Promoting Clean Energy Usage Through Accelerated Localization of E-Mobility Value Chain

May 2022

BCG

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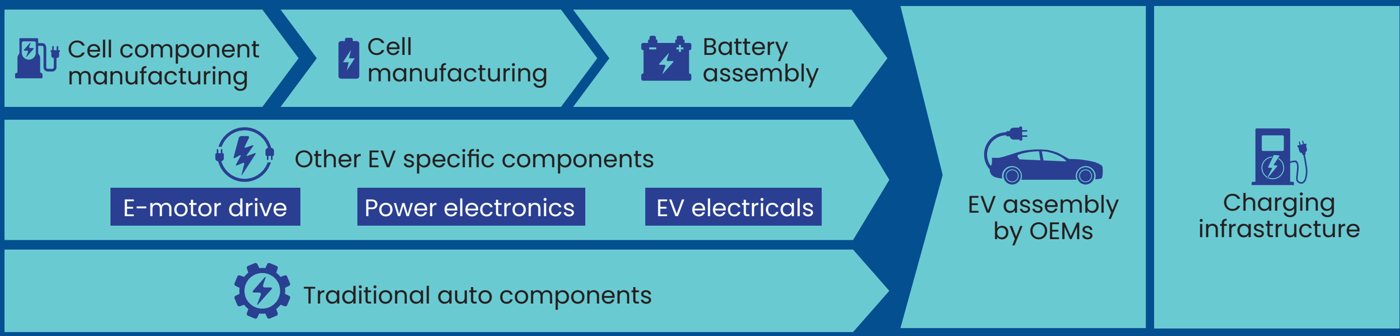
Executive Summary

Automotive industry, globally, is at a tipping point. In the last few years, the discussions have shifted from "will Electric Vehicle (EV) become mainstream?" to "the future of transport is electric". By the end of 2021, more than 15 countries had come forward and committed to the complete phasing out of ICE vehicles. Regulatory targets across many countries in the European Union now aim for a ban on ICE vehicles by as early as 2030 and 2035. Responding to climate change, mitigating pollution levels in urban centers, and reducing dependence and spends on fossil fuels have been the primary drivers behind governments pushing the electrification agenda.

India has been taking rapid strides towards green energy and electrification in the recent past. At COP26, the Honorable Prime Minister announced a net zero target for India by 2070. With the transport sector being one of the biggest emitters, the electrification of vehicles will be crucial in helping India achieve this goal. As part of the National Electric Mobility Mission Plan (NEMMP) 2020, the government has already started setting the stage for rapid uptake of electric vehicles through launch of various demand drivers and ecosystem enablers. With the development of the required EV ecosystem, increased participation from industry, and supportive government policies, electric vehicles in India are set to grow exponentially over the next decade. Overall EV adoption rates are expected to reach 10-12% by FY26 and 30-35% by FY30. It is estimated that 11-13 million EVs will be sold annually in India by FY30, led by E2W where penetration is expected to reach 35-40% by FY30. E3W, E4W (shared) and E-Buses will also witness substantial EV adoption over the next decade (between 15-25%) driven by favorable economics, increased vehicle options and government push towards electrification.

Globally, great strides have been made to drive EV adoption and make EVs the vehicle of choice for consumers. Several policies and regulations have been implemented by governments across the world to build a robust ecosystem that enables EV adoption. To arrive at the appropriate set of learnings for India, best practices across the globe were benchmarked across 11 levers to cover all the three drivers of EV adoption – Demand side, Supply side and Ecosystem enablers. On the demand side, policies cover fiscal incentives, supporting incentives, financing support and consumer awareness initiatives to stimulate demand. Key thrust areas on the supply side include manufacturing and R&D support. Ecosystem enablers include ICE sale restrictions / emission regulations to promote OEM electrification, adoption of charging infrastructure, standards and specifications, upskilling programs for workforce, and creating a circular economy.

Correspondingly, to support the EV adoption trajectory in India, the Government of India has recently launched several initiatives with the aim of developing a full-fledged EV manufacturing ecosystem in the country. Each of the three Production-linked Incentive (PLI) schemes – ACC PLI, Auto PLI and Auto components PLI – have seen strong participation from industry and are expected to localize various parts of the EV value chain. Similarly strong localization momentum has been created with the Phased Manufacturing Program (PMP) for EVs, leading to an accelerated development of local supplier base across components. However, these policies address only certain parts of the value chain and structural gaps remain in key areas. Therefore, as part of this report, a comprehensive analysis of the complete electric mobility value chain (detailed in the figure) was conducted to identify these gaps. The entire e-mobility value chain was broken into components and sub-components to identify those areas where additional government thrust is required to drive localization.



For each element of the value chain, following a comprehensive benchmarking and discussion with industry experts, the current supplier landscape was mapped out for all the key components. Thereafter, for components that are currently being imported, drivers of localization in other key geographies were analyzed to understand key success factors for localization. To emulate the best practices, the key drivers were then contextualized for India along with a mapping of India's starting point against each success factor. This structured methodology was repeated for each element of the e-mobility value chain to identify 13 components where additional government thrust would be required to drive localization

Cell Component Manufacturing	Battery Assembly	Other EV Specific Components	Charging Infrastructure
1 Cathode Active Material (CAM)	6 BMS	8 Rare earth magnets	9 Rectifier
2 Copper foil	7 Contactors		10 Controller
3 Separator			11 Connector (CCS/ CHAdeMO)
4 Electrolyte			12 Connector (Type 2)
5 Anode Active Material (AAM)			13 AC charger assembly

Based on the exhaustive study, the following key challenges to localization have been observed in these components:

1. **Lack of level playing field** for select components owing to structural unit cost disadvantages for production in India (e.g., in the case of CAM NMC and Electrolyte, because of unavailability of RM & RM processing locally).
2. **Limited enabling ecosystem to support high capex greenfield investment in India** vis-à-vis other countries for select Cell components (e.g., investments in CAM, Separators, Copper Foil, AAM have individually received capital grants in Europe along with access to cheap financing, thereby enjoying superior project ROCE).
3. **Lack of local R&D experience** in high-tech Cell component fields like CAM manufacturing, Copper Foil manufacturing, etc.
4. **Low availability of highly skilled labor** e.g., for CAM, Copper Foil, BMS manufacturing, etc.
5. **Limited localization mandate** to ensure enforcement of phased manufacturing programs for EVSE.

To address these challenges and further develop the local EV value chain, a 16-point action agenda across 4 key thrust areas is proposed:

Promoting Clean Energy Usage through Accelerated Localization of E-Mobility Value Chain

EV & EVSE component manufacturing at scale

1. Set up Hi-Tech EV component corridor
2. Project financing commitment from banks for e-mobility projects
3. Offset structural unit cost disadvantages
4. Explore opportunities to attract greenfield project investments
5. Consider localization mandate for EVSE

Mineral security & availability

6. Ensure mineral security of key battery RMs
7. Enable mining of Neodymium in India
8. Set up Raw Materials Investment Platform
9. Promote sustainability standard & ethical sourcing

R&D for EV innovation

10. Develop National strategic R&D agenda for EV
11. Set up EV & Battery Innovation hubs
12. Incentivize investments in R&D

Re-skilling & Up-skilling workforce

13. Upgrade existing infra and faculty skill set
14. Curate curriculum for Univ/ ITIs/ VETs, etc
15. Enable on-demand 'Phygital' learning
16. Set up Centers of Excellence (CoE)

Thrust Area 1 – Enable EV & EVSE component manufacturing at scale by creating an enabling eco-system and a level-playing field for select high priority components

Existing initiatives like PLI programs, PMP deadlines, etc have started the localization journey but there is further opportunity to address need-gaps to accelerate the momentum. Given many of these components would require high capex (greenfield project) investments (200-500M$ for 20-30 GWh plant), creating an enabling investment ecosystem to support at-scale manufacturing will be key to achieving the vision of complete indigenization of and self-sufficiency in the EV value chain. This can be done through concerted focus along the following dimensions:

1. **Develop Hi-Tech EV component corridors, along existing auto belts, in partnership with state governments:** Salient features of the corridor would include earmarked land near auto-clusters, plug-and-play production facilities and access to shared infrastructure to support expedited start of operations.

2. **Provide green financing commitment from banks for supporting large-scale greenfield project investment in India** (especially for CAM, AAM, Copper Foil & Separators): Taking cue from the green financing commitments secured by EU from local banks such as EIB

and EBRD, it is crucial for the government to work with the financial sector to channelize lending towards more sustainable technologies and businesses (e.g., EV Cell component manufacturing projects).

3. **Provide support to offset structural unit cost disadvantages for production in India:** Few components like CAM NMC and Electrolyte face structural unit cost disadvantage for production in India vs peer geographies (E.g. China). Through measures like duty relief for import of PCAM (RM) or inclusion of CAM NMC and Electrolyte into PLI scheme, the government could facilitate creation of a level playing field for the local manufacturing of these components.

4. **Explore opportunities to attract greenfield project investments in select high priority Cell components where need-gap still exists despite the PLI schemes:** Various state governments (E.g., Karnataka) are offering up to 15% of project capex as capital subsidy for Cell manufacturing (which overlaps with ACC PLI). This support could instead be channelized for the need-gap components (i.e., CAM NMC, AAM, Copper Foil & Separators).

5. **Consider localization mandates to accelerate set up of EVSE component manufacturing & assembly in India:** The government could consider introducing localization criteria in tenders by DHI and State Nodal Agencies (under Bureau of Energy Efficiency) across the country for setting up public charging stations (PCS) to accelerate localization of EVSE components & their assembly.

Thrust Area 2 – Ensure consistent availability of critical & strategic EV raw materials to strengthen mineral security of the nation

India is dependent on imports for most raw & advanced Battery materials (E.g., Lithium, Nickel, Cobalt, etc.). Further, India is heavily dependent on specific geographies for Rare-Earth Permanent Magnet – a critical sub-component of E-Motors. To make India self-sufficient across the raw material value chain and to make it resilient to geo-political shocks, it is crucial to diversify India's supply chains and ensure a consistent supply of critical and strategic minerals to Indian domestic market. This would need a holistic focus across following dimensions:

6. **Ensure mineral security of key Battery raw materials:** Key Battery raw materials such as Lithium and Cobalt are already covered within KABIL's ambit. It is imperative to also secure supply of other key Battery RMs like Nickel, Copper (with limited local reserves) and Manganese (with limited local reserves) by identifying on a global level primary sources (mining) and secondary sources (re-cycling), and consequently driving strategic trade partnerships with resource-rich countries. This may be achieved either by setting up a central nodal agency or directing an existing PSU/ group of PSUs to carry out this initiative.

7. **Enable mining of Neodymium in India for producing Permanent Magnets:** There is a need to direct IREL's focus towards Neodymium mining at scale; provide funding support for setting-up Neodymium processing, refining and reduction facilities in India as well as create a level playing field; and incentivize exploration of alternate sources (for e.g., Carbonatite reserves) of Neodymium, beyond Monazite sand.

8. **Set up a Raw Materials Investment Platform (RMIP) to help leverage investment (JVs) in a pipeline of key projects:** Like ERMA in Europe, India could consider setting up a platform for investment matchmaking to ensure high investment success rates across the prioritized cases to secure primary and secondary raw materials' supply.

9. **Establish sustainability standard and certification scheme to ensure high quality and sustainable output by domestic players & promote ethical sourcing and transparency in value chain by enforcing the respective standards:** India needs to establish a minimum quality standard for ensuring sustainability in the raw material(s) value chain.

Thrust Area 3 - Foster centrally coordinated multi-stakeholder efforts for R&D in EV innovation

EV and Battery are key pillars for transition towards sustainable mobility, and to be at the forefront of the e-mobility industry, continuous investment in R&D is critical. India will need to invest ahead of the curve in R&D to accelerate adoption by improving Battery energy density and cycle lifetime, and reducing cost, etc. Given that India presently lacks the process expertise for producing many complex EV and Battery components (E.g., CAM, AAM, Copper Foil, Electrolyte) requiring high technical know-how to ensure high yield, it is even more critical to support indigenous players in developing competitive technology (vis-a-vis global players). This would require focus on the following levers:

10. **Develop India's EV & Battery specific strategic research agenda covering short-, medium- and long-term R&D priorities:** Government could orchestrate the industry-academia-startup collaboration by laying out a national EV and Battery strategic research agenda covering short-, medium- and long-term R&D priorities. Potential short/medium-term priorities include increase battery energy density, improve cycle lifetime, etc. while long-term focus could include developing self-healing functionalities for battery, identify novel chemistries beyond li-ion, etc.

11. **Provide funding to develop the required infrastructure for EV and Battery Innovation hubs within reputed institutions, to promote collaborative research between Industry, Startups and Academia:** E.g., set up of innovation labs providing testing and prototyping infrastructure and supporting commercial product development from lab prototype, creating an innovation platform (digital) to host R&D projects based on identified priorities and invite EV/Battery stakeholders to further the research agenda, etc.

12. **Provide incentives to industry, academia, and start-ups to conduct collaborative research across identified priority areas:** Based on learnings from global benchmarks, it is pertinent to facilitate access to funding sources for conducting research and for prototype/ commercial product testing (as observed in Horizon Europe program in EU). Additionally, incentives can also be provided for development & deployment of proprietary EV software, given its high relevance in purchase decision of consumers.

Thrust Area 4 - Foster industry-academia collaboration for re-skilling and up-skilling the Indian workforce in line with skills and competencies needed to emerge as a leader in the growing Battery & EV manufacturing ecosystem

Given the nascent stage of India's EV and Battery market, we presently lack the skilled expertise and technical know-how required for producing many EV specific components. To support India's high ambition for substantial electrification of transport by 2030, it is critical to design a blueprint for competences and training schemes of the future in collaboration with key EV and Battery stakeholders. The following aspects need to be focused on to set a solid foundation for success:

13. **Develop existing infrastructure and faculty skillset to enable Battery & EV skill development amongst students:** There is a need to upgrade existing training infrastructure for enabling best-in-class EV and Battery skill development, as well as to train faculty for ensuring impartation of requisite industry-ready Battery and EV skills.

14. **Design curated curriculum for skilling new age EV and Battery workforce:** Design and/ or refresh course curriculum across universities, ITIs, VETs, Polytechnics in consultation with industry-academia. Integrate the new/ revamped curriculum in the existing degree, diploma, certification, or training programs.

15. **Work with technology partners to design on-demand 'Phygital' learning courses for up-skilling existing workforce:** Based on skill-gap assessment conducted and inputs received from industry-academia, design on-demand courses to fill knowledge and skill gaps of existing workforce in the Battery and Automotive industry.

16. **Set-up Centers of Excellence in reputed universities, in collaboration with OEMs and key Cell / Battery manufacturers:** The CoEs would work with industry partners to define the curriculum (duration, modules, etc.), that would be directly relevant for industry placement of students.

To realize India's mission of becoming a globally competitive powerhouse in battery & EV manufacturing, it is imperative to have a holistic strategy to drive concerted localization across the EV value chain. If the proposed actions across these 4 key thrust areas (in addition to ongoing efforts) are executed effectively, the results can be transformative for India's e-mobility landscape. It will not only accelerate local EV adoption, but also put India on the roadmap for developing a competitive and self-sufficient domestic manufacturing ecosystem for electric mobility.

Our analysis indicates that the incremental market size of EV & EV components and charging infrastructure is likely to reach ~$22 Bn by 2030. The thrust provided by ongoing government initiatives, coupled with actioning of the additional interventions enlisted in this report, has the potential to substitute imports to the tune of ~18 Bn, i.e. ~80% of the incremental market size of EVs. The opportunity at stake is massive. This reports provides a path to localizing as much of this value at stake, as possible.

Introduction

At COP26, the Honorable Prime Minister announced a five-point agenda, referred as 'Panchamrit', to highlight the role of India towards fighting global climate change. It emphasizes the focus on clean energy to reduce carbon emissions, by increasing non-fossil energy production capacity to 500 GW and achieving 50% of country's energy requirements using renewable sources by 2030. India has also committed to reducing its projected carbon emissions by 1 Bn tonnes by 2030 and to reducing the carbon intensity of the economy to less than 45% by 2030. As the final agenda, India has also pledged to become a 'Net-Zero' economy by 2070.

With the transport sector being one of the biggest emitters, the electrification of vehicles will be crucial in helping India achieve these goals. India is the 4th largest automobile market in the world after China, USA and Japan. Therefore, India will play a pivotal role in the quest for Electric Vehicles (EVs) in the changing global order. The opportunity to drive EV adoption will provide immense opportunities for EV companies and component manufacturers in India. The EV sector is still at a nascent stage in India. For it to offer a real challenge to the traditional automotive industry, it is important that it focuses on key internal aspects such as the supply chain. The EV supply chain needs to be localised, which presents its own set of challenges and opportunities, which are captured in this report.

The first chapter of this report focuses on detailing out the overall outlook for EV adoption in India. The second chapter provides an extensive benchmarking of the best practices adopted across the globe to drive EV adoption and to accelerate localization of the EV supply chain. In the third chapter, the current state of the local EV supply chain has been assessed in depth to identify structural gaps. Findings of this chapter form the bedrock of the proposed reforms and roadmap for India captured in chapter four. As the world speeds towards electric mobility, India too needs to do its bit to ensure that it remains a strong contender in the race.

01

Overview of EV Adoption in India

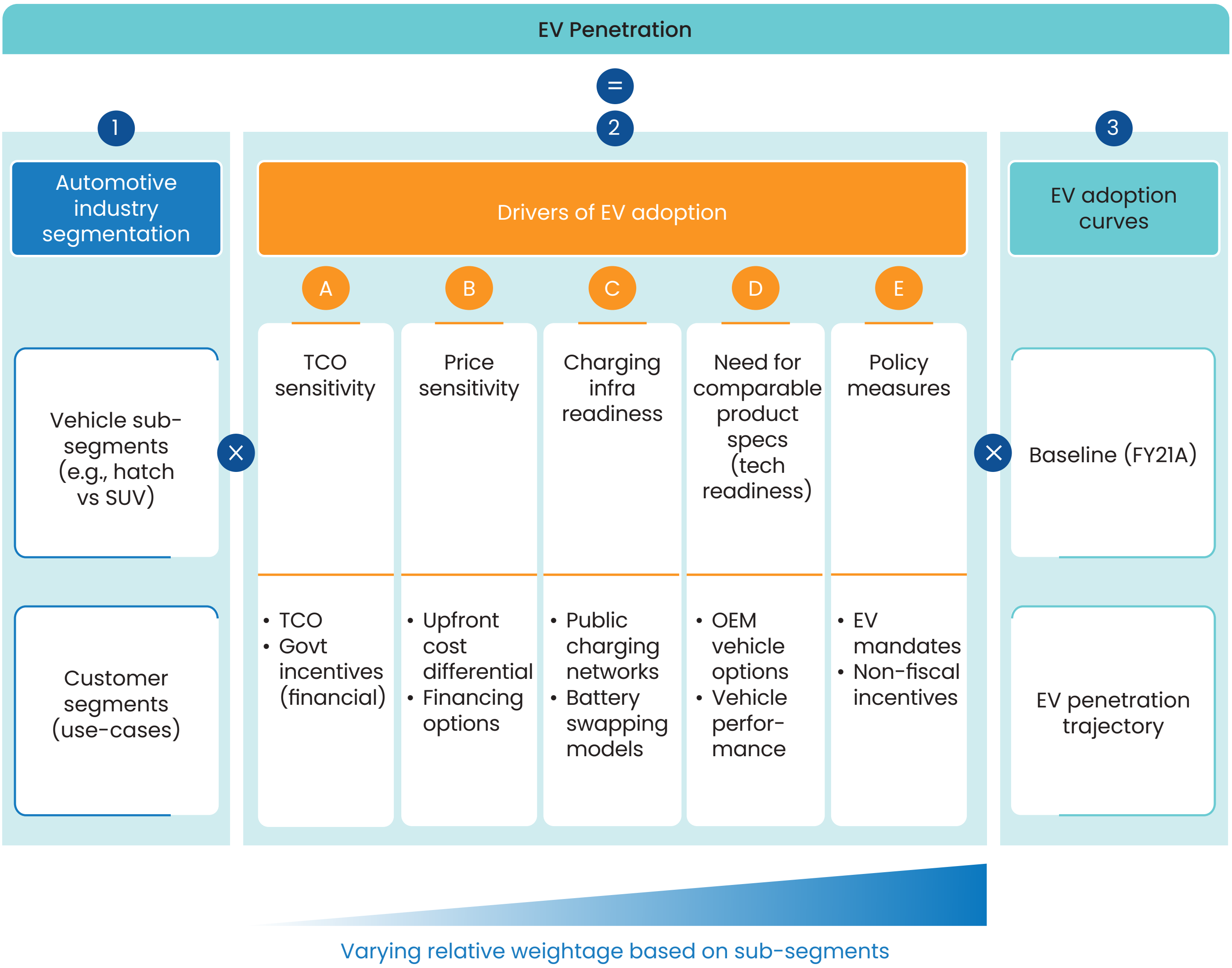
1.1 Approach

Government of India has already set the stage for rapid adoption of EVs through multiple demand drivers like purchase incentives, road tax waivers, scrapping, and retrofit incentives. Still, any sustainable adoption will also be dependent on other factors coming together beyond the fiscal thrust. For example, despite the FAME 1 and FAME 2 subsidy available for the last 5-6 years, categories like E2W / E4W haven't fully taken off (until recently) because of challenges from other drivers to EV adoption like the lack of competitive EV vehicle options, unfavorable economics (TCO parity), high upfront cost and a nascent public charging ecosystem.

Therefore, it becomes important to project EV penetration by understanding and analyzing the outlook across each of these EV adoption drivers. In this report, the demand for electric vehicles has been projected across five different vehicle categories (2W, 3W, 4W, LCV, Bus). Each vehicle category is further split into multiple sub-segments based on product type/use case (i.e., customer segment) given each sub-segment has its own characteristics and is expected to behave differently to the five drivers of EV adoption, thereby having a different adoption timeline and penetration trajectory.

Consequently, the following comprehensive EV penetration framework has been applied for projecting EV adoption across each of the vehicle categories.

Exhibit 1: Framework developed to project EV penetration across each vehicle category



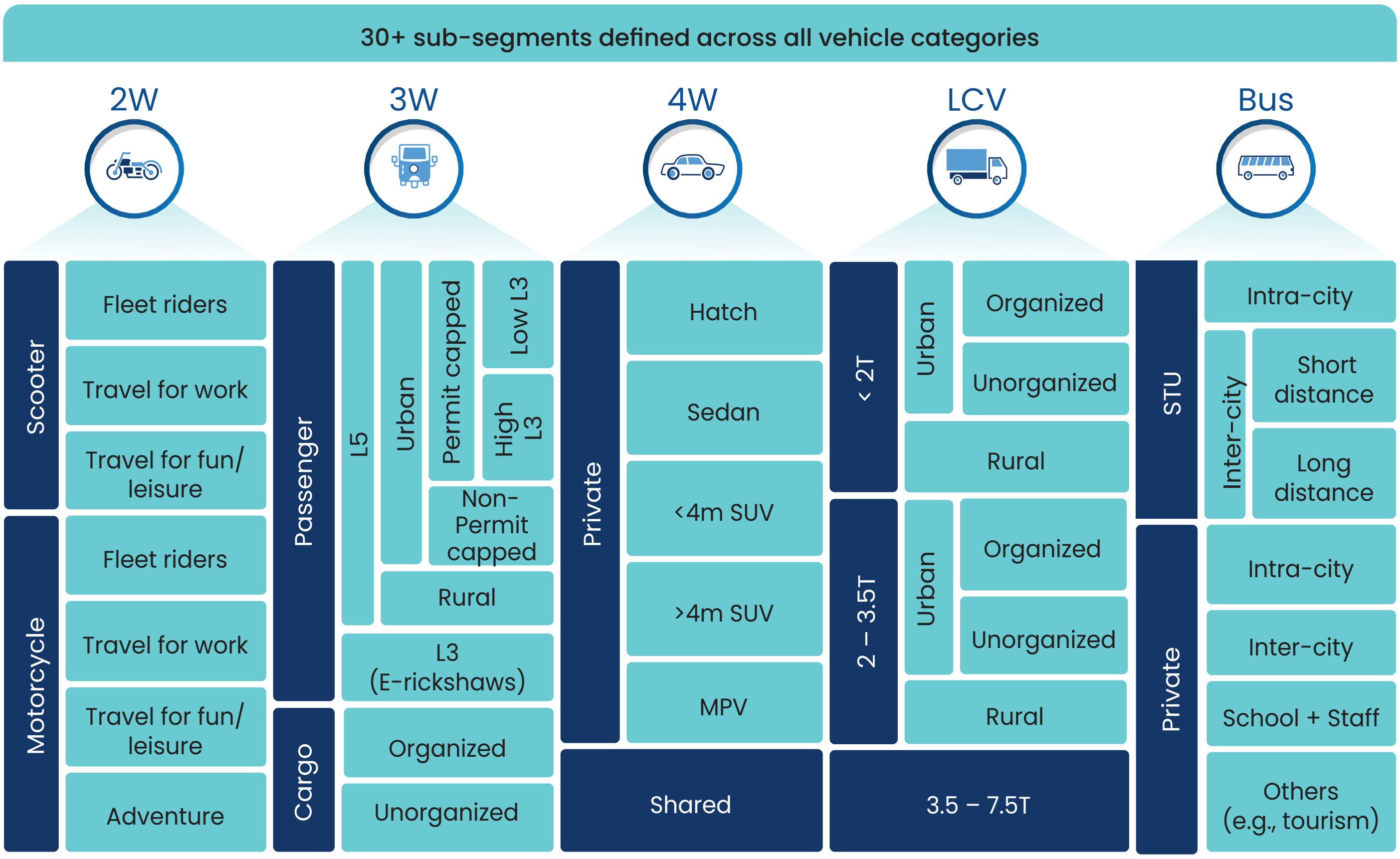
The three elements of the framework have been further detailed out ahead :

1.1.1 Automotive industry segmentation

Electrification trajectory for a Scooter (2W) fleet operator segment (e.g., food delivery aggregators) will be different compared to the user segment which only uses the scooter for commuting to work. For the former, since utilization is high, the TCO is already positive, while for the travel for work segment, TCO parity is expected to be achieved only in 1-2 years driven by declining battery prices. Similarly, for motorcycles even though the TCO viability is favorable for fleet operators, there are currently very few product choices available in the market, hindering adoption. Hence, it is essential to take a de-averaged view of the industry segments to project the likelihood of EV adoption. Each sub-segment has its own characteristics and is expected to behave differently to the five drivers of EV adoption, thereby having a different adoption timeline and penetration trajectory.

Consequently, industry volumes across the five vehicle categories (2W, 3W, 4W, LCV, Bus) are divided into 30+ sub-segments based on product type /use case (i.e., customer segment) to understand the overall EV adoption timelines at a granular level.

Exhibit 2: Industry segmentation across vehicle categories



1.1.2 Adoption drivers

As highlighted earlier, EV adoption is dependent on multiple factors coming together to drive the transition to electric. These factors have been summarized into five key adoption drivers: TCO viability, price sensitivity, charging infrastructure readiness, product readiness, and policy support. Additional details on each driver have been outlined below:

- **TCO viability** compares the total cost of owning and running an EV vs. an ICE vehicle. It is driven by the purchase cost of the vehicle (inclusive of financial incentives by the government), annual operating costs over the vehicle ownership duration, and the residual cost of the vehicle. Purchase of vehicles is a major investment decision for most Indian consumers, with a high emphasis on the overall vehicle economics. Hence TCO viability is a critical driver of electrification. While EV variants have already achieved TCO viability for select sub-segments, TCO viability for other sub-segments is expected to be achieved over the next few years. A sharper decline in the costs is expected to prepone the EV adoption timeline.

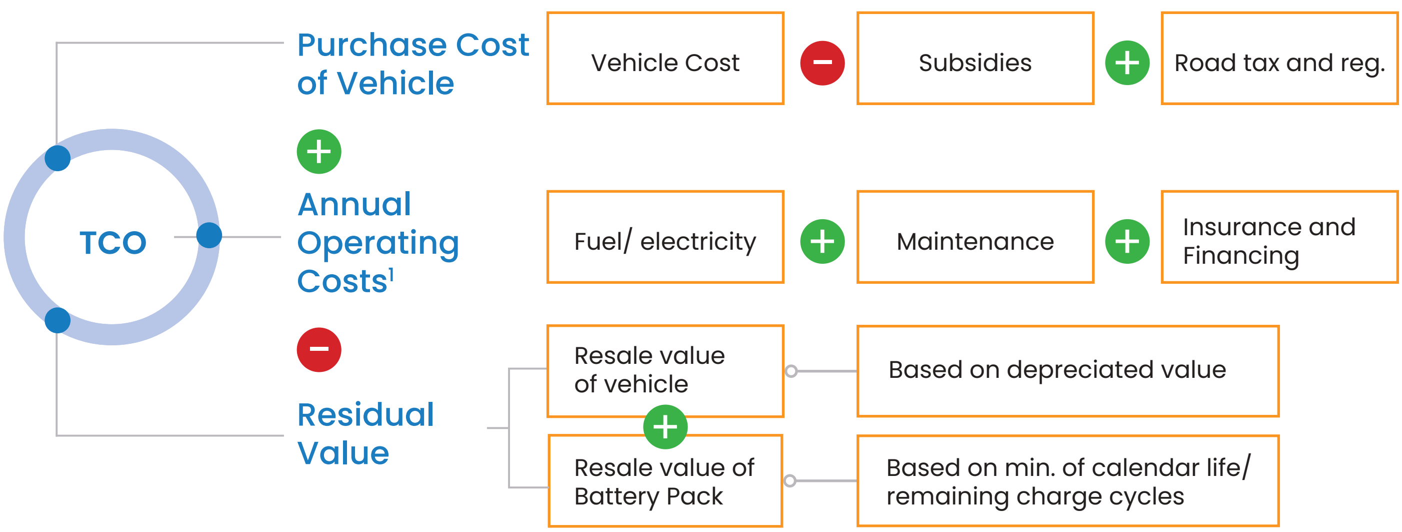
- **Price sensitivity** accounts for the upfront cost differential of EVs vs. ICE vehicles. Even if the total cost of ownership is lower for EV variants vs. ICE vehicles, it is crucial to account for the impact of higher upfront costs during the purchase decision. Availability of attractive financing options has significant potential to drive affordability for purchasing EVs. But due to the initial phase of EVs and the currently nascent secondary market, financing options remain limited in many cases, especially for low-income segments (e.g., E3W) and unorganized commercial segments. Hence, EV adoption is hindered by the upfront price differential and remains dependent on the availability of financing options to bridge the gap.
- **Charging infra readiness** comprises of availability of public charging networks/battery swapping infrastructure to address range anxiety – a major concern for many customers considering EV options. This is even more prevalent for segments with high utilization (e.g., fleet operators, commercial use-cases) and/or those with unpredictable routes (e.g., cabs, unorganized last-mile delivery). Several sub-segments cannot afford prolonged downtime during working hours even if charging stations are available. Hence, the readiness of quality charging infrastructure to accommodate the needs of various customer segments is vital to EV adoption.
- **Product readiness** reflects the breadth of EV models available in the market with features comparable to ICE models. Vehicle performance is a key purchasing criterion, and it is imperative for EV variants to compete with ICE vehicles on performance acceleration, range, payload capacity, speed, etc. Fewer vehicle options hinder choice and thereby act as major inhibitors to EV adoption.
- **Policy measures** include government regulations such as EV adoption mandates and non-fiscal incentives. Regulatory measures, either in the form of additional benefits for EVs or restrictions on ICE vehicles, can influence other drivers and accelerate the EV adoption timeline.

The relative importance of each driver will vary for each segment, depending on the segment characteristics. However, all relevant drivers must be favourable for a segment to embark on the EV adoption trajectory.

Deep-dive: Total Cost of Ownership

EV adoption across vehicle categories is dependent on a favourable Total Cost of Ownership (TCO) for EVs compared to ICE vehicles. TCO is computed based on 3 components – purchase cost of vehicle, annual operating costs and residual value of the vehicle. Each of these components is driven by different drivers as outlined below.

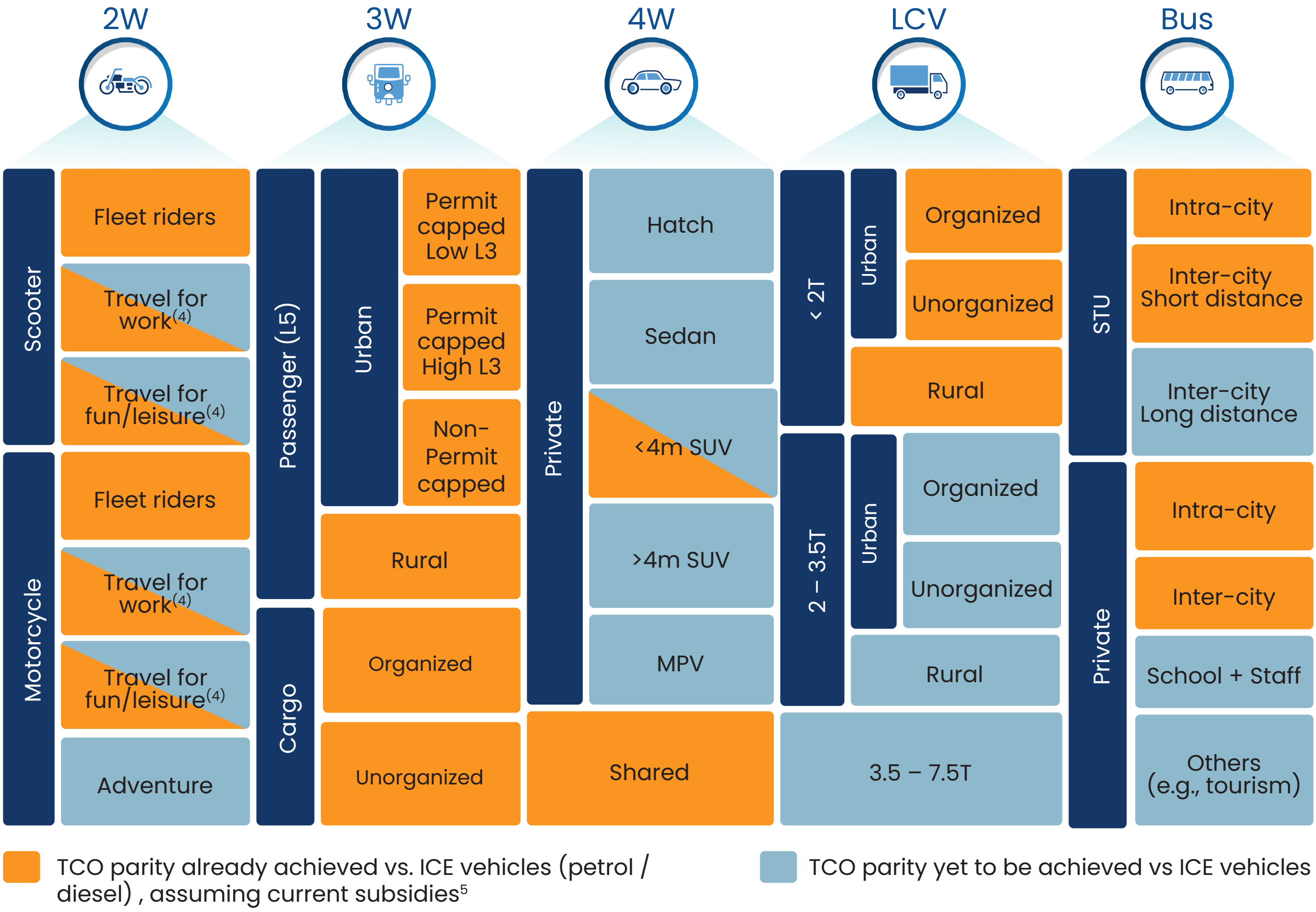
Exhibit 3: Methodology for computation of Total cost of ownership (TCO)



1. Annual operating costs are multiplied by the duration of vehicle ownership when computing the total cost of ownership

Basis the aforementioned methodology, TCO has been calculated for each sub-segment, for EV vs ICE vehicles

Exhibit 4: TCO parity status vs. ICE vehicles (petrol/diesel) for different vehicle sub-segments



1. TCO parity achieved for E3W vs diesel ICE vehicles but not vs CNG ICE vehicles
2. TCO parity achieved for <2T E-LCVs vs diesel ICE vehicles but not vs CNG ICE vehicles
3. No EV model currently available for 2-3.5T LCV, 3.5-7.5T LCV and Inter-city long distance bus segments
4. Varies based on utilization; achieved for segments >3,000 kms annual run
5. Only central subsidies available under FAME-2 assumed for TCO calculation; state-level subsidies are not considered

1.1.3 Adoption curve

As with every new technology or solution, the adoption curve here too will be S-shaped(1). Whenever a new technology comes into existence, the adoption is initially slow because of high uncertainty, potentially higher costs, and few use cases. This leads to very few early adopters but once technology costs come down and the complementary eco-system gets developed, consumer confidence increases significantly. This leads to a surge in adoption rates, until the market is saturated with the new technology, following which the growth rate drops again.

As a new segment in the transport industry, EVs are still in the relatively early stages of adoption. Exponential growth in the future is propelled through various factors such as technological innovations, improved access to charging infrastructure, enhanced product readiness in line with customer requirements, and policy measures driving electrification. The five driving factors discussed in the previous section determine the timeline for acceleration of growth for each of the individual sub-segments.

The sub-segments with low challenges across the five drivers of adoption will display an exponential growth in near future and saturate once the demand is met. Similarly, sub-segments that exhibit high challenge to adoption across one or more drivers of adoption are expected to take relatively longer time for the acceleration of EV growth.

1.2 Overall EV adoption outlook in India

EV adoption in India is currently at a nascent stage with an overall penetration of <1% in FY21. But EV adoption is expected to pick up in India over the next few years driven by reduction in vehicle costs, development of charging infrastructure, wider availability of comparable EV options and policy interventions in the form of incentives and electrification mandates. The E2W and E3W segments are expected to drive the bulk of EV volumes in the short term while E4W volumes are likely to pick up in the long-term.

Consequently, the overall EV adoption rates are expected to reach 10-12% of annual sales by FY26 and 30-35% by FY30.

Exhibit 5: Overall EV adoption projection in India

	EV Penetration Rates		EV Volume (in '000s)	
Vehicle Category	FY26 (E)	FY30(E)	FY26 (E)	FY30 (E)
E2W	13-15%	35-40%	2,500-3,000	10,000-11,000
E3W (ex. rickshaw)	18-20%	26-29%	85-95	160-180
E4W—private	3-4%	9-11%	160-180	550-600
E4W—shared	6-7%	20-25%	20-30	90-100
E-LCV	3-5%	10-15%	15-25	80-90
E-Bus	8-9%	13-16%	5-10	10-15
Overall	10-12%	30-35%	3,000-3,500	11,500-12,500

1. E-rickshaw sales not shown here, E-rickshaw volumes expected ~500K by FY26, ~700K by FY30
2. On a pandemic hit lower industry base of 14-15K (excluding ambulances)

Within the E2W category, scooters (forming ~40% of the 2W category) are geared for EV takeoff driven by favourable economics, multiple new product launches (both by traditional players and neo-disrupters like Ola, Ather), range anxiety unlock through battery swapping solutions and government thrust on fleet electrification. On the other hand, motorcycles are expected to lag scooters in EV adoption because of limited product options currently. But with multiple OEMs announcing plans to introduce EV variants, motorcycles will also pick pace in the 2nd half of this decade.

In the E3W category, capped urban passenger markets (restricted ICE permits) with a low presence of L3 e-rickshaws will continue to drive EV adoption due to unlock of latent demand. Organized players will lead adoption due to fleet electrification mandates, corporate sustainability policies, and easy access to financing options in the cargo segment. Rural passenger and unorganized cargo segments will continue to face challenges because of growing competition from CNG and the need for widespread charging infrastructure.

EV adoption in the E4W category will initially be led by the shared mobility segment (aggregators, fleet operators, etc.) due to government thrust on fleet electrification and favorable economics. The major inhibitor for this segment is the high reliance on public charging infrastructure. Still, EV adoption is expected to pick up with the deployment of charging stations, especially in Metro/Tier-1 cities. In the private segment, EV penetration is expected to grow in the <4M SUV segment in the short term. Several EV alternatives are already available in the market, and TCO parity is expected to be achieved in 2-3 years. Adoption in the hatch and sedan is expected to be slightly delayed given the lack of product readiness and high upfront price sensitivity.

In the LCV category, there has been limited EV adoption till now because of poor access to financing, limited charging infrastructure, a negative TCO vs. CNG vehicles, and thereby limited thrust from OEMs. However, urban organized players (i.e., last-mile delivery operators, e-commerce players, etc.) are likely to be the torchbearers of EV adoption in this category over the next 4-5 years, driven by the push for fleet electrification, availability of financing options, and new product launches.

Electrification in the bus category will be led by STU intra-city sub-segment because of strong government push and subsidy support. Short-distance inter-city sub-segment is likely to pick up adoption towards the latter half of the decade with the development of fast-charging infrastructure, which is a crucial requirement for inter-city travel. School + staff buses (making up for 50%+ of the category) will see limited EV adoption in short to medium term because of negative TCO, driven by low utilization levels.

1.3 Accelerators & Inhibitors

The resulting EV projections, as highlighted earlier, are built considering the base case scenario. However, any aggressive policy intervention from the government or accelerated development of the EV ecosystem can accelerate EV adoption in India.

The following critical factors can accelerate projected EV adoption rates in India:

- Support offered by the government through upfront subsidies and tax incentives has been factored into the base case forecast. Any other aggressive policy stance such as OEM electrification mandates, fleet electrification targets, restrictions on ICE usage in urban centers, and additional thrust on adoption at the state level (e.g., more states with subsidy on private 4W) can further boost EV sales.
- Penetration rates can also be accelerated through the faster than expected roll-out of public charging infrastructure. Along with increased roll-out, private sector participation in developing the infrastructure will further address concerns around range anxiety and boost EV adoption.
- Another factor that can propel the adoption curve will be the accelerated evolution and adoption of new business models like VaaS (Vehicle-as-a-Service) and BaaS (Battery-as-a-Service). VaaS model involves subscription-based ownership, which can accelerate EV adoption in certain segments because of low upfront cost for the consumer and higher utilization for the customer, thereby favorable economics. BaaS models address the issue of limited public charging infrastructure and reduce range anxiety through the development of extensive battery swapping networks.

Conversely, the following critical factors can inhibit projected EV adoption volumes.

- Continued limitations and sub-optimal conditions in financing options can significantly inhibit EV adoption, especially in commercial segments.
- Slower than expected launch of new EV models by OEMs, especially in the 4W and LCV segment, will also inhibit adoption rates due to limited EV model options.
- Adoption will also be impeded by a slower than expected decline in battery prices, leading to higher than expected vehicle costs and the consequent persistence of high-cost differential vs. ICE.

Electric vehicles are the inevitable future, and India is on a strong momentum to achieve electrification of transport.. While the government is trying hard to stimulate EV demand, some challenges remain to be addressed – e.g., availability of competitive financing options to drive affordability, widespread public charging network to address range anxiety, and accelerated thrust from OEMs to launch competitive EV products. Globally, we see governments step in and take an active role in shaping policy measures across all levers of EV adoption (beyond fiscal incentives). Hence, in the next chapter, the best in class policy measures across all the critical drivers of EV adoption have been benchmarked.

References:

1. Maggie Dennis 2021. Are We on the Brink of an Electric Vehicle Boom? Only with More Action. World Resources Institute. https://www.wri.org/insights/what-projected-growth-electric-vehicles-adoption
2. SIAM monthly flash reports

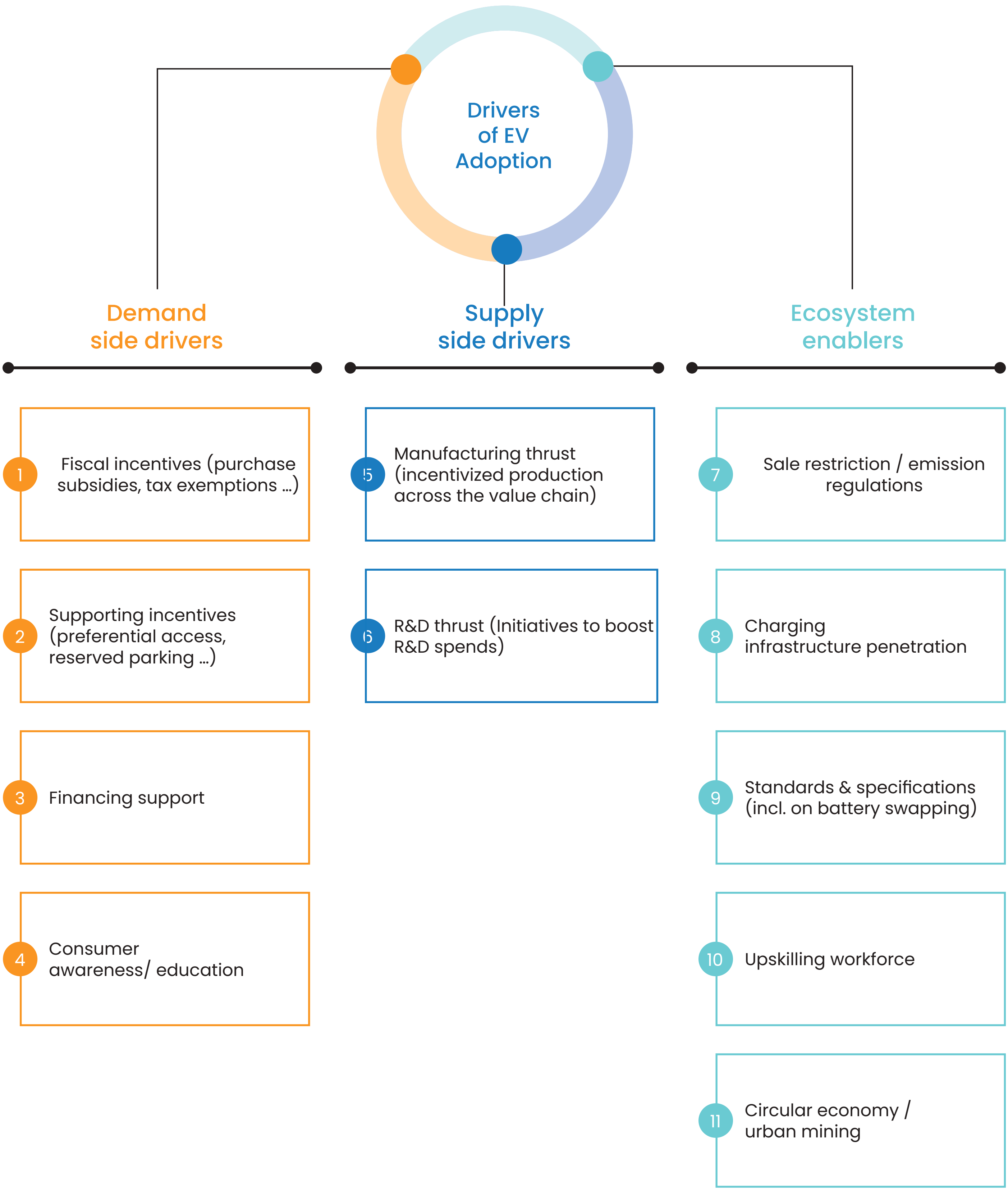
02

Benchmark of Global Best Practices

2.1 Framework and approach

Globally, great strides have been made to drive EV adoption and make EV the vehicle of choice for consumers. Several policies and regulations have been implemented by governments across the world to drive EV penetration. These initiatives can be categorized across 3 types – Demand drivers, Supply drivers and Ecosystem enablers. Within each, different levers have been deployed which are summarized below:

Exhibit 6: 11 areas for government policies & regulations to drive EV adoption



Demand side drivers

1. **Fiscal incentives** – Cover purchase subsidies and tax exemptions (upfront/recurring) for consumers to enable TCO parity
2. **Supporting incentives** - Additional benefits such as preferential access to parking/traffic zones, toll fee waivers etc. exclusively for EVs
3. **Financing support** - Increased affordability through lucrative financing options (subsidized rate of interest, etc.)
4. **Consumer awareness / education** - Activities to educate/engage potential users on EV benefits, e.g., campaigns, EV related website, etc.

Supply side drivers

5. **Manufacturing thrust** – Support for EV OEMs & EV component suppliers like capital subsidies, tax holidays, import restrictions, infrastructure support
6. **R&D thrust** - Initiatives to boost spends in R&D (e.g., funding industrial and academic research projects, building consortiums for increased collaborations, etc.)

Ecosystem Enablers

7. **Sales restrictions / emission regulations -** ICE sale & emission restrictions, mandatory fleet electrification targets, etc.
8. **Charging infrastructure adoption -** Charging stations network planning, subsidies & support to CPO, regulatory guidelines to drive EV charging adoption
9. **Standards & specifications -** Standardization guidelines on charging hardware & battery swapping; achieving interoperability
10. **Upskilling workforce** - Plugging skillset gap to make EV ready workforce
11. **Circular economy / urban mining** - Battery recycling policies & ecosystem development, end of life vehicle regulations

2.2 Global best practices

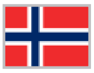
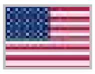
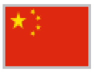
In the next section, best-in-class practices for government policies and regulations have been benchmarked across each of these 11 areas.

2.2.1 Demand side drivers

1. Fiscal incentives

Direct purchase subsidies and tax incentives (one-time or recurring) are popularly used tools by several governments to incentivize the purchase of electric vehicles. Several countries in Europe, China, Japan, Australia, and USA offer varied incentives for the EV consumers.

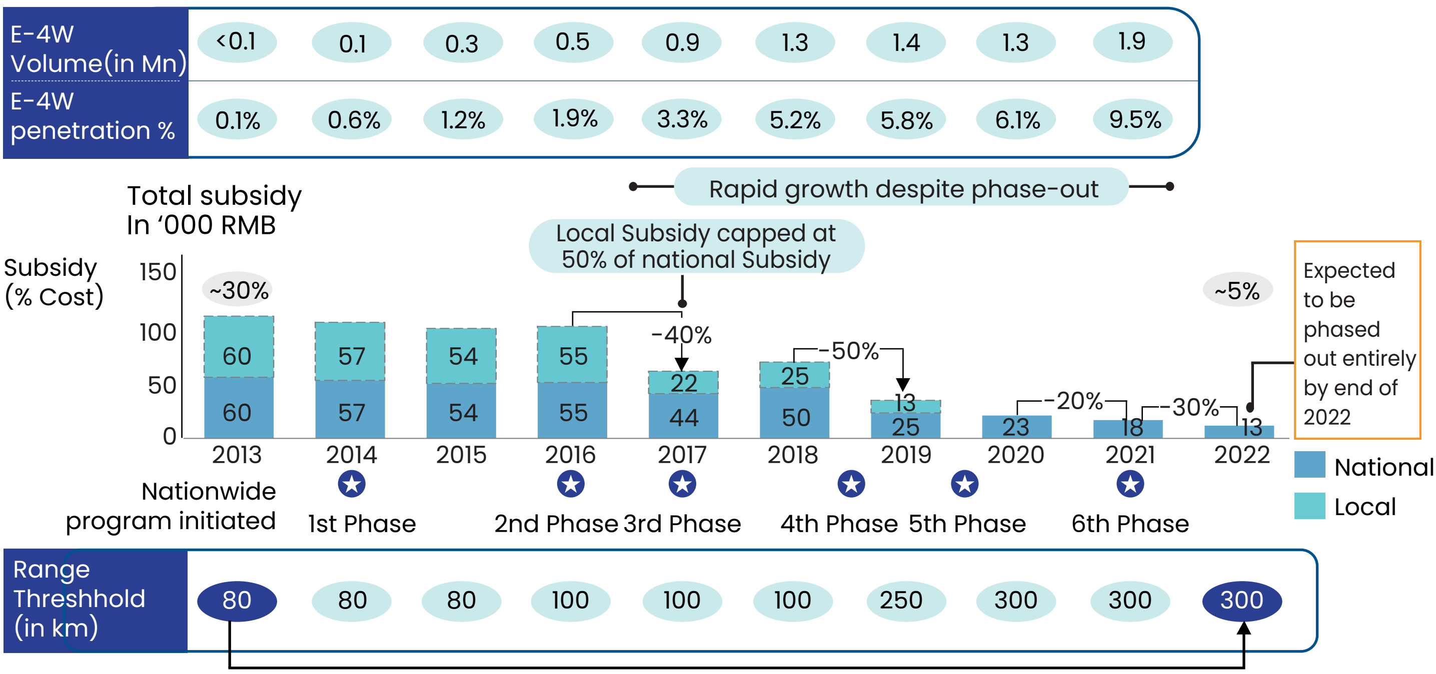
Exhibit 7: Fiscal incentives across key geographies

Geography		Subsidy	Upfront tax reduction	Recurring tax reduction
Europe[3]		€9,000 (if VC < €40K) €12,000 (if €65K > VC > €40K)	–	Road tax exempt for 10 years (~€200/year)
		€6,000	–	Road tax exempt for 5 years (~€170/year)
		€6,000-10,000	–	5-year annual tax exempt, post 5 years 75% lower vs ICE
		–	VAT exempt (~25% of cost)	–
		£1,500 (if VC < £32,000)	–	Road tax exempt (vs £145-£335 for ICE)
		–	$2,500–7,500 income tax credit available	
		JPY 800,000	No purchase tax (vs 3-5% for ICE)	Road tax exempt (vs $75-275 for ICE); Weight tax (vs $45/ton for ICE)
		RMB 9,000-13,000	No purchase tax (vs 10% cost for ICE)	–
		AUD 3,000	Stamp duty exempt (50-100% lower than ICE)	Annual registration fee subsidy (30-100% lower than ICE)

VC: Vehicle cost

It is observed that certain countries have phased-out financial incentives after succeeding in driving EV adoption. For example, China is one of the earliest countries to introduce EV subsidies in 2013 with contributions from both national and state governments. Since then, several phase-out periods have resulted a reduction of subsidies from ~30% in 2013 to ~5% currently with complete removal expected post 2022. However, EV penetration has witnessed a gradual increase over the period. The range threshold, set as a qualification factor to avail subsidy, has also increased over the phase-out period starting from 80km in 2013 to 300km currently.

Exhibit 8: Phase-out of EV subsidies in China from 2013-2022

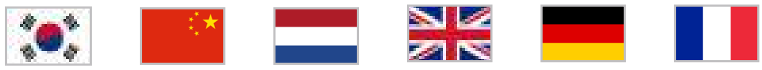


1. BYD's E6 model (RMB 370K before subsidies) considered for 2013; BYD Qin EV300 (RMB 260K before subsidies) considered for 2022
2. Minimum range (set by Finance ministry) to avail subsidy considered here 3. Beijing considered for local govt. subsidy comparison
4. Subsidies vary by range, max. subsidy considered here 5. Phases 1-6 subsidy phase-out through qualification tightening

2. Supporting incentives

In addition to fiscal incentives, governments also offer special privileges and perks to EV owners to influence purchase decision. Some of these mechanisms are highlighted below:

Exhibit 9: Multiple mechanisms used to supplement EV incentives packages

Supporting incentives	Examples
Access to bus lanes	
Free parking	
Dedicated parking areas for EVs in busy locations	
Unrestricted access (traffic zones/ licensing)	
Intermodal transport benefits	
Exemption on toll road charges	

1. 50% reduction of ferry transport for EVs

Zones restricting the usage of ICE vehicles have been established in several countries to promote the usage of electric vehicles. For example, the ultra-low emission zone (ULEZ) in London was created in 2019 and has been expanded 18 times since then covering ~3.8 million people. Today, there are ~44,000 lesser ICE cars driven in the zone each day resulting in a decline of 44% toxic NO_2 emissions, and curtailing emission of ~12,300 tonnes of CO_2 till 2021.

Exhibit 10: Ultra-low emission zone created in London restricting the access to polluting vehicles

Ultra-low emission zone in London since 2021

Ultra-low emission zone (ULEZ)

The ULEZ will operate 24 hours a day, 7 days a week throughout the year except for Christmas

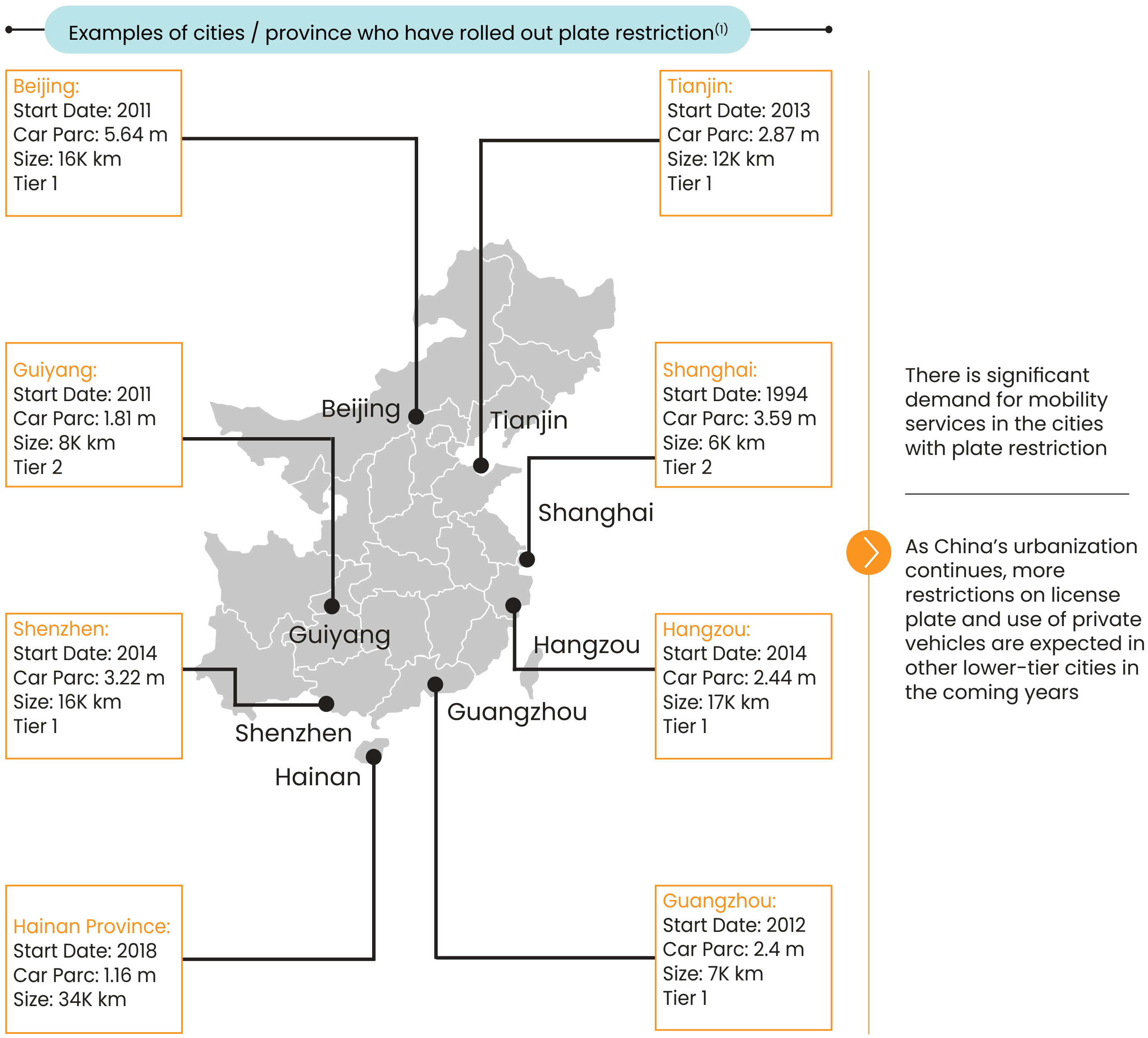
Daily entry charge for ICE passenger vehicles[1] is €12.50, paid on top of congestion zone fee[2] of €15

Cameras read vehicle number plates as they are driven within the zone to check against the database of registered cars

1. Euro 4 (if petrol) or Euro 6 (if diesel) 2. Congestion zone operates around central London in select hours

Several cities and provinces in China have implemented license plate restrictions as a solution to traffic congestion and boost e-mobility. Licenses were issued either through an auction or a lottery controlled by individual states. When first launched, the average price of a license plate in Shanghai costed more than USD 18,000, and there were 200 applicants for each granted registration in Beijing. With EVs being exempt from the restriction, this created a significant incentive for consumers to purchase electric vehicles.

Exhibit 11: License plate restriction policies across cities/provinces in China



1. Urban city tiers defined based on 2020 middle and affluent class consumer (MAC) population, defined by BCG CCI (Center for Customer Insight) 2. Owing to the auto sales slump due to Covid, several state-level government agencies, including the National Development and Reform Commission and the Ministry of Commerce have recommended states to withdraw the restriction; Guangzhou, Shenzhen, Guiyang, Hainan, Shanghai, Tianjin have either agreed to or already removed or relax the restrictions

3. Financing support

Countries like Scotland, Australia, and Norway have created funds to finance purchase of electric vehicles, which have been deemed significant by consumers. Initiatives undertaken include:

- Transport Scotland[4] offers interest free loans on new and used vehicles for both personal and commercial purposes covers all vehicle categories

Exhibit 12: Interest free EV loans provided by Transport Scotland

Transport Scotland — Administrator for the fund → Energy Saving Trust

Products covered under the programme

Purchase of new EVs for personal use

- up to £28,000 to cover the cost of purchasing a new pure electric vehicle (cars)
- up to £10,000 to cover the cost of purchasing a new electric motorcycle or scooter

Purchase of new EVs for commercial use

- Loans up to £28,000 (for cars), £35,000 (for vans), £10,000 (2W)
- Combined upper cap of £120,000 per business; no cap per vehicle on purchase of HGVs, coaches, minibuses, buses
- Businesses eligible if operational for more than 12 months

Purchase of used EVs

- up to £20,000 to cover the cost of purchasing a used electric car/van
- up to £5,000 to cover the cost of purchasing a used electric motorcycle or moped
- Cars and vans costing below £20,000 and motorbikes and mopeds costing below £5,000 eligible for the loan

Switched on Taxi loan

- up to £120,000 to enable owners and operators of hackney cabs or private hire taxis to replace their current vehicle with an eligible ultra-low emission vehicle

~64% % consumers who considered these interest free loans as crucial decision driver in purchase of EV

£85m Total loan amount disbursed (till 2020)

1. Survey by Energy Saving Trust showed 35% consumers believe they wouldn't have purchased an ULEV, 29% believed they would have purchased less quickly without these loans 2. Used EV loans added under Low carbon transport loan since 28 September 2020 3. Low Carbon Transport loan does not include Switched on Taxi loan 5. Energy Saving Trust is an independent not-for-profit organization working to address multiple climate change issues; funded by Transport Scotland to provide zero interest loans to consumers

- Clean Energy Finance Corporation[5] (Australian government - owned Green Bank) partners with banks to provide subsidized loans on purchase of EV and EVSE – total financing of more than AUD 300 Mn
  - Partnership with 6 private banks with dedicated program to finance EV sales
  - More than 5,000 electric vehicles financed at ~70 bps discount

Exhibit 13: EV and EVSE financing programs lead by CEFC through multiple asset finance partners

Asset finance program partners[1]

CEFC

	Dedicated program for EV finance	Total contribution by CEFC[2]
ANZ	ANZ Energy Efficient Asset Finance program	AUD 250 Mn.
BOQ	Bank of Queensland Energy Efficient Equipment Finance	AUD 100 Mn.
Eclipx	Eclipx Group	AUD 50 Mn.
METR	Metro Green by Metro Finance	AUD 50 Mn.
Plenti	Plenti Green Loan	AUD 50 Mn.
Firstmac	Firstmac Clean GreenCar Loan	Not available publicly

AUD 300 Mn+ — Total financing for EV loans till 2021

5,100+ — Total vehicles financed under this programme

70 bps (~10% of total interest outlay) — Resultant discount in ROI on EV loans for customers

1. CEFC has 8 partnership programs in asset financing of which 6 involved in green auto loans 2. Funding across energy-efficient and renewable technologies; allocation for EV loans not available publicly 3. 0.7% deduction in interest rate accounts to ~10% discount (varies by bank e.g., non-green loans 8.2% @ BOQ, 6% @ Firstmac) 4. All numbers as of 2021

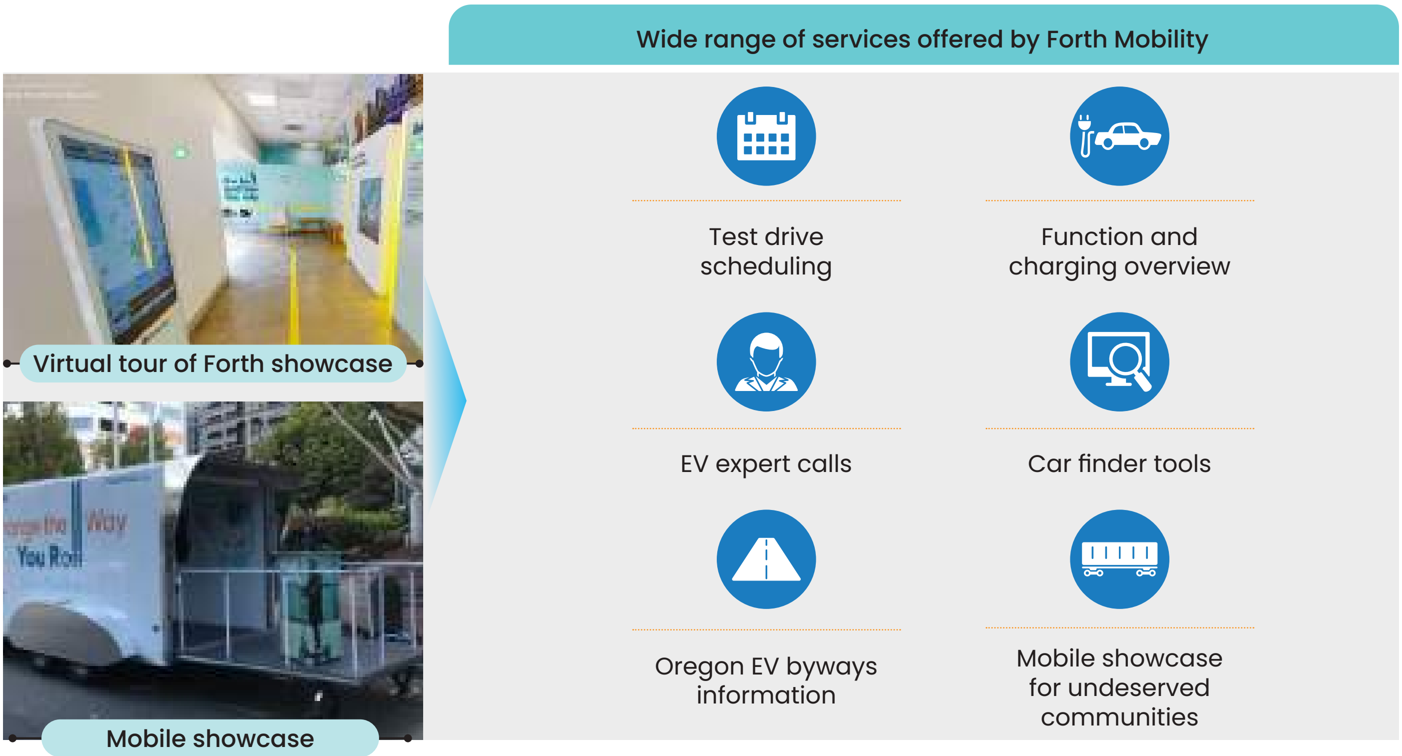
4. Consumer awareness / education

Several governments have launched campaigns to promote EV awareness among consumers. For example:

- The North-Eastern USA state governments have come together to launch the "Drive Change. Drive Electric[6]." campaign through a public private partnership with auto manufacturers. Their mission is to popularize the EV lifestyle through their website and other social media platforms. They drive awareness through various means such as a video series of EV lifestyle featuring famous celebrities, testimonials of EV owners and travel guide of various destinations in North-East USA located on routes with strong EV charging network.
- Similarly, 'Go Ultra Low[7] campaign is a joint initiative of UK government and auto industry that aims to drive EV adoption in UK. The campaign maintains an informative website that provides several tools such as charging point map, journey cost calculator, tax savings calculator, local incentives identifier, energy tariff tool etc. In addition, the website also contains detailed information on EV models from several auto makers and assists in booking test drives.
- Some states in the USA have launched EV academic programs to inculcate awareness of EVs in students. For instance, the University of Michigan[8], in collaboration with the Department of Energy, local transportation authorities, and auto industry players, has launched a K-12 summer program to drive awareness on electric vehicles and create interest in EV related courses for higher education.
- EV experience events are also being organized by governments to further drive awareness of EVs. The Oregon state govt. funded the EV advocacy group Forth Mobility[9] to organize awareness programs by connecting experts with potential EV consumers for discussing any concerns related to EVs. While the physical outlet is based out of Portland, the organization

has also launched a virtual tour of their office to reach out to a wider audience. In addition, a mobile showcase, which is an office on wheels, also organizes several tours across sub-urban localities to reach out to under-served communities.

Exhibit 14: Forth Mobility offerings to promote EV awareness



1. Forth mobility, erstwhile Drive Oregon, is a state of Oregon funded advocacy group 2. Physical outlet at World trade center, Portland currently not operational; virtual tour provides an interactive experience for customers

2.2.2 Supply side drivers

5. Manufacturing thrust

While many countries have provided ad-hoc / case basis grants, only a few governments have launched holistic EV supply chain localization campaigns and policies. Examples of recent local EV supply chain promotion policies are listed below:

- The European Union formed EBA 250 in 2017 to drive localization of entire battery manufacturing value chain. Capital funding in the form of grants was provided under IPCEI(10) for cell component manufacturing, cell and pack manufacturing. Economic support of €3.2 Bn for 17 projects was provided under IPCEI 2019 by 7 member states and €2.9 Bn provided for 46 projects under IPCEI 2021 by 12 member states. Financing support is also available through the European Investment Bank and European Bank for Reconstruction & Development.

Exhibit 15: Projects approved under IPCEI 2019 and IPCEI 2021

2019

Raw and advanced materials	Cell and Modules	Battery Systems	Re-purposing, recycling and refining
BASF	ACC	BMW	BASF
Eneris	BMW	Endurance	Endurance
Keliber	Endurance	Enel X	Elemental
Nanocyl	Eneris	Eneris	Eneris
Solvay	FAAM	Kaiters	FAAM
Terrafame	SEEL	SEEL	Fortum
Umicore	VARTA		SEEL
			Umicore

- 7 Member States
- 17 projects

€8B Total estimated private sector investment

€3.2B Total Economic Support (~40% of total investment)

2021

Raw and advanced materials	Cell and Modules	Battery Systems	Re-purposing, recycling and refining
ACS	Alumina Systems	ACIS	Borealis
Arkema	BMW	Alumina Systems	Enel X
Borealis	Cellforce Group	AVL	Engitec
Ferroglobe	Elring Klinger	BMW	FIAMM
Green Energy Storage	FCA	Endurance	Fortum
Hydrometal	Green Energy Storage	Enel X	Hydro metal
Italmatch Chemicals	InoBat Auto	Energo Aqua	Idealmatch Chemicals
Keliber	Manz	FCA	Keliber
Prayon	Midac	FIAMM	Liofit
SGL Carbon	Northvolt	FPT Induatrial	Little Electric Cars
Solvay	SGL Carbon	Green Energy Storage	Midac
Tokai Carbon Group	Skeleton Technologies	InoBat Energy	SGL Carbon
VARTA Micro Innovation	Sunlight Systems	Manz	Tesla
	Tesla	Miba eMobility	Vaimet Automotive
	VARTA Micro Innovation	Midac	ZTS VaV
		Rimac Automobil	
		Rosendahl Nextrom	
		Skeleton Technologies	
		Sunlight Systems	
		Tesla	
		Valmet Automotive	
		Voltlabor	

- 12 Member States
- 46 projects

€12B Total estimated private sector investment

€2.9B Total Economic Support (~40% of total investment)

Important Project of common European interest (IPCEI)

- The US government has announced grants valued at $7 Bn under the Infrastructure Investment & Jobs Act[12] to localize the entire EV value chain from battery RM processing to EV assembly. Incentives are primarily offered as capital subsidy in the form of competitive grants under 3 programs – Battery Materials Processing Grant ($3 Bn), Battery Manufacturing & Recycling Grant ($3 Bn) and Advanced Energy Manufacturing Grant ($750 Mn) aimed at different parts of the value chain including cell component manufacturing, cell manufacturing, battery assembly, other EV components, and EV assembly. Applications for the respective grants are expected to be opened in Q3 2022.

Exhibit 16: Incentives for EV and EV components manufacturing in USA

Program Objective: Support EV deployment in the country, localize battery manufacturing across the value chain & boost domestic production of ZEVs

	Battery Materials Processing Grant	Battery Manufacturing & Recycling Grant	Advanced Energy Manufacturing Grant
Nature of incentive	Capital subsidy (grants)	Capital subsidy (grants)	Capital subsidy (grants)
Incentives under scheme	$3Bn • $3 billion funding (up to 50% of total cost of project) to support demonstration projects & construction of facilities for RM processing, battery component & battery module manufacturing • $600 million appropriated annually from 2022-2026	$3Bn • $3 billion funding (up to 50% of total cost of project) to support demonstration projects & construction of facilities for battery & battery component manufacturing & recycling	$3Bn • $750 million funding for manufacturing of Advanced Energy products/services– includes all types of EVs and related technologies, EV components, charging & refueling infrastructure
Criteria	• Eligible – States, local governments, institutions of higher education, non-profit & for-profit private entities, national laboratories • Beneficiary to match 50% of total project cost		• Eligible – Businesses with <$100 million gross annual sales, <500 employees, annual energy bill $0.1-2.5 million

In addition to above comprehensive policies, USA, China and countries across Europe have also given incentives on case to case basis to different companies to set up capacity for EV value chain manufacturing. The type of incentives offered include provision of land and/or infrastructure, capital subsidies, financing support, fiscal incentives, and subsidized utilities. Select examples of such projects are listed in the below exhibit.

Exhibit 17: Select examples of ad-hoc incentives provided for EV and EV components manufacturing

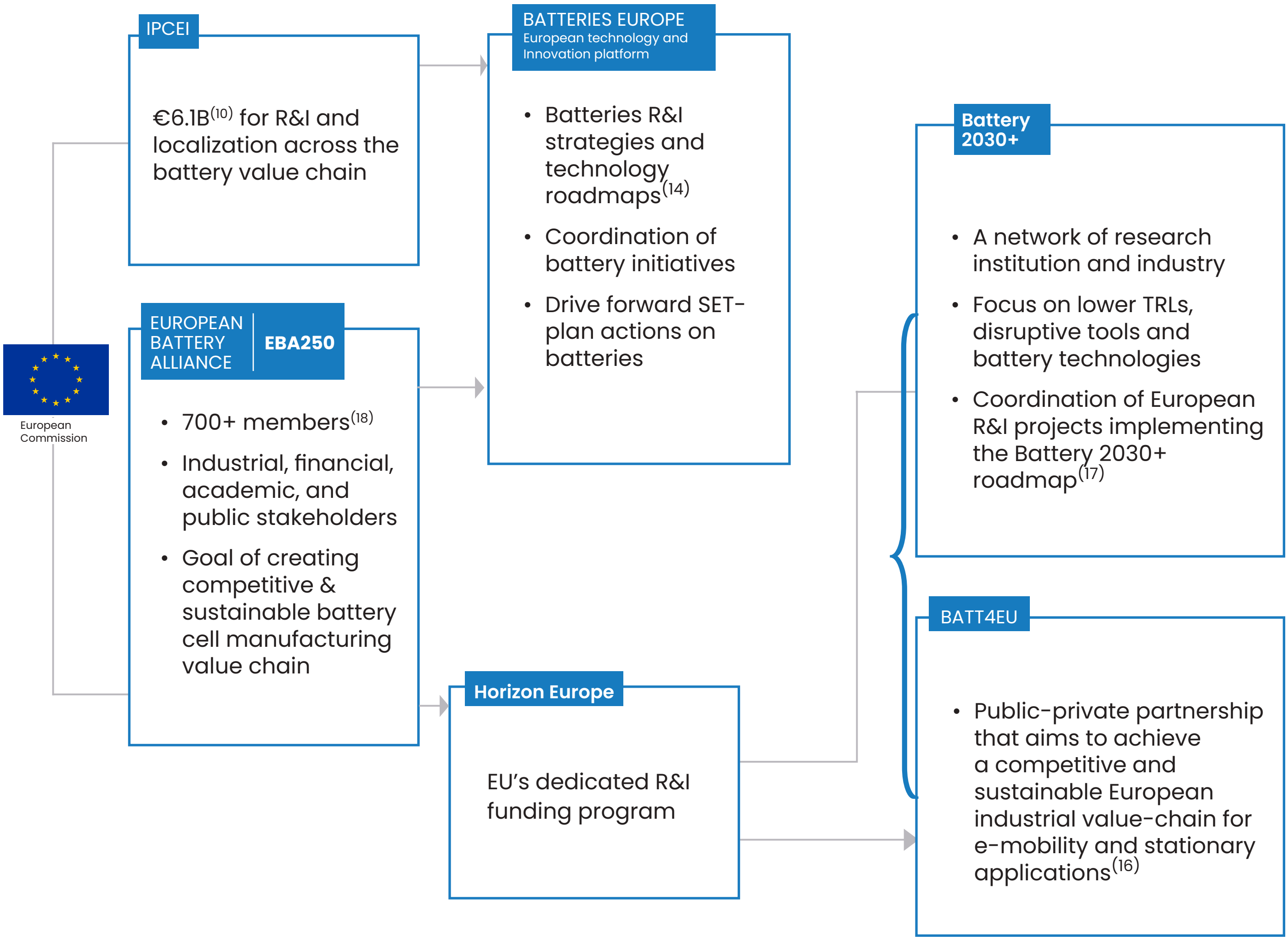
Cell Component	Cell manufacturing	Battery (module / pack)	EV Vehicle Assembly
Toray: €47M (12% of total investment) subsidy for manufacturing Li-ion battery separator films	**LG Chem:** €93 Mn (9% of total investment) subsidy along with subsidized land, tax exemptions & €480 Mn loan agreement from EIB for battery cell, module, packs manufacturing		**Diamler:** €42.2 Mn (30% of total investment) grant to add EV production line existing plant
Umicore: €125 million loan(€370 million total cost) by EIB for cathode production facility	**Farasis:** Direct subsidy up to 50% of equipment cost, free land, 100% refund for CIT & VAT for 5 years and power subsidy for battery cell, module & pack manufacturing		**Tesla:** Low interest loans (3-year $465 Mn); $106 Mn tax break from state of California
Elkem: NOK 10 Mn grant from Enova, €40 Mn loan from NIB to produce natural graphite AAM	**Tesla:** 980 acres free land, tax abatement up to 20 years, discounted electricity rates for Nevada Gigafactory		**BAIC:** $346 Mn subsidies through central and local fiscal funds for manufacture of 100,000+ E-series vehicles
Solus Advanced Materials: Tax cuts worth €11Mn for ultra-thin copper foil production along with $28Mn long-term loan from EBRD	**Freyr:** Grant of NOK 142 Mn from ministry of climate and environment for battery cell production	**SK Innovation:** €90 Mn (10% of total investment) subsidy for battery manufacturing factory	**Nio:** 7 Bn Yuan for 24% share of JV with JAC (state owned auto OEM); JAC to build final EVs in Hefei, will be paid on a per-vehicle basis

6. R&D thrust

EU[15] has provided significant R&D thrust by establishing a centrally coordinated program to drive collaborative, large-scale R&D efforts to create battery market worth €250Bn p.a by 2025[18]. Under the umbrella of EBA250, Batteries Europe has been established[14] to elaborate the strategic R&I agenda and technology roadmap for batteries, encompassing all technology readiness levels (TRLs) and stages of the value chain. Horizon Europe[19], EU's key funding program for R&I, committed a €95B+ funding till 2027 for sustainable mobility and clean energy R&I, including €1.4B+ funding for battery R&I programs. The most important battery projects funded by Horizon Europe include:

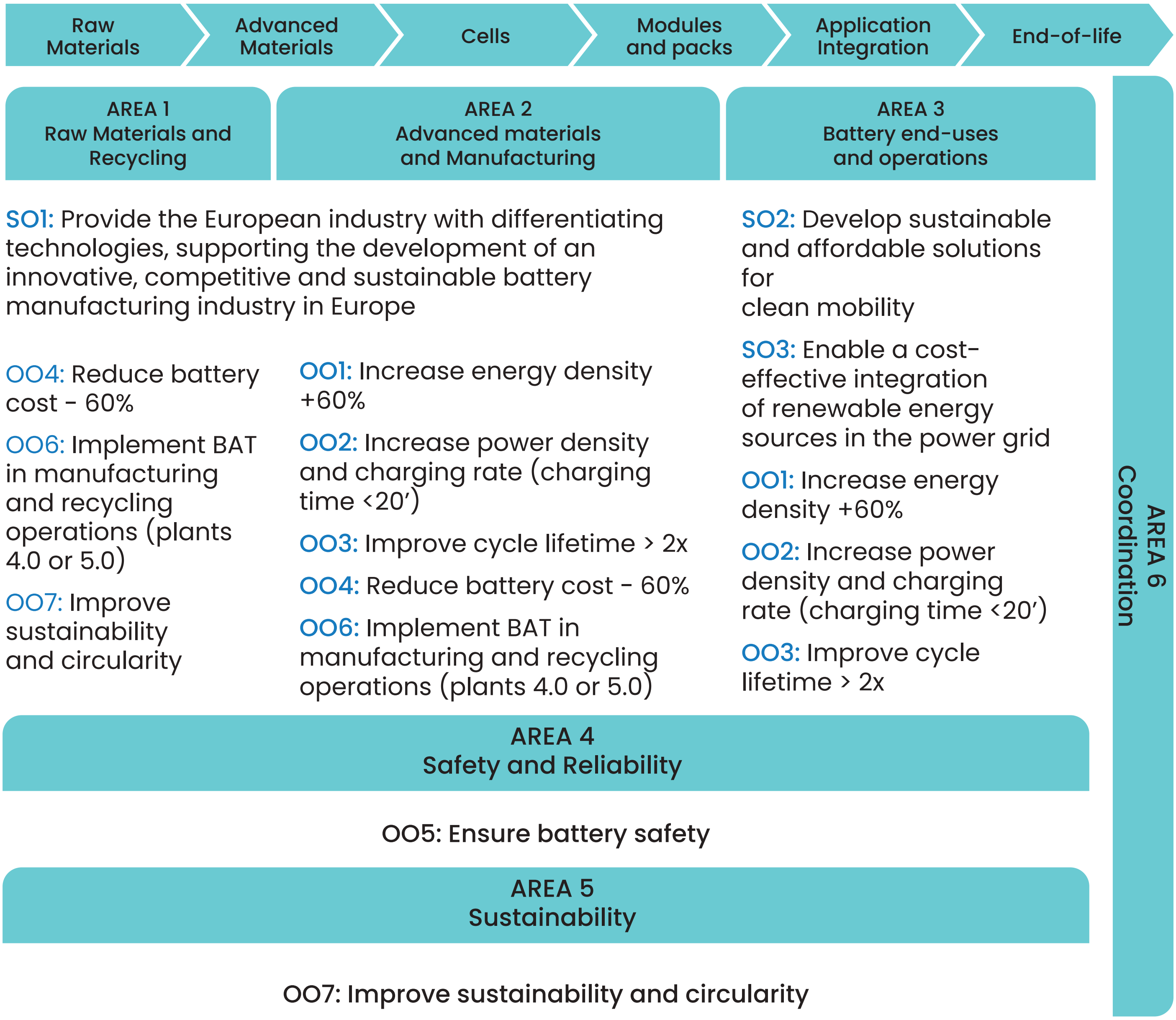
- Battery 2030+[17] is EU's large-scale, long-term research initiative tasked with inventing batteries of the future (for e.g., self-healing batteries). It essentially focuses on low TRLs and identifying disruptive technologies. The initiative has a dedicated budget worth €42M from Horizon Europe, across 7 Battery 2030+ projects. The vision of Battery 2030+ is to invent sustainable batteries of the future, providing European industry with disruptive technologies and a competitive edge across the full value chain.
- BATT4EU[16] [32], a public-private partnership, was set up to focus on the most urgent R&I priorities across the European battery value chain – incremental innovations in existing battery technology (e.g., 60% improvement in energy density, 2x cycle lifetime). The partnership comprises 181 members and 18 topics of discussion, funding support worth €925M from Horizon Europe, and a vision to establish, by 2030, the best-in-class innovation ecosystem to boost a competitive, sustainable and circular European battery value chain.

Exhibit 18: Multiple mechanisms used to supplement EV incentive packages



Note: SET plan: Strategic Energy Technology Plan, R&I: Research & Innovation

Exhibit 19: Key R&I areas of BATT4EU



SO – Specific Objective, OO – Operational Objective, BAT – Best Available Technology

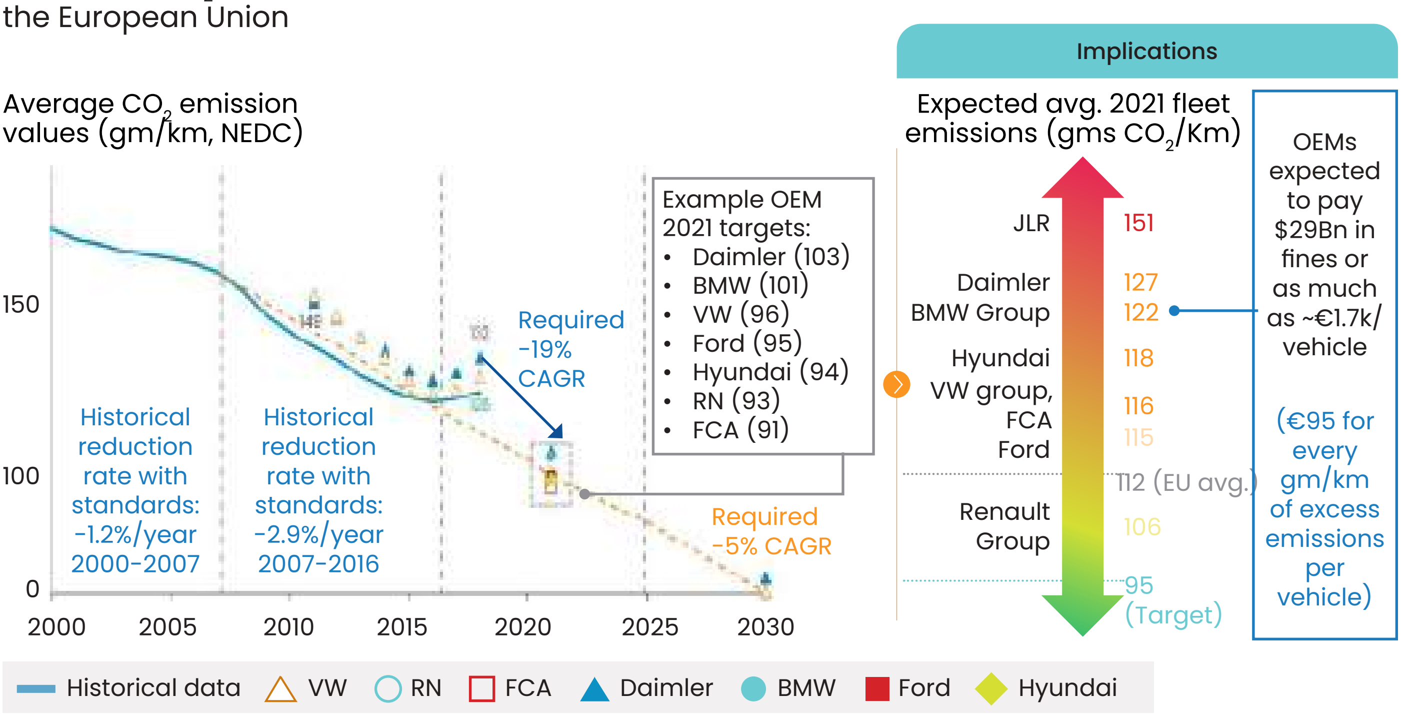
2.2.3 Ecosystem enablers

7. Sales restrictions / emission regulations

Some countries have also taken aggressive regulatory stance by tightening emission norms to drive OEMs to electrify their fleets or announcing targets for national ban on ICE vehicle sales. Some of these exemplars are highlighted below:

- Stringent policies have been implemented by the EU[20][21], China, and the US to regulate the CO_2 emissions. In European Union, OEMs are penalized €95 for every g/km of excess emissions per vehicle. With emission targets becoming even more stringent over the next decade, OEMs in Europe are accelerating the roll out of electric vehicles. Similarly, in China, stricter emission standard (China VI) and dual credit program[22] are driving rapid EV penetration growth (EV target % requirement has increased from 8% in 2018 to 16% in 2022; expected to be 27% by 2025).

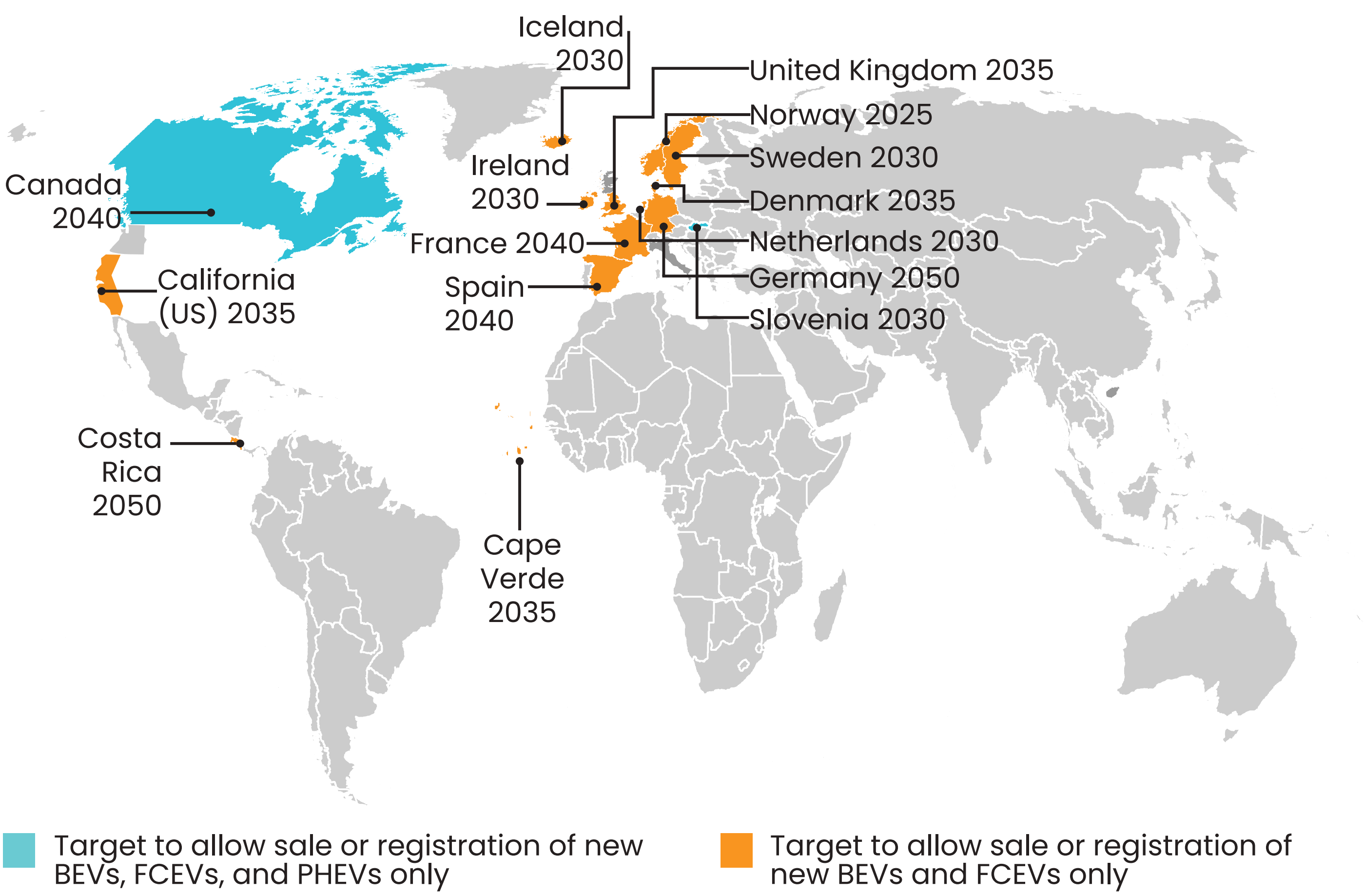
Exhibit 20: CO_2 emission targets for Europe set by the European Parliament and the Council of the European Union



1. Each OEM has its own 2021 emissions target based on average vehicle mass

- Several countries across the world have announced national bans on sale of ICE vehicles[(23)]. Europe is leading the ICE phase-out with several countries banning the sales of fossil-fuel based vehicles in the upcoming decade (Norway from 2025; Iceland, Netherlands, Ireland, Sweden from 2030; UK, Denmark from 2035; France, Spain from 2040).

Exhibit 21: ICE vehicle sales ban timelines across countries



1. Only includes countries permitting sales of BEVs, FCEVs, PHEVs. Germany considering ICE ban from 2035, currently part of International Zero emission vehicle alliance pledging ban by 2050

- There are several other national/local governments that are mandating electrification of fleets / public transport in the upcoming decade (e.g., California has mandated 90% fleet electrification for ride-hailing players by 2030; Shenzen has already transitioned to 100% electric buses)[24].

Exhibit 22: Fleet electrification targets for state-owned vehicles across countries

Entity	Country	Year	Target
Shenzen Govt.		2020	100% electric bus fleet for public transport (achieved)
Govt. of Amsterdam		2022	100% electric buses in city center
C40 cities (97 cities representing 1/12th global population)[1]	C40 CITIES	2025	Emission free buses only to be procured
Govt. of California		2030	90% of all ride-hailing services' miles to be electrified
Govt. of California		2033	All taxis and private hire vehicles to be zero emission
		2037	Bus fleets to be electrified
USA state govts. (California, New York, Washington)		2035	100% government vehicles to be electrified

1. Pledge taken by state governments as part of Net zero carbon 2040 pledge by 'The Climate Group'

8. Charging infrastructure adoption

Charging infrastructure has been given a significant boost in countries like China, Netherlands, and Germany. Respective governments in all 3 countries have issued several policies to support charging infrastructure deployment at an accelerated pace including a national masterplan, guidelines for subsidies and supporting ecosystem to enable public private partnerships. Highlighted below are the key policies and regulations in each of these countries:

- China followed a public-led model for installation, ownership & operation of charging stations through the State Grid during inception phase. In 2015, China developed a national charging infrastructure masterplan outlining city tier-wise targets for the next 5 years, fast vs. slow charging split, and total investment of RMB 150B by 4 ministries. Capital subsidies on equipment, land and installation cost were provided to attract private sector investment (e.g., 30% subsidy provided in Beijing) and scale up deployment of charging stations across the country to support EV adoption[25] In addition to this, grid upgrades were also mandated as responsibility of the grid operator by the state. The Electric Vehicle Charging Infrastructure Promotion Alliance (ECVIPA) was also formed in 2015 to give policy recommendations related to charging infrastructure in China. The body comprised of representatives from all stakeholders – EV OEMs, grid operators, EVSE manufacturers, CPOs and MSPs along with the relevant ministries.
- In Netherlands, similar to China, charging infrastructure deployment was public led in the inception phase through the ELAAD foundation comprising of 6 state-owned grid operators. Scale up happened through large scale transfer of ownership to private players. Formation of a public-private platform, known as the Formula E Team, by the Ministry of infrastructure in 2009 encouraged dialogue between all stakeholders and helped build trust in the ecosystem in the initial phase. In 2011, the government released the E-Mobility action plan setting national level targets for 2015 and 2020 along with announcing financial support to attract private investment. To improve business case for private sector, both capex and opex subsidies were provided.

Exhibit 23: Public land used as lever to improve business case for private sector in Netherlands

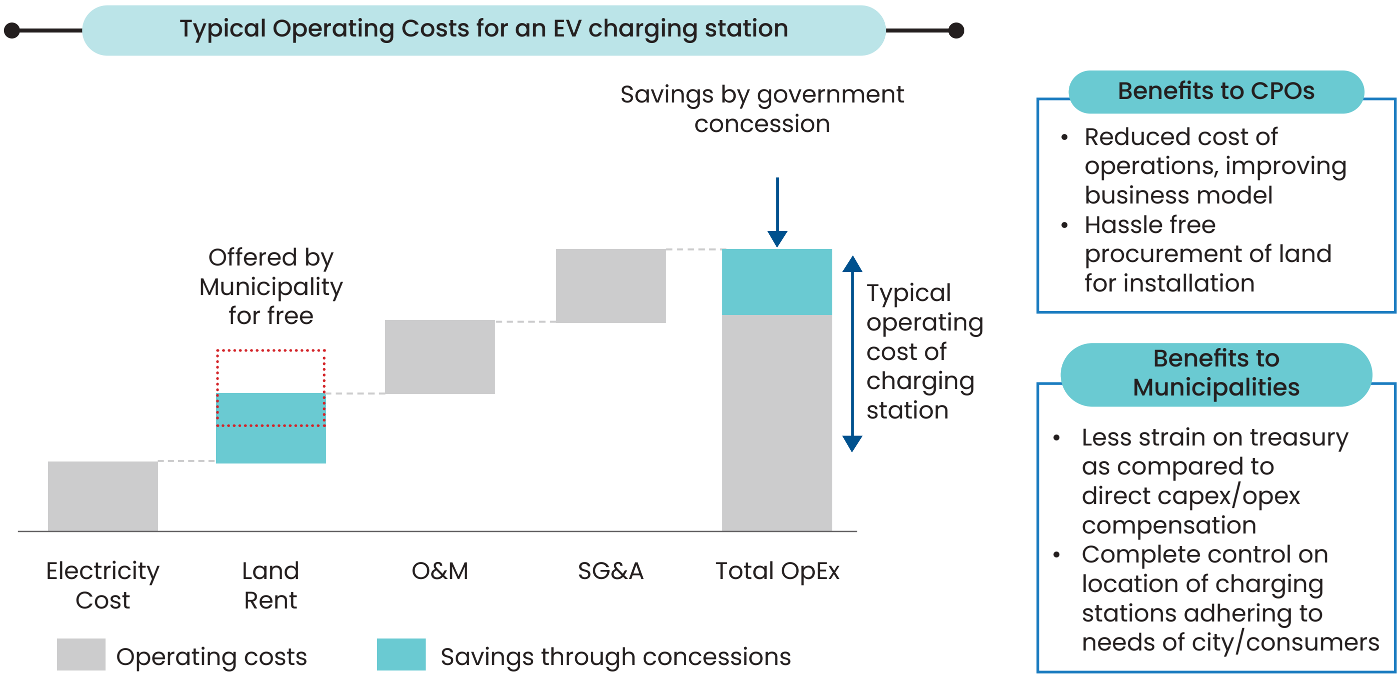
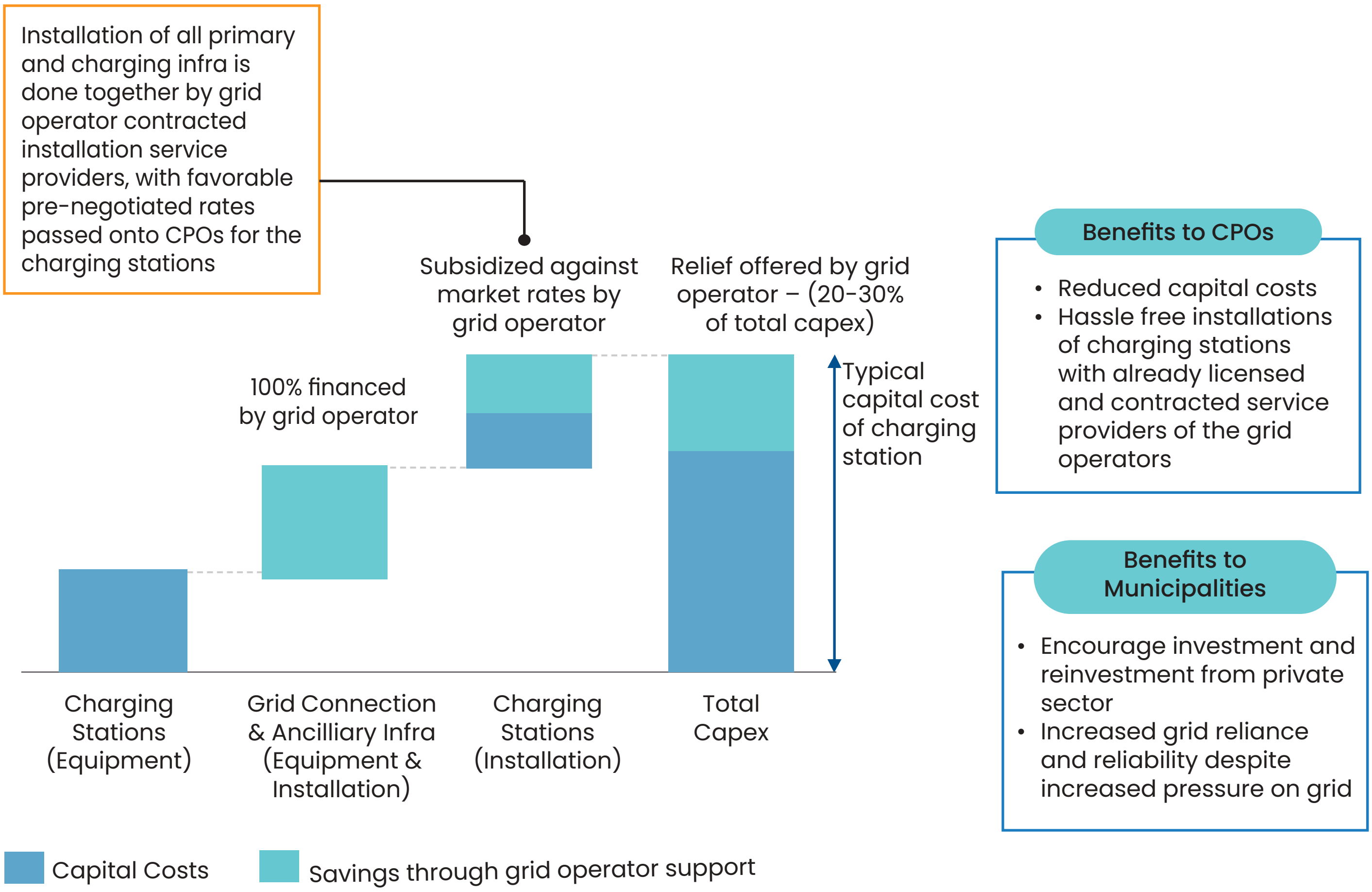


Exhibit 24: Grid connection and installation support offered in Netherlands



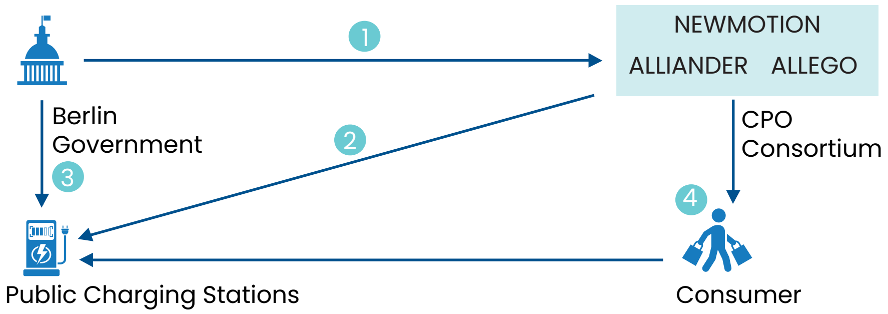
- On the other hand, in Germany, initially charging infrastructure development was private led. Subsidies during this period were distributed without sufficient guidelines and conditions leading to insufficient and sub-optimal charging network with underutilized and commercially unviable stations. 2015 onward, the German government has taken a more programmatic approach with public-led charging infrastructure deployment. The new approach is based on 3 parts – a national masterplan with clear targets for charging infrastructure, public-led ownership and financing, and targeted subsidies program with clear guidelines.

Exhibit 25: Public-led approach to accelerate deployment of charging stations in Germany

1 Top-down approach through a national masterplan helped to guide deployment

- Clear targets for deployment
- Defines support measures
- Clarify regulatory framework

2 Taking ownership of public charging infrastructure allowed public sector greater control over deployment of EV charging stations



1. Awards 5-year contract to consortium through competitive tender
2. Consortium deploys charging stations based on govt requirements
3. Govt finances and owns assets, and is responsible for any major capex
4. Newmotion issues charge card for access to all stations

3 Programmatic and targeted approach to subsidies helped in driving effectiveness

- Six funding calls from 2016/17 to 2020 were executed , guided by "Funding Guidelines for EV Charging Infrastructure in Germany"
- Each funding call of subsidies were targeted to focus on different needs (e.g. areas with high demand)
- Conditions for subsidies were clearly defined (e.g., charging station availability on all days, use of plug types, interoperability)

Key Takeaways

Having a well-defined masterplan with deployment that target specific and known charging needs can help communicate commitment by the government and provide visibility and confidence to both the private sector and the consumers

Provision of subsidies for charging stations that are paired with the supporting guidelines and conditions (e.g. interoperability requirements, obligation to submit biannual reports during service life of charging stations) can help ensure subsidies achieve the desired impact

9. Standards and specifications

Different governments have taken different approaches to standardize EVSE hardware and drive interoperability between charging stations for consumers. While some governments have issued mandates, others have tried to maintain control through tender guidelines and requirements. Details on standards issued by select countries have been highlighted below:

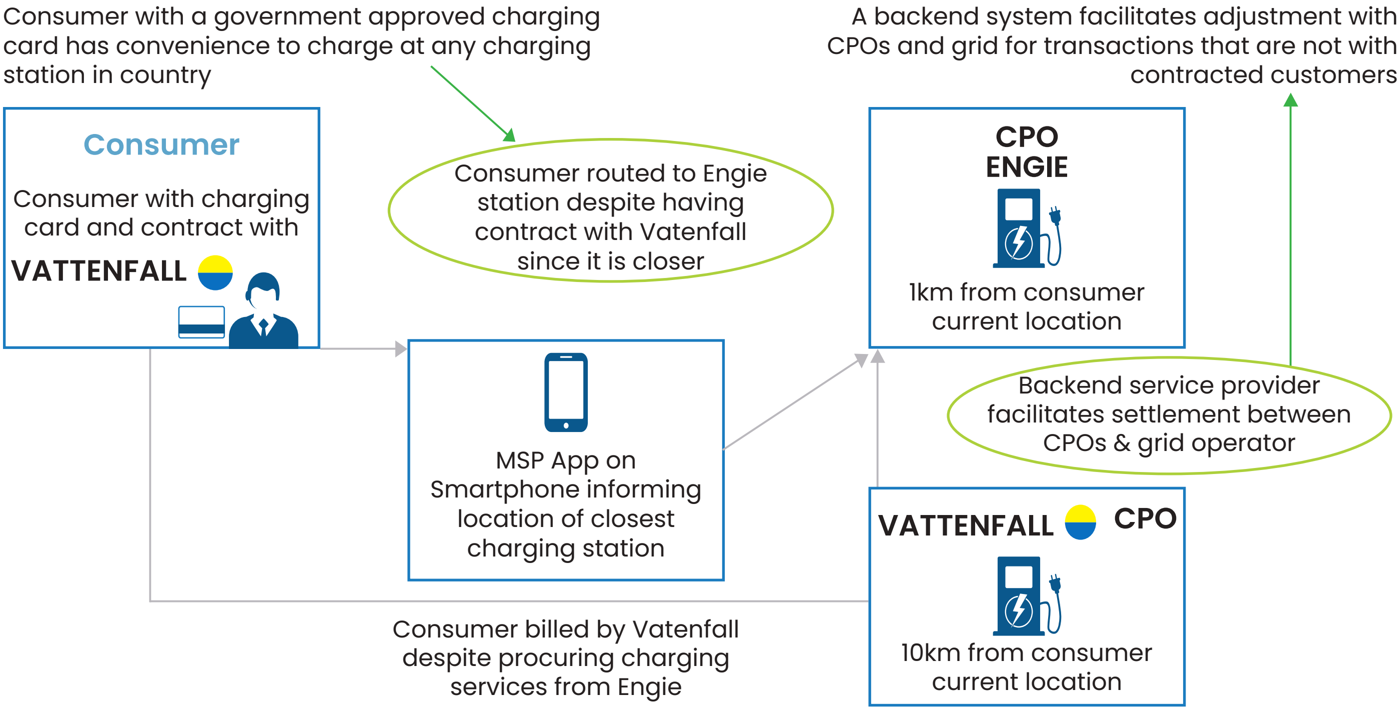
Exhibit 26: EVSE standards and guidelines across countries

	UK	China	USA	Germany	Netherlands
EVSE Standardization	No standard defined	Govt mandated; EV OEMs & EVSE players to adopt national standard	Utilities, CPOs ensure availability of all plugs; no regulation	Minimum technical req. specified in circular for public charging stations	Plug type standards driven through tender requirements
Interoperability (Network)	Interoperability initially achieved through Source London (publicly owned), but declined after privatization	Only stations on subscribed CPO network available to consumers. Govt now pushing for inter-connected platform among CPOs	Multilateral agreements between private players (CPOs & OEMs) to facilitate roaming. No government intervention yet	Consortium for public charging infra provides charge card to access all public EV charging stations	MSPs provide charge card which allows charging at any CPO. Enabled by backend system that settles dues between the CPOs and grid operators.

Low Medium High

In Netherlands, the government has mandated roaming as a requirement for CPOs and facilitated the development of a back-end system for communication between MSPs to ensure seamless interoperability. Consumers with government approved charging cards have the convenience to charge at any charging station in the country.[27]

Exhibit 27: Interoperability of charging infrastructure in Netherlands



In addition to charging stations, guidelines have also been issued for standardization of battery swapping stations by select countries. Taiwan is one of the few countries where battery swapping solutions have been able to ac hieve scale. Government policies have focused on making battery swapping a viable solution right from the early stages in 2011 through standardization and capital subsidies.

Exhibit 28: Battery swapping policies in Taiwan

Policy focus	Focus area	Details
Standardization	Hardware	• Battery specifications: 48V nominal voltage, weight <10kg, dimensions – 270x95x160 mm, capacity – 10Ah • Connector: 4 power pins (30A/pin), 6 signal pins (2A/pin)
	Software	• Protocol interface: CAN bus protocol 2.0
	Safety	• Battery safety standards: CNS15387, CNS15424-1
Ecosystem development	Enforcement mechanism	• Necessary for models with swappable battery to adhere to above standards to be eligible for purchase subsidy offered by EPA
	Incentive for BSS operators	• Offered 200,000 NTD construction subsidy to Gogoro. 300 GoStations fully funded & subsidized by CPC (national oil company) • Currently, offers 300,000 NTD or 49% installation cost as subsidy

10. Upskilling workforce

European Union has launched following key initiatives to upskill or reskill its workforce to transition the automotive industry to electric vehicles:

- EU's ALBATTS[30] is a collaboration across 20+ organizations and 11+ EU countries to develop a blueprint for education and training for the battery production sector (conduct skill-gap assessment, identify skills of the future and curate relevant L&D modules)

Exhibit 29: EU's ALBATTS is working towards mapping current state of technology and syncing new skills demand with supply of education and training in battery sector

> Vision: To make Europe a competitive player in the battery ecosystem, by empowering European industry with a high-skilled workforce and expertise in batteries development and production.

ALBATTS

€3M EU funding

- Brings together 20 organizations from 11 EU countries
- To promote cooperation between all stakeholders in the battery and electromobility value-chain, to develop a blueprint for education and training for the battery production sector

Key thrust areas

Sectoral Intelligence
- Monitor developments in the battery sector

Sectoral skills strategy
- Recommendations to assure efficient education and training in emerging battery sector

Education and Training
- Detailed curricula, training materials and pilot training courses

Dissemination measures
- Promotion of the project's activities towards supporting of the skills agenda

Select examples of programs underway

- Fostering partnerships with industry players to identify battery skills of the future, for e.g., ALBATTS[2] in collaboration with Northvolt has identified job roles & skills for battery manufacturing and competencies required now vs. in the future
- MOOC[1] 2020: ALBATTS[2] and DRIVES[3] jointly launched a platform to reskill and upskill workforce in the Automotive sector through home education. Sample courses below:
  - » Energy Storage – understanding the battery revolution
  - » Battery Manufacturing: Trends in Battery Engineering
  - » Innovation Strategies for Electric Mobility: The StreetScooter Case

1. Massive Open Online Course 2. The Alliance for Batteries Technology, Training and Skills 3. Development & Research on Innovative Vocational Education Skills

- European Battery Academy[31] set up, with €10M+ funding, to provide a comprehensive learning service offering, convening the knowledge of industry and academia from 18 countries to upskill local workforce. The European Battery Academy woks in close coordination with EBA250 members to identify key skills needed across the value chain.

Exhibit 30: New EBA Academy launched to boost skills for battery ecosystem in Europe

> **Vision:** To provide an education and training ecosystem for businesses, convening the knowledge and experience of researchers, entrepreneurs, businesses, thought leaders, and key players from 18 different countries into a single, comprehensive learning service offering

€10M EU funding

- Based on continuous input and feedback from European projects (e.g ALBATTS, Battery 2030+, etc) the urgent need for skills is identified
- 30 modular learning packages, based on real-world scenarios, launched to bridge the growing skill-gap

Key thrust areas

Not exhaustive

Awareness
- Understanding battery storage
- Energy Systems Integration: an intro

Discovery
- Battery bash (AR)
- Battery workbench (VR)
- Battery storage opportunities & uses

Basic
- Battery storage & smart grid applications
- Fundamentals on batteries

Advanced
- Battery management systems
- Managing Energy Analytics
- Materials to electrodes, Electrodes to cells

Expert
- Solid-state batteries
- Master in Energy Storage

Endeavor to upskill 8,00,000 workers by 2025

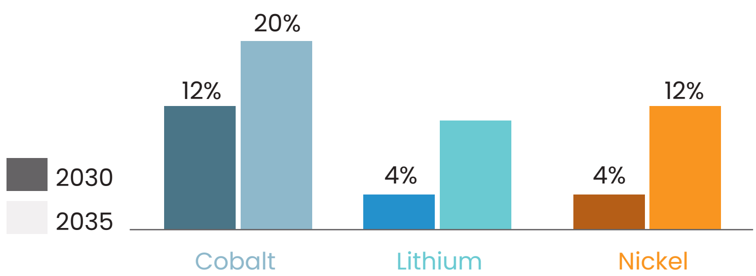
- Spain and France have already signed up to train up to 150,000 workers each under EBA Academy training programme
- Hungary is looking to up-skill up to 40,000 workers with the help of the Academy

11. Circular economy / urban mining

EU's new proposal[23] for Waste Battery Regulations (expected to go live by end of this year) increases OEM responsibility and introduces guidelines and targets on battery/ELV recycling and recovery. The initiatives are briefly discussed in Exhibit 30 (next page). The proposal covers 4 key areas - cell tracking mechanism, battery management system, recycled content requirement, and recovery and recycling efficiency.

China also has strong policies around the treatment of end-of-life batteries. OEMs have the responsibility to collect the used batteries. Traceability of batteries and cells is ensured through encoding and tracing via national database (as per National Standard Coding Regulation for Automotive Traction) that enables tracking at the cell level. Battery design circularity is mandatory for the battery manufacturers in order to improve the scalability of recycling process. Target recovery rates are set for different battery components - 98% for Nickel, Cobalt, Manganese, 85% for Lithium to ensure high efficiency.

Exhibit 31: EU's proposal for Waste Battery Regulations

Key Area	Proposed regulations and timelines	OEM responsibilities
Cell tracking mechanism	• Unique QR code to be created (acting as a passport) that records key battery characteristics such as manufacturing date, battery composition, expected lifetime, etc. in a centralized data system to ensure traceability throughout battery life cycle • Centralized data system accessible by third parties to be set up by European Commission • Regulation effective by 01/2026, implementation acts by 12/2024	• Accuracy and completeness of data to be ensured • Updation of battery status in case of repair or repurposing
Battery mgmt. system	• (BMS) to be included with data on relevant parameters for determining state of health and expected lifetime • Access to data provided to purchaser of battery and any third party acting on their behalf to assess residual value, capability for future use, facilitate reuse, repurpose or remanufacturing	• Collection of required parameters by BMS to be ensured • Interface for third parties to access relevant parameters to be created
Recycled content requirements	• Usage of recycled content (material recovered from waste) of Co, Li, Ni in the batteries to be reported from 1/2027 • Recycled content targets set for Co, Li, Ni from 1/2030; targets to get stringent from 1/2035; Recycled content targets: 	• Documentation of recycled content of active materials to be ensured • Targets on recycled content to be met post 2030 for batteries that are either purchased or manufactured
Recovery and recycling efficiency	• Recycling efficiency targets for Li-ion batteries set to 65% of average battery weight from 1/2025 and 70% of average battery weight from 1/2030 • Target recovery rates at material level set from 2026; targets to get stringent post 2030 Cobalt 1/2026:90% 1/2030:95% Lithium 1/2026:35% 1/2030:70% Nickel 1/2026:90% 1/2030:95% Copper 1/2026:90% 1/2030:95%	• Batteries to be designed to ensure recyclability • Recycling targets to be met through collaboration with suitable recyclers

Conclusion

To drive adoption of EVs, globally governments have taken a holistic approach in building policies & regulations across demand & supply side drivers along with focus on ecosystem enablers.

For example, across Europe there are several examples of targeted policies across each of these levers to accelerate adoption of EVs. To stimulate demand, European countries offer both direct purchase subsidies and tax exemptions, supported by other incentives like preferential access to bus lanes, free parking, etc. and availability of lucrative financing options (e.g., low-interest loans) for EV and EVSE projects. They have also launched several campaigns to raise consumer awareness, e.g., `Go Ultra Low' campaign in UK.

To support this growing demand, the European Union has also put in place several mechanisms to boost the local supply chain. EBA250 has been created with the objective of localizing the entire battery supply chain - from raw materials to final EV assembly. Incentives for manufacturing are offered in the form of capital grants through IPCEI and financing support from EIB, EBRD. They have also established a strong R&D thrust through centrally coordinated programs like Batteries Europe and Horizon Europe covering both strategic agenda for R&I and funding mechanisms.

Along with demand and supply side levers, governments in Europe have also focused on building ecosystem enablers by imposing ICE sale restriction targets and tighter emission norms for OEMs to drive portfolio electrification. Emphasis has also been laid on the development of a widespread public charging infrastructure through building national network masterplan, fostering public-private partnerships, and providing subsidies for charger installation. Governments in countries like Germany and Netherlands have also set mandates to facilitate standardization and interoperability between charging stations. In addition to this, EU is also actively working on upskilling the workforce through centrally co-ordinated initiatives like ALBATTS and EBA Academy as highlighted earlier. To round this up, Waste Battery Regulations are also currently in the proposal stage aimed at creating a circular economy for EVs.

As evident from above, it is essential to develop policies & regulations covering the entire EV ecosystem to boost adoption. In the next section, the current policy landscape in India for the manufacturing drivers has been covered, followed by a comprehensive deep dive of the entire EV value chain to identify areas where additional government thrust is required to further develop the local supply chain.

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78%
EV

03

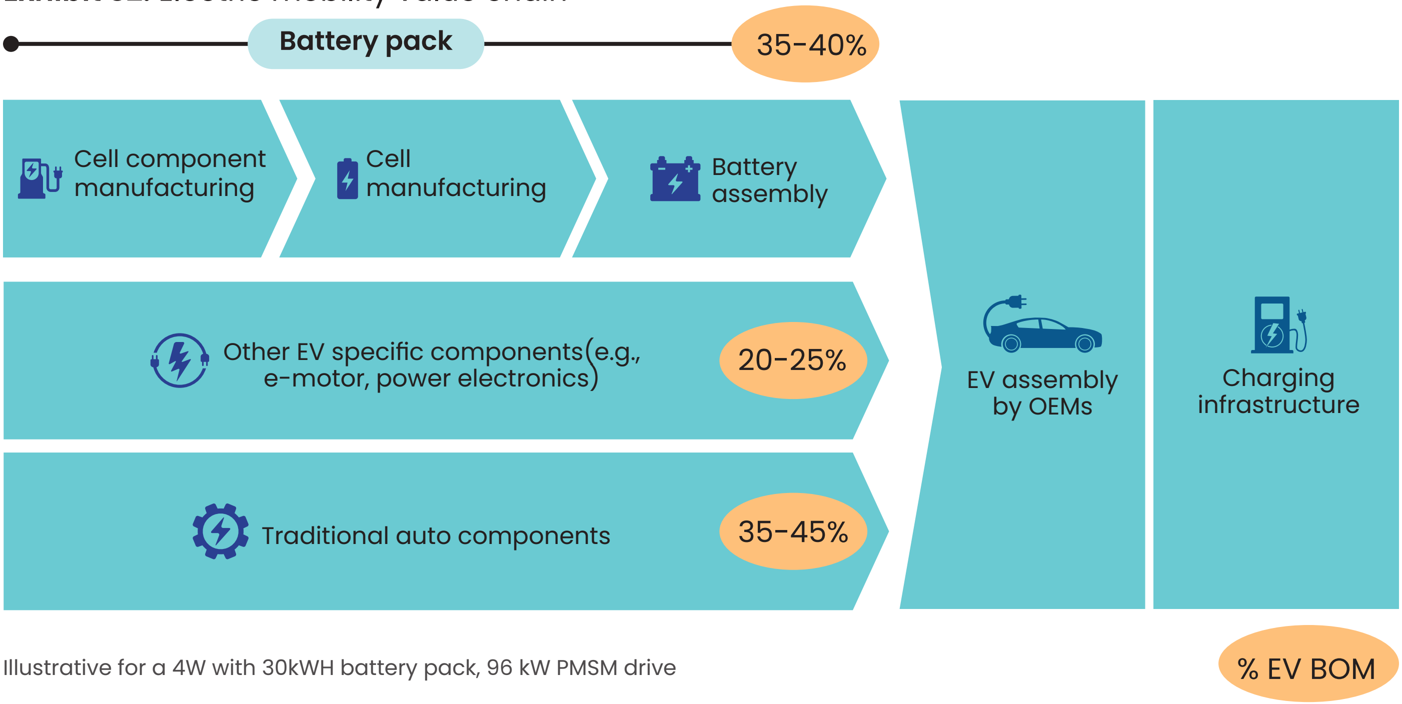
Assessment of EV Supply Chain


EV
CHARGER
6
Charging
Ready

3.1 The EV value chain

The electric mobility value chain includes the battery pack, consisting of cell components, cell manufacturing and battery assembly; other EV specific components like e-motor, power electronics, etc., and traditional auto components. EV specific components form bulk of the cost of the EV – around 55-65% out of which the battery pack is the highest cost component comprising 35-40% of total bill of materials. Traditional auto components form the remaining 35-45%. The value chain further consists of assembly of EVs by OEMs and the set-up of supporting charging infrastructure.

Exhibit 32: Electric mobility value chain



Illustrative for a 4W with 30kWH battery pack, 96 kW PMSM drive

The following components have been considered under each part of the value chain:

1. **Cell component manufacturing-** Cathode Raw Materials (E.g., lithium, nickel, cobalt, manganese), Cathode Active Mix, Aluminum Foil, Carbon Powder, Copper Foil, Graphite, Electrolyte, Separators and Other Consumables (E.g., Packaging Foil, Binder, Tape, Glue, etc.)
2. **Cell manufacturing-** Assembly of cell components to form a cell
3. **Battery module and pack assembly-** Sensors, Battery Management System, Thermal Management System, Module Casing, Interconnects & Circuit Protection, High Voltage Electric Cables, Pack Housing
4. **Other EV specific components-** E-motor drive (e-motor & transmission), Power electronics (motor controller, onboard charger, dc-dc converter, power distribution unit, vehicle control unit), EV electricals
5. **Traditional auto components-** Components common to EV and ICE cars, e.g., chassis/body, electronic control units, etc.
6. **EV assembly by OEMs-** Final assembly of electric vehicles for 3W, 4W, LCV and Buses
7. **Charging infrastructure-** AC and DC charging infrastructure equipment (EVSE) for all vehicle categories

3.2 Impact of current government initiatives

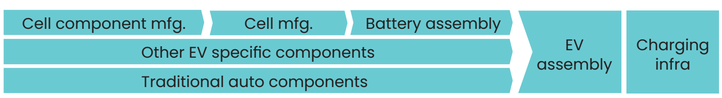
The Government of India has launched multiple initiatives of late to drive localization of the EV value chain. From the different PLI schemes to localization mandates via the Phased Manufacturing Programs, significant steps have been taken in this direction. Many state governments have also come up with EV manufacturing promotion policies to enable setup of local EV supply chain footprint.

Exhibit 33: Current policies targeting EV supply chain localization

	Policy	Targeted value chain segment	Implementation stage	Key elements
Financial incentives	**ACC PLI**[36][37]		• Announced in 2021 • Bidding completed, 4 players selected	• 50GWh capacity to be set up by 2026/27 • INR 18.1k crore incentives by govt.; 60% domestic value add criteria within 5 years
Financial incentives	**Auto PLI**[38]		• Announced in 2021 • 20 players approved across vehicle segments	• Budgetary outlay ~INR 26k crore • Proposed investment of INR 45k crore by approved players (only by EV OEMs) • 50% domestic value addition criteria
Financial incentives	**Auto Component PLI**[38]		• Announced in 2021 • Bidding completed, 75 players selected	
Financial incentives	**Large Scale Electronics Mfg. PLI**[39][2]		• Announced in 2020 • 1st round results declared • 2nd round bidding opened	• INR 11k Cr investment committed in 1st round by 20 companies • 30 companies to be chosen in Round 2
Financial incentives	**Semiconductor & Display Fab PLI**[40][2]		• Announced in 2021 • Bidding completed; results to be announced	• INR 76k crore comprehensive program • 20 companies have submitted EOIs
Financial incentives	**State-level incentive programs**[41]		• Varying incentives available across 13 states	
Localization mandates	**PMP program (xEV components)**[42]		• Announced in 2019 • Deadlines extended in Oct'21	• 16 key EV components targeted to be localized by Apr'22
Localization mandates	**PMP program for (EVSE components)**[43]		• Announced in November 2021	• 12 key EVSE components targeted to be localized by Jan'23

1. Eligibility criteria for FAME 2 subsidy

2. Certain electronic components like semi-conductors are used to produce key battery sub-components like BMS



These initiatives have resulted in varied starting positions across the EV value chain. Current policies are expected to bring high localization in some set of components while additional thrust will be needed to drive further localization of other parts of the value chain

High localization expected

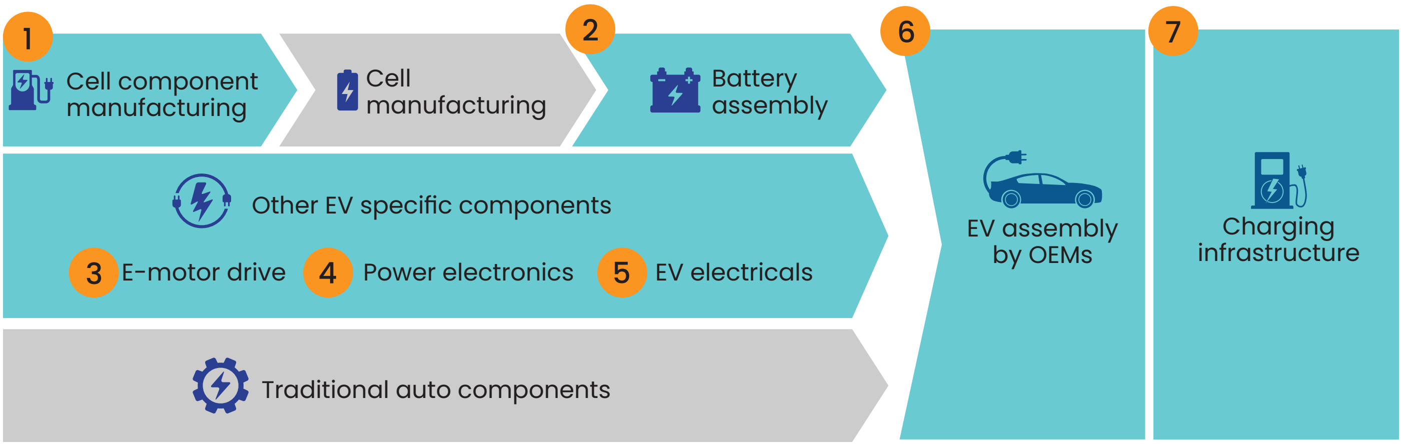
1. **Cell manufacturing -** ACC PLI is expected to achieve 50GWh of Li-ion cell capacity in next 4-5 years, in line with current policy measures.
2. **Traditional auto components –** Many components are already localized at scale in India. Assembly for components which are not already localized is covered under Auto Component PLI.
3. **EV assembly-** This segment is already localized at scale in India for 2W, with the current policies ensuring an INR 45k crore investment proposed for Auto PLI.
4. **Other EV specific components-** Existing policies such as Auto Component PLI (covering motors, motor controllers, high voltage harnesses and connectors, power electronics, onboard chargers, etc) and PMP are driving local component assembly, with several players entering and announcing investments.
5. **Charging infrastructure-** Driven by increasing scale and PMP thrust, assembly of DC chargers and software programming is already localized.

Additional thrust required

1. **Cell component manufacturing -** While the ACC PLI will accelerate pace of cell manufacturing indigenisation, targeted interventions will be required to boost development of local cell component supply chain in India.
2. **Battery assembly –** There is strong expectation of the assembly being localized at scale in India, owing to the current policies. However, contactors are currently being imported due to nascent semiconductor and electronics manufacturing ecosystem in India.
3. **Other EV specific components –** Some sub-components like rare-earth magnets for e-motor are still imported due to lack of local RM processing and limited enforcement of PMP. Additional support for ensuring consistent supply of key RMs is required to power localization.
4. **Charging infrastructure –** Potential gaps, caused by limited enforcement of PMPs for EVSE hardware sub-components, need to be closed to drive localization.

Based on the above analysis, 7 areas have been prioritized for benchmarking. An in-depth supply chain benchmarking has been carried out for each of these 7 areas, at a sub-component/category level.

Exhibit 34: 7 areas prioritized for benchmarking



3.3 Methodology for deep-dive

A step-by-step approach was followed for each of the 7 priority areas to prioritize sub components that are still imported and identify additional government interventions that would be required basis global benchmarks.

Understanding the detailed value chain and current localization landscape for 7 priority areas

Across the globe, barring a few large Chinese players like BYD and CATL, the EV and EV component supply chain is fragmented with multiple different players operating across the value chain. Our analysis elucidates that there is limited backward integration in this industry implying that localization of one component in the value chain would not necessarily accelerate localization of another. Therefore, for each of the priority areas, the value chain was understood and each component was broken into subcomponents. E.g., cell component manufacturing was further disaggregated into cathode mix, aluminum foil, carbon powder, copper foil, graphite, electrolyte, separators, and other consumables to identify the key bottleneck(s) to localization. Next, the current supplier landscape and localization status at a sub-component level was charted out to identify components still being imported and prioritize those for further analysis.

Exhibit 35 : Exemplar of Steps 1 & 2 - Cell component manufacturing supply chain landscape in India

Salience of key components in cell manufacturing

	Raw Materials	Cathode Mix CAM	Aluminium Foil	Carbon Powder	Copper Foil	Graphite Anode Active Material	Electro-lyte	Separa-tors	Other
Key Players	Lack of lithium, nickel and cobalt reserves in India Limited reserves of Manganese in India	Cathode active Material (only global players) Cathode binders Select Indian players	Only Global Players	Select Indian players	Only Global Players	Graphite Anode Material Select Indian players are conducting pilots Anode binders Select Indian players	Only Global Players	Only Global Players	Packaging foil, binder tape, glue etc.
Cost Salience	24-26%	14-16%	9-11%			6-8%	9-11%	6-8%	4-6%
Localization Status	Imported as part of cell	Imported as part of cell ✓	Imported as part of cell ✓	Manufactured in India	Imported as part of cell ✓	Manu-facturing pilots ongoing in India ✓	Imported as part of cell ✓	Imported as part of cell ✓	Manufac-tured in India

Imported components manufactured only by global players

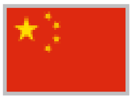
✓ Prioritized for benchmarking

1. As a % of Total material cost of battery (NMC 811 cylindrical) ; module & pack assembly make up the remaining 19-23%

For prioritized sub-components, mapping drivers of localization in key geographies and starting point in India

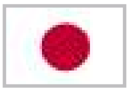
For each prioritized sub-component, geographies where the subcomponent is already localized at scale as well as those geographies where localization is currently underway were identified. Next, a thorough analysis was conducted to identify key drivers of localization in each of the identified geographies, e.g., proximity to raw materials, capital subsidies or subsidized land form the government, technology leadership, etc. These learnings will help emulate the tried and tested best practices from across the globe to accelerate localization in India. Therefore, next, key success factors for India were contextualized to identify imperatives that would drive capacity investment in India. Having done that, India's starting position against each of the success factors was baselined based on industry outlook, investment activity, policy support, structural challenges like cost non-competitiveness, etc. This structured methodology was repeated for each area of the e-mobility value chain to identify key challenges to localization..

Exhibit 36: Exemplar of Steps 3 to 6 for cell component CAM - Outlook for localization in India



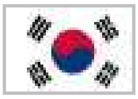
China

- Downstream demand
- Cost Leadership
- Policy Support
- (E.g., subsidized land)



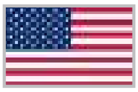
Japan

- Technology leadership in CAM processing



South Korea

- Downstream demand and proximity to battey makers
- Technology leadership in CAM processing



USA

- Grants given by government to set up CAM facility

Europe

- Downstream demand andproximity to customers
- Capex grants given by European government as well as supportive battery eco-system created by EC

Key Success Factors	Criticality	Current Starting Point	Details
Sufficient local downstream demand (~20-30GWh)			• Being addressed by ACC PLI; 50GWh Li-ion cell capacity expected by 2026/27
Enabling eco-system to support large scale investment			• 8-10% disadvantage at unit cost for manufacturing locally compared to China, due to unavailability of local RM and RM processing facility • 10-15% capital grants provided by European countries to invite local investment (providing superior ROCE)
R&D experience in CAM to ensure high yield; Labor skilled in inorganic chemistry			• Individual university research groups have initiated research in this field (e.g., CAM research being conducted by IIT Madras and KIT2, Germany) • Lack of skill development programme to upskill workforce

Strong Moderate/On-track Weak

1. Localization underway 2. Karlsruhe Institute of Technology

Exhibit 16 highlights the above-mentioned process for one of the prioritized sub-components viz. CAM NMC. Further, the unit cost of producing CAM NMC in India vs that in China was also analyzed to bring to light any structural disadvantages facing India. Our analysis shows that China enjoys local processing of CAM precursor (PCAM), which is not the case for India, leading to additional import duty burden, logistics costs, and higher RM (PCAM) cost for ex-Chinese buyers. Secondly, China enjoys 10-15% cheaper power owing to policy support. These factors contribute to ~8-10% disadvantage for production at unit cost in India as compared to China.

Separately, it was also observed that globally, governments are attracting investments in CAM plants by offering ~10-15% capital grants to improve project ROCE. E.g. BASF received €175M capex grant through EC's IPCEI for setting up a CAM production facility in Finland.

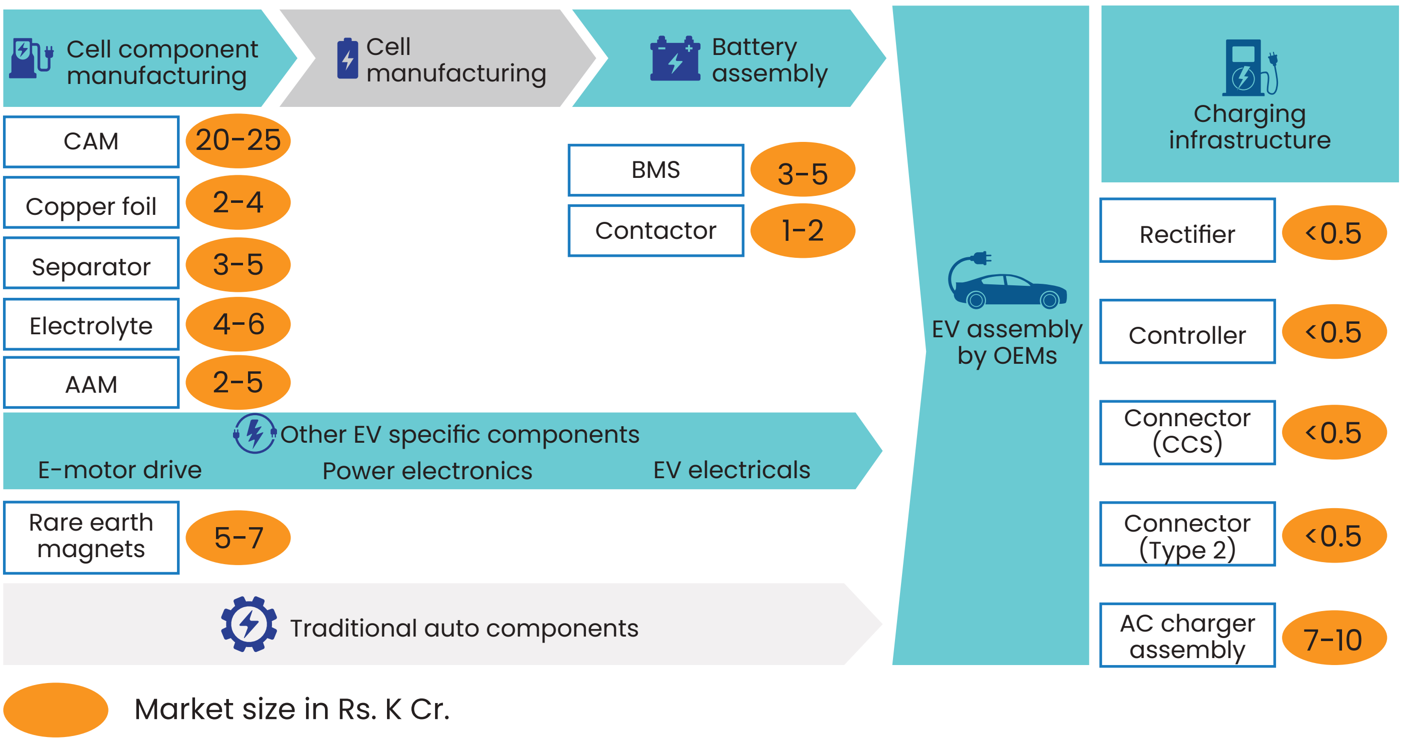
Creating a view on potential government interventions to drive localization

Having developed an intricate understanding of the key challenges to localization, the possibility of localization at a sub-component level was estimated. This facilitated the identification of specific government interventions that are required to drive localization of each prioritized sub-component across the EV value chain.

3.4 Challenges to localization & key interventions required

The above deep-dive approach was carried out across the 7 priority areas using industry expert discussions and benchmarking of the global and local supply chain landscape. Consequently, 13 components were identified which will require additional government thrust to drive localization.

Exhibit 37: Components requiring additional intervention for localization



As detailed out in Chapter 2, a thorough benchmarking of how governments world over are stepping in to drive localization has been carried out. Emulating the key learnings, certain interventions have been proposed below to combat challenges to localization in India.

Component	Challenges to localization	Key interventions required
CAM	• 8-10% disadvantage at unit cost due to unavailability of RM and RM processing locally • Capital intensive component requiring $300-400M for 20-30GWh plant • R&D experience in CAM to ensure high yield • Low availability of labor skilled in inorganic chemistry	• Incentives in short-term to offset structural unit cost disadvantages for production in India. Potential levers can be import duty relief for RM imports (observed in Europe), production-linked subsidy or subsidized power cost • Securing access to critical RM (E.g., Lithium, Cobalt, Nickel) • Capital subsidy from the government and financing support / commitment from banks, to create an enabling ecosystem and improve project ROCE • Offering R&D grants, as observed in Europe (Battery 2030+, BATT4EU, Horizon Europe) • Fostering industry-academia collaboration to upskill local talent, as observed in Europe (E.g., ALBATTS, EBA Academy), can help significantly
Copper foil	• Capital intensive component requiring $150-250M for 20-30GWh plant • Lack of R&D experience in producing ultra-thin Copper foil(insure consistent thickness, foil integrity and RPM of Drum) • Limited copper reserves are another challenge	• Project finance support through financing commitments from banks and capital subsidies from government • Offering R&D grants to encourage joint research on national EV and battery R&D priorities • Up-skilling/ re-skilling local workforce by joining hands with industry and academic participants to create employable EV and battery workforce • Securing access to critical RM (Copper).
Separator	• Highly capital-intensive component ($300-500M for 20-30GWh plant) • Lack of labor with experience in operating separator lines and coating process know-how.	• Financial grants from government to attract large capital investments in India vis-a-vis other geographies. Project finance support through preferential loans from banks, government guarantees, etc. • Foster industry academia collaboration to upskill local talent
Electrolyte	• 2-3% unit cost disadvantage due to unavailability of RM locally • Absence of R&D in electrolyte formulation & technologies. • Lack of labor skilled in electrochemical techniques	• Securing access to critical RM like lithium salts • Offering R&D grants in line with European examples. • Creating a specialized curriculum (E.g. familiarity with physico chemical properties of electrolyte measurement) in partnership with industry-academia to support up-skilling of local workforce

<table>
<thead>
<tr><th>Component</th><th>Challenges to localization</th><th>Key interventions required</th></tr>
</thead>
<tbody>
<tr><td>Anode Active Material (AAM)</td><td>• Capital intensive component ($160-250M for 20-30GWh plant)
• R&D required for mastering the technology needed to produce higher performance AAM</td><td>• Capital subsidy from govt. and financing support from banks, as observed in Europe, can help create an enabling eco-system
• Offering R&D grants in line with European example</td></tr>
<tr><td>BMS</td><td>• Lack of Expertise in SMT and production of semiconductors</td><td rowspan="2">• Fostering industry academia collaboration to upskill local talent, as observed in Europe.</td></tr>
<tr><td>Contactors</td><td>• Lack of expertise in producing contractors</td></tr>
<tr><td>Rare earth magnets</td><td>• Mining of Rare Earth element Neodymium is not done in India currently</td><td>• Expanding IREL's focus towards Rare Earth element Neodymium mining for producing permanent magnets.
• Incentivize exploration of alternate sources of Neodymium (E.g. Carbonatite reserves)</td></tr>
<tr><td>Rectifier</td><td>• Assembled modules from China are 15-20% cheaper
• Limited semi conductor manufacturing capability in India</td><td rowspan="3">Support existing PMP program for EVSE components with the following interventions:
• Promote EVSE suppliers procuring locally by adding localization as qualification criteria in tenders
• Phased increase of import duty on completely assembled components (e.g., in line with PMP program on xEV parts)</td></tr>
<tr><td>Controller</td><td>• Lack of R&D capability for power-line communication but global players with existing capabilities (e.g., Bacancy) already entering the market
• Limited semiconductor manufacturing capability in India</td></tr>
<tr><td>Connector (CCS/ CHAdeMO)</td><td>• Availability of low-cost Chinese products
• Limited import restrictions making it easier for assemblers to import</td></tr>
</tbody>
</table>

Component	Challenges to localization	Key interventions required
Connector (Type 2)	• Availability of low-cost Chinese products in the market • Limited import restrictions making it preferable for assemblers to import	Support existing PMP program for EVSE components with the following interventions: • Promote EVSE suppliers procuring locally by adding localization as qualification criteria in tenders • Phased increase of import duty on completely assembled components (e.g., in line with PMP program on xEV parts)
AC Charger Assembly	• Availability of lower priced products from China, given the large scale of manufacturing (40-50% difference in cost for large players when assembling in China vs. locally at current scale)	

Broadly, the following key challenges to localization have been observed:

- **Lack of level playing field** for select components because of structural unit cost disadvantages for production in India (e.g., in the case of CAM NMC, because of unavailability of RM processing locally)
- **Limited enabling ecosystem to support high capex greenfield investment in India** vis-à-vis other countries for select cell components (e.g., investments in CAM, separators, copper foil, AAM have individually received capital grants in Europe, coupled with access to cheap financing, thereby enjoying superior project ROCE)
- **Lack of local R&D experience** in high-tech cell component areas like CAM manufacturing, copper foil manufacturing, etc
- **Low availability of highly skilled labor e.g.,** in CAM, Copper Foil, BMS manufacturing, etc
- **Limited localization mandate** to ensure enforcement of phased manufacturing programs for EVSE

In the ensuing chapter, key interventions have been proposed to address these challenges and further develop the local EV value chain.

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04

Proposed Reforms and Roadmap for India

4.1 Proposed Interventions

Based on the exhaustive analysis of the e-mobility value chain, benchmarking of global best practices for EV policies and regulations and discussions with industry experts, a 16-point action agenda across the following 4 key thrust areas is proposed to address the challenges to localization to further develop the local EV value chain.

1. Enable EV component manufacturing at scale by creating an enabling eco-system and a level-playing field for select high priority components
2. Ensure consistent availability of critical & strategic EV and Battery raw materials to strengthen mineral security of the nation
3. Foster centrally coordinated multi-stakeholder efforts for R&D in EV innovation
4. Facilitate industry-academia collaboration for re-skilling and up-skilling the Indian workforce in line with skills and competencies needed to emerge as a leader in the growing Battery & EV manufacturing ecosystem

The 4 key thrust areas have been further detailed out across 16 Action Items, covering the need for proposed intervention (context), key activities or scope of each intervention, key roles for operationalization, and expected impact.

Promoting Clean Energy Usage through Accelerated Localization of E-Mobility Value Chain

EV & EVSE component manufacturing at scale	Mineral security & availability	R&D for EV innovation	Re-skilling & Up-skilling workforce
1 Set up Hi-Tech EV component corridor	6 Ensure mineral security of key battery RMs	10 Develop National strategic R&D agenda for EV	13 Upgrade existing infra and faculty skill set
2 Project financing commitment from banks for e-mobility projects	7 Enable mining of Neodymium in India	11 Set up EV & Battery Innovation hubs	14 Curate curriculum for Univ/ ITIs/ VETs, etc
3 Offset structural unit cost disadvantages	8 Set up Raw Materials Investment Platform	12 Incentivize investments in R&D	15 Enable on-demand 'Phygital' learning
4 Explore opportunities to attract greenfield project investments	9 Promote sustainability standard & ethical sourcing		16 Set up Centers of Excellence (CoE)
5 Consider localization mandate for EVSE			

Thrust Area 1 – Enable EV component manufacturing at scale by creating an enabling eco-system and a level-playing field for select high priority components

I. Context

India faces structural unit cost disadvantage in the production of select cell components (e.g., 8-10% for CAM NMC and 2-3% for Electrolyte). Further, certain cell components such as Separators, CAM NMC, Copper foil, Anode Active Material (AAM), etc. require large scale capital (greenfield project) investment (200-500M$ for 20-30 GWh plant).

Globally, governments are stepping in to support localization of the EV component supply chain:

- IPCEI fund (€ 6.1B) set up by EU to provide capital grants (for greenfield investments) for cell component manufacturing
- Individual state-aids (capital grants) given by EU countries (typically 10-15% of project cost), e.g., Hungary and Poland, to attract local investments (providing superior ROCE)
- Land cost subsidies provided in China

To promote localization of cell component manufacturing in India, it is imperative to offset the structural cost disadvantages and create an enabling eco-system to attract large-scale capex investment vis-à-vis other geographies.

Moreover, there has been limited localization at scale in EVSE manufacturing in India thus far. Across DC Chargers, larger 120kw+ chargers are presently imported as completely built units while 50-60kW chargers are assembled locally. However, 60-70% components by value continue to remain imported even for chargers assembled locally. Key imported components include Rectifier, CCS/CHAdeMO Connectors and Controller. Further, AC chargers are imported as completely built units by large EVSE OEMs. Startups that assemble locally are currently importing 30-40% components by value - Type 2 connector (25-30% of total cost) is the key imported component.

Based on our analysis, following are key challenges to EVSE localization in India: Low scale to manufacture EV specific components, e.g.., rectifier, connectors; Availability of cheap Chinese alternatives, e.g., 40-50% difference in cost for large OEMs if they assemble AC chargers in India vs. China; and nascent semiconductor manufacturing industry in India. While the Ministry of Heavy Industries has launched Phased Manufacturing Program for EVSE components in 2021 to drive localization, currently, localization criteria are not included in tenders by state nodal agencies deploying charging networks.

II. Proposed Initiatives (Actions 1 to 5)

#1 – Develop Hi-Tech EV component corridors, along existing auto belts, in partnership with state governments

Developing Hi-tech industrial corridors, earmarked for EV related investments can help in creating the enabling ecosystem required for localization of select strategic components in India. The EV component corridor should be located in the existing auto belts (thereby leveraging existing ecosystem & market linkages). E.g.:

I. **South –** Chennai-Hosur-Coimbatore cluster where OEMs like Ford, Hyundai, Renault, Mitsubishi, Nissan, BMW etc. are located

II. **North –** Delhi-NCR cluster (Delhi, Gurugram, Ghaziabad, Faridabad) where the country's largest car manufacturer, Maruti Suzuki, is based

III. **West –** Mumbai-Pune-Nashik-Aurangabad; Audi, Volkswagen, and Škoda are located in Aurangabad. Mahindra and Mahindra has a vehicle and engine assembly plant at Nashik. Tata Motors, Mercedes Benz, Land Rover, Jaguar, Fiat, and Force Motors have assembly plants in the Pune-Pimpri area

The salient features of the corridor would be the following:

Must haves:

- Good connectivity with EXIM gateways along with on-site custom clearance
- Located in proximity of existing auto cluster
- Production facilities (ready-made sheds, warehouses, assembly units) for purchase/lease
- Dedicated single window clearance support along with competitive incentive package, transparent disbursal process
- Shared infrastructure - Common testing circuits, workshop & tool sharing facilities for MSMEs

Good to have:

- Skilling centers and academic institutions easing transition from ICE to EV and developing specialized skill
- Social infrastructure - Mixed use residential complexes, schools, colleges, hotels & conference centers, hospitals
- Sustainability - Common wastewater/effluent treatment plants and captive renewable power plants

It would also be critical to attract 2-3 anchor investments across cell / battery value chain to create a virtuous cycle of investments across the corridor. This would include creating attractive value propositions and pitching to key cell / battery value chain players to attract investments in the corridor. Below is an illustrative list of key stakeholders that could be approached:

Stakeholders for outreach (Illustrative list):

1. **Battery Assembly:** Exide, Amara Raja, Ola Electric, Uno Minda, Trontek, Amptek
2. **Cell Manufacturing:** Hyundai, Reliance New Energy Solar Ltd, Ola Electric, Rajesh Exports Ltd, Amara Raja, Exide, Lucas TVS, Samsung SDI, LG Chemicals
3. **CAM:** Posco, BASF, Ecopro, Umicore, Sumitomo, Nichia, Johnson Matthey, Mitsubishi Chemical, Hitachi Chemical, Epsilon
4. **Separators:** Daramic, SKIET, Toray, Asahi Kasei, UBE, Sinoma, Senior, Yunnan Energy
5. **Copper Foil:** Iljin, SK Chemicals, KCF, Nippon Denkai, Furukawa Electric, CCP, Wason
6. **Aluminium Foil:** Hindalco, Lotte Aluminium, UACJ, Chinalco, Longding Alu
7. **Electrolyte –** Mitsui Chemical, Mitsubishi Chemical, UBE, Enchem, Soulbrain, Shanshan, Tinci
8. **Anode Active Material:** GFL, Himadri, Epsilon, Elkem, Posco, Showa Denko, Mitsubishi Chemical
9. **Start-ups/ MSMEs innovating in the cell component manufacturing space:** Allox, Log9 Materials

#2 – Green financing commitment from banks for supporting large-scale greenfield project investment in India (especially for CAM, AAM, Copper Foil & Separators)

Taking cue from the green financing commitments secured by EU from local banks such as EIB and EBRD, it would be crucial for the government to work with the financial sector to channelize lending towards more sustainable technologies and businesses (E.g. EV Cell manufacturing projects). This would be very important for attracting greenfield project investments in certain capital-intensive high priority items like CAM, Separators, Copper Foil and AAM.

#3 - Provide support to offset structural unit cost disadvantages for production in India

Further, the central government would need to work with the state governments to offset structural unit cost disadvantages for production in India, specifically for CAM NMC and Electrolyte manufacturing which suffers from 8-10% and 2-3% disadvantage respectively. This could be done via any of the following levers: import duty relief for import of PCAM (RM), subsidized power, inclusion of CAM NMC into PLI scheme etc.

#4 - Explore opportunities to attract greenfield project investments in select high priority cell components (i.e., CAM NMC, AAM, Copper Foil & Separators) where need-gap still exists despite the PLI schemes

Moreover, as highlighted previously, certain cell components are highly capital intensive (200-500M$ investments for 20-30 GWh plant). Existing schemes like PLI / state-level incentive programs could be channelized towards these to incentivize investments in these components in India vis-à-vis other geographies. E.g., Karnataka state government is offering upto 15% of project capex as capital subsidy for cell manufacturing (which overlaps with ACC PLI). This support could instead be channelized for these need-gap components (i.e., CAM NMC, AAM, Copper Foil & Separators). Research indicates that globally, governments are typically providing 10-15% capital grants for attracting greenfield investments in cell components (providing superior ROCE) e.g., €175M capex grant received by BASF through EC's IPCEI for setting up a CAM production facility in Finland, €47M capex grant received by Toray for setting up a separator facility in Hungary, etc

#5 – Consider localization mandates to accelerate set up of EVSE component manufacturing & assembly in India

Introduce localization criteria in tenders by DHI(49) and State Nodal Agencies (under Bureau of Energy Efficiency) across the country for setting up public charging stations (PCS), i.e., ensure following components are localized with minimum 50% domestic value addition by respective dates

Targeted value chain segment	Localization phases (as per PMP)
Charger Enclosure, Internal Wiring Harness, IEC 60309 connector, Software, Auxiliary Power Supply, SMPS	Phase 1
Energy Meter, HMI / Display / RFID, Input Switchgears (Fuses, MCBs, etc.), Output Switchgears (DC/AC Contactors, Relays, etc.)	Phase 2
Charging guns (CCS, CHAdeMO, Type2, Bharat DC001), Charger Controllers, Rectifier Modules	Phase 3

Further, mechanism for tenders (e.g., L1 bidder with localization above threshold to be given preference over other bidders with similar pricing) would need to be detailed out.

Additionally, increase import duty on select components such as Rectifier, Connectors (CCS, CHAdeMO, Type 2), Controller & completely built units for AC chargers in line with PMP, to further drive localization. It would be important to decide quantum of import duty to be levied for different components based on PMP & enforce recommendation through Ministry of Finance. E.g.., BCD rates on EV auto components increased from 0% to 15% from April 2021 (post PMP deadlines of all components)(50).

To operationalize these initiatives, it would be pertinent to establish a working group comprising representatives from DHI, BEE and EVSE OEMs to detail policy recommendations (e.g., localization criteria, quantum of import duty to be levied by component, etc.). It would be advisable to set up a up 6-month review frequency to track enforcement of localization criteria by testing agency of MHI through documents submitted at tender RFP stage.

III. Expected Impact

- Faster inflow of greenfield project investments in EV component manufacturing owing to proximity to downstream (auto) players
- Indigenized production of EV components at competitive costs of production (reduced reliance on imports)
- Accelerated creation of jobs for EV component manufacturing
- Boost to logistics and other infrastructure development through creation of EV component corridor
- Accelerated development of local supply chain for EVSE components (both AC and DC chargers)
  - » Development of local assembly capability for Rectifiers, Controllers for EVSE
  - » Development of local supplier ecosystem for CCS, CHAdeMO, Type 2 Connectors
  - » Self-sufficiency in EVSE manufacturing (reduced reliance on China)

Thrust Area 2 – Ensure consistent availability of critical & strategic EV raw materials to strengthen mineral security of the nation

I. Context

Given lack of local mineral reserves, India is dependent on imports for most raw & advanced battery materials (E.g., Lithium, Nickel, Cobalt, Copper, Manganese). Further, India is heavily dependent on specific geographies for Rare-Earth Permanent Magnet – a critical sub-component of E-motors. To increase India's independence across the raw material value chain and to make it more resilient to geo-political shocks, it is crucial to diversify its supply chains and ensure a consistent supply of critical and strategic minerals to Indian domestic market.

II. Proposed Initiatives (Actions 6 to 9)

#6 - Ensure mineral security of key battery RMs

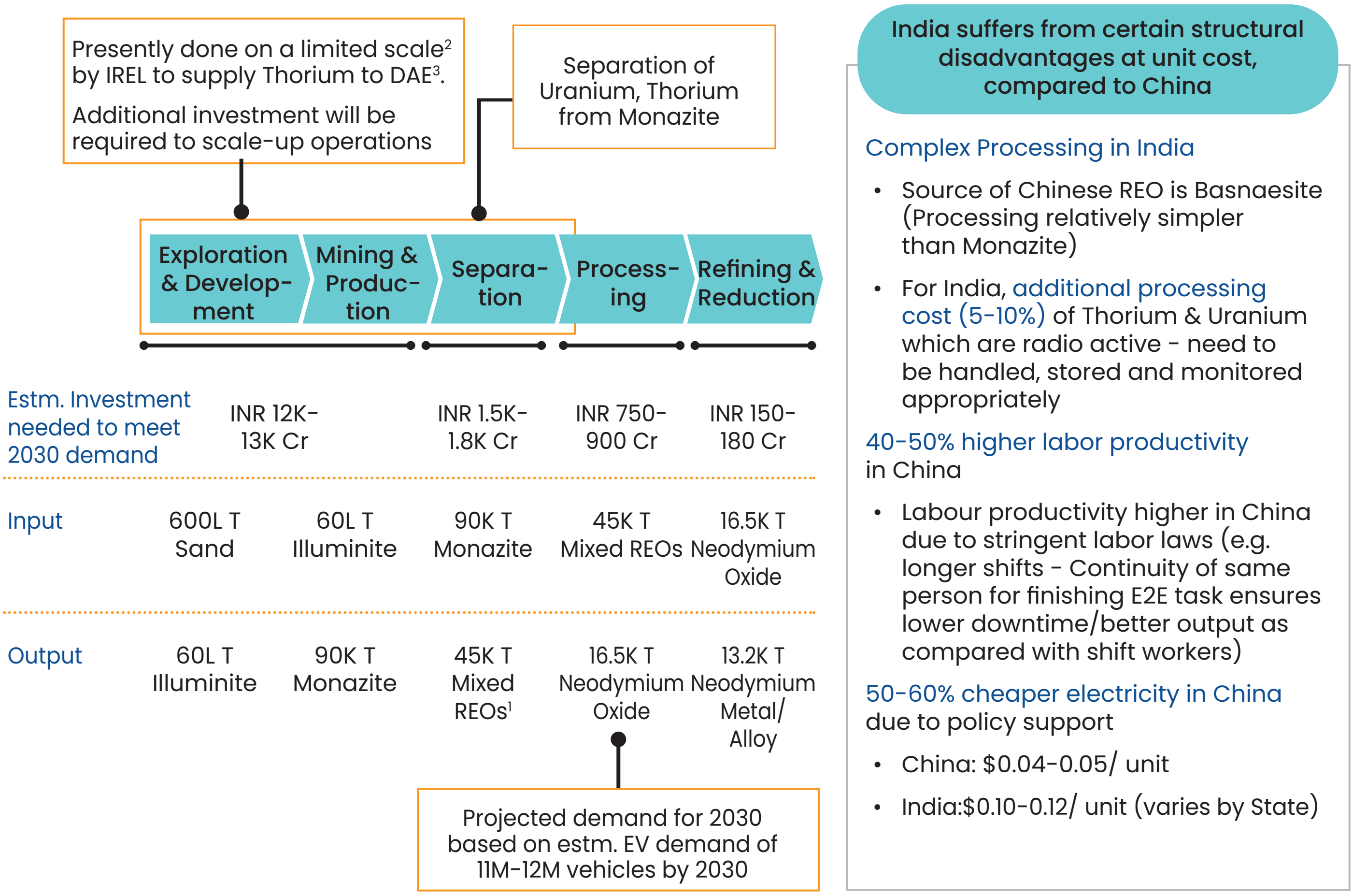
Presently, KABIL(47) has been tasked with securing consistent supply of 12 critical and strategic minerals for India – including 2 key battery RMs viz. Lithium and Cobalt. However, consistent access to certain other key battery RMs like Nickel, Copper (limited local reserves, India is a net importer) and Manganese (limited local reserves, India is a net importer) also needs to be secured. This could be achieved by establishing a central nodal agency or leveraging existing PSUs to further the aforesaid agenda.

For each of these critical minerals, the government (through central nodal body/PSU) would need to establish an agile and inclusive stakeholder consultation process to identify bottlenecks such as regulations, permits or operating licenses across the raw material value chain. For minerals that are locally scarce, the government would need to identify on a global level primary sources (mining) and secondary sources (re-cycling) of critical RMs and consequently drive strategic trade partnerships with resource-rich countries. Further, the government could also explore regulatory measures to incentivize exploration, mining, and a full critical raw material circular economy, across the entire value chain (E.g., through waste directives, legislation promoting retention of End-of-Life products, etc.).

#7 - Enable mining of Neodymium in India for producing Permanent Magnets

Currently, Indian Rare Earths Limited (IREL)[(46)] has been given a monopoly over the primary mineral that contains REEs: Monazite beach sand. IREL's focus is to provide thorium — extracted from Monazite — to the Department of Atomic Energy. IREL produces rare earth selling these to foreign firms that extract the metals and manufacture end products. KABIL would need to work with IREL to direct its focus towards Neodymium mining, at scale, to localize production of NdFeB magnets. By 2030, projected EV demand in India is 11-12M vehicles. This translates to NdFeB demand of ~16,500 T by 2030. Accordingly, additional capital investment may be required to expand IREL's existing mining set-up to meet the growing NdFeb demand, as well as to start processing, refining and reduction operations in India. Further, India suffers from certain structural disadvantages at unit cost, in comparison with China, as highlighted below. The government will need to offset these disadvantages to accelerate indigenization of Neodymium mining.

Exhibit 38: Additional capex investment required for processing Neodymium Oxide (from Monazite) and additional support required to create a level playing field



1. Rare Earth Oxide (REO) 2. ~2300T REO produced in 2016-17 3. Dept. of Atomic Energy (DAE) 4. EVs use ~1.5kg NdFeB magnets for PM motors

It would be crucial to provide funding support / capital incentives for setting-up Neodymium processing, refining and reduction facilities in India and bridging structural disadvantages for production at unit cost.

Moreover, it is imperative to identify alternate sources (E.g., Carbonatite reserves) of Neodymium, beyond monazite sand to further stabilize supply of Neodymium for producing Rare-Earth Magnets. The ever-increasing demand for Rare Earth Elements necessitates a concerted effort to augment the resource position of our country. The Geological Survey of India, as a part of routine mineral survey, has been carrying out preliminary investigation for identifying REE rich zones in selected sectors. Similarly, while the Atomic Minerals Division (AMD) of the Department of Atomic Energy has been actively engaged in the exploration of such mineral deposits in different parts of our country, discussions with subject matter experts indicate that less than 5% reserves have been explored for Carbonatite by state-owned enterprises (Gujarat and Rajasthan are the few known sources currently). Therefore, it would be beneficial if the government incentivizes exploration of alternate sources (E.g., Carbonatite reserves) of Neodymium to accelerate this effort.

#8 - Set up a Raw Materials Investment Platform (RMIP) to help leverage investment (JVs) in a pipeline of key projects

Based on our analysis, certain key learnings from Europe could be emulated by India. to ERMA[44][45] in Europe, set up a platform for investment matchmaking to ensure high investment success rates. The prioritized cases to secure primary and secondary raw materials supply for European industrial ecosystems are listed on the platform which aims to bring investors and investees together and define case-specific financing strategies (grant, equity, loan, mixed) and investment structures.

#9 - Establish sustainability standard and certification scheme to ensure high quality and sustainable output by domestic players & promote ethical sourcing and transparency in value chain by enforcing the respective standards

The government and industry players will need to align on a framework for establishing sustainability in the raw material(s) value chain. This would involve leaders from the downstream industry, particularly the automotive industry, and would include the analysis of existing schemes by a dedicated taskforce. E.g., ISO/TC298 Rare Earth group – the leading standardization initiative in Rare Earths worldwide today – should be followed by domestic players. Subsequently, it would be crucial to promote ethical sourcing and transparency in value chain by enforcing the respective regulation(s) made applicable above.

III. Expected Impact

- Consistent supply of critical raw materials through primary (mining) and secondary (recycling) sources
- Domestic capabilities across the raw material value chain built (as domestic players form JVs to enter the upstream play)
- Mitigation against geo-political risks and increased import substitution (E.g., Reduced dependence on China for Neodymium (Permanent) Magnets)
- Locally processed critical raw materials to come with quality standards and transparent supply chains

Thrust Area 3 – Foster centrally coordinated multi-stakeholder efforts for R&D in EV innovation

I. Context

EV and battery are key pillars for transition towards sustainable mobility, and to be at the forefront of the e-mobility industry, continuous investment in R&D is critical. Globally, governments are investing heavily in e-mobility R&D (especially for battery) and stepping up to support coordinated efforts around R&D to keep up with the ever-evolving industry. E.g., EU has launched multiple R&D initiatives (industry-academia collaborations) such as Batteries 2030+, BATT4EU, with dedicated funding support from Horizon Europe (€95B+ till 2027 towards R&D in sustainable mobility, including € 1.4B+ till 2021 across Battery R&D).

India will need to invest ahead of the curve in R&D to accelerate adoption, by improving battery energy density, cycle lifetime, reducing cost, etc. Given that India presently lacks the process expertise for producing many complex EV and battery components (E.g., CAM, AAM, Copper Foil, Electrolyte) requiring high technical know-how to ensure high yield, it is even more critical to support indigenous players in developing competitive technology (vs global players). Presently, e-mobility research is happening independently in fragments across institutions with no coordinated roadmap of the nation's key R&D vision/priorities (E.g., CSIR-CECRI are working on electrochemical research, IIT Bombay and Bar-Ilan University are jointly conducting R&D on solid state batteries, IIT Madras and Karlsruhe Institute of Technology are jointly researching to improve performance of LIB cathode materials, IIT Madras' C-BEEV focuses on R&D in battery and EV). A centrally coordinated effort bringing together some of India's brightest minds, complemented by shared R&D infra and financial incentives, will accelerate the journey from prototyping to industrialization.

II. Proposed Initiatives (Actions 10 to 12)

#10 - Develop India's EV & battery specific strategic research agenda covering short-, medium- and long-term R&D priorities

India has many academic institutions and national laboratories that have facilities that conduct e-mobility research, E.g. research pertaining to batteries. However, to accelerate indigenization of energy storage manufacturing, Indian R&D centers need to focus more on collaborative research with the industry to solve problems associated with current battery technologies as well as collaboratively develop next-generation technologies to become truly independent. There is a pressing need for the government to orchestrate the industry academia-startup collaboration by laying out a national EV and battery specific strategic research agenda covering short-, medium- and long-term R&D priorities. This initiative could be fostered centrally through some of the existing set-ups such as – C-BEEV's[1] CoBE[2] (under DHI[3] & MEIT[4]); ARAI's[6] TechNovuus[7] (under DHI[3]); iCAT's[8] ASPIRE[9] (under DHI[3]); DHI[3]-DST[5] Technology Platform for Electric Mobility (TPEM)[(48)].

The unified body would need to baseline the extent of R&D done in India in this space in smaller fragments across start-ups, universities, and industry and then hold industry-academia consultation to understand current challenges (E.g., competitiveness, sustainability, industrial upscaling, uptake, etc.) across the battery value chain (Similar to C-BEEV-CoBE's consultation with key players like ABB, Exide, Amara Raja, Exicom, etc.). Accordingly, India's R&D priorities would be identified. Based on global benchmarks, below is an illustrative list of R&D priorities that have been identified for battery innovation as an exemplar.

1. Centre of Battery Engineering and Electric Vehicles (C-BEEV) 2. Centre of Battery Engineering (CoBE) 3. Dept. of Heavy Industries (DHI) 4. Ministry of Electronics and Information Technology (MEIT) 5. Department of Science & Technology (DST) 7. TechNovuus is an indigenous, multi-domain collaborative platform developed with the aim of enabling our brightest minds to unlock the potential of new technologies and innovations to shape the future of mobility 8. The International Centre for Automotive Technology (iCAT) 9. Automotive Solutions Portal for Industry Research & Education (ASPIRE) – A Technology platform to facilitate the Indian auto industry (including OEMs, Tier 1 Tier 2 & Tier 3 companies), R&D institutions and academia to come together for R&D, technology development, shop floor/ quality/ warranty issue's resolution, expert opinions etc. on issues involving technology advancements

Exhibit 39 : Potential R&D priorities

Illustrative, based on global benchmarks

a) Potential short/medium term priorities

- Increase battery energy density
- Improve cycle lifetime
- Increase battery power density and charging rate
- Reduce battery costs
- Enhance battery safety in the different targeted application sectors
- Decarbonization of battery raw materials processing
- Aqueous, dry and alternative coating processes

- Recovery of metals and chemicals from new sources such as industrial or urban wastes
- Automating the dismantling of batteries, reducing costs by avoiding manual work and improving sorting of parts for their replacement or recycling
- Digitalization of battery testing

b) Potential long term priorities

- Develop self-healing functionalities for batteries
- Identify novel chemistries beyond li-ion
- Develop advanced all solid-state batteries
- Create autonomous, 'self-driving' labs capable of designing and synthesizing novel battery materials, and of orchestrating and interpreting experiments on the fly (using AI, ML & Robotics)
- Developing a shared and interoperable data infrastructure for battery materials and interfaces, linking data from all domains of battery discovery and development cycle
- Development of secure, real-time, knowledge-based and data-based open access battery management system
- Increased traceability of raw materials and components in the battery value chain
- A digital twin of the manufacturing process: manipulating the complete virtual representation can actuate the physical world, improving the control of manufacturing facilities and processes

#11 - Provide funding to develop the required infrastructure for EV and Battery Innovation hubs within reputed institutions, to promote collaborative research between Industry, Startups and Academia

To accelerate the establishment of a globally competitive Indian EV and battery industry and to drive the implementation of EV and battery-related research and innovation actions, the following key actions would need to be focused upon.

- Setup innovation labs providing testing and prototyping infrastructure and supporting commercial product development from lab prototype
- Provide linkages to other researchers to facilitate research progress and reduce barriers to commercialization
- Create an innovation platform (digital) to host R&D projects based on identified priorities and invite stakeholders to further the research agenda

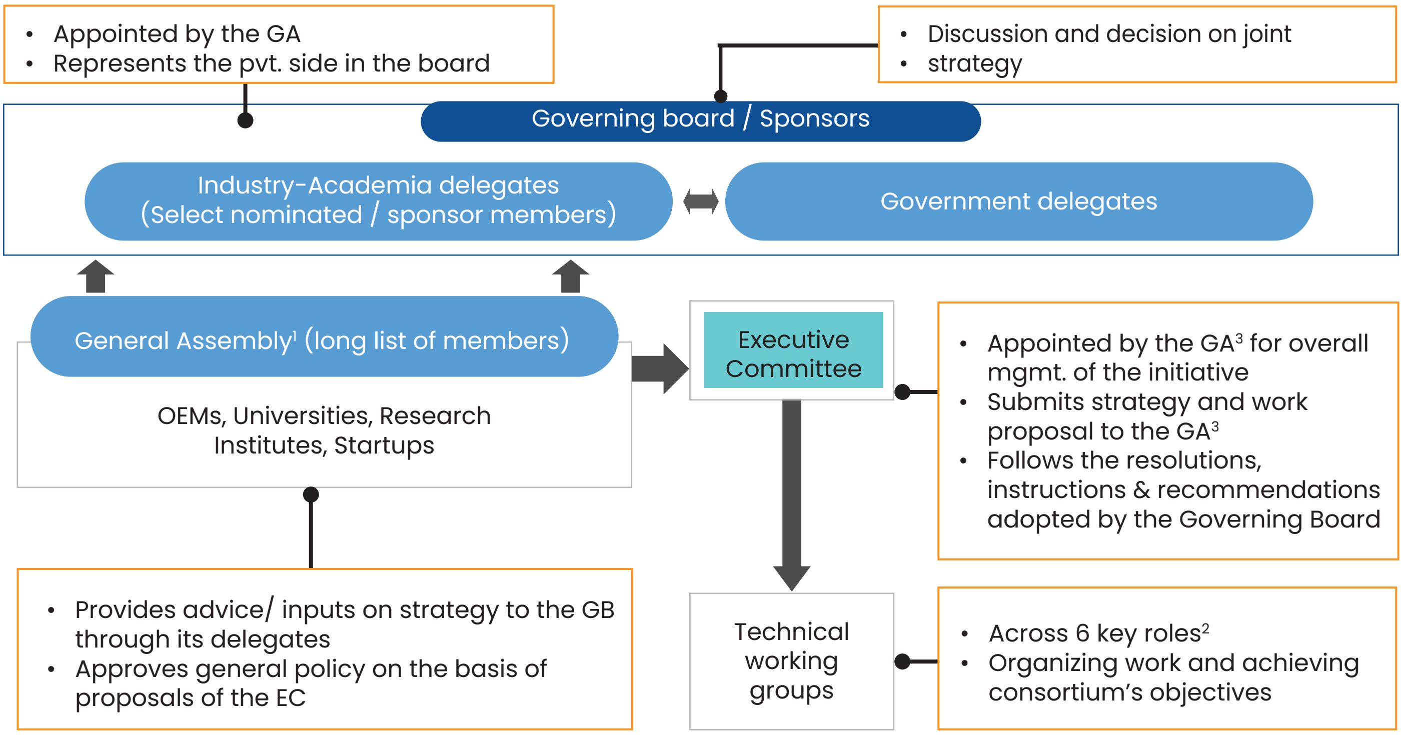
#12- Provide incentives to industry, academia, and start-ups to conduct collaborative research across identified priority areas

Based on learnings from global benchmarks, it is pertinent to facilitate access to funding sources for conducting research and for prototype/commercial product testing. This will promote faster and greater collaboration across players to work towards common research priorities laid out for the nation. As observed in Europe, EU's Horizon Europe (major R&D funding program) has been greatly successful in developing collaborative partnerships between industry and academia to focus on the R&D projects listed on EU's portal. Further, incentivizing R&D projects for laid out priorities would also speed up the commercialization of newly discovered technologies, materials, etc.

Moreover, EVs will have complex proprietary software. In fact, software features are likely to be differentiating factors in a consumer's purchase decision. While hardware upgrades are slow and difficult, regular software upgrades are easily achievable through over the air updates. To stay competitive, auto supply chains need to focus on continuous software development and hence focused R&D in areas such as decoupling software – hardware development cycles is essential for faster deployment. While India has a naturally good starting point in automobile software development, incentivizing development of proprietary EV software will be crucial to ensure momentum.

This intervention (Actions 10-12) could be operationalized through the following governance structure and operating model, benchmarked based on global best practices.

Exhibit 40: Proposed governance structure and operating model



1. Illustrative list of members on subsequent slide 2. Illustrative roles enlisted on subsequent slide 3. General Assembly (GA) 4. Executive Committee (EC) 5. Governing Board (GB)w

The unified body could approach the following players, for creating a stellar network of joint R&D partners, to join the General Assembly.

Exhibit 41: Collaboration required between industry leaders, battery startups, local universities, and leading international universities to drive cell & battery innovation (Illustrative list)

1. **Foreign and local universities/ Research Institutes** (E.g.. Council of Scientific and Industrial Research - Central Electro Chemical Research Institute (CSIR-CECRI) | Indian Institutes of Technology (IITs) | International Centre for Automotive Technology (I-CAT) | Karlsruhe Institute of Technology

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2. **Industry players across the battery value chain** Raw Materials, Processing, Cell component manufacturing, Cell assembly, Battery component manufacturing and assembly, Re-cycling, Charging Infra). For e.g.:
   - OEMs – Ola Electric | TVS | Tata | Mahindra Electric | Hero Electric | Suzuki | Hyundai
   - Cell components – Hindalco | GFL | Himadri | Epsilon | Daramic
   - Battery manufacturing and assembly – LG Chem | Samsung| Panasonic | Amara Raja | Exide | RIL | Rajesh Exports | BHEL
   - Charging Infra – Exicom | Okaya | Amara Raja | Delta | Continental | BorgWarner, Panasonic | Napino
   - Battery start-ups – Inverted, | Gegadyne Energy | Lohum Cleantech | Ziptrax Cleantech, Nexus battery | Ion Energy | Grinntech

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3. **Industry Associations** (E.g.. Indian Energy Storage Alliance (IESA) | Indian Battery Manufacturers Association (IBMA) | Indian Battery and Accessories Industries Welfare Association (IBAIWA) | The Society of Indian Automobile Manufacturers (SIAM))

The key roles of the technical working groups could be structured across the following 6 themes:

1. **Raw materials & recycling -** R&D activities across sustainable sourcing of raw materials and recovering valuable metals and materials from end-of-life electronics
2. **Advanced materials and manufacturing -** R&D activities across advanced materials (Cathode, Anode, Separator, Electrolyte materials) towards improving their performance and reducing their cost
3. **Accelerated discovery of next-gen battery interfaces and materials -** R&D activities across alternative battery technologies to provide the Indian battery industry with disruptive tools and battery technologies to be developed in the long-term
4. **Safety -** R&D activities across developing battery safety – particularly the intrinsic safety of the electrochemical components - to ensure the confidence in and widespread adoption of e-mobility and electrical energy storage
5. **Sustainability -** R&D activities to ensure that the sustainability of batteries is developed from a holistic perspective (economic, social, and environmental

- **Co-ordination and project management -** Reliable strategic coordination and alignment across the value chain to create tangible economic impact from the R&D efforts

III. Expected Impact

- Well-coordinated Indian research initiative gathering excellent scientists and innovators and paving the way to industrial exploitation of future battery technologies
- Advanced batteries delivering on cost, performance, safety, and sustainability with clear prospects for cost competitive large-scale manufacturing
- Industrial readiness in alternate battery technologies providing India with key leadership opportunities
- Improved prototyping and safe testing infra along with financial incentives for developing prototypes and for first commercial industrialization

Thrust Area 4 - Facilitate industry-academia collaboration for re-skilling and up-skilling the Indian workforce in line with skills and competencies needed to emerge as a leader in the growing Battery & EV manufacturing ecosystem

I. Context

India's EV and EV component market is expected to gain huge momentum owing to the Auto and Auto Component PLI, ACC PLI and other schemes launched here. Given the nascent stage of India's EV and battery market, India presently lacks the skilled expertise and technical know-how required for producing most of the components. Globally, governments are stepping in to drive creation of a future ready battery workforce. E.g., EC launched The Alliance for Batteries Technology, Training and Skills (ALBATTS) for syncing new skills demand with supply of education and training in battery sector.

There is a need to re-skill and up-skill local workforce in key battery and EV component skills such as inorganic and organic chemistry, expertise in surface mounting technology (SMT), Separator coating process know-how, electrochemical techniques, etc. Based on our analysis, given local EV demand of 11-13 Mn units/ year by 2030, we estimate that at least 200,000 to 250,000 people would need to be skilled by 2030 for manufacturing roles across the EV value chain (cell component manufacturing, cell assembly, battery assembly, manufacturing of e-motors, power electronics, charging infrastructure, and high voltage EV cables, and EV assembly). While specialized skilling programs are taking place in pockets (E.g., IIT Madras has started a 12-week online certification course focused on EV), a government orchestrated, and industry-academia led, central program is required to ensure standardization of curriculum, contributing to consistently high-quality workforce. To support India's high ambition for electrification of transport by 2030, it is critical to centrally design a blueprint for competences and training schemes of the future in collaboration with key EV and battery stakeholders.

II. Proposed Initiatives (Actions 13 to 16)

#13 - Develop existing infrastructure and faculty skillset to enable Battery & EV skill development amongst students

Feedback from industry indicates that obsolete skillsets are being created due to training performed on outdated machines/softwares in universities. There is a need of upgrading equipment, partly funded by government and partly by industry players, to ensure best in class infrastructure for enabling EV & Battery skill development amongst students. Further, investments would need to be made in training the faculty to ensure impartation of requisite new-age battery and EV skills.

#14 – Design curated curriculum for skilling new age EV and battery workforce

The new wave of e-mobility initiatives will result in a swathe of requirements for new age skills and opportunities for employment. Successful planning and execution of these initiatives will depend on the available capacity in terms of both personnel & skills. In India, multiple bodies offer capacity building programs, and these efforts need to be synchronized for effective outcomes. There is a critical need for a centralized task force covering multiple dimensions of up-skilling & re-skilling across the e-mobility value chain, at central and state level. Given Automotive Skill Development Council's (ASDC) relevant expertise in this area, ASDC, under the aegis of the Directorate General of Training (DGT), could provide guidance and inputs on leading this centralized task force.

A skill-gap assessment would need to be conducted (similar to the one ASDC conducted in 2019 for the Automotive sector). This would involve baselining existing skill sets and relevant battery courses in India and holding industry consultations to understand modern requirements for skills and job roles. Partnerships could be formed with a few leading OEMs (E.g., Tata Motors, Mahindra, etc.) who could anchor the industry consultation process. The inputs from industry would be crucial in determining the extent of re-skilling required and the extent of up-skilling required across various functions (E.g., manufacturing, research and development, operations, and maintenance/ servicing, etc.). Once the bifurcation has been made across re-skilling and up-skilling needs, skill sets emerging through the skill gap assessment would need to be compared against existing National Occupational Standards (NOS), to identify need for development of new NOS. Expert groups involving industry and academia would need to be formed to define curriculum requirements across each skilling need – E.g. Duration of module, National Skill Qualification Framework (NSQF) level, mode of learning and training, eligibility criteria, learning outcomes, assessment criteria, etc.

This exercise will require close collaboration across inter-ministerial departments as the curriculum would need to be designed across Universities, ITIs, Polytechnics, and VETs.

Based on interviews with multiple industry experts, below is an illustrative initial list of skills and knowledge that would be required:

Exhibit 42: Initial list of skills / knowledge required

Illustrative, based on industry expert interviews

Initial list of skills/knowledge required

- Advanced inorganic and organic chemistry
- Slurry preparation and coating
- Electrode drying and calendering
- Expertise in SMT
- Separator coating process know-how
- Skill to control pH levels of acid, voltage and RPM of drums for manufacturing copper foil
- Technical skills like smelting, rolling, welding
- Electrochemical techniques such as cyclic voltammetry, electrochemical impedance spectroscopy

- Familiarity with physicochemical properties of electrolyte measurement, such as HF, density, viscosity, conductivity, etc.
- Material sciences and Electrochemistry (E.g. Cell design and formation cycles, battery component combinations' optimization, etc.)
- HV electrical/Power Electronics (Electrical circuitry, PCBA design, microprocessor design, etc.)
- Software development (Electrochemical modeling, Telemetric programming experience (BMS development), etc.)
- Thermal Management (E.g. Heat distribution physics, Electrode-drying technology, etc.)
- Mechanical/Structural Design (E.g. Fluid dynamics (Hypermesh and Star-CCM+), Testing and troubleshooting electro-mechanical systems (FEA, FMEA, 8D, APQP), etc.)

Once the skill-gap assessment is completed by the centralized task force and the exact re-skilling and up-skilling requirements have been detailed out, the course curriculum would need to be designed and/or refreshed as required, in consultation with universities, academicians, training institutions, VET centers, battery manufacturers and OEMs. E.g., ASDC partnered with Hero MotoCorp for designing 2W short-term training course. This will drive standardization of curriculum across institutions to ensure high and consistent quality of workforce. Once the course curriculum has been designed/ revamped, it would need to be integrated across existing degree, diploma, certification, or training programs by Universities, ITIs, Polytechnics, and VETs.

To create a successful industry-academia collaboration for up-skilling the workforce, ASDC would need to expand its network and forge partnerships across the EV & battery value chain. An illustrative list of key players that may be approached for skilling partnerships has been detailed in Exhibit 41

Additionally, to ensure global knowledge transfer for EV and battery value chain, ASDC can promote collaboration with leading international universities offering new-age courses.

Exhibit 43: International Universities offering e-mobility courses

Stanford University	Delft University of Technology	Oxford Brooks University
Focus areas: • Battery system design specifications • Battery cell design • Battery cell modeling • Battery management systems (BMS) • Battery degradation modeling and health-conscious control • Power electronics interfaces • Battery system thermal management • Battery system safety • Battery system design for EVs • EV charging networks • Battery systems for the grid • Battery life cycle value	Focus areas (Electric Cars: Technology) • Operation principle of electric cars • Motors and power electronics in an electric cars • Battery technology • Relevant charging infrastructure technologies and innovations, such as smart charging • Future technology for EVs such as wireless charging and solar EVs	Focus areas: • Noise, Vibration and Harshness • Advanced Powertrain Engineering • Engineering Business Management • Advanced Vehicle Dynamics • Advanced Vehicle Propulsion • Engine and powertrain modelling

Lastly, talent absorption programs via internships/placements into Battery/ EV manufacturing, would need to be set-up, in collaboration with Industry.

To operationalize this intervention, the following four key roles would need to be performed:

i. **Gathering Sectoral Intelligence** - Identify current and future skills required for development of batteries, in collaboration with key industry and academic players.

ii. **Facilitating Training & Education** - Develop designs for courses, define and make education setups for new work roles, and make solutions for addressing individual knowledge and skills gaps in an effective way.

iii. **Publicity & dissemination** - Ensure the appropriate visibility and wide dissemination of the work of this initiative through establishment of a stakeholder's database, creation of a social media strategy, etc.

iv. **Project Management, implementation, and evaluation** - Ensure the project is conducted on time, according to the budget and directed towards the overall project objective; Ensure smooth integration/ implementation across universities and other learning institutes

#15 - Work with technology partners to design on-demand 'Phygital' learning courses for up-skilling existing workforce

Based on the skill-gap assessment results from initiative 14 above and the key inputs received from industry-academia, it would also be important to create on-demand 'Phygital' learning courses to fill knowledge and skill gaps of existing workforce in the battery and automotive industry. E.g. ASDC partnered with TCS iON for designing 'phygital' learning courses to up-skill existing workforce in the Automotive sector. The recently announced DESH-Stack e-portal for boosting skill development and digital infrastructure may also be leveraged for this initiative.

#16 - Set-up Centers of Excellence in reputed universities, in collaboration with OEMs and key cell / battery manufacturers

Centers of Excellence (CoE) can be set up at premier institutes to offer specialized programs in collaboration with industry partners. Partner institutes would need to be identified. The government could provide viability gap funding (if required) to partner institutes to develop land and infrastructure for CoE. Further, ASDC could tap into its member network to provide networking support to help institutes pitch CoE to industry players. The CoE would work with industry partner(s) to define the curriculum (duration, modules, etc.), that would be directly relevant for industry placement of students. E.g. RV College of Engineering, Bangalore (RVCE) set up a CoE in collaboration with Mercedes Benz to offer an advanced diploma in Automotive Mechatronics.

Exhibit 44: Case study: RVCE-Mercedes Benz advanced diploma in automotive mechatronics

RVCE - Mercedes Benz advanced diploma in automotive mechatronics

Curriculum
1-year program with 5 modules spanning mechanics, electronics, advanced automotive systems, soft skills, and a workshop module with Mercedes

Setup
Mercedes is involved in planning the syllabus, development of training labs equipped with its cars, supply of tools & equipment, and training of faculty

Exposure
Regular interaction with experts from Mercedes Benz through guest sessions, industrial visits, and webinars

Outcome
Students awarded with globally valid diploma and secured placements across Mercedes Benz, Volvo, Bosch, and EV start-ups

III. Expected Impact

- Provision of future ready, skilled workforce for the EV and battery players to support the growth of this sector
- Clear blueprint of the skills/ competencies needed for emerging job roles in the EV and battery sector and India's starting point against each
- On-demand 'Phygital' learning & training courses available at scale to up-skill existing workforce
- Integration of new curricula and certifications in the national frameworks
- Creation of a sustainable industry-academia partnership in this emerging economic sector

4.2 Conclusion and Way Forward

4.2.1 Key activities

While the previous section covered the need for, scope of and expected impact from the proposed interventions, the ensuing paragraphs summarize the key activities that need to be focused on to make each of the 4 interventions a success.

Thrust Area 1 - Enable EV component manufacturing at scale by creating an enabling eco-system and a level-playing field for select high priority components

In order to achieve high scale manufacturing of EV components, it is vital to develop Hi-Tech EV component corridors along existing auto belts in partnership with the governments. Firstly, suitable auto belts have to be identified and with the help of corresponding state governments, appropriate land has to be earmarked to build the corridors. Relevant stakeholders and anchor investors have to be identified and onboarded. EV corridors need to be equipped with plug-and-play production facilities and other shared infrastructure for the eco-system players.

Financing support is crucial to set up a strong EV eco-system due to intensive capital requirements especially for CAM, AAM, Copper foil & Separators. Partner banks need to be identified for securing green financing commitments towards greenfield large-scale projects and particulars (E.g., percentage commitment, terms, eligibility, etc.) have to be worked out.

Levers to offset structural unit cost disadvantage across identified components need to be finalized (e.g., import duty relief for import of PCAM (raw material)). Relevant central and state government agencies have to work together to implement the identified levers.

New opportunities to attract greenfield project investments in select high priority cell components (i.e., CAM NMC, AAM, Copper foil & Separators), where need-gap exists despite the PLI schemes, need to be explored. Committees with representatives from states would need to be set up to detail the specifics on channelizing existing schemes for providing capital incentive packages. Competitive incentive packages need to be rolled out while ensuring transparent disbursal process.

Localization mandates are essential to accelerate the set-up of EVSE component manufacturing & assembly in India. Committee to be set up to detail specifics on localization criteria and selection mechanism. Mandates have to be rolled-out while ensuring adherence to tender criteria by DHI and state nodal agencies for PCS. Post completion of PMP deadlines, localization criteria need to be re-assessed.

Thrust Area 2 - Ensure consistent availability of critical & strategic EV raw materials to strengthen mineral security of the nation

To ensure mineral security of key battery raw materials, an agile and inclusive stakeholder consultation process needs to be established that can identify bottlenecks such as regulations, permits or operating licenses across the raw materials' (RMs) value chain. Global primary sources (mining) and secondary sources (re-cycling) of critical RMs need to be identified and strategic trade partnerships with resource-rich countries need to be executed.

Ministry directive to drive IREL's focus towards Neodymium mining needs to be secured to produce rare earth permanent magnets in India. Viability gap funding has to be provided as required while setting up the mining facilities. In addition, exploration of alternate sources (e.g., carbonatite reserves) of Neodymium needs to be incentivized.

Setting up of Raw Materials Investment Platform (RMIP) helps in leveraging investments (JVs). A digital platform needs to be set up where prioritized RM projects would then be listed. Investor-investee matchmaking for the pipeline projects would need to be monitored and supported through the platform.

Sustainability standards and certification schemes have to be established to ensure high quality and sustainable output by domestic players & to promote ethical sourcing and transparency in the value chain. Committee for setting the minimum standards across RMs has to be formed that would benchmarks global best practices across critical RMs. Additionally, downstream players have to be consulted with and aligned on certification framework.

Thrust Area 3 - Foster centrally coordinated multi-stakeholder efforts for R&D in EV innovation

EV & battery specific research needs to be promoted through industry outreach and raising awareness of R&D activities. There is a need to understand the current extent of challenges in R&D faced by industry, start-ups and universities across India and expand the industry-academia-startup consortiums to aid in increased collaboration. An R&D roadmap with short, medium term priorities like reducing battery costs, enhancing battery safety, increasing battery density, cycle life, charge rate, recovery of metals and recycling, and long-term priorities like improved traceability of components in battery value chain, self-healing batteries, novel chemistries, solid state batteries, creation of autonomous 'self-driving labs' for experiments on the fly, developing a shared and interoperable data infrastructure for battery materials, real time data based open access BMS and digital twins for cell manufacturing; needs to be laid out to solidify India's strategic research agenda.

EV and Battery innovation hubs in reputed institutions have to be developed through appropriate funding. Innovation labs, in identified partner institutes, providing testing and prototyping infrastructure to be set-up to drive strategic research across identified focus areas. Linkages with other researchers will aid collaboration and reduce barriers to commercialization. Innovation platform to host identified R&D projects to be developed that serves as a gateway for interested stakeholders to take part.

Collaborative research between industry, academia, and start-ups and R&D projects across identified priority areas need to be incentivized which will aid in speeding up commercialization of new R&D findings. EV software features are key differentiators for customers and given their complexity in EVs, decoupling hardware and software development and incentivizing development of proprietary EV software will be helpful. Dedicated funding pool for carrying out R&D projects needs to be set-up to support selected ventures.

Thrust Area 4 - Facilitate industry-academia collaboration for re-skilling and up-skilling the Indian workforce in line with skills and competencies needed to emerge as a leader in the growing Battery & EV manufacturing ecosystem

Existing infrastructure including machines, software, other training infra across universities/ institutes needs to be upgraded as necessary. Faculty of institutes to be equipped with requisite battery/EV skills through a set of dedicated training programs to ultimately enable EV skill development amongst students. Some of the skills and knowledge required will include – knowledge on advanced inorganic and organic chemistry, electrochemistry and material sciences, HV electrical and power electronics, software development, thermal management and mechanical and structural designs of a battery as well as skills to control process parameters and precision manufacturing of cells, expertise in SMT and technical skills like smelting, rolling and welding.

Curated curriculum to be designed for skilling new age EV and battery workforce. Industry outreach and industry-academia consortium expansion is crucial to raise awareness of skill' agenda. Skill-gap assessment has to be carried out to finalize courses to be offered in higher-degree university programs. This includes revamping diploma/certification programs to be included in ITIs / VET centers / Polytechnics. Additionally, MoUs have to be signed with industry players to design internship/placement programs for students undergoing industry approved curriculum.

'Phygital' learning courses for up-skilling existing workforce to be created with the help of technology partners. After assessment of skill-gap, suitable technology partner(s) need to be onboarded for creating 'Phygital' content that needs to be updated with on-demand learning modules based on inputs received from industry-academia. The role of industry outreach and industry-academia consortium expansion is essential to support the process and drive awareness of skills' agenda. Reputed universities should be partnered with to set-up centers of excellence (COE) in collaboration with OEMs and key cell/battery manufacturers. After identifying partner institutes, the institutes should also be enabled to pitch COE to leading industry players for forging partnerships. Dedicated learning & training modules need to be created by the COE. To realize India's mission of becoming a globally competitive powerhouse in battery & EV manufacturing, it is imperative to have a holistic strategy to drive concerted localization across the EV value chain. If the proposed actions across these 4 key thrust areas (in addition to ongoing efforts) are executed effectively, the results can be transformative for India's e-mobility landscape. It will not only accelerate local EV adoption, but also put India on the roadmap for developing a competitive and self-sufficient domestic manufacturing ecosystem for electric mobility.

4.2.2 Action roadmap

For each of the proposed initiatives, a high-level roadmap of key activities has been created that would need to be carried out to make the initiative a success.

Proposed Initiative & Key Activities	Year 1	Year 2	Year 3 Onwards
1 Develop Hi-Tech EV component corridors, along existing auto belts, in partnership with state governments			
Identify suitable auto belts (and corresponding states) for the set up EV component corridor(s)			
Work with state governments to identify and earmark land for EV component corridor			
Onboard stakeholders/ anchor investors			
Build plug-and-play production facilities			
Set up shared infra in EV component corridor			
2 Green financing commitment from banks for supporting large-scale greenfield project investment in India (especially for CAM, AAM, Copper Foil & Separators)			
Identify partner banks			
Work with banks to set up green financing programs (design contours, terms, eligibility, etc)			
3 Provide support to offset structural unit cost disadvantages for production in India, esp. for CAM (e.g., import duty relief for import of PCAM (RM), etc.)			
Finalize levers to offset structural unit cost disadvantage across identified components			
Work with relevant central / state govt agencies to implement the identified levers			
4 Explore opportunities to attract greenfield project investments in select high priority cell components (i.e., CAM NMC, AAM, Copper Foil & Separators) where need-gap still exists despite the PLI schemes			
Set up committee with representatives from states to detail specifics on channelizing existing schemes for providing capital incentive packages			
Roll-out competitive incentive packages and ensure transparent disbursal process			
5 Consider localization mandates to accelerate set up of EVSE component manufacturing & assembly in India			
Set up committee to detail specifics on localization criteria and selection mechanism			
Roll-out and ensure adherence to tender criteria by DHI and State Nodal Agencies for PCS			
Re-assess localization criteria post completion of PMP deadlines			

Proposed Initiative & Key Activities	Year 1	Year 2	Year 3 Onwards
6 Ensure mineral security of key battery raw materials			
Establish an agile and inclusive stakeholder consultation process to identify bottlenecks such as regulations, permits or operating licenses across the raw material RMS value chain			
Identify global primary sources (mining) and secondary sources (re-cycling) of critical RMs			
Drive strategic trade partnerships with resource-rich countries			
7 Enable mining of Neodymium in India for producing permanent magnets			
Secure Ministry directive to drive IREL's focus towards Neodymium mining			
Provide viability gap funding as required			
Set-up Nd mining facility			
Incentivize exploration of alternate sources (E.g., carbonatite reserves) of Neodymium			
8 Set up a Raw Materials Investment Platform (RMIP) to help leverage investment (JVs) in a pipeline of key projects			
Set up digital platform			
List prioritized RM projects on the platform			
Initiate Investor-Investee matchmaking for projects			
9 Establish sustainability standard and certification scheme to ensure high quality and sustainable output by domestic players & promote ethical sourcing and transparency in value chain by enforcing the respective standards			
Form Committee for setting certifications standards across RMs			
Benchmark global best practices for standards and certification across critical RMs			
Consult with downstream players to align on certification framework			
Formulate minimum standards to be followed across RM value chain by domestic players			
10 Develop India's EV & battery specific strategic research agenda covering short-, medium- and long-term R&D priorities			
Industry outreach and raising awareness of R&D activities			
Understand extent and challenges in R&D in India across start-ups, universities, and industry			
Expand consortium of industry-academia-startups and identify key R&D priorities			

Proposed Initiative & Key Activities	Year 1	Year 2	Year 3 Onwards
Lay out national EV and battery specific research agenda covering short-, medium- and long-term R&D priorities, fostered centrally through existing set-ups			
11 Provide funding to develop the required infrastructure for EV and Battery Innovation hubs within reputed institutions, to promote collaborative research			
Identify partner institutes			
Setup innovation labs providing testing and prototyping infrastructure			
Set up Innovation Platform to host identified R&D projects and list projects on the Platform			
Application by stakeholders for open R&D projects of interest			
Strategic research across identified focus areas			
12 Provide incentives to industry, academia, and start-ups to conduct collaborative research			
Create a General Assembly consisting of Industry players across value chain, foreign and local Universities and research institutes, start ups and industry organizations			
Set-up dedicated pool of funds for carrying out R&D in battery/EV and for prototype/commercial product testing.			
Create incentive program for R&D projects laid out as national priorities and for development of proprietary EV software			
Decision on R&D projects to be funded			
13 Develop existing infrastructure and faculty skillset to enable Battery & EV skill development amongst students			
Conduct study to understand key machines/ technology/ softwares required			
Upgrade machines, softwares, other training infra across Universities/ Institutes			
Launch training programs for faculty in line with requisite battery/ EV skills			
14 Design curated curriculum for skilling new age EV and battery workforce			
Form a centralized task force for leading this initiative			
Form partnerships with a few leading OEMS (Eg. Tata Motors, Mahindra, etc) to anchor the industry consultation process			
Expand consortium of industry-academia players to define curriculum requirements across each skilling need (E.g. NSQF level, learning outcomes, etc)			
Task force to complete skill-gap assessment			
Identify need for development of new NOS (basis skill gap assessment)			

Proposed Initiative & Key Activities	Year 1	Year 2	Year 3 Onwards
Define curriculum requirements for each skilling need. (E.g. Course duration, mode of learning, eligibility criteria, assessment criteria, etc)			
Finalize courses to be included in higher-degree university program			
Revamp diploma/ certification programs to be included in ITIs/VET centers/ Polytechnics			
Integrate new/ revamped curriculum in degree/ diploma/ certification framework			
Conclude MoUs with industry members for internship/ placement support for students undergoing industryapproved curriculum			
15 Work with technology partners to design on-demand 'Phygital' learning courses for up-skilling existing workforce			
Industry outreach and raising awareness of skills' agenda			
Expand consortium of industry-academia players			
Skill-gap assessment completed			
Identify technology partner for creating Phygital learning content			
Create on-demand learning modules based on inputs received from industry-academia			
16 Set-up centers of excellence in reputed universities, in collaboration with OEMs and key cell / battery manufacturers			
Identify premier institutes for setting up COE			
Enable institutes to pitch CoE to industry players, identify industry partner(s)			
Create learning & training modules			

To realize India's mission of becoming a globally competitive powerhouse in battery & EV manufacturing, it is imperative to have a holistic strategy to drive concerted localization across the EV value chain. If the proposed actions across these 4 key thrust areas (in addition to ongoing efforts) are executed effectively, the results can be transformative for India's e-mobility landscape. It will not only accelerate local EV adoption, but also put India on the roadmap for developing a competitive and self-sufficient domestic manufacturing ecosystem for electric mobility.

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Acronym	Full Form
AAM	Anode Active Material
AC	Alternating Current
ACC	Advanced Chemistry Cells
ALBATTS	The Alliance for Batteries Technology, Training and Skills
APQP	Advanced Product Quality Planning
ARAI	Automotive Research Association of India
ASDC	Automotive Skills Development Council
ASPIRE	Automotive Solutions Portal for Industry Research & Education
BCD	Basic Customs Duty
BEE	Bureau of Energy Efficiency
BMS	Battery Management System
BOM	Bill Of Material
bps	Basis points
BSS	Battery Swapping Stations
BWMR	Battery Waste Management Rules
CAFC	Corporate Average Fuel Consumption
CAFE	Corporate Average Fuel Economy
CAM	Cathode Active Material
CAN	Controller Area Network
C-BEEV	Centre for Battery Engineering and Electric Vehicles
CBU	Completely Built Up
CCS	Combined Charging Cystem
CECRI	Central Electro Chemical Research Institute
CNS	Chinese National Standard
CoBE	Centre of Battery Engineering
CoE	Centre of Excellence
CoP	Conference of the Parties
CPO	Charge Point Operator
CSIR	Council Of Scientific and Industrial Research
DAE	Department of Atomic Energy
DC	Direct Current
DHI	Department of Heavy Industries
DRIVES	Development & Research on Innovative Vocational Education Skills
DST	Department of Science & Technology
EBA	European Battery Alliance
EC	European Commission
ELV	End-of-life vehicle
EPA	Environmental Protection Administration

ERMA	European Raw Materials Alliance
ETP	Effluent Treatment Plant
EU	European Union
EV	Electric Vehicle
EVCIPA	Electric Vehicle Charging Infrastructure Promotion Alliance
EVSE	Electric Vehicle Supply Equipment
EXIM	Export-Import
FAME	Faster Adoption and Manufacturing of Electric and Hybrid Vehicles
FEA	Finite Element Analysis
FMEA	Failure Mode and Effects Analysis
GB/T	Guo Biao / Tuijian (Chinese recommended national standard)
HMI	Human-Machine Interface
IBAIWA	Indian Batteries and Accessories Industries Welfare Association
IBMA	Indian Battery Manufacturers Association
iCAT	The International Center for Automotive Technology
ICE	Internal Combustion Engine
IEC	International Electrotechnical Commission
IESA	Indian Energy Storage Alliance
IGBT	Insulated Gate Bipolar Transistor
IIT	Indian Institute of Technology
IM	Induction Motor
IPCEI	Important Projects of Common European Interest
IREL	Indian Rare Earths Ltd.
ISO/TC	International Organization for Standardization / Technical Committee
ITI	Industrial Training Institute
JV	Joint Venture
KABIL	Khanij Bidesh India Ltd.
MHI	Ministry of Heavy Industries
MOQ	Minimum Order Quantity
MOSFET	Metal-Oxide-Semiconductor Field-Effect Transistor
MSME	Micro, Small and Medium Enterprises
MSP	Mobility Service Provider
NEDC	New European Driving Cycle
NMC	Nickel-Manganese-Cobalt
OEM	Original Equipment Manufacturer
O&M	Operations and Maintenance (costs)
PCBA	Printed Circuit Board Assembly
PCS	Public Charging Stations
PLI	Production Linked Incentives
PMP	Phased Manufacturing Programme
RM	Raw Material

RMIP	Raw Materials Investment Platform
ROCE	Return on Capital Employed
ROI	Rate of interest
SEZ	Special Economic Zone
SG&A	Selling, General and Administrative (costs)
SIAM	Society of Indian Automobile Manufacturers
SKD	Semi Knocked Down
SMPS	Switched-Mode Power Supply
SMT	Surface Mounted Technology
STU	State Transport Undertakings
TMS	Thermal Management System
TCO	Total Cost of Ownership
TRL	Technology Readiness Level
ULEZ	Ultra-Low Emission Zone
VET	Vocational Education and Training