinels

Source: Roland Berger

Indian suppliers need to swiftly catch-up on their EV tech. & business readiness by tech. acquisitions, collaborations & capability demonstrations

Recommendations for Indian suppliers

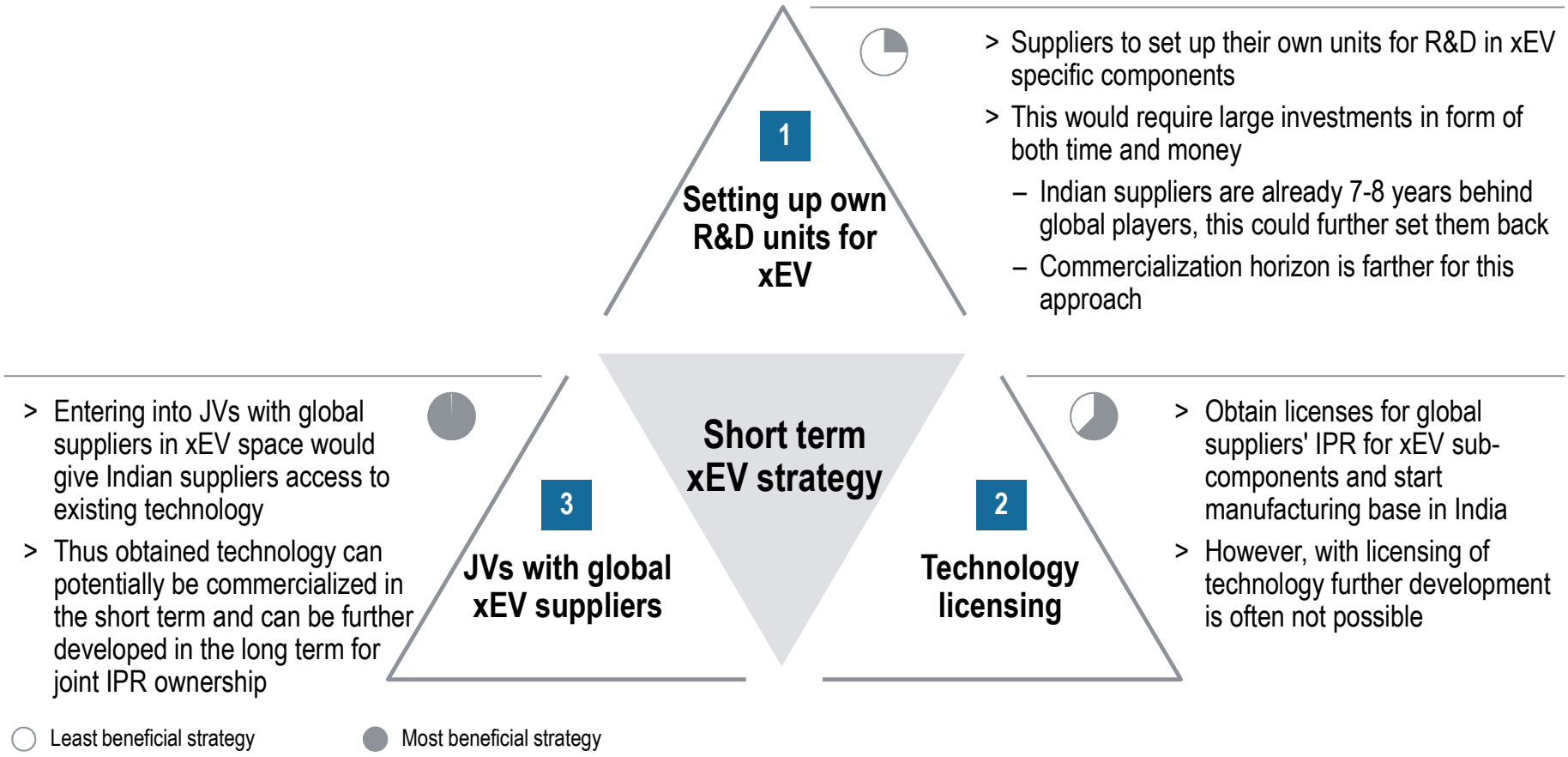


1. De-risk your current business by pivoting towards - a) EV opportunities, b) non-automotive opportunities that leverage supplier capability
2. Tie-up with international partners to complement their technology capability with own frugal engineering approach
3. Conduct non-competitive R&D by leveraging EV ecosystems (research institutions, suppliers, OEMs, etc.)
4. Demonstrate technology capabilities to Indian and global OEMs, e.g., in e-motors, electronics and battery packaging

Source: Roland Berger

Engaging in technology tie-ups with global counterparts with strong regulatory support is a potential way forward for local suppliers

Indian component manufacturers: HOW TO PLAY



Source: Roland Berger

Suppliers need to acquire technology through inorganic routes, given they are 7-8 years behind global counterparts

Potential sources for tech. acquisition for various traditional supplier segments (select)

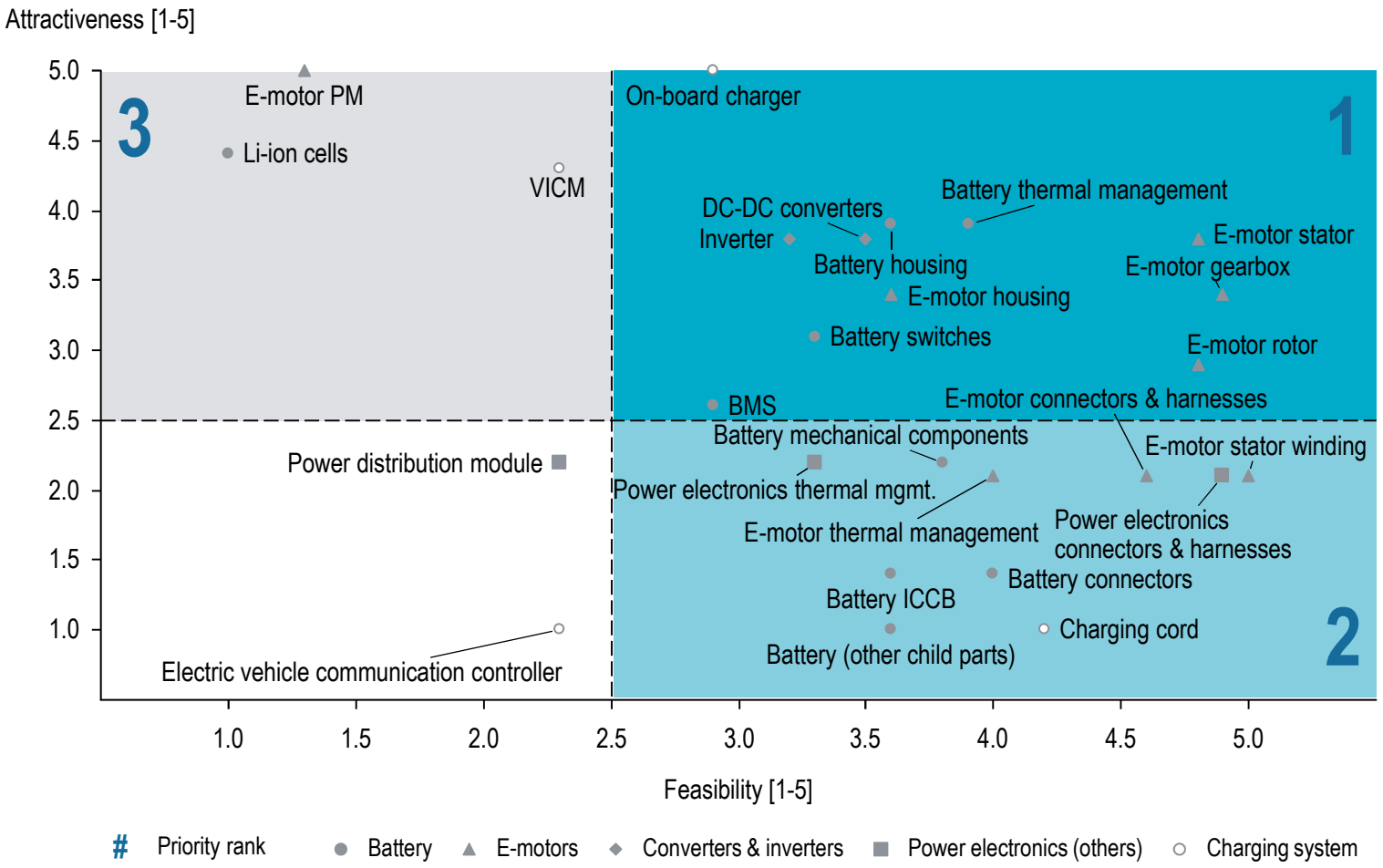
	Technology topics	Potential global tech. partners	Potential R&D institute partners
Engine component suppliers	Battery cooling & packaging, e-motors, etc.	MAHLE, LG Chem, GS YUASA, CATL, DENSO, MAGNA, AISIN, Continental, Valeo	ARAI, ISRO, Oak Ridge, Ohio State
Transmission component suppliers	E-motors, single speed reduction gears, efficiency improvements, shift-by-wire, etc.	MAHLE, MAGNA, Continental, ZF, oerlikon, AISIN, Valeo, Punch	ISRO, Fraunhofer, Ohio State
Body/Chassis component suppliers	Lightweighting, battery cooling & packaging, etc.	MAHLE, LG Chem, GS YUASA, DENSO, CATL, Valeo	ISRO, Oak Ridge, Fraunhofer
Suspension/ Braking component suppliers	Regenerative braking & suspensions, brake-by-wire, etc.	BOSCH, Continental, ZF, Hyundai MOBIS, Autoliv, ClearMotion, Intertronic Gresser GmbH	

	Technology topics	Potential global tech. partners	Potential R&D institute partners
Steering & other equipment suppliers	Steer-by-wire, power consumption reduction, etc.	DENSO, Valeo, BOSCH, NISSAN, JTEKT, SCHAEFFLER	KIT
Electronic components suppliers	Power consumption reduction, thermal mgmt., BMS, power electronics, etc.	LG Chem, DENSO, AISIN, Continental, ZF, Valeo	ARAI, ISRO, Oak Ridge, Imperial College London, Fraunhofer
New suppliers	Battery production, synthetic graphite production, recycling & extraction of materials, charging stations, BMS, telematics, etc.	LG Chem, GS YUASA, CATL, DENSO, chargepoint, MAGNA, IMERYS, EVgo, Panasonic, Valeo, ABB	ARAI, ISRO, Oak Ridge, KIT, Ohio State, Fraunhofer, Argonne, University of Delaware

Source: Roland Berger

Potential EV opportunities for local suppliers incl. parts & assemblies for e-motors, thermal mgmt., connectors & power electronics (excl. PDM[1])

Indian component manufacturers: WHERE TO PLAY



Source: Primary interviews, Roland Berger

- Chinese dominance and lack of raw material supply chain in Li-ion cells and permanent magnet makes it difficult for Indian OEMs to enter these segments
- For power electronics and other components of battery and e-motors – Indian suppliers can potentially offer a more cost effective solution once OEMs start outsourcing these sub-components on a larger scale
- Except for Lucas TVS, TACO & Spark Minda, majority of the suppliers lack a comprehensive xEV components strategy
- Suppliers need to formulate their xEV strategy along priority components and acquire technologies through JVs and licensing in the short term

1) Power distribution modules

Suppliers need to next demonstrate capabilities to global & Indian OEMs & build initial scale through supply contracts with global OEMs

Supply chain creation approach for Indian suppliers

Leverage newly acquired technologies with own frugal engineering approaches to demonstrate capabilities to global & Indian OEMs

> Leverage global & Indian platforms like conferences, exhibitions, etc.
> Arrange factory visits for OEMs
> Publish newsletters and news reports on capabilities

Business development with global OEMs

> This could help provide initial scale even though local EV volumes remain low
> It can provide opportunities for learning & technology co-development

Collaborative product development with Indian OEMs

> Develop supply lock-ins
> Apply learnings from relationships with global OEMs

Business development & collaborations with both global & Indian OEMs

> Ensure future business & mitigate technological obsolescence in a fast evolving xEV landscape through continuous collaborations & business development

Own research & development

> Suppliers need to keep investing in own R&D & collaborative R&D with universities & research institutions (global and Indian) to ensure future sustenance

Year -> **2020** **2022** **2025**

Source: Roland Berger

Indian OEMs need to keep a nimble xEV powertrain strategy and work together & with the govt. to develop capabilities & roadmaps

Recommendations for Indian OEMs

Define an agile xEV powertrain strategy & roadmap, collaborate on research and increase R&D efforts

1. Quickly commit to a defined but nimble powertrain strategy through continuous exposure to global EV ecosystem, overlapping supply chains in HEVs & EVs and core in-house capabilities common to HEVs & EVs
2. Proactively collaborate on pre-competitive research for development or acquisition of basic non-differentiating catch-up technology and manufacturing capabilities
3. Proactively work with the government ministries, SMEV & suppliers to develop an EV roadmap for the industry through SIAM
4. Dedicate additional budgets for EV R&D & start collaboration projects with Indian and global research institutes

Source: Roland Berger

ACMA needs to enable information exchange & collaborations, keep close alignment with SIAM & market local capabilities globally & locally

Recommendations for ACMA

1. Create awareness for EV and shared mobility disruptions and their impact on supplier
2. Align with SIAM to ensure adequate collaboration and representation of industry needs to government
3. Support efforts for global technology tie-ups by Indian suppliers
4. Create awareness around technological and manufacturing capability of Indian suppliers globally and within India

Source: Roland Berger

ACMA would need to setup EV focused platforms aimed at awareness creation, match-making for tech. tie-ups & demonstration of capabilities

Detailing of recommendations for ACMA

Create awareness among suppliers

> Setup a platform for exchange of information & knowledge between ACMA, SMEV, SIAM, government, global suppliers, global OEMs, global & Indian research institutes and knowledge organizations
> Publish & distribute EV focused monthly newsletters among members compiling developments in EV landscape (both technology and business) globally and locally
> Organize visits for suppliers to EV facilities of global OEMs & suppliers, research institutes and EV exhibitions

Support efforts for tech. acquisition

> Organize match-making events for technology tie-ups
> Establish a technology buying organization for collective technology acquisition of basic pre-competitive tech. from global tech. owners
> Create awareness of existing government schemes for technology acquisitions & R&D for MSMEs
  – Internally become accustomed to the process and help handhold suppliers through the process of availing the schemes

Demonstrate technology and manufacturing capabilities

> Setup events consisting of conferences, networking platforms and exhibitions for suppliers to demonstrate their capabilities
> Publish annual brochures or booklets demonstrating technology developments, patents and publications by Indian suppliers and share these with global and Indian OEMs. This could be part of the newsletters

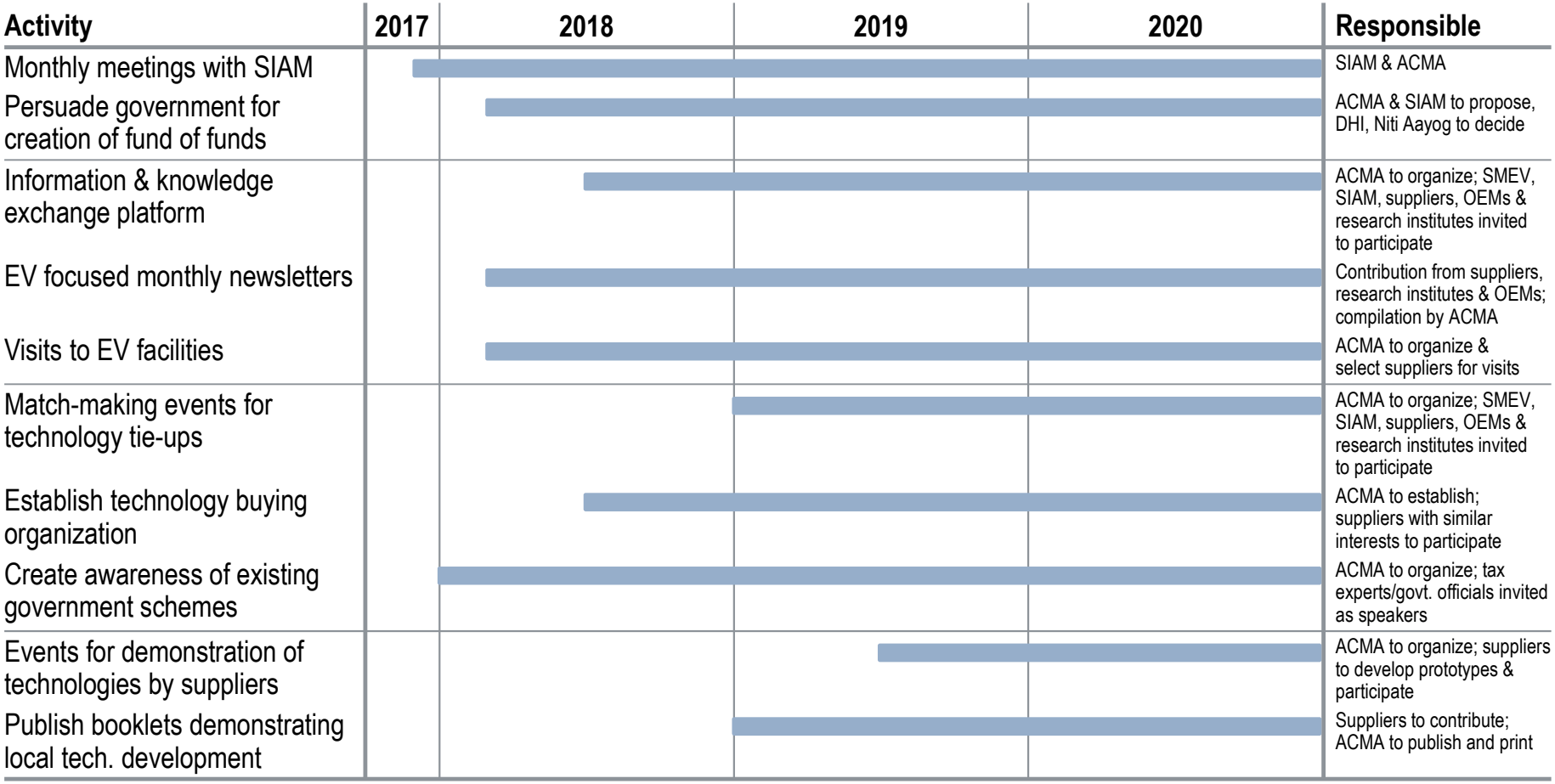
Align with SIAM & communication to government

> Monthly meetings with SIAM to align on communication to government, OEM plans & roadmaps and opportunities for collaborations
> Persuade government for creation of a dedicated auto R&D fund of funds for supporting core EV collaborative R&D projects & supplier startups

Source: Roland Berger

As the way forward, ACMA needs to adopt an implementable action plan that involves SIAM, OEMs, suppliers and research institutes

Roadmap for implementation



Source: Roland Berger

Think:Act