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India's Electric Vehicle Transition

Impact on Auto Industry and Building the EV Ecosystem

Report | October 2019

Abhinav Soman, Karthik Ganesan, and Harsimran Kaur

The electric vehicle ecosystem in India is in a fledgling state.

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Acknowledgments

The authors of this report would like to thank the team at Shakti Sustainable Energy Foundation for supporting this research on India's electric mobility ecosystem and its impact on the automotive industry and the economy. This study is of critical importance today given India's policy agenda to increase the use of electric vehicles.

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"The auto industry is a key stakeholder in India's transition to sustainable mobility. Whether or not we should target electric vehicle sales in India, the extent of their manufacturing within India, and the rate at which we make a transition to electric mobility are all open questions today – this report will hopefully assist decision makers in tackling these questions."

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An engineer by training, Karthik leads The Council's work on the power sector. His research focus includes the operational reform of discoms in India and the competitiveness of various power generation sources. He has also led a first-of-its-kind evaluation of the impact of industrial policies on the renewable energy sector in India. Karthik holds a master's degree in Public Policy from the Lee Kuan Yew School of Public Policy at the National University of Singapore. He also holds an undergraduate degree in Civil Engineering and an MTech in Infrastructure Engineering from the Indian Institute of Technology, Madras.

"As the most dominant contributor to manufacturing, there is little public data available to back how big the auto sector is, and what the impact of a transition could actually be. We hope this study provides that objective assessment and informs the country's mobility transition."

Harsimran Kaur
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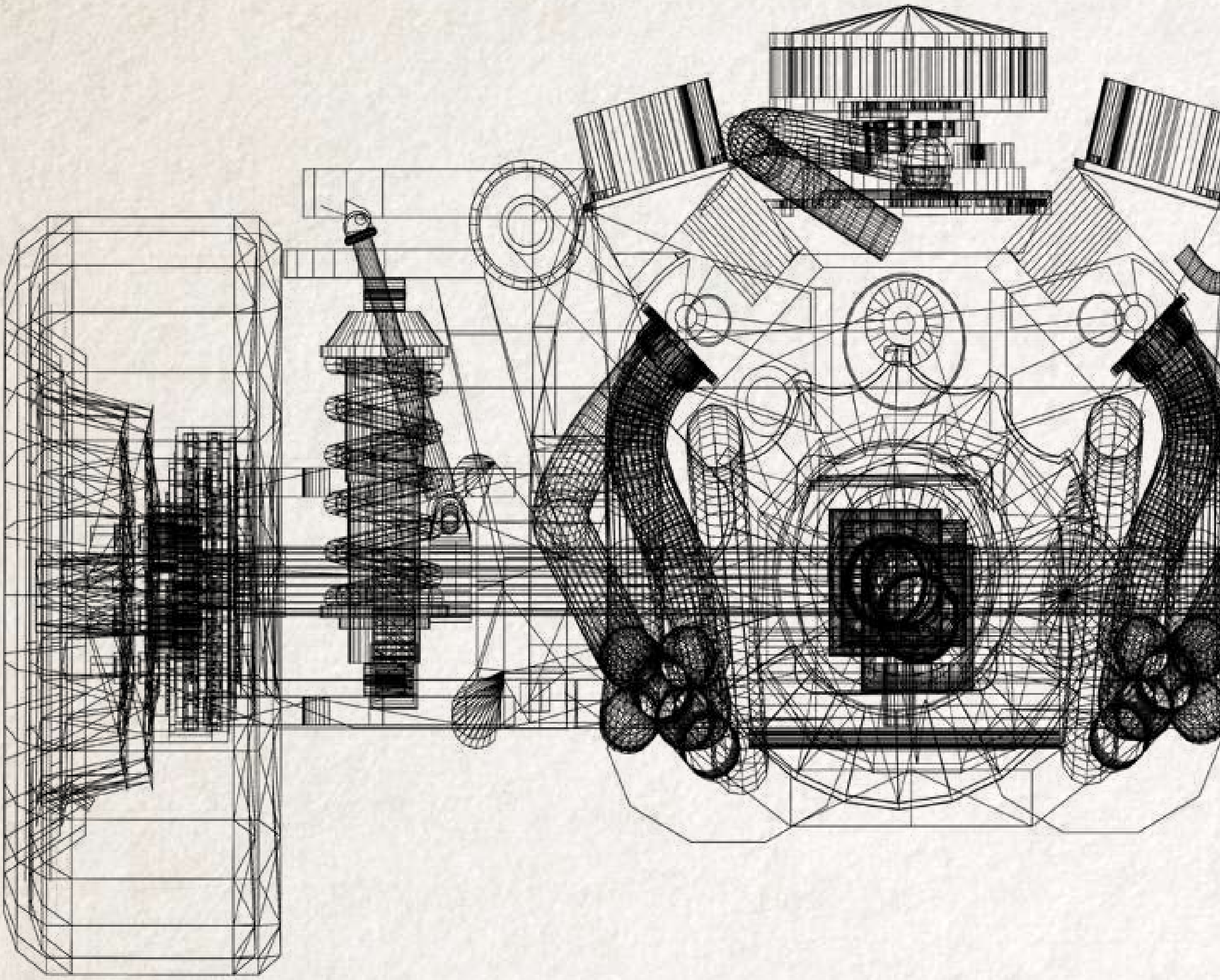
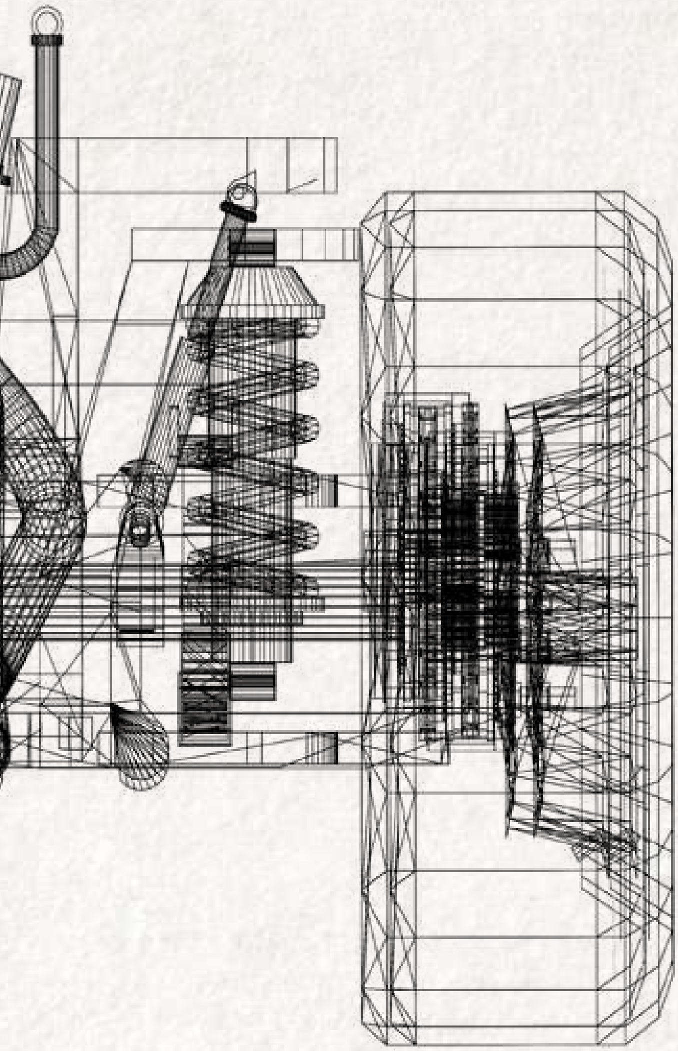
Harsimran is a Research Analyst at The Council. Her research focuses on the economic impact of a transition to electric vehicles and policy interventions for promoting sustainable mobility. In the past, she has worked on estimating subsidies to fossil fuels and analysing the key policy drivers to accelerate the adoption of electric vehicles in India. She holds an MTech degree in Renewable Energy Engineering from TERI School of Advanced Studies, New Delhi, and a BTech in Electrical and Electronics Engineering from GGS Indraprastha University, New Delhi.

"As Indian cities vie to become the 'Detroit of electric vehicles', we find that the auto industry will stand to gain on many fronts – value add, trade balance, and the environment. However, before that happens, a local supply chain and an EV ecosystem will have to be in place. This report explores a range of barriers impeding the development of an EV ecosystem today, and busts misconceptions regarding the downsides of an EV transition."



The EV powertrain consists of fewer components than the ICE powertrain

Image: iStock



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Abbreviations

ACMA	Automotive Component Manufacturers Association of India
AMP	Automotive Mission Plan
NAP	National Auto Policy
BEV	battery electric vehicle
BNSVAP	Bharat New Safety Vehicle Assessment Program
BS-VI	Bharat Stage VI emission norms
DHI	Department of Heavy Industry
PPP	Public–private partnership
EV	electric vehicle
EVSE	electric vehicle aupply equipment
FAME	Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles
FY	financial year
GDP	gross domestic product
GVA	gross value added
HS	Harmonized System
ICEV	internal combustion engine vehicle
MoHI&PE	Ministry of Heavy Industries and Public Enterprises
NATRIP	National Automotive Testing and R&D Infrastructure Project
NEMMP	National Electric Mobility Mission Plan
NIC	National Industrial Classification
OEM	original equipment manufacturers
SIAM	Society of Indian Automobile Manufacturer
STU	state transport undertaking
TCO	total cost of ownership
2W	two-wheeler
3W	three-wheeler
4W	four-wheeler

Glossary

Battery pack	It consists of the battery management system (BMS), its mechanical components, housing, and thermal management and venting unit
Commercial vehicles	It includes motor vehicles that are intended for the carriage of passengers more than nine persons (including the driver) or for the transport of goods
Financial year	April 1 to March 31
Import burden per car	Amount of the crude oil imports (in INR) required for running one ICE car over a lifetime of 10 years
Passenger vehicles	It includes road motor vehicles, other than motorcycles, intended for the carriage of passengers and designed to seat no more than nine persons (including the driver).
Powertrain	The mechanism by which power is transmitted to the axle of the vehicle. It includes electric drives, power electronics, and vehicle interface control modules.
Value add	It pertains to market value of goods and services produced by an enterprise. Output value add includes income, value of stock, value of electricity, value of construction, sale goods, and gross sale value as per the Annual Survey of Industries (ASI) schedule.
2W	Any two-wheeled vehicle propelled by any type of power other than pedalling (including but not restricted to internal combustion engines and electric motors) intended for private use only.
3W	Any three-wheeled vehicle propelled by a motor, generally used for commercial transport of passengers.
4W	Any four-wheeled vehicle propelled by an internal combustion engine or an electric motor intended for private or commercial use. It includes cars, jeeps, vans, buses, light and heavy commercial vehicles, and trucks.

EVs can address local air pollution, climate change goals and energy security concerns for India

Image: iStock

Executive summary

The automotive industry in India is facing headwinds – from a general economic downturn to the need to improve emissions performance and the impending shift to electrification. Charting the future course of the auto industry, especially with regard to electrification, will require an in-depth understanding of the opportunities and impacts that can be expected. In this study, we have attempted to assess these by comparing a scenario with 30 per cent electric car (EV) sales in 2030 against a business-as-usual (BAU) scenario with limited EV penetration.

Beyond 2030, several countries with a significant export share of car and car auto components today are targeting 100 per cent EV sales. This may present a lost opportunity for the Indian auto industry if they are unable to capture the fast-growing global EV market due to limited capability and expertise in EV manufacturing.

We find that, despite the fewer components needed for producing an electric car, the localisation of electric powertrain and battery pack assembly can result in a 5.7 per cent higher output value addition for the auto industry in a 30 per cent electric car sales scenario, when compared to value addition in a BAU scenario in 2030. However, with limited indigenisation of powertrain and battery pack assembly, there will be an 8 per cent lower value addition from an EV transition in 2030.

Around 20 to 25 per cent fewer additional car manufacturing jobs will be created in a 30 per cent electric car sales scenario, but there will be no job losses as a result of the transition. However, it is critical to ensure that a trained workforce is made available for the new EV manufacturing jobs that will be created, which would require new and different skill sets.

Electric car use can have positive impacts from macroeconomic and environmental standpoints. Specifically, the import burden per internal combustion engine (ICE) car is 4.1 times higher for private cars and 5.7 times higher for commercial use cars when compared to electric cars over their lifetimes, when comparing oil and battery cell imports in 2030. CO_2 emissions per electric car are, in addition, 2 to 16 per cent lower than that of an equivalent ICE car over its lifetime in India.

Further, based on consultations with 28 stakeholders from the EV ecosystem in India, we have identified supply chain, policy, and financing barriers that are impeding the growth of EVs in India today. Overall, while there is a strong case for transitioning to EVs, as identified in this study, a policy package will be needed to address the existing barriers and develop a thriving EV ecosystem in India.

EV manufacturing will require a skilled workforce which does not exist today. Re-skilling and training of a new workforce is a critical area for EV transition.

Image: iStock

1. Introduction

India is at the cusp of an e-mobility revolution. While it is not a global frontrunner in promoting and developing an e-mobility ecosystem, a range of compelling reasons make this paradigm shift in mobility seem inevitable. A transition to electric mobility has the potential to reduce oil imports, address air pollution in cities, and help meet India's climate commitments by reducing the energy intensity of the gross domestic product (GDP). In addition, an electric vehicle (EV) transition can spur the growth of new industries and activities. Further, India's current competence in auto manufacturing may be threatened by a global shift towards electric mobility, particularly as the industry aims to become an internationally competitive manufacturing hub and ramp up its exports. To those providing mobility services, including state transport undertakings (STUs), e-mobility is an opportunity to reduce the total cost of ownership (TCO) and improve financial sustainability and profitability. A smooth transition, however, is unlikely without prescient and strategic policy interventions and private initiatives to support market development, infrastructure deployment, and financing.

A major uncertainty surrounding the EV transition in India is the impact it would have on the automotive value chain, particularly on the automotive components industry and the jobs in this sector. The industry has witnessed a continuous decline in sales over the last year. While this may point to broader macroeconomic conditions that deter investments in vehicles, there is also the added pressure of transitioning to BS-VI and EVs. These are being used as possible reasons to explain why consumers are delaying purchase decisions ahead of the roll-out of these new vehicles. Notwithstanding this cyclical downtrend, fewer components are required in an EV powertrain as compared to that of an internal combustion engine vehicle (ICEV), and this will lead to a loss in value addition in powertrain manufacturing. Further, in case of limited indigenisation as in the current scenario, most high value addition components in an electric car will have to be imported, resulting in a further loss in potential value addition from local manufacturing of electric cars.

This report explores these scenarios in detail to understand and quantify these impacts and to propose strategies to ensure a transition trajectory that can mitigate any adverse fallout. Further, we also map the current e-mobility ecosystem in India and compile the various policy, finance, and supply chain challenges that the various stakeholders in the ecosystem face today.

1.1 The auto industry landscape

The auto industry is a critical driver of macroeconomic growth and technological advancement in India, contributing up to 7.1 per cent to India's GDP and 5.9 per cent of gross value added (GVA) in 2017 (MoHI&PE 2018; PIB 2017). The industry supports 8 million direct and 29 million indirect jobs.[1] While these numbers are often cited in the media and are even endorsed by the Government of India and industry publications, there is not much clarity on the methodology used to arrive at these estimates.

India is the world's largest manufacturer of two-wheelers (2W), three-wheelers (3W), and tractors (MoHI&PE 2018). About 30 million vehicles across various segments were produced in FY19. This represents a growth of 6.3 per cent over the previous year. However, sales across all segments have been on the decline since November 2018 (Ghosh 2019). Figure 1 provides a snapshot of the declining sales in the car segment starting November 2018. Additionally, 2W account for 80.6 per cent of the total vehicles sold, and passenger vehicles constitute the next big segment, and represent 12.9 per cent of all domestic sales. Domestic brands have higher market shares in the commercial vehicles and 2W segments. A total of 46,29,054 vehicles were exported in FY19, the lion's share (70.9 per cent) of which comprised 2Ws followed by passenger vehicles (SIAM 2019b).

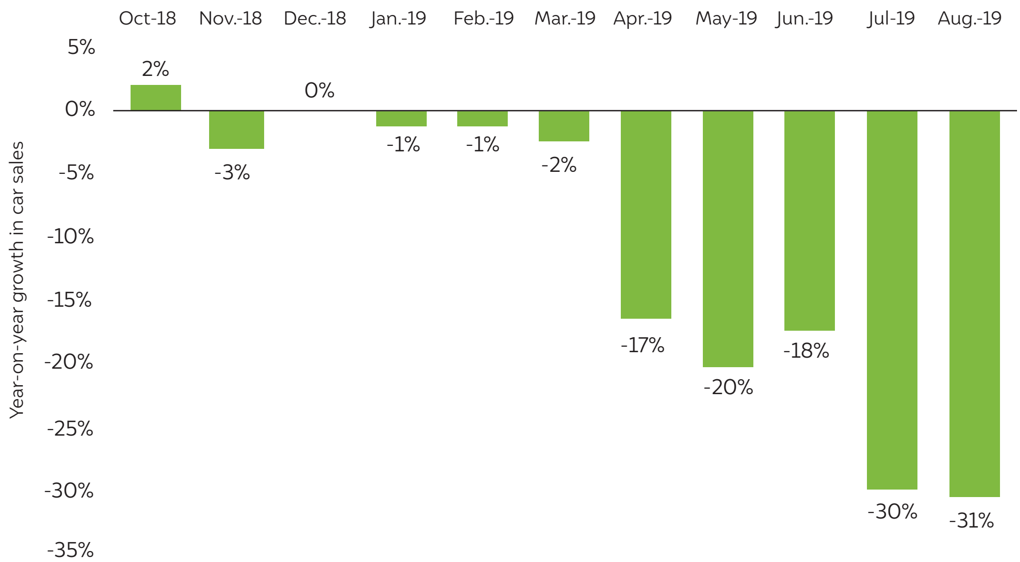


Figure 1
Car sales have been on the decline since November 2018

Source: Authors' compilation from TeamBHP. 2019. "Indian Car Sales Figures & Analysis".

The auto components industry in India has enhanced the localisation of auto components for foreign and Indian original equipment manufacturers (OEMs). It is largely unorganised, comprising 10,000 unorganised players and 700 organised players (Grant Thornton 2018). The sector has grown at a CAGR of 10 per cent from 2012 to 2018. It registered a turnover of INR 3,45,635 crore (USD 48.1 billion)[2] in FY18 (ACMA 2018), and represents about 2.3 per cent of the national GDP (Invest India 2019). Exports of auto components added up to INR 90,571 crore (USD 12.6 billion) in 2018, while the value of imports amounted to INR 1,06,672 crore (USD 14.8 billion) during the same period (ACMA 2018).[3] Auto components exports (for cars and 2Ws) contributed to about 57 per cent of exports of cars and 2Ws and auto components (of cars and 2W) in FY19 (see Figure 2).

1 Figures provided by Society of Indian Automobile Manufacturers (SIAM).

2 Exchange rate considered: 1 USD = 71.77 INR.

3 As per our analysis on data from the Export Import Data Bank, the value of exports and imports of auto components amounted to INR 61,753 crore (USD 8.6 billion) and INR 57,408 crore (USD 7.9 billion), respectively. Please see the detailed list of Harmonized System (HS) codes we considered to arrive at these values in Table 8 in Annexure IV.

The performance of the automotive sector as a whole directly impacts the performance of other related manufacturing sectors such as iron and steel, aluminium, and chemicals, as well as services including banking, fuels, and logistics. This backward linkage with other key contributing sectors of the economy is clear, and the impacts of an EV transition will percolate both vertically and horizontally.

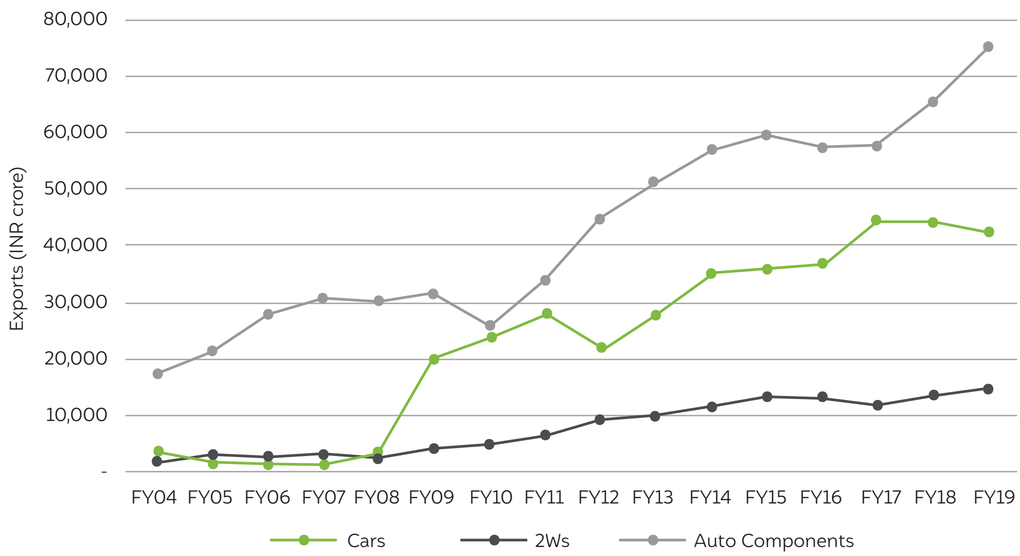


Figure 2
Key automotive exports – cars, 2Ws, and auto components (for cars and 2Ws) – have shown a steady growth

Source: Ministry of Commerce & Industry. 2019. "Export Import Data Bank".

Note: Values in the figure are in 2019 constant prices. The value of exports of auto components constitutes only the major, high-value auto components, and the actual numbers are expected to be higher. See Table 8 in Annexure IV for the detailed list of HS codes.

1.2 India's automotive vision

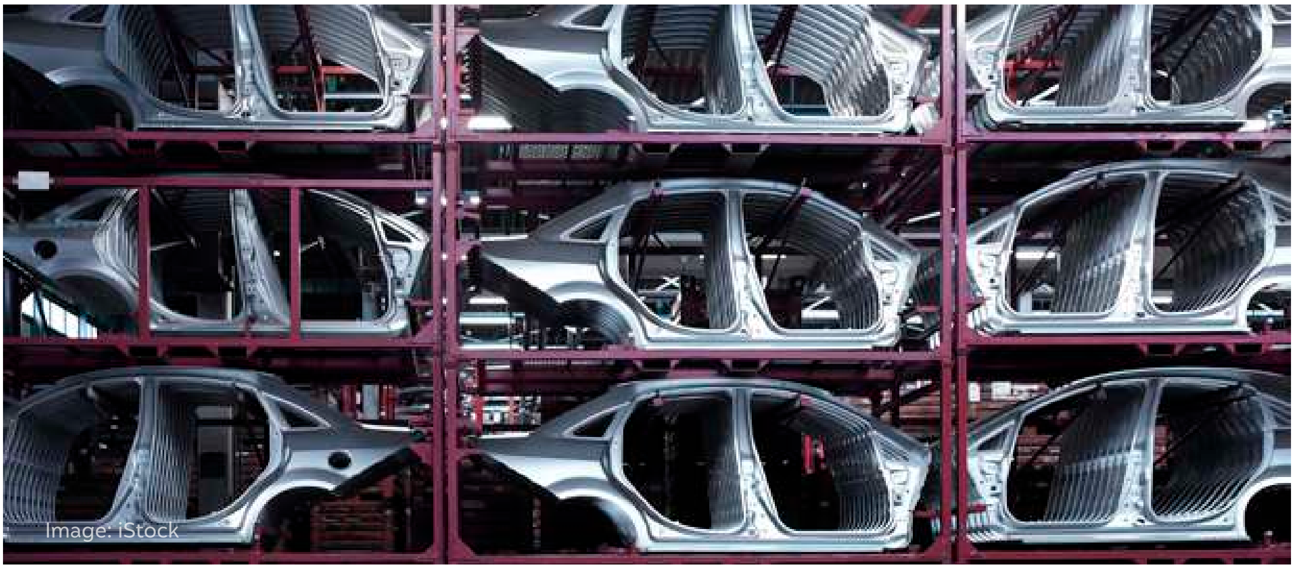
The *Automotive Mission Plan* (AMP) 2016–26 captures the collective ambition of the Indian government and automotive industry regarding the size of the industry and its contribution to India's development and its global footprint and competitiveness. The AMP envisions that the sector will contribute more than 12 per cent to India's GDP and constitute more than 40 per cent of the manufacturing sector by 2026. Around 65 million direct and indirect jobs are estimated to be created by the auto sector over the next decade. Further, the draft *National Auto Policy* (NAP) envisages India as being among the top three in the world in terms of engineering, manufacturing, and exporting vehicles and auto components in the coming years (DHI 2018). The policy prescribes measures such as setting up a technology acquisition fund and incentivising public–private partnership (PPP) based industry investments in research and development (R&D), import duty exemption on auto component prototypes, and support for auto component cluster programmes. India recently overtook Germany to become the fourth-largest automobile manufacturer in the world (HDFC 2019).

A key area of intervention in order to realise these goals is exports. Extant studies and assessments suggest that the Indian auto industry has the potential to increase its exports to 35–40 per cent of its overall output by 2026 compared to 28.3 per cent in FY15 (MoHI&PE 2017). At the same time, import intensity is slated to increase in the coming years due to the increased use of electronics and the enhanced design and engineering value adds in vehicles and components. These are areas where India is deficient in skills and capabilities at the moment. As such, automotive electronics, lightweighting materials, moulds and dies, and machinery are segments of the value chain prioritised by the AMP (MoHI&PE 2017). At present, imports address 60–70 per cent of the OEM demand for electronics. It is anticipated that auto electronics will constitute 45 per cent of the total automobile cost in India by 2030, even for ICEVs (McKinsey & Company 2018). The *Bharat New Vehicle Safety Assessment Program* (BNVSAP), which is to be implemented soon, will also require additional sensors and electronic stability control (ESC), further increasing the share of electronics (BT 2018).

Import intensity is slated to increase in the coming years due to the increased use of electronics and the enhanced design and engineering value adds in vehicles and components

However, the AMP expects ICEV powertrains to continue to remain dominant for the duration of the plan and for hybrid and battery electric vehicles (BEV) to increase their share significantly. Policy measures such as the *National Electric Mobility Mission Plan 2020* (NEMMP) launched in 2013 and the *Faster Adoption and Manufacturing of (Hybrid) and Electric Vehicles* (FAME) subsidy scheme have stoked interest and activity in the EV space. The government issued a statement recently saying that it aims to increase sales of EVs to 30 per cent of the new vehicles sales in India from 2030 onwards (Shah 2018). These and other recent developments indicate an increasing ambition for transition to EVs in India.

2. Impacts and opportunites for the auto industry in the BAU and EV transition scenarios



Increasing the share of EV manufacturing within India will be accompanied by certain disruptions in the automotive sector. To begin, the share of EVs in the future can have important implications for the sector, including decisions regarding investments for further capacity for production of ICEVs. Figure 3 compares the current installed capacity for 4Ws production against actual production today and the projections for 2030 under two scenarios, indicating the room for deploying additional capacity. Also, OEMs including Mahindra & Mahindra and Tata Motors have invested around INR 1,000 crore each towards transitioning their fleet to BS-VI. A ban on ICEV sales or a dampening of ICEV sales due to EVs could impact the prospects of recouping these investments (Thakkar and Chaliawala 2019; RushLane 2019).

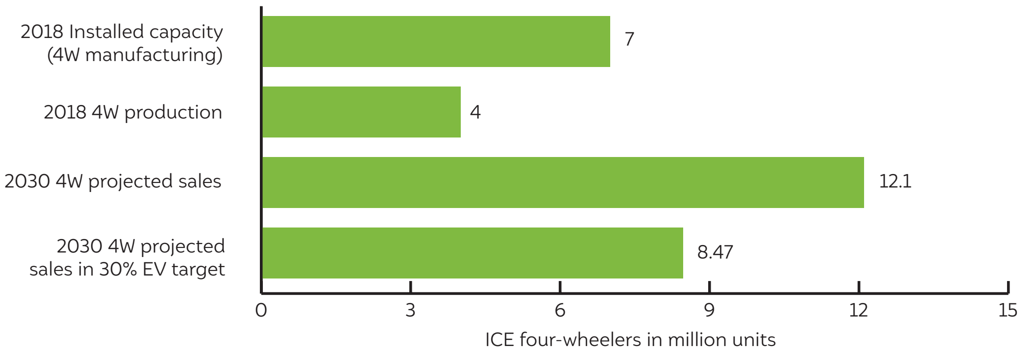


Figure 3
Comparison of installed capacity versus production for ICE 4Ws in 2018 and 2030

Source: Authors' adaption from MOSL. 2018. "Batteries: Huge Opportunites, but challenges too"; SIAM. 2019a. "Automobile Production trends".

Further, given that a high level of indigenisation, of close to 90 per cent, has been achieved across all vehicle categories in the auto components industry, a transition to EVs would impact this industry as it currently has limited expertise in electronics, electrical, and system supplies (McKinsey & Company 2018). These power electronics components constitute higher value add (MoHI&PE 2018). Similarly, given that India is a smaller player compared to China, South Korea, and Japan in lithium ion battery manufacturing, capturing value in the EV batteries segment will be difficult without concerted efforts. Batteries constitute about 40–50 per cent of the cost of an electric car today (ACMA and Roland Berger 2018; Fries et al. 2017). By 2030, however, it is expected that the share of batteries in total cost will come down to 18–23 per cent (BNEF 2017). Battery cells are the largest value add component in a battery, constituting 40–60 per cent of the battery cost today (ACMA and Roland Berger 2018). The loss in value addition in the auto components industry as a result of limited indigenisation of high value add components, and the associated reduction in job creation, are potential opportunity costs of an EV transition in India.

The loss in value addition in the auto components industry as a result of limited indigenisation of high value add components, and the associated reduction in job creation, are potential opportunity costs of an EV transition in India

At the same time, global shifts towards e-mobility also pose a risk to the incumbent ICEV dominant Indian auto industry, which is gearing up to increase its share of exports as indicated in the AMP vision. It is interesting to note that several countries to which India exports today have plans to increase EV sales to 100 per cent starting in 2030.

In the sections below, we attempt to quantify and compare these impacts under a business-as-usual (BAU) and 30 per cent EV sales scenario for 2030 in the car segment for India. We begin by examining opportunity costs, first under BAU (impact on exports), and then under an EV scenario (changes in value add, job additions, oil imports, and environmental impact). It is to be noted that our analysis of the 'auto industry' is limited to car manufacturing and not other segments due to the limited availability of data.

2.1 Business-as-usual (BAU)

In the BAU scenario, we assume that there is no concerted effort to indigenise electric car component manufacturing, and no demand-side incentives to promote uptake in India. This would result in electric cars accruing a 2 per cent share in total domestic car sales in 2030 (MOSL 2018).

2.1.1 Impact on export

A total of 17 countries have announced plans for 100 per cent electrification as detailed in Figure 4. Among those with targets for 2030, Israel commanded the highest share of exports in value terms at INR 455 crore (USD 63.3 million) in FY19 closely followed by Netherlands

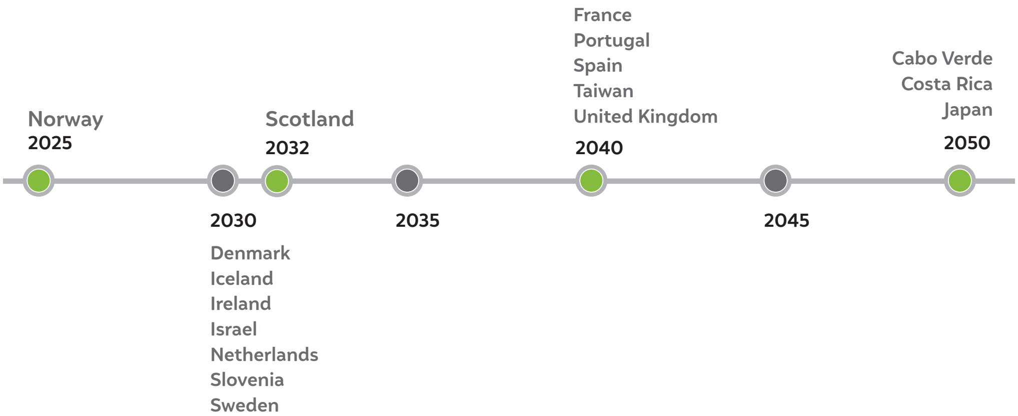


Figure 4
Timeline for 100 per cent EV policy implementation in countries that import from India

Source: Authors' compilation from IEA. 2019. "Global EV Outlook"; Partnership on Sustainable and Low Carbon Transport. 2019. "E-mobility Trends and Targets".

at INR 390 crore (USD 54.3 million) in the same year. UK, France, and Spain accounted for much higher shares of exports in FY19, but their 100 per cent EV sales targets are slated to be implemented from 2040 onwards, and so we have not considered them in our analysis.

Countries with a 100 per cent EV sales target for 2030 (as of August 2019), and which import Indian manufactured cars and car auto components, constitute 1.1 per cent of total car and car auto components exports in FY19. Similarly, countries that have 100 per cent EV sales targets beyond 2030 account for 4.6 per cent of the total of such exports. Exports to these countries have not followed a steady trend as mapped in Figure 5. A five-year (FY15–19) average of the value of auto exports to countries with 2030 targets amounts to INR 1,996 crore (USD 278 million) and those with targets beyond 2030 amounts to INR 5,860 crore (USD 816 million). Assuming this average is maintained in 2030 and beyond, there are opportunity costs in terms of failing to capture global EV markets, and reduced exports to countries with EV targets, who will gradually phase down their ICE vehicle and components imports from India by 2030.

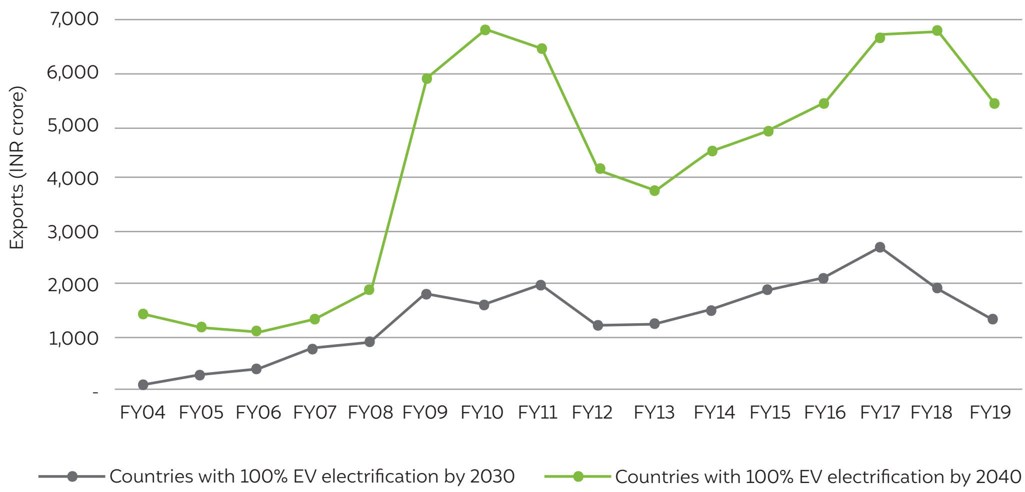


Figure 5
The value of car and car auto components exports to countries with 100 per cent EV targets have not been exhibiting a steady trend

Source: Ministry of Commerce & Industry. 2019. "Export Import Data Bank".

Note: Values in the figure are in 2019 constant prices.

Mexico, USA, and South Africa were the major importers of Indian cars and car auto components in FY18 (see Annexure VI). While these countries do not have national targets, Mexico and US have city- and state-level sub-national 100 per cent EV targets by 2025 (International Energy Agency 2019; Partnership on Sustainable and Low Carbon Transport 2019).

2.1.2 Domestic value add generated

We estimate the domestic value add[4] from the ICE and electric car powertrains as the product of estimated sales volume and the cost of powertrain components in an ICE and an electric car in 2030, respectively (see Equation 1 in Annexure II). We assume that new car sales are projected to increase from 33,77,436 in FY19 to 1,18,97,000 in FY30 (MOSL 2018) (see Table 7 in Annexure III). The costs of powertrain components (both electric and ICE cars) have been obtained from the *Study on xEV Market and Opportunities for xEV Component Suppliers* report for 2018 and have been projected for 2030 as shown in Table 5 and Table 6 (see Annexure III) (ACMA and Roland Berger 2018). We assume that the cost of powertrain components in an ICE and an electric car will remain the same in real terms. However, the cost of batteries are expected to go down from USD 260 per kWh in 2018 to USD 83 per kWh in 2030, based on an average of projections from various studies (Goldie-Scot 2019; Mosquet et al. 2018; NITI Aayog and Rocky Mountain Institute 2017). We assume that the value add from the non-

4 Value add pertains to the output value add which is inclusive of input value as defined in Annual Survey of Industries (ASI) schedule.

powertrain components of an ICE car will be retained in an electric car, and hence consider the domestic value addition from the manufacturing of powertrains only. Finally, we do not estimate domestic value add from additional EV manufacturing specifically for export.

We find that the domestic value added from car manufacturing in 2030 will be INR 3,42,403 crore (USD 47.7 billion). The value of imports in this case will be INR 43,415 crore (USD 6 billion), which is a notional loss to the economy and the industry, because this value add could have been captured domestically by sourcing 100 per cent of the powertrain components locally.

2.2 Thirty per cent electric car sales in 2030

To determine the economic implications that a strong push to promote EVs will have on the auto industry, we developed two sub-scenarios with varying assumptions. The scenarios offer a granular understanding of potential impacts, given different levels of indigenisation of powertrain components as detailed in Table 1. For instance, the current level of indigenisation of powertrain components for ICE cars is 90 per cent. However, achieving 90 per cent indigenisation of electric powertrain components would be possible only with an aggressive push, given the limited competence of the current auto components industry in this area. Therefore, we explore two sub-scenarios within the 30 per cent electric car penetration by 2030 scenario – an ambitious one with 90 per cent indigenisation (high indigenisation – EV30-High) and another with 50 per cent indigenisation (low indigenisation – EV30-Low) of electric car powertrain components. The indigenisation indicated here pertains to only electric drive[5] components. Although the *National Mission on Transformative Mobility and Battery Storage* intends to establish battery manufacturing with integrated cell manufacturing at giga-scale by 2021–2022 (PIB 2019), we assume that in all the scenarios, battery manufacturing in India in 2030 will be limited to battery pack assembly, and there will be no domestic cell manufacturing. This assumption is based on consultations with industry stakeholders in the EV ecosystem. Thus, we assume up to 90 per cent indigenisation of the battery pack value under the high indigenisation scenario (EV30-High) and 70 per cent under low indigenisation scenario (EV30-Low) (where we assume that battery management system (BMS) and other electronic components required for thermal management are imported).

Table 1 Electric car penetration scenarios in 2030

Scenarios	ICE car share of sales	Electric car share of sales	Indigenisation level
BAU	98%	2%	90%
EV transition – high indigenisation scenario (EV30-High)	70%	30%	90% 90% 90%
EV transition – low indigenisation scenario (EV30-Low)	70%	30%	90% 50% 70%

Source: Authors' analysis

ICE car powertrain | Electric car powertrain | Battery pack

5 The electric drive components include the electric motor, gearbox, connectors and harnesses, and housing.

2.2.1 Domestic value add generated (powertrain only)

Following a similar approach as discussed in Section 2.1.2, we estimate the domestic value added in case of 30 per cent sales penetration of electric cars in 2030 (see Equation 1 for the formula in Annexure II, and Tables 5–7 in Annexure IV for assumptions on powertrain costs and sales). We find that the domestic value added (at 2018 prices)[6] in the EV30-High (excluding battery pack) scenario will be INR 3,30,262 crore (USD 46 billion) and in the EV30-Low (excluding battery pack) scenario will be INR 2,90,610 crore (USD 40.5 billion). At the same time, the value of component imports in case of the former will be INR 36,696 crore (USD 5.1 billion) and the latter will be INR 76,348 crore (USD 10.6 billion) (see Table 2). Thus, effectively, we observe a 3.1 per cent lower domestic value add in a EV30-High scenario compared to BAU. The domestic value added in the EV30-Low scenario will be 17.3 per cent lower compared to BAU in 2030 (see Figure 6).

Table 2
Domestic value added, and additional value add lost to imports of ICE car and electric car powertrain components excluding the battery, in 2030

Source: Authors' analysis

Scenarios	Domestic value add (INR crore)	Difference in domestic value add (INR crore)	Value of component imports (INR crore)
BAU	3,40,766	-	40,800
EV30-High (excluding battery pack)	3,30,262	–10,503	36,696
EV30-Low (excluding battery pack)	2,90,610	–50,156	76,348

Note: All values are in INR crore at 2018 prices.

'Value of component imports' is the potential value add India could capture by pushing for a higher level of indigenisation of powertrain components in 2030, thereby reducing imports.

'Difference in domestic value add' is the difference between the domestic value adds in the BAU and EV transition scenarios.

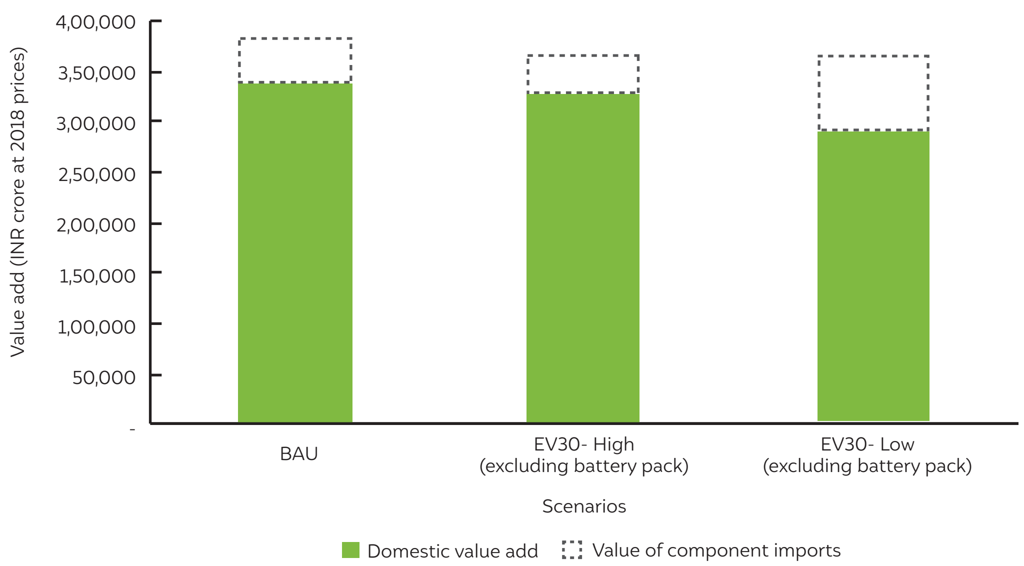


Figure 6
Domestic value added from manufacturing ICE and electric car powertrain (excluding battery) components under both EV30 scenarios will be lesser compared to BAU in 2030

Source: Authors' analysis

6 Unless otherwise specified, all value add estimates are at constant 2018 prices.

2.2.2 Domestic value add generated (powertrain + battery pack assembly)

When we include battery pack assembly in our calculation of the value add from electric car powertrain manufacturing, we observe that the domestic value add in the EV30-High scenario is 5.7 per cent higher (INR 3,61,835 crore; USD 50.4 billion) in 2030 than BAU. On the other hand, the domestic value added in the EV30-Low scenario will be INR 3,15,166 crore (USD 43.9 billion) in 2030, which is about 8 per cent lower than BAU (see Table 3). Thus, if India were to focus on the indigenisation of EV powertrain components as well as battery pack assembly, the EV30-High scenario shows that there will be an effective increase in the domestic value add of the auto industry compared to the BAU scenario (see Figure 7).

Table 3
Domestic value added, and additional value add lost to imports of ICE car and electric car powertrain components, including the battery, in 2030

Source: Authors' analysis

Scenarios	Domestic value add (INR crore)	Difference in domestic value add (INR crore)	Value of component imports (INR crore)
BAU	3,42,403	–	43,415
EV30-High	3,61,835	19,432	68,906
EV30-Low	3,15,166	–27,237	1,15,575

Note: All values are in INR crore at 2018 prices.

'Value of component imports' is the potential value add India could realise by pushing for higher levels of indigenisation by 2030, thereby reducing imports.

'Difference in domestic value add' is the difference between the domestic value adds in the BAU and EV transition scenarios.

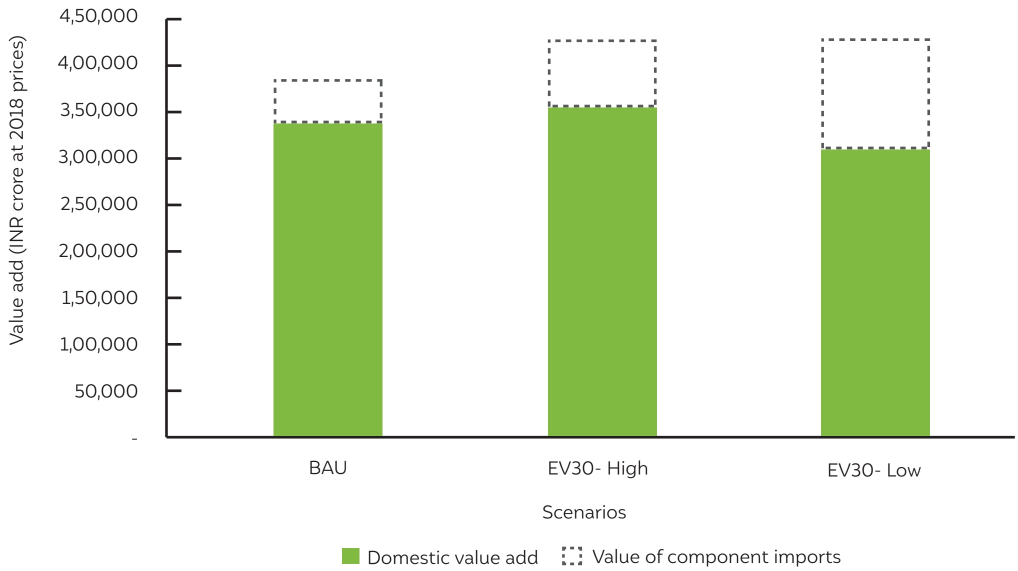


Figure 7
Domestic value added from manufacturing ICE and electric car in the EV30-High scenario will be higher compared to BAU in 2030

Source: Authors' analysis

To conclude, an EV transition can generate a higher value add than BAU if both, powertrain components and battery pack assembly, are highly indigenised. This analysis does not, however, provide any insights into the distributional impacts of the change in the manufacturing mix of the automotive sector, which is explored in the next section.

2.2.3 Impact on employment

In this section, we estimate the number of jobs that the domestic value add generated from manufacturing powertrains and related auto components (excluding batteries) can support at high and low levels of indigenisation in the EV30 and BAU scenarios. The ICE industry today supports jobs across the manufacturing value chain – from components to OEMs. However, in all the scenarios in this section, we consider the value added from manufacturing of car powertrains and associated components only and estimate its impact on jobs.

The number of jobs has been estimated based on the underlying job co-efficient (jobs/output (INR crore)) and output value add. The job co-efficient for manufacturing ICE car powertrains and related auto components has been obtained from *Annual Survey of Industries (ASI)* data for 2016. We used National Industrial Classification (NIC) codes (29101, 29104, and 29301) to filter the ASI data for output and jobs calculations (see Table 9 in Annexure IV). We apportioned the share of output and jobs in manufacturing of ICE car powertrains in each of the aforementioned NIC codes using the more detailed National Product Classification for Manufacturing Sector (NPCMS) codes of the products associated with powertrain components (see Table 10 in Annexure IV). This was necessary as the ASI reports information at an aggregate level, making it impossible to split the jobs that are generated within the factory according to the different components manufactured or assembled. Thus, we arrive at the job co-efficient for powertrain-related manufacturing activities by taking a ratio of jobs and output (in INR crore) – 1.59 jobs/INR crore of output.

The number of jobs has been estimated based on the underlying job co-efficient (jobs/output (INR crore)) and output value add

The job co-efficient for electric car powertrains (i.e., 0.35 jobs/output (INR crore)) has been obtained from the *ELAB 2.0 – The Effects of Vehicle Electrification on Employment in Germany* study (Fraunhofer IAO 2018), as there is limited India-specific data on the same on account of the nascency of EV manufacturing in India. However, it should be noted that the job intensity of electric car powertrain manufacturing may be higher for India due to the lower levels of automation in manufacturing processes in India compared to Germany. Hence, the estimated number of jobs[7] is the minimum number of such jobs that will be created in 2030.

The job co-efficient, in conjunction with the output value add from manufacturing of the powertrains of electric and ICE cars (calculated as discussed in the previous sections) is used to estimate the total jobs that will be supported in 2030 (see Equation 2 in Annexure II).

We find that about 5,38,644 jobs will be supported in the BAU scenario in 2030 through the manufacturing of powertrain components for both ICE and electric cars (excluding battery pack). Based on the level of indigenisation of electric car powertrains in the EV30 scenario (excluding battery pack) in 2030, between 4,01,388 and 4,15,369 jobs will be supported. This is 23–25 percent fewer jobs than in BAU (see Figure 8). Thus, the number of jobs supported is lesser due to the lower value add and lower job intensity associated with manufacturing the powertain of an electric car.

Exploring the case of ICE car powertrain manufacturing jobs specifically, we find that the total number of jobs is 1,85,333 in 2018 (calculated based on the formula in Equation 2 (see Annexure II)). In 2030, the number will increase to 3,83,913 jobs, even with a 30 per cent electric car penetration, indicating an overall growth of 7 per cent between 2018 to 2030 (see figure 9). Thus, no job losses will result from a 30 per cent EV transition; instead, fewer additional ICE car powertrain jobs will be created when compared to the BAU scenario.

7 These jobs inlcude direct and contractual employment.

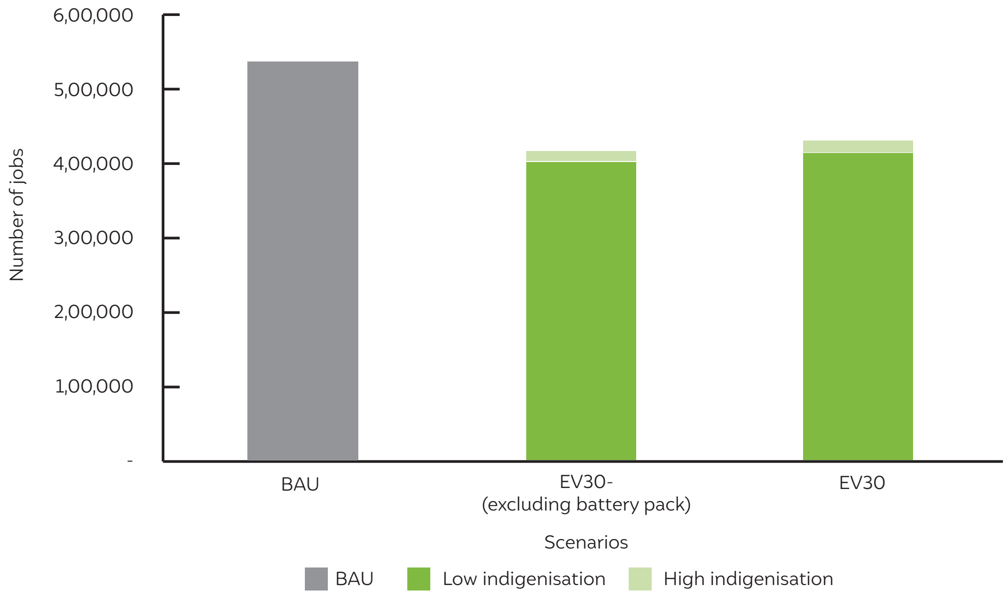


Figure 8
Jobs supported by manufacturing ICE and electric car powertrains will be fewer under the EV30 scenarios in 2030

Source: Authors' analysis

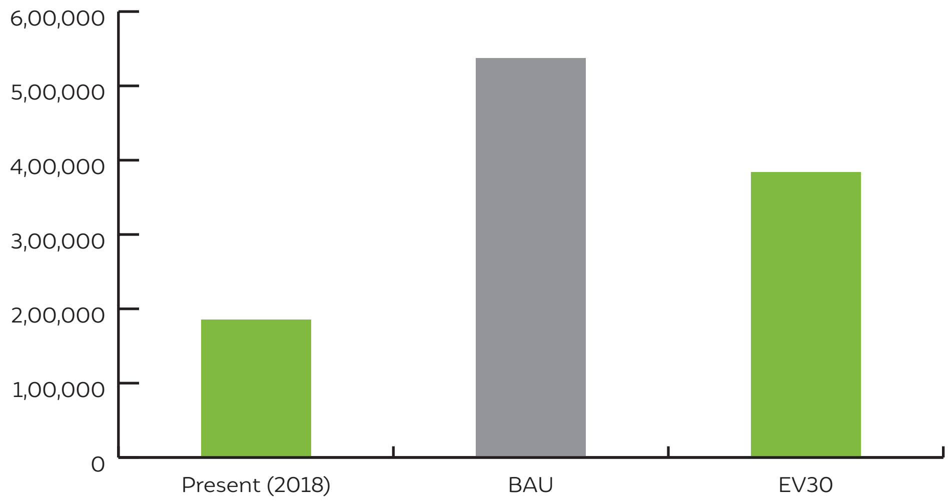


Figure 9
The number of jobs in ICE powertrain manufacturing will grow in 2030 even with 30 per cent penetration of electric cars

Source: Authors' analysis

It is worth noting the total number of automotive jobs reported in the ASI. The ASI captures manufacturing units registered under the Factory Act, 1948. The total number of jobs attributed to the auto industry was 11,45,554.[8] The total job intensity of the sector works out to 1.63 jobs/INR crore output – 0.68 jobs/INR crore output for OEMs and 2.43 jobs/INR crore for components manufacturers. OEMs account for 21 per cent of the total jobs in the sector and component manufacturers account for the remaining 79 per cent.

While on the one hand, there will be fewer jobs in the manufacturing of powertrains, new jobs can be created by indigenising the assembly of battery packs (see Figure 8). Owing to the lack of a job co-efficient for lithium-ion battery manufacturing in India, we assume the job co-efficient (i.e., 0.45 jobs/INR crore of output) from a study conducted in Germany (Fraunhofer IAO 2018).

Thus, as per our estimates, about 11,019 to 14,167 additional jobs will be supported through the indigenisation of battery pack assembly in the EV30 scenario. This reduces the overall gap in manufacturing jobs between EV30 and BAU to 20–24 per cent from 23–25 per cent.

8 As it is clear, these are only a fraction of the total jobs the auto sector claims to support, and these are the jobs in registered manufacturing units across the country. It is likely that component manufacturers are under-represented in the ASI, but the job intensity figures are representative and are a more crucial input.

2.2.4 Impact on India's trade balance and the environment

While the impact of EV transition on the Indian automotive industry is positive in case of a higher level of indigenisation, it is imperative that the impact of a possible EV transition be looked at from a trade lens. In this section, we estimate the impact of an EV transition on the economy by analysing the import burden of cars over their lifetime. Next, we estimate the impact on the environment by calculating the CO_2 emissions specifically from the car segment in 2030.

We consider the import burden over the lifetime of the cars sold in 2030, i.e., for private use ICE cars, we consider the value of the petrol or diesel required for running the car over a period of 10 years, while for commercial use cars we assume five years of lifetime, as a typical car engine lasts for about 3,00,000 to 4,00,000 kms (see Equation 3 in Annexure II). For electric cars, we calculate the import burden as the cost of importing cells and 10 per cent of the battery pack value (which will remain unindigenised under the best case (EV30-High) scenario) required for a 30 kWh battery per car (see Equation 4 in Annexure III). We assume that new car sales in 2030 will be split in the ratio of 73:27 between private cars and cars for commercial use. We also assume an annual mileage of 12,600 km and 70,000 km, respectively, as per the assumptions in *India's Energy Storage Mission* report (NITI Aayog and Rocky Mountain Institute 2017).

For electric cars, based on the cycle life of lithium ion batteries (i.e., 1,200 cycles), we assume that private cars will not require battery replacements, but that commercial use cars will require two battery replacements over the lifetime of 5 years. Further, we consider the cost of the battery to be USD 83/kWh in 2030, based on the average of projections from various studies (Goldie-Scot 2019; Mosquet et al. 2018; NITI Aayog and Rocky Mountain Institute 2017). Thus, we estimate 10 per cent of the unindigenised value of the battery pack to be INR 9,829 (in 2018 prices) in 2030 (see Table 6 in Annexure III for a component-wise breakup of an electric car in 2030).

For ICE cars, we assume 20.4 kmpl fuel efficiency for 2030, based on the Corporate Average Fuel Economy (CAFE) emission norms target for FY22 onwards (Ministry of Power and Bureau of Energy Efficiency 2014). While these norms are for an average fleet and cars of different size will together comply with the slated target, we assume that an average car meets these norms. We consider the cost of crude oil in 2030 to be INR 5,015/bbl based on the average for FY19. We further assume that 80 per cent of India's crude oil requirements will be imported.

Thus, as per our estimates, the import burden to the economy per private electric car in 2030 will be INR 90,247 (USD 1,257), while that of a private ICE car will be 4.1 times higher – INR 3,72,693 (USD 5,192). Similarly, the import burden per commercial use electric car will be INR 1,80,494 (USD 2,515), while that of a commercial use ICE car will be 5.7 times higher – INR 10,35,259 (USD 14,425) (all values are in 2018 prices). Thus, there is an economic case to electrify commercial use cars due to the lower import burden from cells as compared to oil.

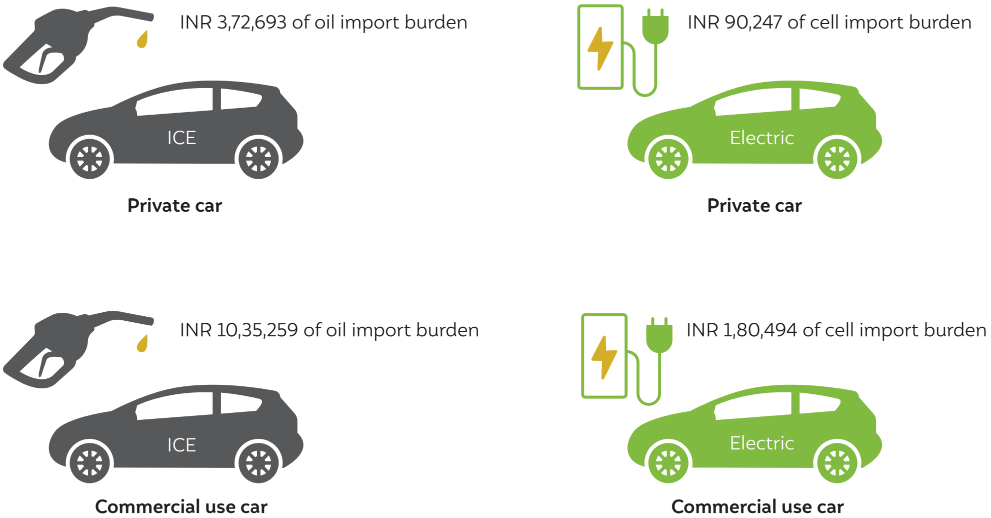


Figure 10
The import burden of an electric car will be lesser compared to an ICE car in 2030

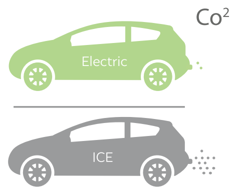
Source: Authors' analysis

Note: All import values are in 2018 prices

Similarly, we compare in-use[9] CO_2 emissions between an ICE car and an electric car. We assume the CO_2 emissions from an ICE car to be 130 gCO_2/km based on the CAFE emission norms for the period between FY17 and FY21, which yields a fuel efficiency of 17.8 kmpl (Ministry of Power and Bureau of Energy Efficiency 2014).

At present (2019), about 9 per cent of the total generation is from renewable sources of energy, and the resulting grid emission factor is 722 gCO_2/kWh (CEA 2018). We assume EV efficiency to be 7.5 km/kWh[10] based on the current fleet, and tramission and distribution (T&D) losses to be 16 per cent based on the *Exploring Electricty Supply-Mix Scenarios to 2030* report (Pachouri, Spencer, and Renjith 2019) (see Equation 5 and 6 in Annexure III). We estimate the resulting in-use CO_2 emissions per electric car today to be ~ 116 gCO_2/km, which is 12 per cent lower compared to the current average CO_2 emissions from a single ICE car – 130 gCO_2/km.

Considering the proposed CAFE emission norms for FY22 onwards, the average fleet CO_2 emissions will be restricted to 113 gCO_2/km. We assume that by 2030, India will be able to achieve this target. Based on the *Exploring Electricty Supply-Mix Scenarios to 2030* report, the grid emission factor for 2030 in the current trends scenario works out to 715.78 gCO2/kWh, which will result in about 110.71 gCO_2/km of emissions from a single electric car (Pachouri, Spencer, and Renjith 2019). The CO_2 emissions from an electric car will be about 2 per cent lower than that from an ICE car in case of 22 per cent penetration of renewable energy (current trends scenario) in 2030. However, with the increased penetration of renewable energy (high renewables scenario – 31 per cent renewable energy penetration with a grid emission factor of 610.17 g CO_2/km), the CO_2 emissions per electric car would fall to 94.37 g CO_2/km, which is 16 per cent lower than that of a comparable ICE car in 2030.

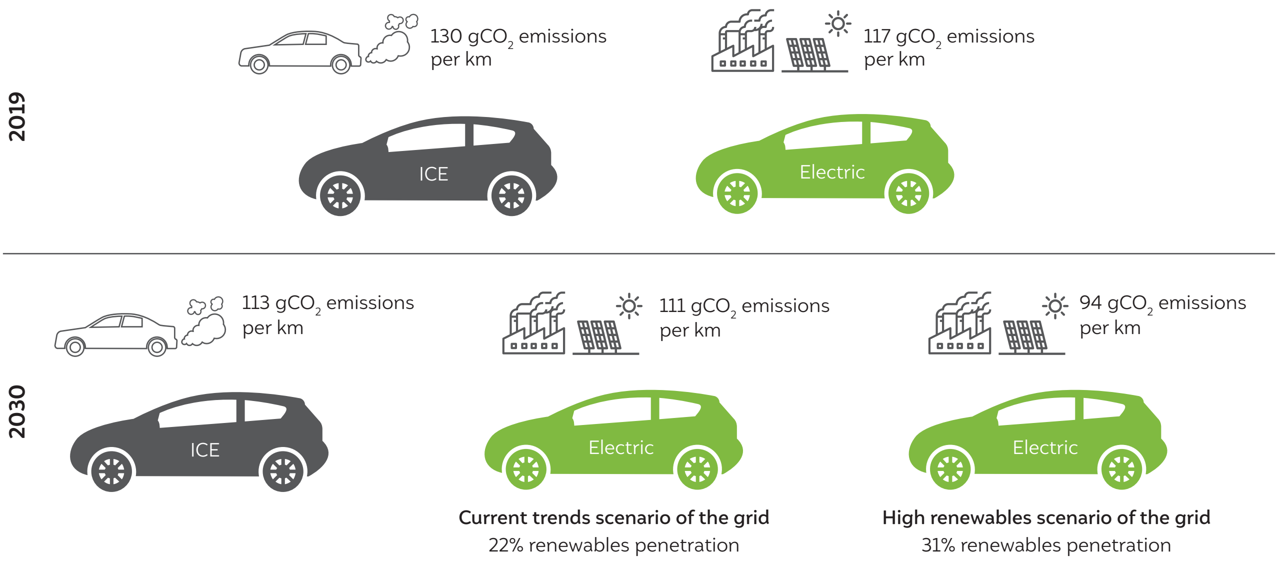


The CO_2 emissions from an electric car will be about 2 per cent lower than that from an ICE car in case of 22 per cent penetration of renewable energy (current trends scenario)

9 For an ICE car, 'in-use' emissions mean tank-to-wheel tailpipe emissions. While for an electric car, we consider CO_2 emissions resulting from the generation and transmission of electricity required to charge the battery.

10 Provided by an electric car fleet operator.

Figure 11 **CO_2 emissions per kilometre will be lower in an electric car compared to an ICE car in 2030**



Source: Authors' analysis

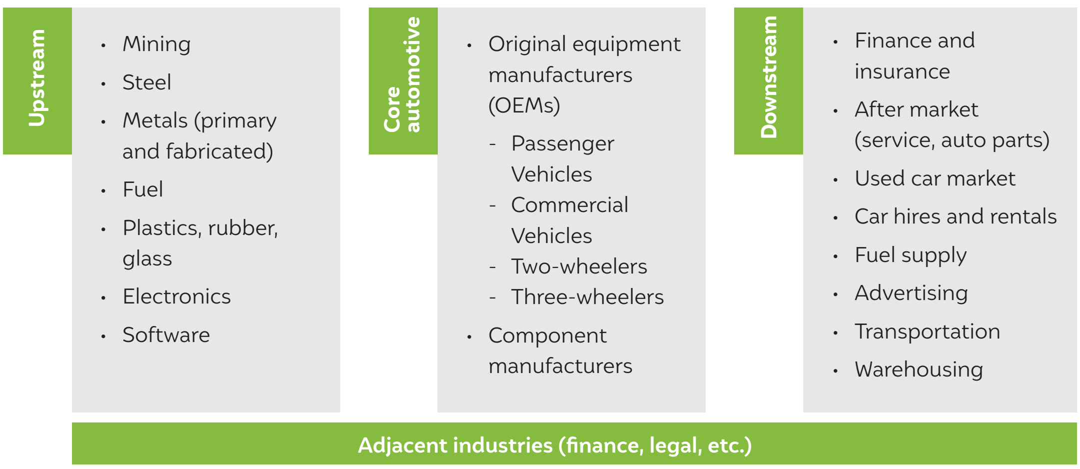


Figure 12
Industries impacted by the core automotive sector

Source: Ministry of Heavy Industries & Public Enterprises. 2018. "Draft National Auto Policy"

While the above assessments explore economic and environmental impacts based on changes in value add, it is important to note that a transition to EVs will simultaneoulsy cause disruptions in other dependant sectors of the economy as represented in Figure 12 (FTI Consulting 2017). Therefore, a thorough and objective analysis of the economic impact of an EV transition will require a macroeconomic modelling approach to capture systemic effects and interdependancies between various economic sectors (Cambridge Econometrics 2018). The forthcoming report, *Electric Vehicle Transition in India: Impact on GDP and Jobs* by CEEW will estimate the economy-wide impacts of an EV transition on the GDP and jobs in India.

Concerted efforts will be required to build an EV ecosystem in India.

3. Building an EV ecosystem in India

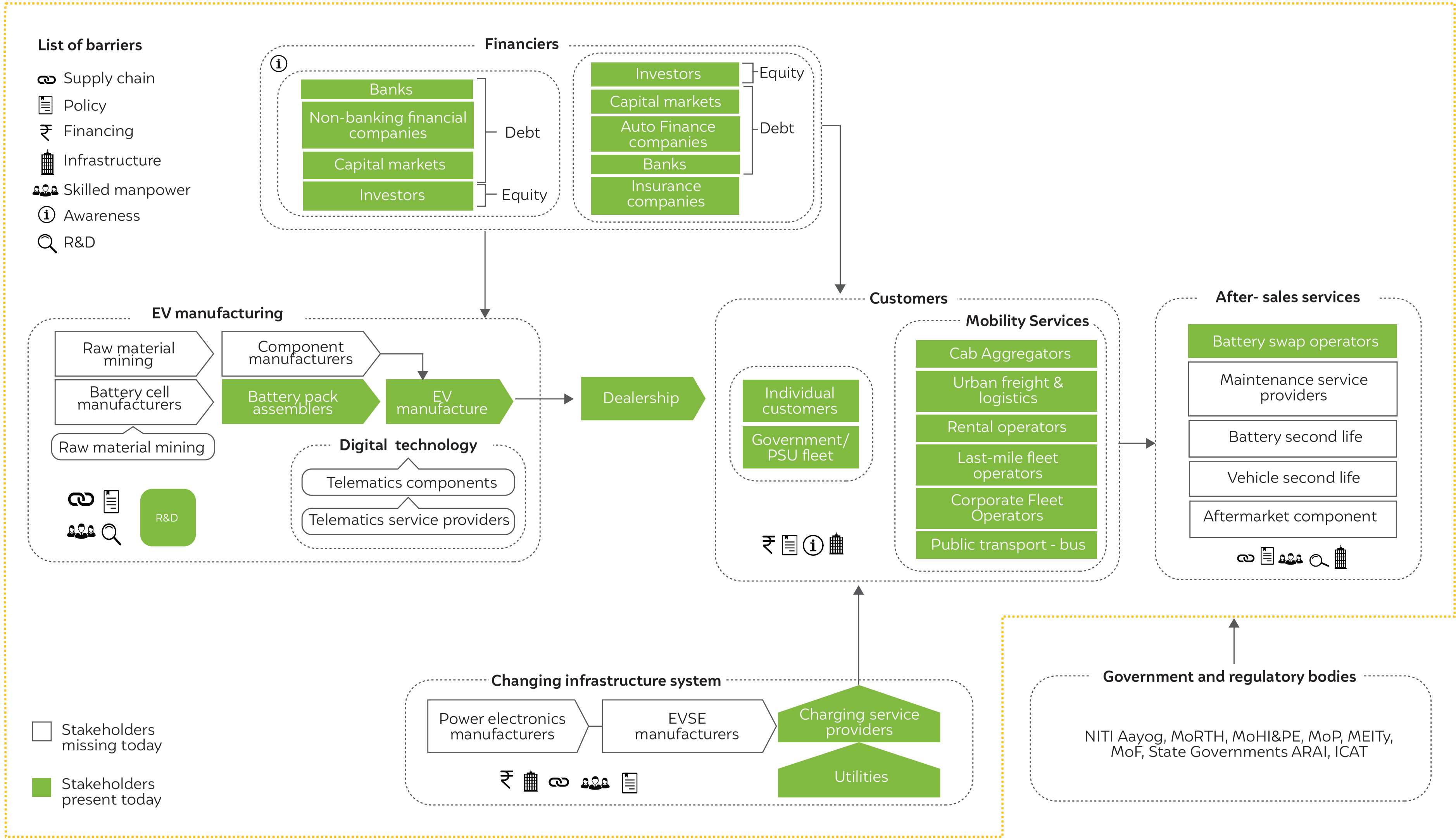
While the end products and services of the EV value chain are designed to meet similar mobility needs as the conventional automobile value chain, the supply chain and ecosystem required for manufacturing and operating these vehicles is fundamentally different as depicted in Figure 13. The EV manufacturing value chain is a confluence of the automotive, electrochemical, and power electronic component value chains.

Today, there are three Indian electric cars and six high-power electric 2W models available in the market. There are about 352 publicly accessible EV charging stations catering to 2.7 lakh electric vehicles (both hybrid and pure battery electric) in India (International Energy Agency 2019; National Automotive Board 2019b). Most of the components that go into an EV are imported today.

We consulted with 28 stakeholders working in the EV ecosystem (including components and battery manufacturers, OEMs, electric vehicle supply equipment (EVSE) operators, financiers, and mobility service providers) to understand the ecosystem and the activities they engage in. The parts of the EV ecosystem that exhibit some level of activity in India today have been highlighted in green, whereas those in white show limited or no activity. It must be noted that while EVs for private use do receive financing, including a recently announced discounted loan from the State Bank of India (SBI), lending from traditional financial institutions is limited for commercial use EVs, due to the perceived risk associated with emerging business models by virtue of their dependence on EVs and EVSE, which constitute a new asset class (Livemint 2019).

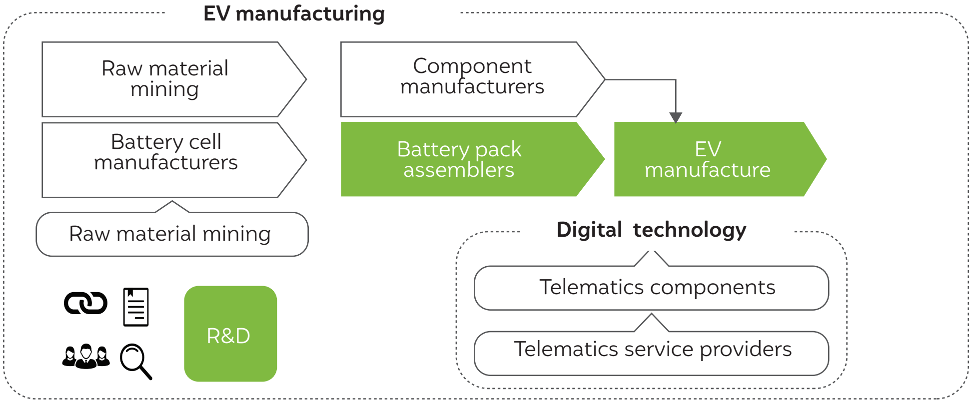
While the NEMMP envisaged 15–16 million cumulative sales of hybrids and EVs by 2020, the cumulative sales till date stand at 0.28 million (National Automotive Board 2019a). There are several barriers to the development of an EV ecosystem in India at scale, as gleaned from interviews with the relevant stakeholders. The types of barriers faced by the different stakeholders are not uniform and are specific to that part of the value chain. Below is a summary of the major supply chain, policy, and financial barriers as stated by interviewees. Supporting evidence from existing studies have been summarised in the boxes 1-4.

Figure 13 The EV value chain and ecosystem



MoRTH - Ministry of Road Transport and Highways; MoP - Ministry of Power; MEITy - Ministry of Electronics and Information Technology; MoF - Ministry of Finance; ARAI - Automotive Research Association of India; ICAT - International Centre for Automotive Technology

3.1 Stakeholders' comments



3.1.1 EV manufacturers

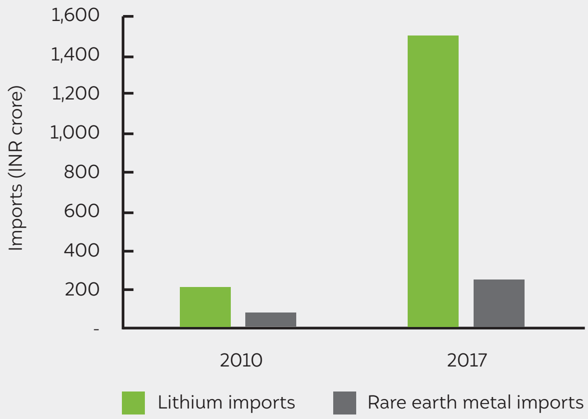
	Barriers	Views
Supply chain	• Lack of supply chain for motors, controllers, power electronics, and batteries. • Auto components suited for Indian driving and climatic conditions are not available. • India lacks competence in basic semiconductor and power electronics manufacturing compared to China from where these components are currently being imported. • Better and advanced technologies for motors and controllers are currently available but are difficult to launch in the market due to higher costs. • Lack of mineral resources for manufacturing critical components indigenously. • Longer turn-around times and stock-out issues are some of the major issues that start-ups face.	• EV-specific platforms need to be developed to make them more energy efficient. • Standardisation of cell form factor is required. • Power electronics better suited to Indian temperatures, humidity, and dust conditions must be explored. • Different battery chemistries that use resources abundantly available in the country must be developed. • In addition to the cathode, various temperature-resistant materials for the anode and the electrolyte must be explored. • Composite materials need to be developed for lightweighting. • Battery recycling needs to develop.
Policy	• No clear roadmap for EV deployment from the government. • Lack of policy implementation following announcements. • The requirements for certifications of approval need to be more stringent, and Conformity of Production (CoP) needs to be done every two years.	• A combination of mandates and incentives are required for both, the demand and supply sides. • A strict timeline to come out with better EV products must be imposed on EV manufacturers. • Academic research institutions and industry must come together to develop new products that are cheap and suited to Indian climatic conditions and use.
Finance	• Banks and microfinancing organisations are reluctant to fund EVs due to their lack of confidence in the technology. • Lack of long-term investment in R&D of new technologies and products for EVs.	• EV-specific loans with lower interest rates are required.

Jobs	Other insights	Future trends
• Jobs in ICEV manufacturing will continue to grow as IC engine manufacturers continue to improve the efficiency of engines for the next 20 to 30 years. • Hiring skilled manpower is a major barrier today. Most companies are training their employees in-house. • Training is also required on the safety aspects associated with manufacturing EVs.	• R&D on basic machine control is required. • There is potential for indigenising motor manufacturing. • Urban agglomeration does not lend itself to creating an EV ecosystem. There is limited parking space in cities for EV charging.	• Mobility services and 'electric mobility as a service' is likely to emerge. • Car refurbishing could grow as an activity, since the life of the EV will be longer due to lower wear and tear. • Digital technologies such as telematics for battery and vehicle diagnostics will develop, which will further help in optimising the performance of the battery and vehicle.

Box 1 : Lack of mineral resources for manufacturing critical components indigenously

India has limited known reserves of the minerals required for the manufacturing of EV powertrains and batteries. About 58 per cent of the world lithium reserves are in Chile and about 43 per cent of rare earth mineral reserves are in China. As per the analysis by The Energy and Resources Institute (TERI), India's lithium imports have increased by about 6.5 times, while rare earth mineral imports have increased by about 2.4 times over the period from 2010 to 2017 (Bhattacharjya, et al. 2018) (see Figure 14).

Figure 14 Lithium and rare earth metal imports to India have increased tremendously between 2010 and 2017



Source: Bhattacharjya, Souvik, Nitish Arora, Shilpi Kapur Bakshi, Garima Jasuja, and MK Bineesan. 2018. "Towards Resource Efficient Electric Vehicle Sector in India."

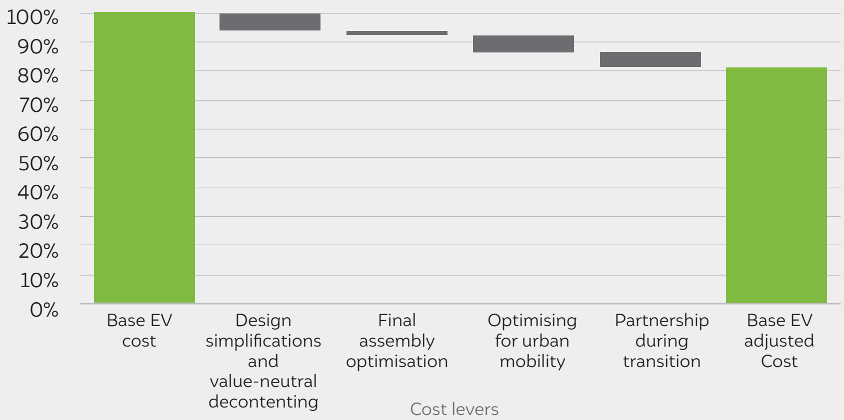
Box 2: India lacks competence in basic semiconductor and power electronics manufacturing

India at present lacks competence in manufacturing basic semiconductor and power electronics components and thus ends up importing a large chunk of its EV components from China. Chinese imports of auto components exceed India's exports to China by 10 times (Philip 2019). In FY13, India imported about USD 3.3 billion worth of Chinese auto components. This increased by 27 per cent to about USD 4.3 billion in FY18. Thus, the EV supply chain is essential for the development of the EV ecosystem in India as well as to save on imports of EV auto components.

Box 3: EV-specific platforms need to be developed to make them more energy efficient

Most OEMs globally today produce EVs based on modified ICE vehicle platforms. Manufacturing EV-specific platforms leads to higher fixed costs, especially in the case of lower volumes, due to the additional capital investments in new, standalone platforms. However, they lower material costs and allow for better performance in range, acceleration, and interior space. As per McKinsey's research, strategic decontenting paired with a purpose-built EV platform can bring down the vehicle cost by about 18 per cent (Baik, et al. 2019) (see Figure 15). These savings come from having fewer components to assemble and requiring less capital in EV-only plants versus complex plants that combine ICEV and EV lines. Additionally, the benefits from a purpose-built EV platform will be even greater if OEMs share EV platforms and plants. As per McKinsey's estimates, two OEMs codeveloping a dedicated EV platform could lead to two to three times the volume spread across a similar fixed-cost base – reducing costs by 4–6 per cent per vehicle.

Figure 15 Cost reduction levers for bringing down EV costs

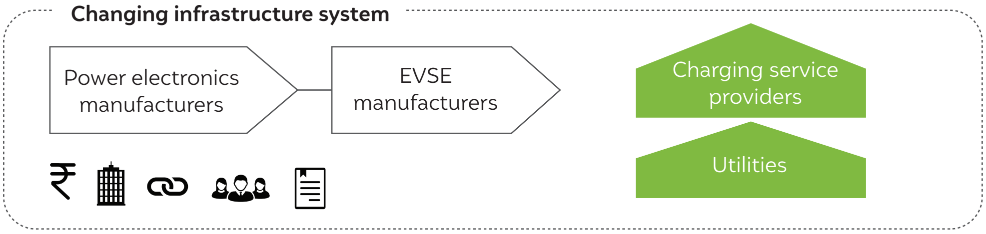


Source: Baik, Yeon, Russell Hensley, Patrick Hertzke, and Stefan Knupfer. 2019. "Improving Electric Vehicle Economics."

Note: Value-neutral decontenting means reducing non-ICE content that does not affect safety.

While it is true that most EV manufacturers are not generating profits today, OEMs must not wait for battery costs to reduce to change this dynamic. Figure 15 shows the various cost reduction levers that OEMs could leverage, even today, to bring down the costs of EVs.

3.1.2 EVSE ecosystem



	Barriers	Views
Supply chain	• Lack of a local supply chain for EVSE. • Poor availability of fast chargers in the Indian market. • Imported EVSE chargers are not suited for Indian weather and are not reliable.	• Low cost and compact EV slow chargers that are easy to install need to be developed indigenously.
Policy	• The EVSE guidelines by the Ministry of Power require every charging point to cater to all three (CCS, ChaDeMo, and Bharat AC/DC) standards, and has set certain rules for the location of charging points. This reduces market flexibility for charging service providers.[11]	• A mechanism is required for discoms to be involved in EVSE deployment. • Deployment of EV charging infrastructure should be classified as CSR.
Finance	• High cost of setting up an EV charging station. • High cost of power. • Limited land availability and higher expectations of rent for the same. • Banks are reluctant to lend finance due to a lack of information on business model viability and technology. • Higher inventory costs leading to storage issues.	• New financing models need to be explored for the EV ecosystem.

Jobs	Other insights	Future trends
• There is no talent crunch, but reskilling will be required as the EV ecosystem evolves for EVSE deployment. • Charging service provider companies conduct training for their employees in-house.	• The battery swapping model is capital intensive and works only for e-2Ws and e-3Ws. • A franchisee model should be followed where every small shop owner is a potential EV charging services provider.	• Data analytics will help develop better EVSE for the optimum utilisation of assets.

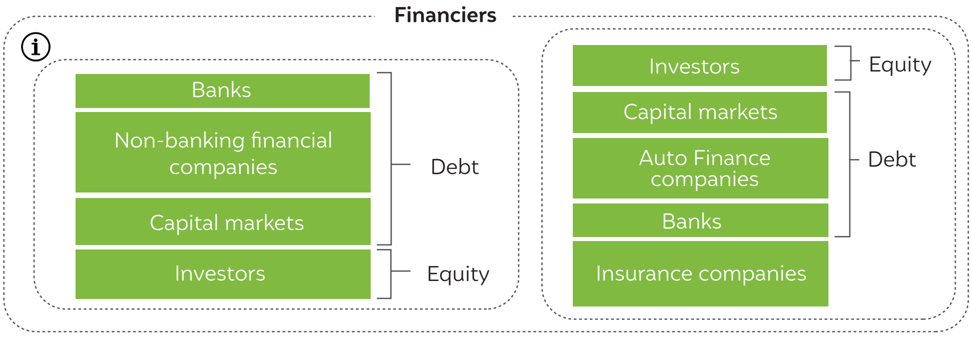
Box 4: High costs of setting up an EV charging station

India's first multimodal electric mobility pilot by Ola at Nagpur helped bring to light various crucial operational issues with respect to running an EV fleet. The economics of charging infrastructure was one of the main concerns that came up (Arora and Raman 2019). The high electricity tariffs for EV charging coupled with the limited fleet size of EVs had led to under-utilisation of the existing EV charging stations. The average utilisation rate was 40 per cent for fast chargers and 5 per cent for slow chargers, indicating that drivers prefer shorter charging times for battery top-ups. Moreover, the land lease rental at INR 23–28 per sq feet made it the largest component, accounting for over 31 per cent of the overall operational expenses, while the commercial electricity tariff (at INR 17.7 per unit) was the second-largest contributor. The implementation of the special EV tariff proposed in the *Maharashtra's Electric Vehicle Policy 2018* reduced the electricity tariff considerably. However, land lease rent continues to be the larger contributor (43 per cent) to high operational expenses.

The limited availability of EV charging infrastructure led to longer waiting times for drivers, and a considerable share of their login hours was spent off-road for charging. While setting up more charging stations reduced the waiting time from 3–4 hours to 15–20 minutes, it significantly increased the land lease rent and affected the overall economic viability of the project.

11 On October 4, revised guidelines were issued by the Ministry of Power addressing this concern. The new guide-lines allow flexibility for the public charging station owners to install the number and type of chargers as per market requirements (PIB 2019).

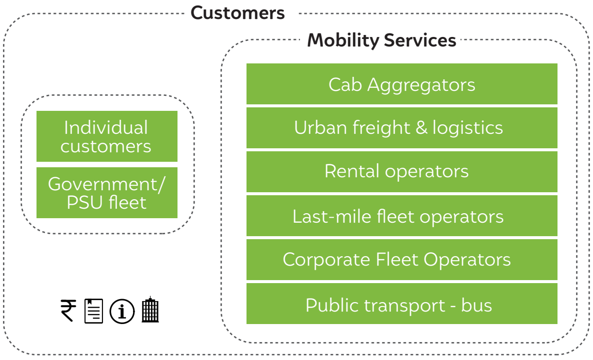
3.1.3 Financiers



	Barriers	Views
Finance	• Banks lack awareness regarding the life of the asset, end-of-life value, and resale value. • Investors are concerned about the viability of EVs, as they are dependent on upstream policies (subsidies) for now. • Cars without a battery are not eligible for the subsidy. • For financial institutions, it is too long an investment, and capacity utilisation and recurring revenues are not clear.	• Innovative models to provide subsidies and ensure bank guarantees for loans are required.
Policy	• Lack of a clear policy on EV deployment. • Lack of clarity in the legislative framework. • There is risk associated with lending for EVs owing to the lack of clarity on subsidies and other incentives once the subsidies and other incentives are terminated.	• Policies must focus on the usage of EVs than its ownership. • A combination of incentives and disincentives are required.

Other insights	Future trends
• Savings from reduced oil imports can be used to invest in EVSE infrastructure. • Awareness and education are key to a successful EV transition.	• Vehicle insurance based on telematics data.

3.1.4 Customers



	Barriers	Views
Supply chain	• There are not enough models for private users. • Current EV products are not suitable for urban freight and logistics with respect to payload capacity and speed. • EVs better suited for corporate fleet services are not available owing to lesser seating capacity in the current models. • Longer charging times. • Limited availability of charging infrastructure.	• High voltage EV products must be introduced to ensure fast charging capability and better quality.
Policy	• Lack of consistency in policy and actions by the government. • With respect to buses, the FAME II subsidy extends to the acquisition of buses by public sector undertakings only. Private buses must also be made eligible for subsidy. • Exemptions and flexibility with stage and contract carriage is required for buses. This will allow for an attractive TCO for e-buses by increasing the range of services that the e-bus can offer.	• The cost of pollution from ICEVs also need to be factored in the form of disincentives such as a carbon tax.
Finance	• Higher upfront cost of EVs. • E-buses have to run more than 250 km/day to be competitive against ICE buses on a total cost of ownership (TCO) basis. • Green/climate funds are not currently available at better rates of interest. Hence, companies in the EV space use commercial loans to raise capital. • Difficulty in availing low-interest loans from banks. • Bank financing is difficult to access because the value of the EV would be derived from the value of its battery, which in turn depends on the life of the battery. Thus, residual values need to be established. • For EV service providers, it is difficult to access both debt and equity. • The gross cost contract (GCC) model is not sustainable for e-bus OEMs in the long run due to the lock-in of a large amount of capital, which is instead required for business development and expansion.	• Innovative schemes from banks and financial institutions are required.

Other insights

- EV retrofitting could emerge as a viable business.[12]
- Business models for electric mobility services must focus on multiple use cases for greater asset utilisation, which in turn will make the TCO favourable. This is particularly the case with e-buses.
- There is a need to develop more business models for e-mobility services.

12 However, OEMs argued that retrofitted kit may not be up to the required standards. Additionally, it creates a brand equity issue for the OEM. Moreover, retrofitted vehicles are not energy efficient and end up performing poorly.

3.2 Market entry analysis

Further, we use Porter's Five Forces framework to categorise and analyse these barriers. This framework is generally used to gauge the attractiveness of an industry based on a clear understanding of five competitive forces (Porter 2008). We explore the case of a new EV manufacturer (either an existing OEM venturing into EV or a new EV OEM) entering the existing automotive industry in India:

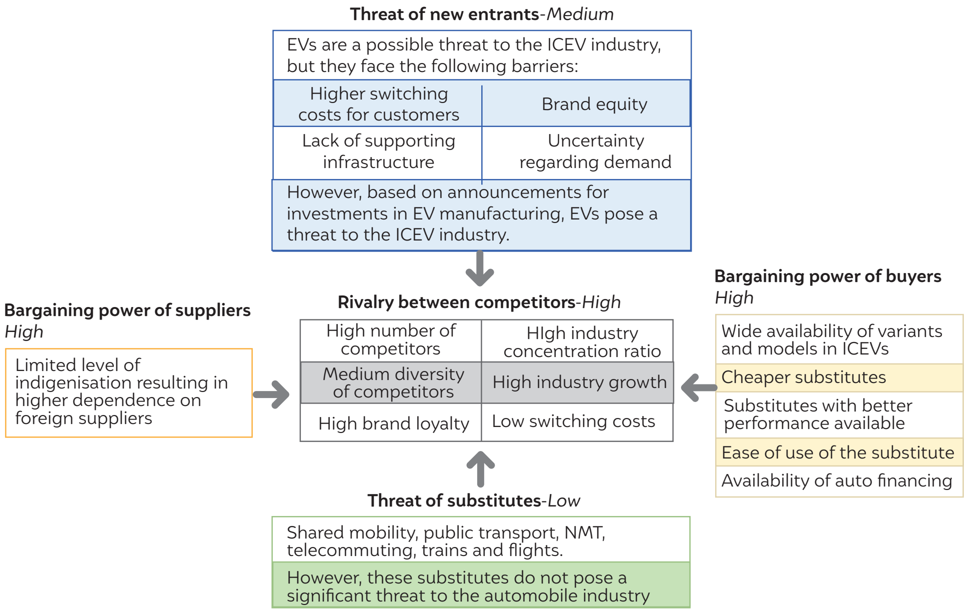


Figure 16
Porter's Five Forces framework

Source: Authors' analysis

Bargaining power of suppliers – high

There is limited indigenisation in EV manufacturing. About 60–70 per cent of the value addition in an EV is currently imported, including batteries and power electronics. In the current scenario, foreign suppliers have more bargaining power given the limited domestic availability of several high-value components. The EVSE manufacturing value chain is likely to face the same challenges due to the large share of power electronics in such systems.

Battery suppliers (including cell manufacturers and battery pack assemblers) and domestic power electronics and motor manufacturers were cited by most interviewees as key parts of the value chain that are missing in the current EV ecosystem. The components imported from countries like China are standardised and are not always compliant with standards in India. Any further customisation poses a significant cost to the OEM.

Bargaining power of buyers – high

The Indian ICE car market has a wide range of variants and models. Buyers today have about 25–29 different brands to choose from, while there are only two major OEMs manufacturing electric cars in India (see Figure 18). The ICE cars fare better in terms of performance and have lower upfront costs.

Table 4 Comparison of the performance characteristics of an ICE and an electric car

Characteristics	ICE car	Electric car
Mileage/range	790 km	110 km
Max power	65 hp @ 4,000 rpm	41 hp @ 4,000 rpm
Max speed	151 kmph	86 kmph
Max torque	160 nm @ 2,000 rpm	91 nm @ 3,000 rpm
Refuelling time	3 minutes	11 hours 30 mins (slow)/ 1 hour 20 mins (fast)
Fuel economy	17.8 kmpl	7.5 km/kWh
Cost	INR 7.6 lakh	INR 9.25 lakh

Source: Authors' compilation

The 'high asset utilisation' segments will see an earlier and higher uptake of EVs, as indicated in several studies, on account of the favourable TCO (Engelmeier, Gaihre, and Anand 2018; EY 2018; NITI Aayog and RMI 2017). These include public transport, corporate and government fleets, taxis, and urban freight. So long as the barriers to EV adoption, such as adequate charging infrastructure and upfront costs, remain, customers in all segments will have higher bargaining power.

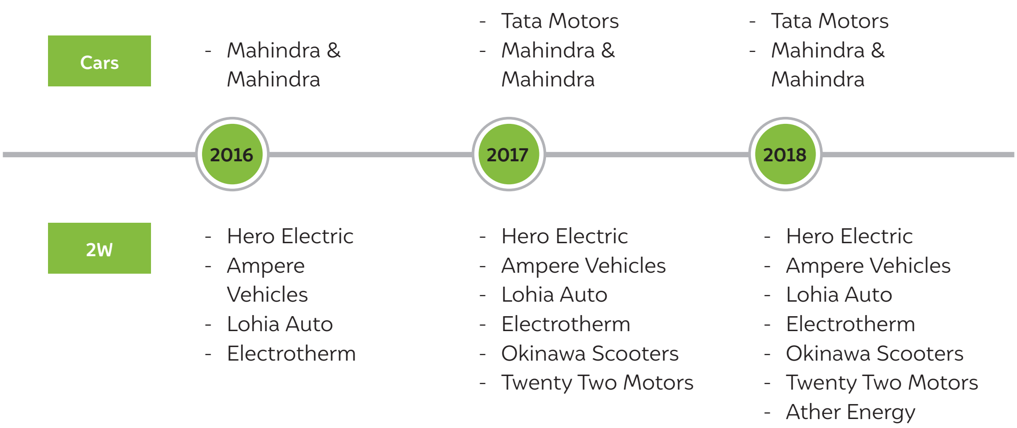


Figure 17
Electric car and 2W models in the Indian market

Source: Authors' compilation

Threat of new entrants – medium

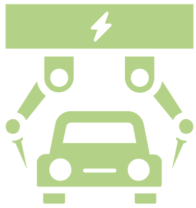
EVs present a threat to the current ICEVs in the Indian auto industry. Given that fuel cell vehicles (FCV) are far from reaching market maturity in India, and barriers such as the high cost of setting up hydrogen refuelling stations continue to exist, they do not represent a threat to ICEVs at the moment (KPMG 2019). A key barrier to entry in the automotive industry is the significant capital required to enter the market.

This barrier, however, is currently being tackled by vehicle manufacturers. Mahindra Electric is slated to invest INR 1,000 crore (USD 1.4 billion) in product development and capacity expansion. Electric 2W manufacturer, Okinawa, is slated to invest INR 270 crore (USD 40 million) over and above the INR 34 crore (USD 49 million) already invested, in the next few years (Hindu BusinessLine 2017). Moreover, EV manufacturing is less complex than manufacturing an ICEV, making it easier for new players to enter the market. For instance, Micromax, a home-grown smartphone brand, has plans to introduce an AI-enabled electric 2W (Dogra 2019).

But an EV ecosystem will, in addition, require a reliable supply of batteries and charging infrastructure. A battery plant, 50 GWh in size, will have to be established for India to produce globally competitive lithium ion batteries. Setting up such a facility would require an investment of INR 30,000 crore (USD 4.6 billion) (Sarkar et al., 2017). A total investment of INR 1.8 lakh crore will be needed to set up charging stations and the associated infrastructure in India as per a report by Feedback Consulting (Hindu BusinessLine 2017a).

The lack of certainty regarding the demand for EVs also poses a significant barrier according to the stakeholders consulted. While globally, countries like the UK have come out with clear EV policies and targets, India does not have official targets for EV penetration at present, and this is leading to delayed investments and hesitancy in developing full-fledged supply chains. EV sales (including 2Ws and 4Ws) in FY19 numbered 56,000, and formed only 0.53 per cent of the total passenger vehicle and 2W sales in India. This makes it difficult for the OEMs entering the EV industry to achieve economies of scale.

Lower market demand can be attributed to price sensitivity and higher switching costs for consumers (see Figure 19). EVs are expensive compared to ICEVs of the same segment that offer similar performance. This has been cited as one of the most critical barriers to the adoption of EVs (Shukla et al. 2014). Another barrier is the lack of adequate supporting infrastructure for charging of EVs in India. Currently, India has only 352 publicly accessible charging stations (International Energy Agency 2019).



EV manufacturing is less complex than manufacturing an ICEV, making it easier for new players to enter the market

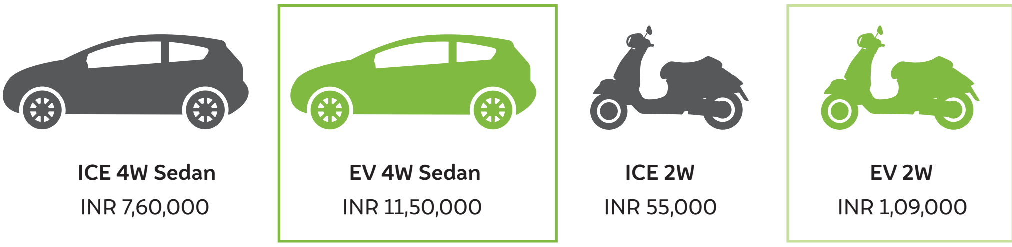


Figure 18
Purchase price of EVs is higher compared to their ICEV equivalents

Source: Authors' analysis

Threat of substitutes – low

EVs and ICEVs primarily fulfil mobility needs, and alternatives to transport by cars are the primary substitutes that we consider. In India, this includes public transport (within cities), non-motorised transport (NMT), buses and trains (for longer distances), and flights. Substitutes to automotive transport are not a significant factor that could dampen the sales of EVs or ICEVs, as trends indicate a increase in private vehicle ownership and a decrease in the use of NMT and public transport (NITI Aayog 2018).

Emerging trends in mobility, such as shared mobility allowing for the shared ownership and use of cars, could potentially impact EV sales. However, as there is currently no regulatory push to pursue shared mobility, it does not pose a significant threat.

Rivalry between competitors – high

From Figure 19, it is apparent that the top four firms in the 4W segment together make up about 82 per cent of the market share, indicating a high concentration ratio and thus low competition. The number of competitors in the Indian automobile industry has grown significantly in the last decade, and many others are expected to emerge over the next few years as a result of 100 per cent foreign direct investment (FDI) being allowed in the Indian automobile sector, and the sector being included in the Make in India campaign (Bhatia 2016). The cumulative FDI inflow in the automobiles sector was around USD 19.29 billion between April 2000 to June 2018 (India Brand Equity Foundation 2019)

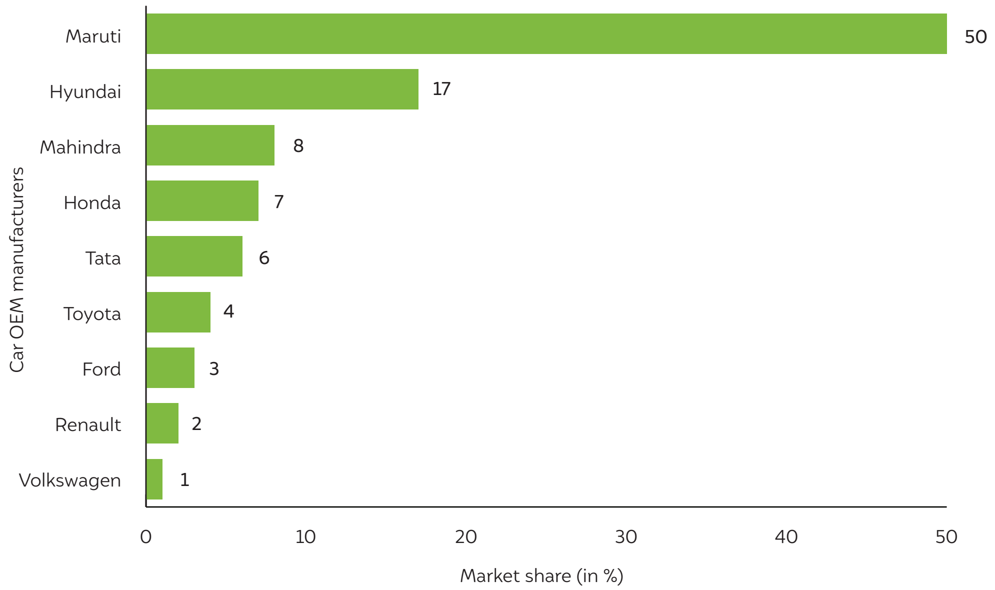


Figure 19
Top four 4W OEMs make up 84 per cent of the market share

Source: Authors' analysis

To summarise, it is evident that any new EV entrant is likely to face a range of barriers from an inadequate supply chain to consumer demand. Supporting the indigenisation of the supply chain will enable OEMs to build more cost competitive products. New OEMs should focus on R&D and developing new business models that offer a better value proposition and cost reduction. Both existing and new OEMs must engage in developing the EV ecosystem simultaneously to meet infrastructure, skill development, and financing needs.

Further, policymakers can accelerate EV adoption by supporting the development of the EV manufacturing supply chain in India and promoting financing for EVs, both of which will make EV acquisition less expensive. Together with measures to disincentivise ICEVs, such as more stringent fuel efficiency standards (CAFE standards), zero emission zones, feebates, and a zero emission vehicle (ZEV) mandate, the government can play a part in making EVs more attractive than ICEVs. Given the current slump in the auto industry, implementing additional policy interventions that increase the cost of ICE vehicles will be an uphill task. The EV policy should be a package of supply-push and demand-pull measures that boost the penetration of EVs in India. The lack of a clear roadmap coupled with volte-face and delayed announcements on schemes and policies have led to confusion within the auto industry resulting in slower industry efforts to make an EV transition. As a result, financial institutions have also been reluctant to provide support to the EV ecosystem. Following the approval of FAME II scheme outlay, a number of OEMs came forward with ambitious plans for the next 2–3 years. Thus, it is evident that clear government policies are paramount to realising the EV vision and can act as a driver to building an EV ecosystem in India.

Conclusion

Image: iStock

The automotive industry has been an important contributor to macroeconomic growth and employment in India since its inception. The industry is undergoing a transition on many fronts, with the introduction of stringent emissions norms, automation, and policies in favour of electrifying transport. We looked at how a transition to electric vehicles will impact the auto industry to determine arguments for and against electrification.

At the outset, while there is room for growth in ICE car sales even with 30 per cent electric car sales in 2030, investment decisions regarding whether to expand ICE car manufacturing capacity will require information on projected EV sales.

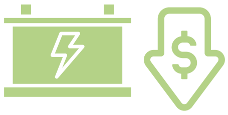
Countries across the world are undertaking EV transitions, and given India's ambition to become a global hub for auto manufacturing, building an EV ecosystem in India is of strategic importance. The burgeoning global EV market is a potential opportunity that the Indian automotive industry could exploit.

With a concerted effort to indigenise both electric car powertrain and battery pack assembly, the Indian automotive industry can produce a 5.7 per cent higher value add in a 30 per cent electric car sales scenario than in a business-as-usual (BAU) scenario with limited electric car penetration. On the other hand, with limited indigenisation of powertrain and battery pack assembly, there will be an 8 per cent lower value addition from car manufacturing in 2030 as compared to BAU. While we have not considered cell manufacturing in India, it is an additional avenue for creating further value addition.

Given the lower job intensity associated with manufacturing the powertrain of an electric car, around 20–25 per cent fewer jobs will be supported in a 30 per cent electric car scenario as compared to BAU depending on the level of indigenisation. This does not translate to 'job loss' due to an EV transition as is often claimed and is true of countries where car sales have plateaued. Instead, for India, this means that fewer additional jobs will be created in car manufacturing in the future in case of 30 per cent electric car penetration in new sales. The new EV jobs will, however, require a trained workforce which does not exist in India today, and therefore reskilling as well as vocational training will be critical to achieving the EV sales target.

With a concerted effort to indigenise both electric car powertrain and battery pack assembly, the Indian automotive industry can produce a 5.7 per cent higher value add in a 30 per cent electric car sales scenario

Importing battery cells for electric cars will be cheaper than importing the oil needed for ICE cars in 2030. The import burden per ICE car is 4.1 times higher for private vehicles and 5.7 times higher for commercial vehicles compared to the import burden of an electric car over its lifetime, considering oil and cell imports, respectively. The economic benefits of reduced spending of forex reserves on oil imports make a strong case for an EV transition. We also find that in addition to reducing local air pollution, CO_2 emissions per electric car will be 2 to 16 per cent lower in 2030 (depending on renewable energy penetration in the grid), highlighting the environmental case for an EV transition in India.



Importing battery cells for electric cars will be cheaper than importing the oil needed for ICE cars in 2030

While compelling reasons for electrifying transport abound, the EV ecosystem in India is still in its infancy. Various existing and upcoming stakeholders today face supply chain, policy, and financing barriers as documented in this report. Market entry for potential EV manufacturers is challenging on account of these factors, which explains the lacklustre performance against the existing NEMMP target for 2020. Additional policy interventions that improve the attractiveness of electric cars vis-a-vis ICE cars, targeting both supply and demand, are urgently needed if EV targets are to be pursued for 2030.

A transition to e-mobility will upend the automotive industry and will have commensurate impacts on other sectors of the economy. A thorough assessment of the net impact of such a transition on the economy, and the extent to which it addresses externalities, should shape India's decisions to develop this emerging industry. Meanwhile, it is also important to be cognizant of the efforts required to develop an EV ecosystem in India, and the timelines involved in building competence indigenously in manufacturing so as to reap the maximum benefits from this transition. While the EV transition seems inevitable and is gaining momentum in India, a concrete pathway for the future of e-mobility, that expounds on priorities and incorporates Indian realities, is the need of the hour.

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Annexure I
Description of the EV ecosystem and value chain

1. EV manufacturing

A range of actors are involved in the EV manufacturing chain, including raw material miners, EV components manufacturers, battery cell manufacturers, battery pack manufacturers, and original equipment manufacturers (OEMs).

1.1 Components manufacturing

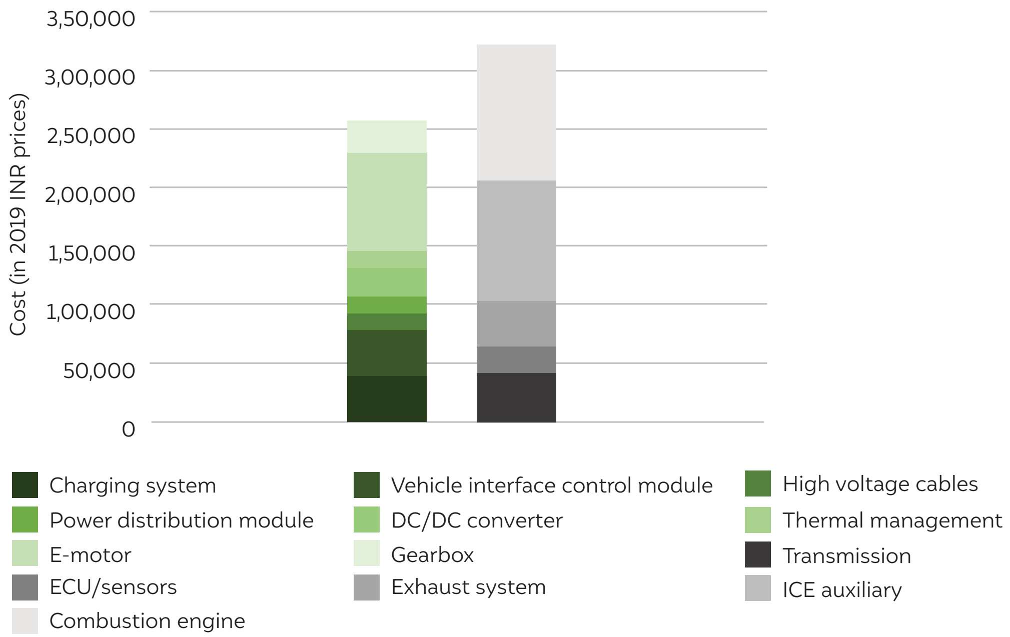


Figure 20
The cost of powertrain components are lower for EVs than ICEVs

Source: ACMA and Roland Berger (2018a)

The number of moving components in an EV is 21 per cent lesser that in a conventional ICEV, and at the same time, the number of semiconductor components in the EV powertrain is 6 to 10 times higher (ACMA and Roland Berger 2018). Some of the major new components in EVs are the DC/DC converter, inverter, power distribution module, onboard charger, battery management system (BMS), vehicle interface control module (VICM), and EV communication controller (EVCC). This results in the increased complexity of electronics in EVs. While the vehicle interiors and exteriors are not typically different, the vehicle transmission system is significantly different, owing to components such as the clutch/torque control and start-stop system becoming redundant. The combustion engine and exhaust-related components such as pistons, spark plugs, and turbochargers become obsolete in EVs. The gearbox, on the other hand, is highly simplified and typically needs a single speed type.

At present, Bosch, Motherson Sumi, KPIT, and Tata AutoComp manufacture EV components. Mahindra Electric, which currently sources 50 per cent of its components locally, plans to increase this percentage by setting up EV components manufacturing in the country (Raj 2018). Renault, one of the heavy investors in electric mobility, also plans to make India an EV components manufacturing hub in the long term (Ghosh 2018a). Auto components manufactuers cite lack of clarity on the anticipated demand for EVs as the reason for not venturing into EV components.

1.2 Battery manufacturing

The battery, one of the critical components in an EV, has a multi-stage manufacturing process. It starts with the mining of minerals, the production of anode and cathode materials, and the production of a cell. The next step is assembling these cells into a module and electronic management according to the required technical specifications.

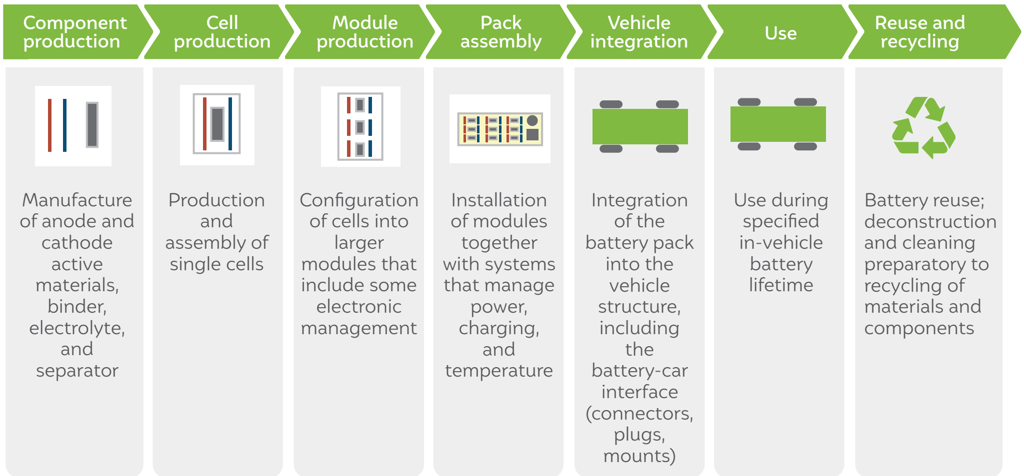


Figure 21
EV battery value chain

Source: Dinger et al. (2010)

Due to absence of lithium cell manufacturing in this area in India, the cells are imported from major lithium ion cell manufacturing companies such as LG Chem and Panasonic. Battery pack assembling is presently being carried out in India. Acme, Exicom, and Delta are some of the major companies assembling li-ion battery packs in India (Innovation Norway 2018). India's second largest battery manufacturer – Amara Raja – is in the process of building a 100 MWh assembly plant in Andhra Pradesh (Chaudhary and Afonso 2018). Exide Industries has also signed a joint venture with Leclanche SA of Switzerland to set up a lithium ion cell manufacturing and assembly plant in Gujarat (Hirtenstein 2018).

1.3 Vehicle manufacturing

The OEMs manufacture and assemble passenger cars, utility vehicles, commercial vehicles, 2Ws, and 3Ws. There are nine OEMs manufacturing low-speed and high-speed electric 2Ws in India – Hero Electric, Ather, and Okinawa to name a few. Comparatively, there are only two major OEMs manufacturing electric 4Ws – Mahindra & Mahindra and Tata Motors. Maruti Suzuki is slated to launch EVs in India in 2020 (Dhabhar 2018). Olectra Greentech Ltd (formerly Goldstone Infratech Ltd) has stated that it will create 10,000 jobs in India by 2022 through its operations, which will include R&D, assembly, and after-sales services (PTI 2018).

The electric 2W and 3W segments, on the other hand, are seeing participation from both OEMs and start-ups. Ather Energy, Tork Motorcycles, Okinawa Scooters, and Ampere

Vehicles are some of the start-ups in this space. Start-ups focusing on electric 3Ws include Smart-E, Gayam Motor Works, and Kinetic Green. At present, Goldstone-BYD, Tata Motors, and Ashok Leyland have won electric bus contracts for about 10 cities in India (Economic Times 2018).

2. Financiers

Financiers in the EV ecosystem are required to cater to EV manufacturing, EV uptake by various customer segments, and EVSE manufacturing and deployment.

2.1 Capital markets

Stocks, government securities, and corporate bonds are possible avenues for established OEMs to raise capital for financing EV manufacturing. Start-ups, however, do not have access to these debt sources on account of their lack of established cash flows and business models and the limited scale of investment sought.

2.2 Investors

Angel investment and venture capital are the main source of financing for start-ups across the EV value chain engaged in manufacturing. Ather has raised venture capital from marquee global investors such as Tiger Global, along with investments from Hero Motorcorp (Singh 2017). Hero Motorcorp, the largest 2W manufacturer in India, does not produce any electric 2Ws of its own, but has instead invested INR 335 crore in Ather Energy, and owns a third of the company (Ghosh 2018b). Smart-E is a 3W fleet operator and has raised USD 5 million from private equity funding and is seeking to raise USD 20 million (Kashyap 2018).

2.3 Banks and non-banking finance companies (NBFCs)

Due to their limited familiarity with EV technology and the associated risks, banks are reluctant to lend to start-ups engaged in EV manufacturing. The poor performance of certain electric 3Ws imported from China has made banks hesitant to lend to this segment as a whole, as told to us during an interview. Established OEMs have been able to raise capital from these traditional lending organisations based on the strength of their balance sheets. State Bank of India (SBI) has introduced a Green Car Loan that offers a 20 basis points discount on EV loans with a long repayment period of up to eight years (Dutta 2019). Also, Mannapuram Finance, a gold loan company, has signed an MoU with Autolite India Ltd. (AIL) to provide end-to-end financing support for EVs sold to consumers and dealerships (Business Standard 2019).

2.4 Insurance companies

The Insurance Regulatory and Development Authority of India (IRDAI) notified premium rates for private third-party liability insurance cover for FY20 (Dubey 2019). The premium rates were 15 per cent lower compared to rates for general private cars of similar categories. Earlier, insurance companies did not have separate premium rates for EVs, and hence, insurance packages did not make any distinction between ICEVs and EVs.

3. Charging infrastructure ecosystem

3.1 Power electronics manufacturers

Power electronics components include wires, capacitors, transformers, and other electronics parts. There are very few power electronics manufacturers in the Indian market today – Delta Electronics, Infineon, and ABB are some of the major ones. Most the components required for constructing an EV charging station are imported.

3.2 EVSE manufacturers

The power electronics components, charge controller, and network controllers are then integrated to manufacture an EV charger. There are a few EVSE manufacturers in the EV ecosystem today. While some of them manufacture power electronics components along with EVSE, others provide charging services as well.

3.3 Charging service providers

There are various business models being pursued for EVSE service provision:

- Turnkey EVSE solution providers: They provide a complete end-to-end EV charging solution. This includes manufacturing the EVSE charger, installing it, and operating it. They own the asset and provide charging solutions for consumers.
- EVSE operators: They install and operate the EVSE charger. They own the asset and provide charging services to consumers. E.g. Magenta Power.
- Charge network operators: They aggregate different EVSE outlets on a common platform for the consumers to charge their EVs. E.g. Fortum's Charge & Drive.

4. Digital rechnology

- Vehicle telematics consists of four key elements:
- Vehicle tracking using a GPS-based hardware device
- Partnership with a telecom operator to provide data services
- Partnership with a cloud hosting provider to provide a stable and reliable system
- Phone-based applications to provide data to consumers using a smart user interface

EV telematics are different from conventional telematics in that they not only provide simple track and trace solutions, but they also offer onboard diagnostics device based solutions. It is projected that EVs will be a stepping stone in devising intelligent transport infrastructure in India. Telematics-based services are likely to become standardised offerings as part of the overall EV package in the medium to long run (Taumar 2018). Today, vehicle telematics are being developed by major OEMs like Mahindra in-house, and at the same time, companies like iTriangle are providing end-to-end solutions.

5. Customers

5.1 Individual customers

These are the private vehicle users who purchase EVs for their own use such as office commuting or travelling for shopping or recreational activities. Electric 2Ws and 4Ws cater to these categories of customers.

5.2 Government fleet operators

This is essentially Energy Efficiency Services Ltd. (EESL), a government-owned energy services company, which did bulk procurement of EVs by floating tenders. It leased out electric sedans to the government and its agencies.

5.3 Cab aggregators

The 2Ws, 3Ws, and 4Ws aggregators that provide mobility services such as ride-hailing or ride-sharing belong to this category. They bring individual cab operators onto a single app-based platform to provide mobility services. Ola is the first major electric cab aggregator to provide mobility services in India. It announced Mission Electric in April 2018, an initiative to accelerate EV adoption across the company's platform and did a 200-vehicle pilot in Nagpur. Ola further plans to add 10,000 electric rickshaws to its fleet by April 2019 and 1 million EVs by 2021 (Sen 2018).

5.4 Car rental operators

Self-drive car rental services allow users to rent cars by the hour, day, week, or month. It also offers a membership-based service that enables individuals to rent vehicles on an hourly or daily basis. ZoomCar is one major company that offers EV-based car rental mobility services to consumers.

5.5 Fleet operators

Last-mile fleet operators: These fleet operators provide first- and last-mile connectivity to users of public transport. SmartE is one of the major electric fleet operators, with about 600 electric 3Ws providing last-mile connectivity to and from metro stations, bus stations, residential colonies, corporate hubs, and shopping areas.

Corporate fleet operators: They cater to corporate customers exclusively. Lithium Technologies and Bhagirathi Travel Solutions are the only two major corporate electric fleet operators in India.

5.6 Urban freight and logistics

Logistics services and last-mile urban freight service providers fall under this category. Today, Ikea, BigBasket, Grofers, and Gati-KWE use electric 3Ws manufactured by Gayam Motor Works (GMW), a start-up based out of Hyderabad.

6. After sales services

6.1 Battery swap operators

These battery top-up service providers allow EV users to swap discharged batteries for fully charged ones. Sun Mobility has partnered with SmartE to provide Quick Interchange Stations (QIS) for electric 3W users to top-up their batteries in under two minutes (P. Shah 2018).

6.2 After sales service providers

Due to fewer components in an EV, the aftermarket industry is likely to take a hit. According to a study by Union Bank of Switzerland, aftermarket revenues could reduce by up to 60 per cent in case of a switch to an electric car (Ganter et al. 2019).

There are two kinds of after sales services providers that are likely to emerge as EVs go mainstream.

- Maintenance service providers – where they provide maintenance services for EV owners. Currently, OEMs provide these services.
- Parts replacement service providers – where they provide battery and damaged parts replacement services for EV owners.

6.3 Battery second-life business

- *Battery remanufacturing:* Remanufacturing is, essentially, replacing the cells within a battery that can no longer hold sufficient charge to meet the standards for use in a vehicle. Remanufacturing involves partial disassembly of the battery, removal of substandard cells, replacement of these cells, and reassembly of the battery (Foster et al. 2014).
- Nissan has launched a Nissan LEAF batteries replacement program in Japan, where the owners can turn in their used EV batteries and receive remanufactured batteries for a fee (GreenTec Auto 2019).
- *Battery repurposing:* Repurposing involves transforming a post-vehicle-application battery for use in an off-road application, such as in an energy storage system. Repurposing requires dismantling batteries into cells and reassembling cells into a different configuration as well as developing the control system, both hardware and software, for the application. Each configuration may require a specifically designed battery case (Foster et al. 2014).
- *Battery recycling:* Recycling has to do with dissembling a cell into its components and properly disposing off each component. The cost savings from recycling come from two areas – the recoverable commodities extracted from the battery during the actual recycling process, and the avoided costs for storing post-vehicle-application batteries. The extractable materials can be divided into four categories: cobalt, lithium salts (carbonate), aluminium, and others – steel, plastic, paper, and miscellaneous metals (Foster et al. 2014).

6.4 Vehicle/component recycling business:

Just like end-of-life recycling of conventional ICE vehicles, recycling of EVs is another area that could potentially develop with the increasing penetration of EVs.

7. Government and regulatory bodies

7.1 Department of Heavy Industries, Ministry of Heavy Industries and Public Enterprises

The Department of Heavy Industries (DHI), under the Ministry of Heavy Industries and Public Enterprises, works to promote the engineering industry, viz. machine tools, heavy electrical, industrial machinery, and auto industry. It is a nodal authority for the automotive sector. It introduced the National Electric Mobility Misison Plan (NEMMP) 2020 and was also in charge of drafting and implementing the Faster Adoption and Manufacturing of Electric and Hybrid Vehicles (FAME) scheme.

7.2 National Automotive Testing and R&D Infrastructure Project (NATRIP)

NATRIP is a project implementation unit, a special purpose vehicle (SPV) created as an autonomous body and registered as a society under the Ministry of Heavy Industries, Government of India. The project is funded by the government and aims to create testing, validation, and R&D infrastructure. The facilities present at NATRIP at Manesar and Automotive Research Association of India (ARAI) Pune provide comprehensive homologation and product testing and validation facilities for vehicles and components.

7.3 Automotive Research Association of India

ARAI, a premier research and certification institute in the country, aims to support the automotive industry for EV development, evaluation, and certification. Under the FAME project, ARAI has set up the comprehensive state-of-the-art Centre of Excellence (CoE) for Electric Vehicles (2W, 3W, passenger cars, buses and commercial vehicles) and their components such as traction batteries, motors, controllers, chargers etc. By undertaking testing and validation, as well as by designing such vehicles, ARAI is playing its part by offering standard solutions and creating a simulation environment for fast development of EVs.

7.4 International Centre for Automotive Technology

The International Centre for Automotive Technology (ICAT) has facilities for vehicle homologation as well as testing laboratories for noise, vibration, and harshness (NVH) and passive safety. It also includes a powertrain laboratory, engine dynamometers, an emissions laboratory with Euro-V capability, a fatigue laboratory, a passive safety laboratory, and vehicle test tracks.

Annexure II
List of formulae

Domestic value added

$$Domestic\ value\ add\ in\ 2030\ (INR) = \left(Cost_{2030}^{ICEV-PT} \times\ Sales_{2030}^{ICEV}\right) + \left(Cost_{2030}^{EV-PT} \times Sales_{2030}^{EV}\right)$$

$$= Domestic\ value\ add_{2030}^{ICEV-PT} + Domestic\ value\ add_{2030}^{EV-PT}$$

Equation 1 Domestic value added:

Where,

$Cost_{2030}^{ICEV-PT}$ = cost of indigenised powertrain components in an ICE car in 2030 in INR (see

Table 5 in Annexure III).

We consider the cost of ICE car components to be the same for 2018 and 2030 (see *Table 5* in Annexure III).

$Sales_{2030}^{ICEV}$ = new sales of ICE cars in 2030, based on the scenarios discussed in Table 1 (see

Table 7 for sales projections in Annexure III).

$Cost_{2030}^{EV-PT}$ = cost of indigenised powertrain components in an electric car in 2030 in INR

(see Table 6 in Annexure III).

We consider the cost of powertrain-related components in an electric car to remain the same in 2018 and 2030, but we assume the cost of the battery to fall. Additionally, the battery, in 2018, comprises 40 per cent of the cost of an electric vehicle, and we estimate this share to decrease to 18 per cent by 2030 (ACMA and Roland Berger 2018; Goldie-Scot 2019).

$Sales_{2030}^{ICEV}$ = new sales of electric cars in 2030, based on the penetration of electric cars in

the scenarios discussed in Table 1 (see Table 9 for sales projections in Annexure III).

Employment

Equation 2 Employment:

$$Jobs\ supported = \left(Domestic\ value\ add_{2030}^{ICEV-PT} \times Job\ coefficient^{ICEV-PT}\right) + \left(Domestic\ value\ add_{2030}^{EV-PT} \times Job\ coefficient^{EV-PT}\right)$$

Where,

$Job\ coeffient^{ICEV-PT}$ = number of jobs supported by manufacturing ICE car powertrains per INR crore of value added, which is 1.59 jobs/INR crore of output. The NIC codes considered for arriving at the average job co-efficient from the ASI data have been listed in the Table 6.

$Job\ coefficient^{EV-PT}$ = number of jobs supported by manufacturing electric car powertrains per INR crore of value added, which is 0.35 jobs/INR crore of output (Fraunhofer IAO 2018).

Import burden

Equation 3 Import burden on an ICE car:

$$Import\ burden\ per\ ICE\ car\ in\ 2030\ (INR) = \left(\frac{\frac{Annual\ VKT}{Fuel\ economy_{2030}}}{x}\right) \times \left(\frac{1}{y}\right) \times (1 + Refining\ losses) \times Percentage\ of\ imported\ crude\ oil$$

Where,

x = 159, which is the conversion factor for bbl to llitre,

y = 0.45, which is the bbl of petrol that can be obtained from 1 bbl of crude oil (US EIA 2019),

$Annual\ VKT$ = annual vehicle kilometres travelled.

We assume that private cars will travel 12,500 km and a car for commercial use will travel 70,000 in 2030 (NITI Aayog and Rocky Mountain Institute 2017).

$Fuel\ economy_{2030}$ = distance travelled by the car per litre of petrol consumed in kilometres per litre.

We assume cars to have fuel economy of 20.4 kmpl in 2030 based on the CAFE emission norms FY22 onwards (Ministry of Power and Bureau of Energy Efficiency 2014).

Refining losses = Losses during the refining of petrol from crude oil. We assume it to be 8.4 per cent as per data from *Indian Petroleum and Natural Gas Statistics 2017–18* (MoPNG 2018).

Percentage of imported crude oil = Percentage of the total crude oil requirement that will be imported.

We assume this to be 80 per cent based on the assumptions in *India's Energy Storage Mission* (NITI Aayog and Rocky Mountain Institute 2017).

Equation 4 Import burden on an electric car:

$$Import\ burden\ per\ electric\ car\ in\ 2030\ (INR) = \left(\left(Cost_{2030}^{Cell} + Cost_{2030}^{Battery\ Pack}\right) \times Battery\ size\right) \times Battery\ replacements$$

Where,

$Cost_{2030}^{Cell}$ = cost of the cell of the battery in 2030 in INR/kWh.

We consider the cost of the battery to be USD 83/kWh in 2030 (based on an average of projections from various studies), of which 45 per cent of the value will contributed by cells (ACMA and Roland Berger 2018; Goldie-Scot 2019; Mosquet et al. 2018; NITI Aayog and Rocky Mountain Institute 2017).

$Cost_{2030}^{Battery\ Pack}$ = cost of the unindigenised part of the battery pack in 2030.

We consider about 10 per cent of the battery pack value to be imported in 2030 under the best case (high indigenisation) scenario in 2030 as explored in Table 1 (see Table 8 for the component-wise cost breakup of an electric car in 2030 in Annexure III).

Battery size = size of the battery in an electric car. We assume all cars to be of 30 kWh battery size, including private cars and commercial use cars.

Battery replacements = number of battery replacements over the lifetime (10 years) of an electric car with an efficiency of 7.5 km/kWh (based on the current fleet of Mahindra e-Verito). Considering that a li-ion battery has 1,200 cycles (ThermoAnalytics 2015), a private car with 1,25,000 km of distance travelled over its lifetime of 10 years will not require a battery replacement, while a commercial use car travelling 7,00,000 km in a similar lifetime will need three battery replacements.

CO_2 emissions

Equation 5 CO_2 emissions from an ICE car:

$$Emissions_{2030}^{ICEV} = \frac{z}{Fuel\ economy_{2030}}$$

Where,

z = 2,310 gCO_2/km is the CO_2 emission factor per unit of petrol consumption (Davies 2019).

$Fuel\ economy_{2030}$ = distance travelled by the car per litre of petrol consumed in kmpl. We assume cars to have fuel economy of 20.4 kmpl in 2030 based on the CAFE emission norms FY22 onwards (Ministry of Power and Bureau of Energy Efficiency 2014).

Equation 6 CO_2 emissions from an electric car:

$$Emissions_{2030}^{EV} = Grid\ emission\ factor_{2030} \times Electricity\ consumption_{2030}^{EV} \times (1 + T\&D\ losses)$$

Where,

$Grid\ emission\ factor_{2030}$ = CO_2 emissions per unit of electricity provided by the electricity system in CO_2/kWh.

We assume the grid emission factor in 2018 to be 721 gCO_2/kWh, and 715.78 gCO_2/kWh and 610.17 gCO_2/kWh in the current trends and high renewable scenarios, respectively, as per *Exploring Electricty Supply-Mix Scenarios to 2030* (CEA 2018; Pachouri, Spencer, and Renjith 2019).

$Electricity\ consumption_{2030}^{EV}$ = electricity consumed by an electric car per unit kilometre of distance travelled in kWh/km. We assume electric car consumption to be 0.133 kWh/km based on the currently deployed fleet.

$T\&D\ losses$ = transmission and distribution losses. We assume it to be 21.17 per cent today and 16 per cent in 2030 based on *Exploring Electricity Supply-mix Scenarios to 2030* (Pachouri, Spencer, and Renjith 2019).

Annexure III
Assumptions

Table 5
ICE car component-wise cost breakup in 2018 and 2030

ICEV	2018 (in INR)	2030 (in INR)
Transmission	41,808	41,808
ECU/Sensors	22,512	22,512
Exhaust System	38,592	38,592
ICE Auxiliary	1,02,912	1,02,912
Combustion Engine	1,15,776	1,15,776

Source: (ACMA and Roland Berger 2018)

Table 6
Electric car component-wise cost breakup in 2018 and 2030

EV Components	Share of cost in 2018	Cost in 2018 (in INR)	Share of cost in 2030	Cost in 2030 (in INR)
Battery	40%	5,59,806	18%	1,78,707
-- Lithium ion cell	*60% of battery cost*	*3,35,884*	*45% of battery cost*	*80,418*
-- Battery pack	*40% of battery cost*	*2,23,922*	*55% of battery cost*	*98,289*
Electric drive		1,38,875		8,33,300
Power electronics		97,212		
Vehicle interface control		41,662		
Non-powertrain components		5,55,550		
Cost of electric car		13,93,106		10,12,007

Source: (ACMA and Roland Berger 2018); Bloomberg New Energy Finance (2018)

Table 7
Car sales projections for 2030

Segment	FY18	FY19	FY20	FY25	FY30
Passenger vehicles	32,87,965	33,77,436	52,48,000	80,97,000	1,18,97,000

Source: Motilal Oswal (2018)

Annexure IV
List of Harmonized System (HS codes) and National Industrial Classification (NIC) codes

Table 8 **List of HS codes considered for the analysis on exports and imports**

	Auto components
8706	Chassis fitted with engine for 8701 to 8705
8707	Bodies for motor vehicles of headings 8701 to 8705
8708	Parts and accessories of motor vehicles under headings 8701 to 8705
8714	Parts and accessories of motor vehicles under headings 8711 to 8713

	Engines and parts
	Reciprocating piston engines of a kind used for the propulsion of vehicles of Chapter 87
840731	Of a cylinder capacity not exceeding 50 cc
840732	Of a cylinder capacity exceeding 50 cc but not exceeding 250 cc
840733	Of a cylinder capacity exceeding 250 cc but not exceeding 1,000 cc (motor cycles)
840734	Of a cylinder capacity exceeding 1,000 cc
840820	Compression-ignition IC piston engines of a kind used for the propulsion of vehicles of Chapter 87
	Parts suitable for use solely or principally with spark-ignition internal combustion piston engines
84099111	Valves, inlet and exhaust
84099112	Pistons
84099113	Piston rings
84099114	Piston assemblies
84099120	Fuel injection equipment excluding injection pumps
84099191	Other: of petrol engines for motor vehicles
	Other: diesel engine
84099911	Valve, inlet and exhaust
84099912	Pistons
84099913	Piston rings
84099914	Piston assemblies
84099920	Fuel nozzles
84099930	Fuel injection equipment excluding injection pumps
84099941	Other: of diesel engines for motor vehicles
84099990	Other parts suitable for use solely or principally with the engines of heading 84.07 or 84.08
84831091	Crank shaft for engines of heading 8407
84831092	Crank shaft for engines of heading 8408
	Fuel, lubricating, or cooling medium pumps for internal combustion piston engines
84133010	Injection pumps for diesel engines
84133090	Other
841520	Air-conditioning machines for motor vehicles

	Tyres
4011	New pneumatic tyres of rubber
4012	Retreaded or used pneumatic tyres
401310	Of a kind used on motor cars (including station wagons and racing cars), buses or lorries
40139020	Other: for motor cycle
40139041	For tractors: rear tyres
40139049	For tractors: other
40139050	Of a kind used in tyres of cycle-rickshaws and three-wheeled powered cycle-rickshaws
40139090	Other
40169320	Rubber rings (O-ring)
40169330	Rubber seals (Oil seals and the like)
6813	Brake lining and pads
	Safety glass
70071100	Toughened (tempered) safety glass: of size and shape suitable for incorporation in vehicles, aircraft, spacecraft, or vessels
700721	Laminated safety glass: of size and shape suitable for incorporation in vehicles, aircraft, spacecraft, or vessels
	Glass mirrors
700910	Rear-view mirrors for vehicles
	Others
73201011	Leaf springs for motor vehicles
73201020	Leaves for springs
73202000	Helical springs
83012000	Locks of a kind used for motor vehicles
830230	Other mountings, fittings, and similar articles suitable for motor vehicles
8512	Electrical lighting or signalling equipment, windscreen wipers, defrosters and demisters, of a kind used for cycles or motor vehicles
	Radio broadcast receivers not capable of operating without an external source of power, of a kind used in motor vehicles
85272100	Combined with sound recording or reproducing apparatus
85272900	Other
85443000	Ignition wiring sets and other wiring sets of a kind used in vehicles, aircraft, or ships
91040000	Instrument panel clocks and clocks of a similar type for vehicles, aircraft, spacecraft or vessels
94012000	Seats of a kind used for motor vehicles
94019000	Parts: seat

Table 9 List of NIC codes related to automobile manufacturing

NIC code	Description
29101	Manufacture of passenger cars
29104	Manufacture of motor vehicle engines
29301	Manufacture of diverse parts and accessories for motor vehicles such as brakes, gearboxes, axles, road wheels, suspension shock absorbers, radiators, silencers, exhaust pipes, catalysers, clutches, steering wheels, steering columns and steering boxes, etc.
29102	Manufacture of commercial vehicles such as vans, lorries, over-the-road tractors for semi-trailers etc.
29109	Manufacture of motor vehicles n.e.c.
29202	Manufacture of trailers and semi-trailers for transport of goods or passengers
30911	Manufacture of motorcycles, scooters, mopeds, etc., and their engine
30912	Manufacture of three-wheelers and their engines
29103	Manufacture of chassis fitted with engines for the motor vehicles included in this class
29104	Manufacture of motor vehicle engines
29201	Manufacture of bodies, including cabs for motor vehicles
29302	Manufacture of parts and accessories of bodies for motor vehicles such as safety belts, airbags, doors, bumpers
29303	Manufacture of car seats
29304	Manufacture of motor vehicle electrical equipment, such as generators, alternators, spark plugs, ignition wiring harnesses, power window and door systems, assembly of purchased gauges into instrument panels, voltage regulators, etc.
22111	Manufacture of rubber tyres and tubes for motor vehicles, motorcycles, scooters, three-wheelers, tractors and aircraft
27202	Manufacture of electric accumulator including parts thereof (separators, containers, covers)
29209	Manufacture of other attachments to motor vehicles n.e.c
22112	Manufacture of rubber tyres and tubes for cycles and cycle-rickshaws
30913	Manufacture of parts and accessories of three-wheelers and motorcycles including side cars
22113	Retreading of tyres; replacing or rebuilding of tread on used pneumatic tyres

Note: We consider NIC 29101, 29104 and 29301 only for the assessment on jobs in powertrain manufacturing of cars.

Table 10 Share of output and jobs considered for calculating jobs

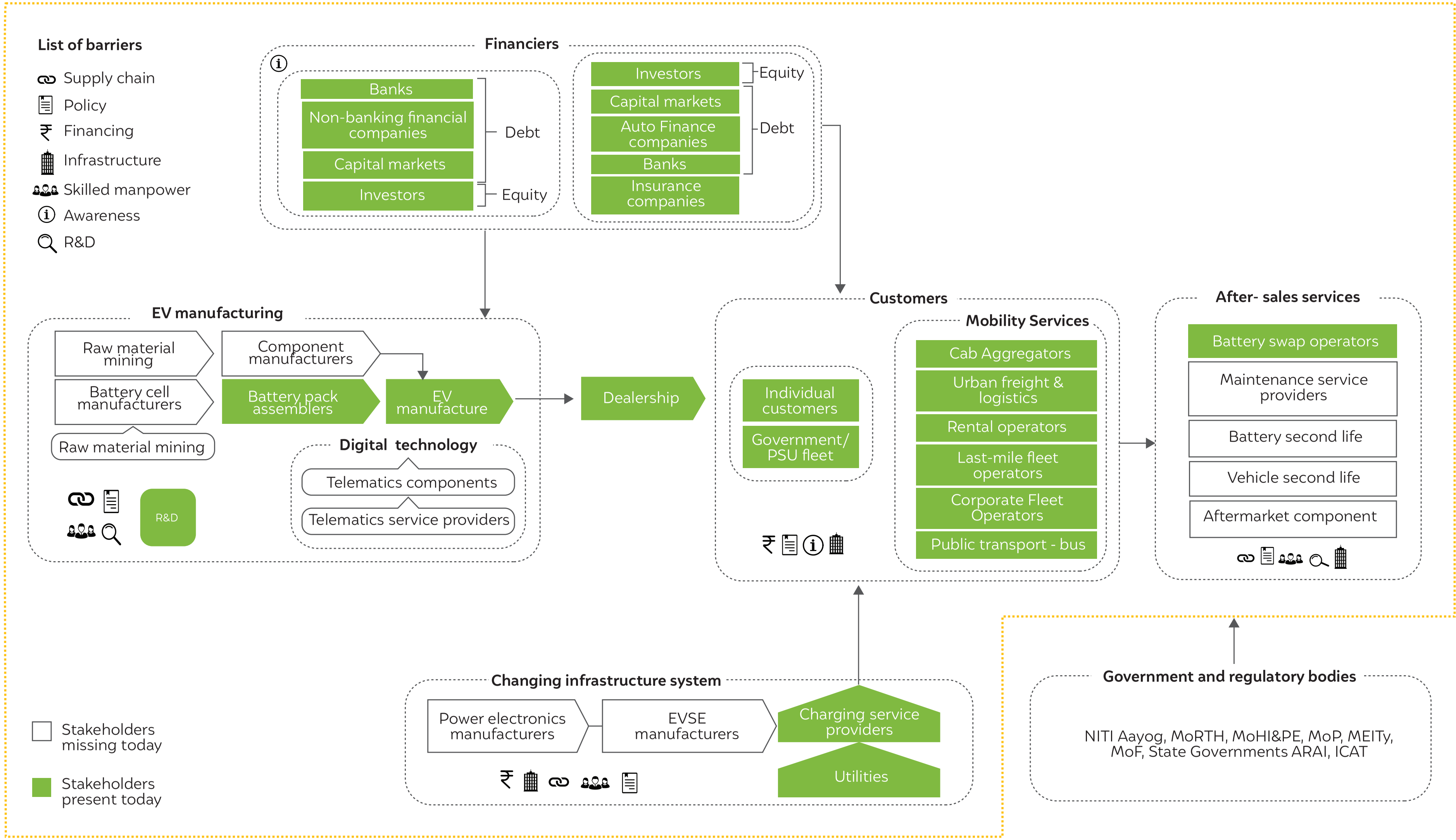
NIC code	Description	Output (in INR at 2018 prices)	Jobs	Share (in %)
29101	Manufacture of passenger cars	1,902,593,088,040	102,549	100%
29104	Manufacture of motor vehicle engines	36,434,581,414	6,501	100%
29301	Manufacture of diverse parts and accessories for motor vehicles such as brakes, gearboxes, axles, road wheels, suspension shock absorbers, radiators, silencers, exhaust pipes, catalysers, clutches, steering wheels, steering columns and steering boxes etc.	1,981,179,499,781	486,349	61%

Note: 'Output' indicates the total output under the NIC codes in FY16 converted to the 2018 prices.

'Jobs' indicates total jobs under each of the NIC codes.

'Share' indicates the apportionment based on the share of the NPCMS codes associated with manufacturing of powertrain and related auto components.

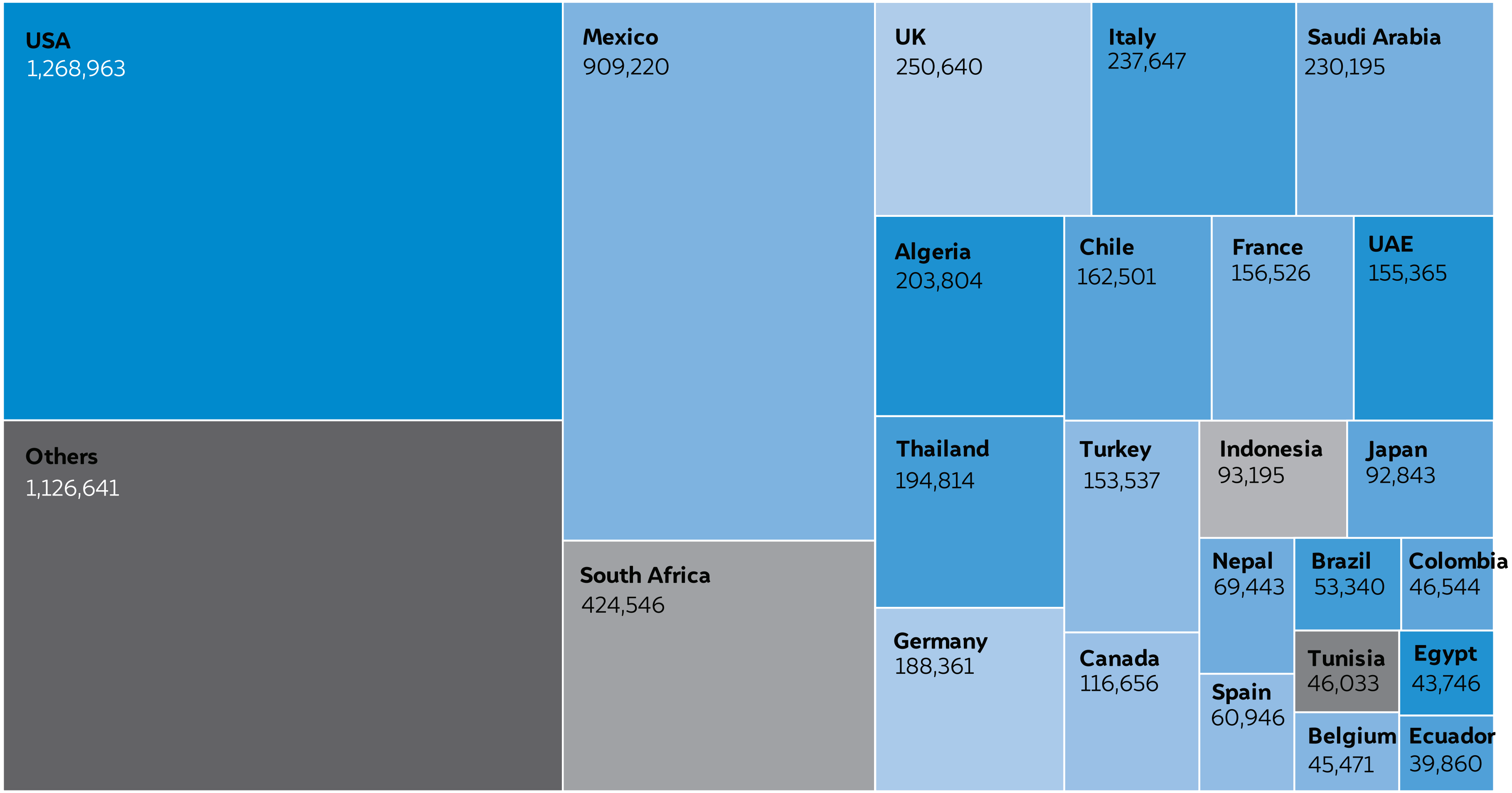
Annexure V
Stakeholders in the EV ecosystem present today



MoRTH - Ministry of Road Transport and Highways; MoP - Ministry of Power; MEITy - Ministry of Electronics and Information Technology; MoF - Ministry of Finance; ARAI - Automotive Research Association of India; ICAT - International Centre for Automotive Technology

Annexure VI
Country-wise automotive exports share in FY19

(in value terms)



Source: Ministry of Commerce & Industry (2019)

Annexure VII
Interviewee list

Ashok Leyland

Ather Energy

Bosch India

Ernst & Young

EV Motors India

Fortum India

Gayam Motor Works

Gegadyne Energy

Goenka Electric Motor Vehicles Pvt Ltd

Hero Electric

India Energy Storage Alliance (IESA)

Indian Institute of Technology Madras – Centre for Battery Engineering and EVs (C-BEEVs)

International Finance Corporation (IFC)

KPIT Technologies

Lithion Power

Log 9 Materials

Magenta Power

Mahindra & Mahindra Ltd (M&M)

Olectra Greentech

Ola Cabs

PluginIndia

Shuttl

SIAM

SmartE

Tata Motors

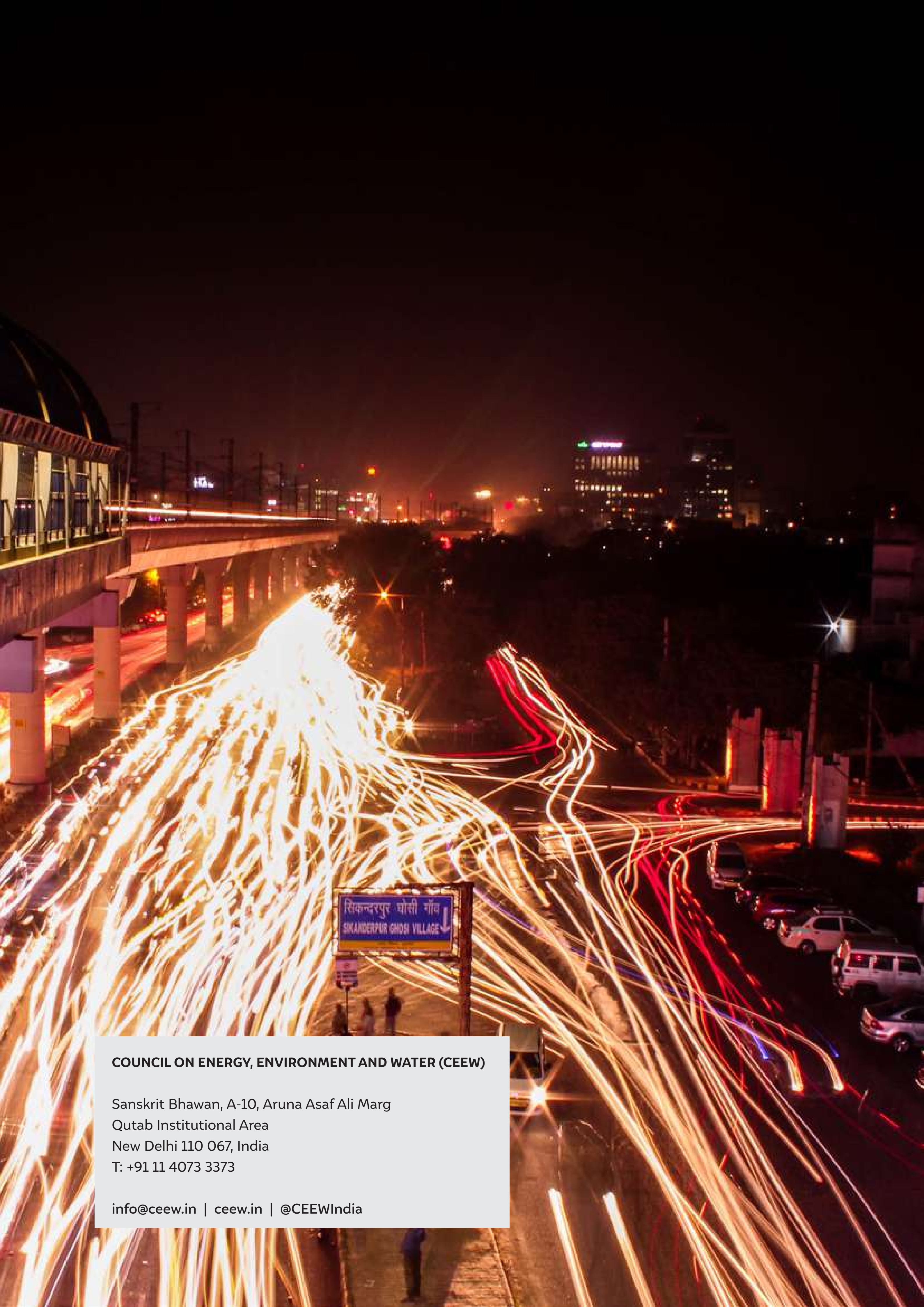
Toyota Kirloskar Motor

Twenty Two Motors Pvt Ltd

WeCharge Technologies Pvt Ltd

An EV charging station at Khan Market, New Delhi.

Image: iStock



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