Assessment of Industry Readiness for Manufacturing of Battery Electric Vehicles

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South Asian Association of Regional Cooperation (SAARC) Energy Centre (SEC) Islamabad, Pakistan

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LIST OF ACRONYMS

ARAI	Automotive Research Association of India
BEB	Battery Electric Bus
BEV	Battery Electric Vehicle
BHP	Brake Horse Power
BMS	Battery Management System
BYD	Build Your Dreams
CAFÉ	Corporate Average Fuel Economy
CoBE	Centre for Battery Engineering
CoEV	Centre for Electric Vehicles
C-BEEV	Centre for Battery Engineering and Electric Vehicles
CBU	Completely Built Unit
CKD	Completely Knocked Down
CO2	Carbon Dioxide
CPEC	China-Pakistan Economic Corridor
EV	Electric Vehicle
FFV	Fossil Fuel Vehicle
FY	Fiscal Year
FAME	Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India
GHG	Green House Gases
HV	Hybrid Vehicle
ICE	Internal Combustion Engine
IIMB	Indian Institute of Management Bangalore
LIB	Lithium-ion Battery
LUMS	Lahore University of Management Sciences
MWh	Mega Watt Hours
NEV	New Energy Vehicle
NiCd	Nickel–cadmium
NiMH	Nickel Metal Hydride
OEM	Original Equipment Manufacturer
PHEV	Plug-in Hybrid Electric Vehicle
PKR	Pakistan Rupee
R&D	Research and Development
SAARC	South Asian Association of Regional Cooperation
SEC	SAARC Energy Centre

TBS	Tariff Based System
TWh	Tera Watt Hours
TOE	Technology, Organization and Environment
USD	United States Dollar
ZEV	Zero Emission Vehicle

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Dr. Tanvir Ahmad

Program Leader (TT)

FOREWORD

Electric vehicles are gaining popularity the world over. They are becoming the preferred vehicle type by both consumers as well as governments, which has pushed the automotive manufacturers into EV development and technology innovation. Mass adoption of BEVs have been hailed as a significant driver bringing reductions in two of the most threatening issues facing developing countries: pollution levels and oil import bills. The economic potential of EVs is tremendous: holding other factors constant, a 1000 cc fuel (operating on petrol) car has an expense (fuel cost) of PKR 284,760 per annum, whereas a comparable EV has an associated charge cost of only PKR 30,240 per annum. However, electric vehicles in developing countries like Pakistan and India remain a niche offering. This study is a step towards exploring the BEV manufacturing potential in Pakistan and India. Contrary to popular belief, despite energy shortages, BEVs have the potential of gaining widespread adoption in Pakistan and India if adapted to the local context supported with right set of regulatory policies.

Muhammad Naeem Malik
Director SEC

EXECUTIVE SUMMARY

This report provides an assessment of the industry readiness for BEVs in Pakistan and India. The study begins with an exploration of the trends in BEV adoption and manufacturing around the world. It conducts case study analyses of three countries currently leading the global EV revolution: USA, China and Norway, and compares those best practices with the local context.

By making use of two frameworks: firstly, through the value chain framework, the study gains a comprehensive overall picture of the industry and identifies the associated key players in the BEV value chain, and secondly, the Technology-Organization-Environment (TOE) framework is applied on key individual players identified through the value chain framework. The study utilized secondary literature review to understand the global best practices. For primary research, interviews and focus group discussions were held in Pakistan and India. Data was also gathered through questionnaires designed along the TOE lines, company documents, and government policies and reports.

From a global perspective, it is observed that countries leading the BEV revolution have adopted multi-pronged strategies to encourage EV manufacturers as well as consumers. Ranging from provision of research funding to imposition of regulations which directly and indirectly curtail the use of ICEVs, to offers of financial and non-financial incentive packages for purchase and production of EVs and related technologies, the strategies address both the demand and the supply side of the equation across the BEV value chain. This study analyses primary and secondary data to evaluate that if these practices can be replicated and sustained by SAARC member states, Pakistan and India, which have limited financial resources, technological capability and public awareness (regarding environmental concerns) as compared to the leading countries.

The findings suggest that BEV industry in Pakistan is at a nascent stage and understandably below par compared with developed countries. OEMs are struggling to bring down the prices of their electric vehicles so they can compete with the ICE-vehicles. A component analysis of the EV cost structure shows that batteries make up about 50% of the total cost, along with determining the range and performance, thus making it the most crucial EV component. Most players require appropriate set of regulatory environment and significant technical collaborations with international organizations. Potential for the local industry exists in the value-driven segments of the battery value chain (e.g. battery pack manufacturing), where service addition and product variation can lead to a profitable business case for local assemblers. However, the cell manufacturing stage of battery value chain is characterized globally by cut-throat competition and is extremely cost-dominated, thus leaving little room for local players (who cannot compete with the lower-priced imported battery cells). Other BEV components such as electric motors, BMS, cables etc. can be locally manufactured over time. Additional issues influencing the manufacturing base are identified such as lack of charging infrastructure, lack of financial resources, high rates of tax and custom duties, and weak business models. The study concludes by making several recommendations on how to generate domestic demand for BEVs in Pakistan. Interesting enough, the study results from India point to the opposite. Generating demand for EVs is not an issue, as there is already sufficient demand present (being a huge market). The issue in India pertains to scaling up the production capacity to meet the existing and the forecasted demand levels of BEVs.

1 Introduction

1.1 Objectives and Scope of the study

The purpose of this study is to assess the manufacturing readiness of two SAARC Member States (India and Pakistan) in BEV supply chain by surveying local supply industry stakeholders, collecting their feedback and suggestions for potential improvements, and making region-specific recommendations. To accomplish this, the study will develop a framework to assess the readiness of automotive industry in respect to BEV manufacturing. Towards this end, a field study of automotive industry has been conducted through interviews, surveys, and focus group discussions with automotive manufacturers and assemblers and the manufacturers and assemblers of important BEV components including battery, electric motor, controller, cables, and associated hardware and software.

The data is analysed and a comprehensive readiness status of the automotive industry as per the study framework is compiled. The study provides an assessment of the performance of competitively advantageous areas of indigenous automotive industry in BEV manufacturing domain. These findings are supplemented and compared with the global best practices using case study analyses of leading countries in BEV manufacturing and adoption. Lastly, it will propose recommendations to assist indigenous automotive industry in member countries to develop strengths in BEV manufacturing, assembling, and related upstream and downstream businesses along with elaborating sustainable strategies and effective pathways to develop and expand the indigenous BEV related industry.

Given the fact that most SAARC countries do not, at present, have significant local manufacturing base in BEV related business, assessing the indigenous capabilities and ground realities by engaging potential stakeholders, will serve to supplement future policy roadmaps to develop this industry domestically. As the study has assessed the current strengths and identified the crucial needs of the local industry to grow in BEV manufacturing, assembly and related businesses, it will serve as baseline information and guide for the relevant stakeholders of the stated SAARC Member States.

1.2 Battery Electric Vehicles

1.2.1 Electric Vehicles – Types

Hybrid Electric Vehicles (HEVs) are driven by an ICE along with an electric motor that utilizes the battery's energy storage. Through the ICE and the regenerative braking, the vehicle battery is charged without needing to be plugged in to an electricity outlet.

Plug-In Hybrid Electric Vehicles (PHEVs) can be connected to an electric power source to charge the battery as they are driven by both an ICE and an electric motor that makes use of the battery's energy. Some PHEVs can travel nearly 100 miles on electricity alone, and all can operate like a conventional hybrid, i.e. on gasoline only.

Battery Electric Vehicles (BEVs) – In a BEV (also called an all-electric vehicle), electric energy is stored in a battery. The battery powers the motor. The EV battery is charged connecting the vehicle with an electric power source (usually with a charging cable). BEVs are the focus of this study. Today, nearly all vehicles, Light Commercial Vehicles, cars, two/three wheelers, buses and trucks are available in battery electric type, besides the traditional ICE.

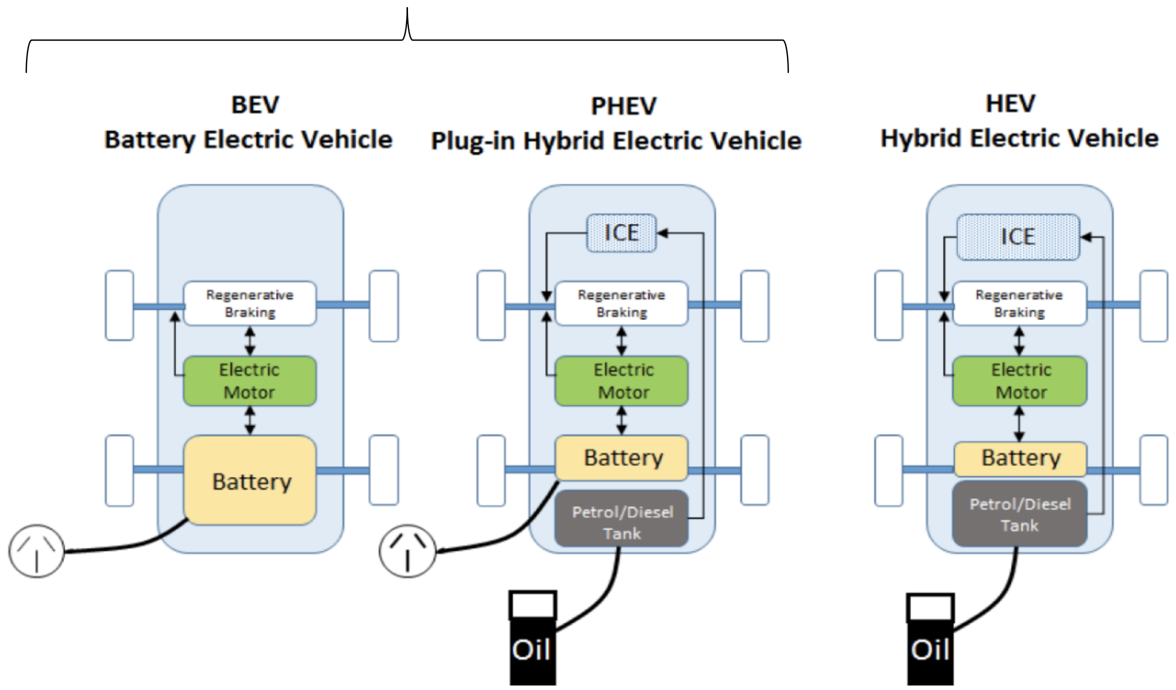

Figure 1 - Electric Vehicle Types

Source: The Driven (2018)

1.2.2 BEVs – Global Adoption and Diffusion Trends

Globally, electric mobility is expanding rapidly. In 2018, the worldwide electric car stock surpassed 5.1 million units, increasing from 2 million in 2017. This represented an almost doubling of the new electric car registrations. The People's Republic of China (from now "China") maintained its position as the world's leading electric car market (highest total stock), followed by Europe (second highest stock) and the United States (third highest). In terms of electric car market share, Norway is the global leader (since 2014), with 46% market share of electric cars.

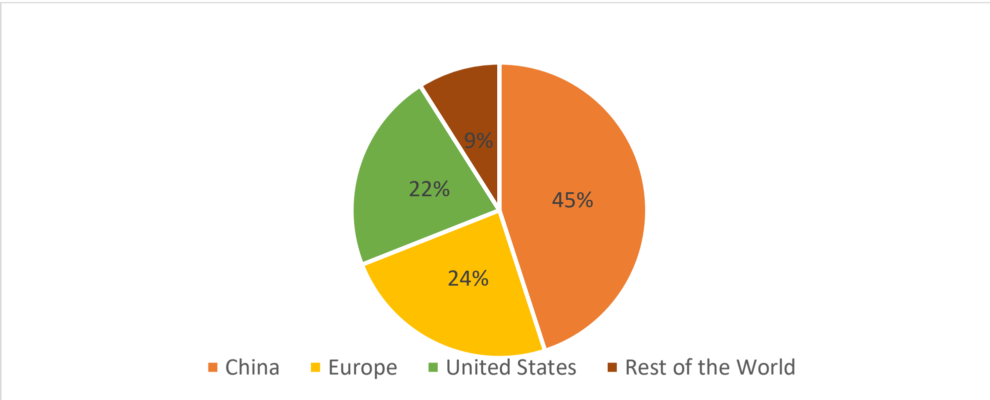

Figure 2 - Global Stock of Electric Cars (%Share)

Source: Global EV Outlook, 2019

64% of the world's electric car fleet is composed of BEVs. Their adoption is being accelerated due to the adoption of global targets such as Vision 30 @ 30, whose signatories (China, Japan, Finland, France, Netherlands and Sweden) aim to reach 30% EV market share by 2030.

Electric two-wheelers stock amounted to 260 million by the end of 2018 and that of the electric buses totalled 460,000 units. The level of electric vehicles in freight transport, touched 250 000 units in 2018.

The stock of EVs was supported by 5.2 million light-duty vehicle (LDV) chargers (end-2018), (540 000 of which are publicly accessible), accompanied by 157,000 fast chargers for buses. This represents a 44% increase from 2017. Majority of this increase was attributable to private charging points, which accounted for over 90% of the 1.6 million installations in 2018. 58 TWh of electricity were consumed to fuel EVs on the road in 2018 (largely attributable to two/wheelers in China). These vehicles were responsible for emitting only 41 million tonnes of CO2 equivalent in 2018, thereby saving 36 million tonnes of CO2 equivalent when compared to comparable ICE- based fleet.

1.2.2.1 Light Commercial Vehicles LCVs

In 2018, approximately 80 000 electric LCVs were sold (mostly BEVs), predominantly in China (54 000 units) and Europe (25000 units). On average, electric LCV sales growth rate was lower in 2018 (24%) as compared to 2017 (94%), although it was higher in Europe in 2018 (42%) than in 2017 (36%).

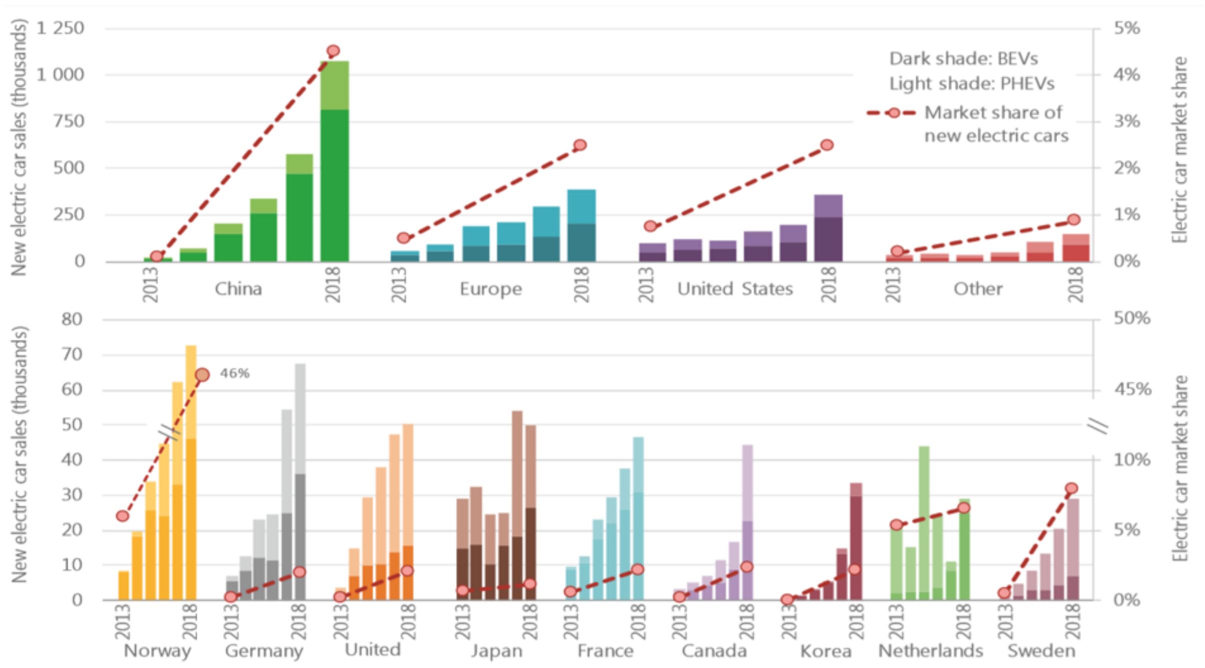

Figure 3 - Global Electric Car Sales and Market Share 2013-18

Source: Global EV Outlook, 2019

1.2.2.2 Buses

The global stock of E-buses saw an increase of 25% (or 100,000 units) in 2018 compared to 2017, reaching a total of roughly 460,000 units. China holds 99% of the global market for electric buses. Most activity in the electric bus market is being undertaken in China as Chinese OEMs are the largest players. Battery Electric Bus (BEB) is the most favoured technology choice as it accounts for 93% of new E-bus registrations.

During 2018, electric buses witnessed dynamic developments as government action and increased interest in electrification of buses was globally more intense relative to previous years. Excluding China, about 900 E-buses were registered in 2018, primarily in Europe. Today, there are over 300 E-buses in the United States[1]. 200 and 40 e-buses were introduced in Chile and Ecuador respectively for the first time in Latin America. A tender for e-bus procurement was also submitted in India under the

[1] Reuters, 2017

FAME scheme. In addition, various state governments in India have also introduced e-buses for mass transportation.

Electric buses in North America are mainly supplied by the following three brands: BYD (China), New Flyer (Canada) and Proterra (United States). New Flyer and BYD have announced to increase investments in e-bus factories in the USA[2]. Daimler has invested in Proterra to jointly develop electric school buses[3]. In Europe and Latin America, Chinese (e.g. BYD and Yutong) and North American (Proterra and New Flyer) companies have been deploying e-buses. Trials have begun on some routes in Australia also, by companies such as Yutong and Zhongtong.[4]

1.2.2.3 Two/Three Wheelers

The electric two/three-wheeler stock, operating on road, surpassed 300 million units in 2018. The electric two-wheeler market is being led by China, followed by India and ASEAN[5] countries. China had 250 million units of electric two wheelers in 2018, over one-quarter of the global two-wheeler stock of almost 800 million units. Two thirds of these have a limited but sufficient performance giving a maximum of 20-25 km/h and covering almost 50 km on a single charge. These characteristics together make low-speed two-wheelers both economical (cost around USD 400) and well-suited for use in congested cities. India's stock of electric three-wheelers is approximately 2.38 million and its annual sales reached 630 000 units in FY 2018-19. ASEAN countries registered a sale of 10 million electric two wheelers in 2018. In European cities these vehicles are mainly introduced by fleet operators of shared rental schemes. There are around 1500 units in Berlin (Germany), 1300 in Madrid (Spain) and 5600 in Paris (France).

1.2.3 Revamping the Supply Chain: BEV Industry Insights

The supply chains for Plug-in Electric Vehicles and conventional vehicles differ substantially (See Figure 4). Therefore, mass deployment of BEVs will reconfigure the existing supply chains, and open up opportunities for battery and cell manufacturers, and their suppliers while reducing or altering the role of conventional component suppliers. Even though electric and ICE vehicles share some of the same component parts, there are several new systems, parts and components in PEVs (Plug-in Electric Vehicles including BEVs) that are incompatible with conventional vehicles. Examples of these new components are: electric power steering, new gear boxes, and water pumps for cooling the electric engine. Manufacturing of basic materials for batteries, cell components and battery packs will necessitate the supply chains to be revamped majorly.

The opportunities for suppliers depend upon which companies and at which tier levels they are supplying. Incumbent automakers generally target to keep their costs low along supply chains so as to ensure the best end-value to their customers and thus negotiate accordingly. This implies that suppliers doing business with battery manufacturers and startup OEMs/entrepreneurial firms may be able to receive better profit margins.

Globally, major automakers have already started or are planning to start BEV production. Incumbent automakers transitioning to EV manufacturing have an advantage over startups since they already have brand recognition, start-up capital, supply chain relationships, manufacturing scale, and customer service channels. However, even they must invest millions of dollars in retooling production

[2] CleanTechnica, 2018; Mass Transit, 2018
[3] Proterra, 2018
[4] Australasian Bus & Coach, 2019
[5] Association of Southeast Asian Nations includes: Brunei Darussalam, Cambodia, Indonesia, Lao People's

lines and ramping up production of EVs. This is where the government comes in by providing the much-needed stimulus in the shape of incentives and regulation to boost domestic manufacturing of batteries and EVs.

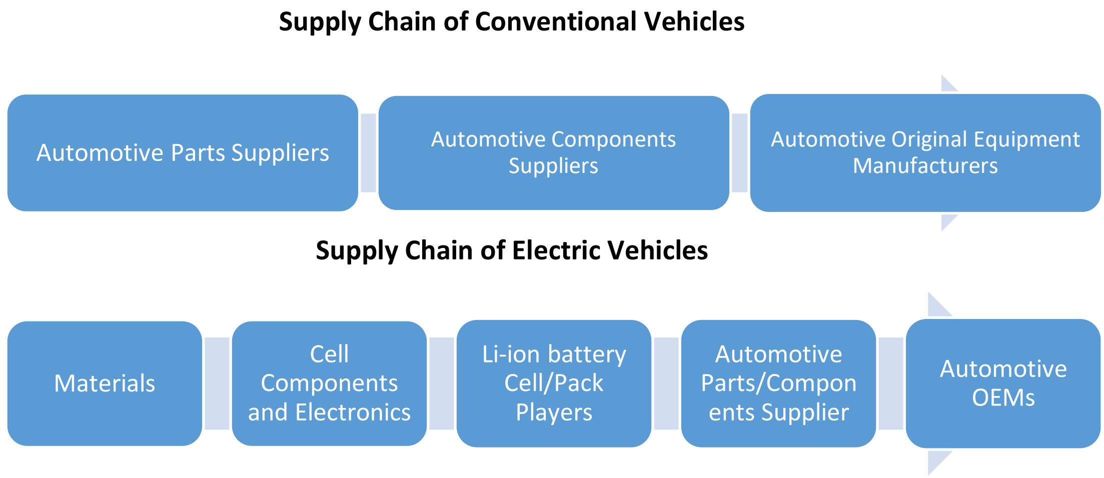

Figure 4 - Supply Chain - Conventional vs. Electric Vehicles

A BEV industry supply chain provides several advantages and can replace or readapt conventional automotive supply chains. Some insights are given below:

- The EV industry supply chain is comparatively horizontally structured (Figure 5). This implies that, compared with the rest of the automotive industry, BEVs use a smaller number of components and usually require less collaboration between vehicle manufacturers and component/part manufacturers. This means that parts manufacturers (Tier one and Tier two suppliers) can be less specialized and generic products can be supplied at various levels in the supply chain[6].
- Another implication of this relatively horizontal structure of EV supply chain is that there are lower barriers to entry for firms along the entire chain[7]. A region can leverage its own competitive advantages —existing high-tech and clean-tech industries (skills are transferable from the traditional automotive industries, consumer electronics industry etc.), cheap labor, availability of raw material, skilled managers and engineers, venture capital resources and supportive public policies — to generate opportunities in the development and retention of new EV-related businesses.
- Upstream activities, which include mining and processing raw materials that are utilized in EV manufacturing, such as metals (Lithium, Cobalt, and Nickel etc.), plastics, and leather and rubber textiles, can represent significant opportunity to some regions.
- EV product development is significantly related to the fields of “Engineering”, “Research and Development” and “Design”. So, having local companies in the EV ecosystem supporting major automotive manufacturers will affect a region’s standing.
- Vehicle manufacturing (assembly and production of finished EVs) generally takes place in regions which are located in close proximity to battery manufacturing countries and which have lower cost of labor, land rentals, and taxation rates.

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[6] Bay Area PEV Readiness Plan. Available at: http://www.baaqmd.gov/plans-and-climate/bay-area-pev-program/bay-area-pev-ready

[7] Zhou et al. 2010

- Component and parts manufacturing firms supply electric motors, vehicle drivetrains, controllers, batteries, cables and other components to EV OEMs. Firms making components tend to form clusters and locate in vicinity of vehicle manufacturers.
- Charging infrastructure includes a wide range of manufacturers and vendors of EV charging infrastructure systems and the related software. Financial and development assistance for EV charging station companies should be extremely targeted, given the fact that industry consolidation is highly expected.
- Downstream EV- related activities, including retail sales, maintenance and repair services, battery recycling, and vehicle sharing, develop as EV sales increase. Hence, targeted strategies are not generally needed to attract these businesses.

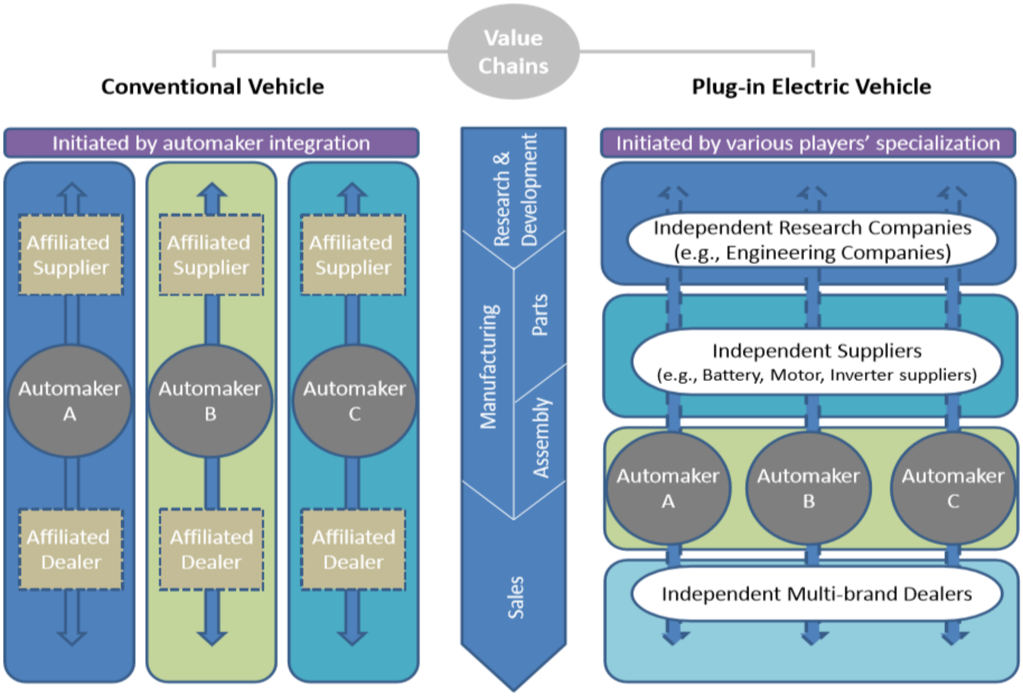

Figure 5 - Value Chains: Conventional vs. Electric Vehicles

Source: Adapted from Zhou et al. (2010)

1.2.4 Building Sustainable BEV Supply Chain

BEV supply chains need to be sustainable; economically, environmentally and socially. This requires a multi-pronged strategy engaging consumers, suppliers, and distributors. The challenges facing a BEV supply chain can be summarized as follows: -

Production Challenges: The development of a new major industrial sector, such as a BEV industry, predictably has consequences for the relevant raw materials and supply chains. As it involves a transition to electric motors and batteries as the main components of the powertrain, it leads to major structural change in the raw materials used in the automotive sector. Some of the challenges frequently encountered in the supply chains of materials include: lack of reserves or resources, under-investment in production capacity, and long lead times (time between initiating and executing) of new capacity.

Requirements for battery production especially point toward increased demand for new materials in this sector. Production challenges surrounding the supply of raw materials make the sustainability of the value chain unstable. Most frequently used battery chemistries require aluminium, graphite, lithium, copper, nickel, carbon, cobalt and manganese in large quantities for battery packs. For instance, an EV holds about five-times more copper than an equivalent ICE vehicle[8], as it is found in the electric motor, battery, and wiring. Large quantities of copper will also be needed for upgrading power grids and extending infrastructure for EV charging. Much of the Cobalt is mined from the Democratic Republic of Congo (DRC) where its extraction is marred with issues of child labour. This has led to a search for battery chemistries which do not depend upon cobalt (such as lithium iron phosphate (LFP)). There is a need to increase responsiveness to raw materials supply. This can be done by ensuring that the supply chains are traceable and transparent, and by developing mandatory regulatory frameworks to ensure that transnational multi-stakeholder collaboration can successfully address these challenges. That being said, cathode chemistries significantly determine the demand sensitivity for these metals and the demand for materials in the automotive sector in future will depend, ultimately, on battery technology and chemistry and the speed of the transition to electric mobility.

Critical Materials related to BEVs

Cobalt, graphite, lithium, aluminium, manganese and rare earth elements (the latter are mostly used in electric motors) are included in critical materials list of several countries (USGS, 2018).

An issue that makes the sustainability of material supply chains difficult to ensure is the lack of identification and traceability of each stakeholder along the material value chains, from the mine to the end-product manufacturer, that is the OEM in the case of electric vehicles (IEA, 2018a). Their international nature and the diversity of local regulations and minimum reporting standards blur the overall view of the value chain. Breaches in the supply chain traceability lead to under-awareness of the social, environmental, corruption and conflict-related risks and hazards associated with each step of the value chain. The limited information for product manufacturers and their customers that results from these gaps in

Social Challenges: Mass BEV adoption and production requires diverse strategies which impact the welfare of people locally, regionally, nationally and even transnationally.

Advancing the development of the EV value chain also requires investment in building the knowledge generation capacity of academic institutions and training centres to ensure that they are well-equipped fulfil any potential skills gap. This is an essential step to enable the opportune development, formation, and consolidation of the professional profiles needed for the entire value chain.

Economic Challenges: EV purchase prices are not yet competitive with ICE vehicles. Governments are juggling with different combinations of supply and demand side incentives, import/export options, production policies and standards while ensuring demand/supply balance and addressing potential supply disruptions, and demand fluctuations.

[8] ANL, 2018

Furthermore, the implications for tax revenues are also important. The growing uptake of EVs may alter the tax revenue derived from vehicle and fuel taxes. If the current taxation schemes are left unadjusted, this can reduce available funding for other developmental projects.

Geopolitical Challenges: Supplies of raw materials are exceedingly reliant on national policies and strategies. Their supply is often exacerbated in cases of geographical concentration of extraction and/or refining. For instance, China, holding a dominant position in the supply of rare earths[9], cut off exports of these minerals to Japan in 2010 when the two governments were locked in a dispute over ownership of some islands east of Taiwan. Although China's share of rare-earths production has fallen from 97% of the world's supply in 2010 to approximately 71% in 2018[10], its recent trade war with U.S.A is bringing up the same old concern of restricted global supply.

Environmental Challenges Emissions emanating from the production of BEVs have impact on local ecosystems and water resources. Life-cycle emissions analysis has shown that electricity generation mix is a major determinant of the emissions saving resulting from electric vehicles use. For instance, Norway with its 98% of electricity generation from renewable resources stands to gain far more environmentally than say China, where 60% of the electricity generation is coal-based. EV manufacturing and adoption should aim to maximise the GHG emissions reduction benefits, and to achieve this, policies aiming to support the acceptance and adoption of EVs must be combined with measures calculated to decarbonise the electricity generation mix.

Furthermore, the battery end-of-life management should be carefully planned both to limit the environmental pollution and to reduce the volumes of critical raw materials needed for batteries. This includes taking steps to establish second-life applications of automotive batteries, standards for battery waste management and environmental requirements on battery design.

It is important that governments and the auto manufacturing industry develop the needed capacity to anticipate the risks associated with these changes and design strategies to manage them.

1.3 Industry Assessment Framework and Methodology

1.3.1 Assessment Framework and Indicators

The study's approach to assess the industry readiness for BEVs, is to make use of two frameworks. Firstly, it will apply the value chain framework to gain a comprehensive overall picture of the industry and to identify the associated key players in the BEV value chain. Secondly, it will apply the Technology-Organization-Environment (TOE) framework on key individual players identified through the value chain framework

Value Chain Framework

Value chains include the full spectrum of activities and services required to take a product from its conception to its sale in the end market. They include inputs suppliers, producers, processors, retailers/distributers and customers. Value chains are supported by various related business, technical, and financial services providers.[11] Since it is unusual for a firm to perform all activities from product design to final product delivery by itself, value chain analysis deals with the entire value system or the supply chain context in which the organization operates.

[9] 17 elements in mineral form, EV makers rely on for lighter-weight battery and motor components.
[10] https://www.bloomberg.com/opinion/articles/2019-05-30/we-all-need-to-calm-down-about-rare-earths
[11] USAID, Briefing Paper

A value chain has both structural and dynamic components. Firm behavioural dynamics are influenced by the structure of the value chain. These dynamics determine how well the value chain performs. Value chain structure comprises five elements: business and its supporting environment, end market, supporting market, and horizontal & vertical linkages.

Figure 6 depicts the Value Chain as applied in the BEV context in this study. End markets represent the last user of the products or services, hence in the BEV context, they imply the final BEV user.

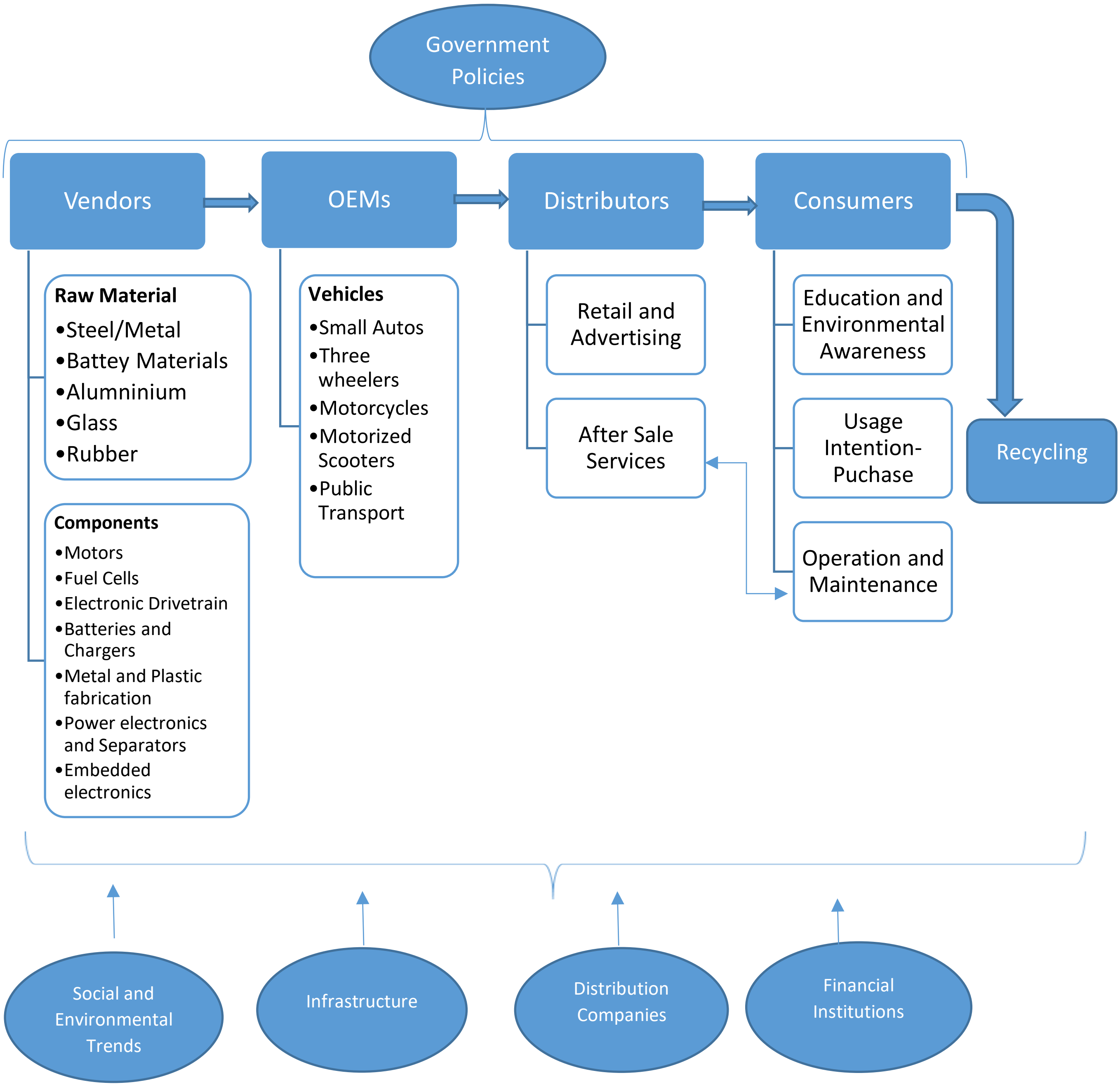

Figure 6 - BEV Value Chain Framework

Technology-Organization-Environment (TOE) Framework

The TOE Framework[12] makes use of three different contexts to explain the factors influencing the adoption of a technological innovation. Firstly, the technological context includes the external and internal technologies that are applicable to the firm. Secondly, the organizational context relates to the individual firm's characteristics and resources, such as its size, extent of centralization and formalization, human resources, managerial structure, surplus resources, and connections among employees. Thirdly, the environmental context encompasses the regulatory environment, the macroeconomic context, industry's size and structure, and the firm's competitors. These three contexts or elements together present both limitations and opportunities for a given technological innovation. The TOE model has wide-ranging applicability and retains explanatory power when applied across various industrial, technological, national and cultural contexts[13].

The study suggests that as BEVs are basically a technological innovation, their adoption and diffusion can be explained with the TOE framework. All the key players identified through the value chain framework will be analyzed through three perspectives: technological, organizational and environmental. The progress of the value chain can be smoothed or hindered depending upon the many factors affecting the market. The three contexts or elements from the TOE framework will help identify both constraints and opportunities for a given technological innovation, i.e., BEV production and adoption.

1.3.2 Survey design & sampling

Before applying the above-mentioned frameworks on Pakistan and India, the study has analysed leading countries in terms of BEV production and adoption to understand the best practices around the globe. For this purpose, the following countries are selected: China, Norway and USA, where the electric car stock is primarily composed of BEVs. The study sought to address whether the best practices of these countries can be replicated in countries like Pakistan and India.

Norway: Norway is the undisputed world leader in electric cars market share, with vehicles charged almost exclusively off the nation's abundant hydro-power resource[14]. It has the highest BEV market share in the world.[15] In 2018, EVs comprised 46%[16] of all vehicle sales. When considering that they were only 20.8% in 2017 and 5.5% in 2013, it shows that in around 5 years Norway has substantially improved EV acceptability amongst its residents.[17] A combination of factors is responsible for this high market penetration. BEV have achieved price parity with a comparable ICEV due to subsidies and non-monetary incentives for BEVs. This is discussed in detail in Section 3.3. Norway is ideal for EVs as the country's persistent budget surplus enables it to grant the generous subsidies. Majority of Norwegians (approx. 73%) live in accommodations with in-house facilities for charging EVs[18] making public charging infrastructure less critical than in other countries.

China: Where Norway outperforms other countries in relative terms, China does so in absolute terms in EV market. Driven by the government policies, which influence both EV buyers and manufacturers, China is pushing ahead to develop its EV industry. Electric mobility is expected to remain a priority of

[12] Proposed by Tornatzky and Fleischer, 1990
[13] Baker, 2011
[14] The Guardian 2017
[15] (ICCT Europe, 2014)
[16] Global EV Report 2019
[17] The independent Norwegian Road Federation (NRF), Reuters, 2019
[18] Statistics Norway, 2014

the auto industry in coming years to come as its market share grows and the government makes the EV adoption a main concern in numerous regions.

China had 45% (5.1 million units) of the world's electric cars in 2018, compared to 39% in 2017. The People's Republic of China (hereafter "China") is the world's biggest electric car market[19], since 2014, BEVs make up about 75% of the Chinese electric car stock share.

In 2016, Chinese market offered customers around 75 EV models. The sales dynamic is supplemented by other facts such as: Chinese OEMs produced 43 percent of total EV stock in the world, Chinese lithium-ion battery-cell players held 25% of the global supply share, and the country expanded its EV-charging infrastructure to 107,000 public outlets[20]. BEVs are exempted from license registration fees (as high as $14000) in Beijing, Shanghai, and Shenzhen.

USA: Although, the United States of America is currently third globally on the stock of electric cars, it is leading the world in terms of Research and Development on BEV and the associated value chains. In USA, the growth of the EV market is most pronounced in the state of California. In 2017, half of all USA's electric vehicle sales were in California**.** Low and moderate income earners typically get rebates of $2,500 for BEVs. At the end of 2017, California had 344 public charge points per million residents, whereas the rest of the USA had only 107.

The study has analysed the above mentioned three countries using the value chain and TOE frameworks. It also explored the local context and assessed how the lessons learned from best practices can be applied to India and Pakistan. Several local characteristics have also been factored in.

1.3.3 Execution

The study executes the above by making use of secondary literature and data review to analyse the cases of leading countries. Global EV Outlook reports, white papers, papers by consulting firms such as McKinsey and Deloitte, are utilized for the secondary literature review. Information is also gathered from the Departments of Energy and Ministries of Transportation and Climate Change of respective countries. In addition to this, secondary data collection from Pakistan comprised a thorough analysis of Economic Surveys of Pakistan, the National EV Policy 2019, relevant research papers, and company documents.

The primary study mainly comprises of a field-based survey of the automotive industry of two SAARC Member States i.e. Pakistan and India. Primary data collection was done in two stages. In the first stage, interviews have been conducted with the key actors identified through the value chain framework. Section 4 elaborates on the nature of participants. The key automotive industry stakeholders surveyed includes manufacturers and assemblers (incumbents and start-ups) of BEVs and BEV components such as battery, battery management system, motor/traction, inverter, and related hardware and software. In addition, a trader/dealer perspective is also collected as a part of the survey. The research segmented 2/3/4 wheelers and interviewed 43 persons from the cities of Karachi, Lahore, Islamabad and Gujranwala. The authors compiled a questionnaire to guide the interviews using the TOE framework. (Refer to table 3 for Interview Questionnaire)

In the second stage, halfway through this project, the project leads held seminars on Industry Readiness for Manufacturing of Battery Electric Vehicles in Pakistan (on 30th August 2019 at LUMS) and India (on 3rd September 2019 at IIMB). The purpose was to:

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[19] Global EV Outlook report 2019

[20] Mckinsey, 2017

- Bring together various stakeholders related to BEV manufacturing in Pakistan and India
- Share research findings by LUMS, Pakistan and IIMB, India
- Discuss current state, opportunities, and challenges of readiness of the manufacturing value chain in Pakistan
- Identify future targets and pathways to achieve those targets

The gathering from Pakistan comprised 68 participants representing:

- Entrepreneurial ventures
- Component manufacturers: motors, cables, batteries
- Original automobile manufacturers (two, three, and four wheelers)
- Local and international technology providers
- Universities, research institutions, and incubation centres
- Allied industries
- Lahore Chamber of Commerce and Industries
- Engineering Development Board

Using the value chain framework to identify key players in Pakistan's BEV manufacturing. Given the nascent stage of the industry, the study takes an exploratory approach and gives an overview of the key players in BEV industry as identified through the value chain framework and interviewed by the project leads during May- August 2019. The report will next apply the TOE framework on the identified players. For the execution, the project leads successfully held a seminar on Industry Readiness for Manufacturing of Battery Electric Vehicles in Pakistan and India. (Exhibit 1 gives the details of the event). The purpose of this session was to bring together various stakeholders related to BEV manufacturing in Pakistan and India and to share with them the research findings made so far by LUMS, Pakistan and IIMB, India. By discussing the current state, opportunities, and challenges of readiness of the manufacturing value chain in Pakistan, the study assessed the competitiveness of the industry, and identified future targets and pathways to achieve those targets. The seminar also contributed to quantitative data collection as almost 40 participants filled out a questionnaire designed along the lines of TOE Framework. The respondents were asked to rank their perception of the current state of factors on a scale of 1 to 5 (with 1 being 'low'; 2 being 'somewhat low'; 3 being 'neither low nor high'; 4 being 'somewhat high'; and 5 being 'high'). The findings are incorporated into Section 5 (Pakistan) and Section 8 (India) as average scores for various parameters along with the quantitative data collected earlier via interviews.

The complete list of the participants from Pakistan is given in Exhibit 3. In short, the participants included top management and/or owners of organizations who have experience, leadership and potential in the BEV industry:

- Entrepreneurial ventures
- Component manufacturers: motors, cables, batteries
- Original automobile manufacturers (two, three, and four wheelers)
- Local and international technology providers
- Universities, research institutions, and incubation centers
- Allied industries
- Lahore Chamber of Commerce and Industries
- Engineering Development Board

The seminar also comprised a panel discussion by following:

- Mawish Ahmad (Managing Director, Power Electronics Pakistan)
- Muhammad Azim (Chairman, Auj Group)
- Shaukat Qureshi (EV Technologies Consultant) Chief Operating Officer, EV Auto Division
- Haider Zaidi (CEO, Haris Enterprises – representing InerZ)
- Zubair Ahmad (General Manager Production, Sazgar Engineering)
- Muhammad Nauman Zaffar (Associate Professor, School of Science and Engineering, LUMS

2. Analysis of Global BEV Supply Industry

This section will analyse the BEV supply industry in general using the value chain framework, with a particular emphasis on manufacturing.

2.1 Original Equipment Manufacturers (OEMs)

2.1.1 Opportunities and Challenges

In the value chain of BEV manufacturing, the OEMS hold chief position. Their actions are being determined by the following factors:

- Government Regulation
- Poor Demand Outlook
- High Cost of capital and Production

Government Regulation: Advanced countries are encouraging vehicle manufacturers to increase investment in and development of EVs by manipulating the regulatory environment. It can be concluded that supply has been mainly driven by policy and regulation. Minimum (EV) sales requirements and stricter fuel efficiency targets when implemented strictly, can only be achieved with higher EV penetration (For instance USA, China). Without regulation, EVs would have probably continued being a niche offering even in the developed world, as manufacturing costs (and thus the sales prices) would have remained exorbitantly high. Government regulation has thus forced OEMs to reallocate and dedicate capital to EV production. OEMs not complying with the government regulations risk being fined and gaining an eco-unfriendly reputation. Similarly, policies, designed to achieve the goal of EV adoption and/or manufacturing, are an important tool. In order to help create demand, subsidies and non-financial incentives are offered as subsidy levels and EV penetration seems to be strongly correlated. In short, financial incentives have been necessary to encourage adoption of EVs at this stage.

Poor Demand Outlook: Thus far, EV adoption is not demand-driven, as EV interest amongst consumers remains subdued. Ingrained buying habits present a challenge for OEMs. Analysis of the relationship between price and power (bhp) and that of between price and CO2 emissions shows that customers are by and large willing to pay for power, but not for fuel efficiency, especially when fuel prices are low. Hence, OEMs have traditionally been hesitant to add fuel-saving content to vehicles given the inadequate financial return of such a venture.

High Cost of Capital and Production: Traditional vehicle manufacturers base their decisions on the potential investment return relative to capital cost. Majority of decisions (particularly those relating to significant resources) require long managerial processes, which can hinder the pace of the projects. Sluggish decision making is becoming a distinctive feature of the incumbent operators, giving new entrants with a competitive edge. Furthermore, automotive OEMs have small margins requiring capital investment decisions to be strictly controlled. The dilemma facing most can be summarized as regarding the split of capital expenditure between "improving existing technologies versus investing in new technologies — like EVs – where demand uncertainty makes outlook unpredictable". The point of inflection for supply will be when cost parity between EVs and ICEVs is reached. Interestingly, this is expected to be sooner rather than later in future as battery costs are expected to decline and the cost of non-compliance with emissions expected to increase further. Till now, the high cost of production has remained a catch-22 for OEMs. High battery cost is a major obstacle for price-reductions for EVs. The high cost in turn is due, partly to the fact that economies of scale are not being attained with the current production volumes. It is thus difficult for manufacturers to reduce their EV's selling price without compromising their financial performance. At the same time, prices need to fall in order to make EVs advance onwards from the 'early-adopters' phase.

The challenge, until cost parity with ICEVs is achieved, is that EVs are far more expensive to manufacture, and unless consumers are to compensate for this 'extra cost', EV production, is not a profitable endeavour without subsidies at present.

2.1.2 OEMs Future Targets

OEMs have been gearing for mass EV-adoption and their actions suggest that EVs do have a sustainable future ahead. There has been a more than 40% increase in EV-related R & D investment expenditure since 2006, and latest announcements from OEMs suggest that the upward trend is expected to continue:

BMW - 15-25% of the Group's sales to be electric and 25 new EV models by 2025.

BJEV-BAIC – targeting 0.5 million E-car sales in 2020 and 1.3 million sales of E-cars in 2025.

Chonquing Changan - 21 new BEV models and 12 new PHEV models by 2025, 1.7 million sales by 2025 (100% of group's sales).

Dongfeng Motor CO - 6 new EV models by 2020 and 30% sales share of electric cars in 2022.

Ford - 40 new EV models by 2022; Geely - 1 million sales and 90% of sales in 2020; GM 20 - new EV models by 2023; Hyundai-Kia - 12 new EV models by 2020.

Honda - 15% electric vehicle sale share in 2030 (part of two-thirds of electrified vehicles by 2030, globally and by 2025 in Europe).

Mazda - One new EV model in 2020 and 5% of Mazda sales to be fully electric by 2030.

Mercedes-Benz - 0.1 million sales in 2020, 10 new EV models by 2022 and 25% of the group's sales in 2025.

Renault-Nissan Mitsubishi - 12 new EV models by 2022. Renault plans 20% of the group's sales in 2022 to be fully electric.

Infiniti - all models electric by 2021; BYD - 0.6 million E-car sales in 2020; Tesla - Around 0.5 million sales in 2019 and a new EV model in 2030.

Toyota - More than ten new models by the early 2020s and 1 million BEV and FCEV sales around 2030.

Volkswagen - 0.4 million electric car sales in 2020, up to 3 million electric car sales in 2025, 25% of the group's sales in 2025, 80 new EV models by 2025 and 22 million cumulative sales by 2030.

Volvo - 50% of group's sales to be fully electric by 2025.

Figure 7 - OEM Announcements

Source: Global EV Outlook, 2019

2.2 EV Batteries

The battery is a key component of the EV, because, the vehicle's range depends almost completely on it. Furthermore, it is the heaviest and most costly electric component in an EV. Most EV batteries are lithium-based with a combination of manganese, cobalt, nickel, graphite and other primary components.

Since the battery forms the core part of an electric vehicle both in terms of technology and cost, this report focuses only on the battery part of the BEV supply chain. The supply chains for the rest of the components (other than the drive train) remain the same as ICE based vehicles and hence will not be dealt with in this report.

2.2.1 Battery Technologies

A battery's main components can be divided into four distinct parts: a negative electrode (anode), a positive electrode (cathode), an electrolyte and a separator. The diversity and properties of anodes and cathodes often differentiates batteries. The separator and electrolyte, generally, are the ones that are commercially available. The electrolyte mainly transports ions from the negative electrode to the positive electrode or/and vice-versa, while ensuring that any reactions with the Li-ions remain minimal. The electrolyte is made up of water with a certain amount of dissolved salts, such as, lithium hexafluorophosphate, to ensure proper ion conductivity. The separator serves to stop the transportation of electrons without interfering in other processes. Various types of high voltage batteries are available, with the electrode chemistry being the chief distinctive factor. Some of the popular types are:

Battery technologies by chemistry with pros and cons

Key performance metrics of cathode chemistries

Cathode level metrics

Strong | Moderate | Weak

Material	Description	Safety	Cost USD/kWh	Energy density kWh/kg	Cycle life Times	Ni content Kg/kWh
LCO ($LiCoO_2$)	Mostly applied to consumer electronics. Limited application for xEVs (e.g., Tesla)	Low	Low	0.58	1,500 - 2,000	0
NMC1 ($LiNi_xCo_xMn_xO_2$)	Applied mainly in consumer electronics but increasing application for xEVs	Mid	Mid	0.60	2,000 - 3,000	0.69 (51 wt²%)
LMO ($LiMn_2O_4$)	Relatively mature technology. Applied in xEVs by Japanese OEMs (e.g., LEAF, iMiEV, Volt)	High	High	0.41	1,500 - 3,000	0
LFP ($LiFePO_4$)	Relatively new technology applied in xEVs and ESS. Driven by A123 and Chinese manufacturers (e.g., BYD, STL)	Very high	High	0.53	5,000-10,000	0
NCA ($LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$)	Applied mostly in consumer electronics (often blended with other chemistries) and e-vehicles (e.g., Tesla)	Mid	Mid	0.72	NA	0.68 (49 wt²%)

Figure 8 - Battery Technologies by Chemistry with Pros and Cons

Source: Azevedo et al. (2018) Lithium and Cobalt - A tale of Two Commodities, McKinsey and Company

- Lead acid batteries – mainly used in electric two wheelers
- Li-ion batteries - further divided into following types:
- Lithium Manganese Oxide (LiMn2O2)
- Lithium Nickel Manganese Cobalt Oxide (NMC)
- Lithium Cobalt Oxide (LCO)

- Lithium Nickel Cobalt Aluminium (NCA)
- Lithium Iron Phosphate (LiFePO4)

Lithium-ion batteries are known for their high energy- and power-density. They also have high lifetime compared to other types due to intercalation of lithium-ions in the electrodes. However, as lithium goes through numerous side-reactions, over time, the concentration of lithium available for intercalation reduces. This causes the battery capacity to fall over its lifetime.

Battery technology is being improved. Lithium-titan ate and lithium-iron-phosphate, for example, are gaining popularity in the EV landscape as they don't need cobalt (which has supply shortages as already stated). Magnesium, lithium-sulphur and sodium-based battery chemistries are also gaining prominence as these can potentially out-perform lithium-ion batteries in terms of energy density and cost. In automotive applications, phosphate lithium-ion batteries have been proven to be safer in terms of chemical and thermal exposure.

Trade of lithium-ion batteries increased by 24% per annum during the time period 2015-18 in terms of battery capacity, reaching over 148,000MWh. In comparison, trade of NiMH batteries totaled below 10,000MWh and that of the NiCd batteries was less than 1,000MWh in 2018. The share of lithium-ion battery shipments used in automotive applications is increasing steadily: it was 6% in 2010, 43% in 2015, and more than 70% in 2018.

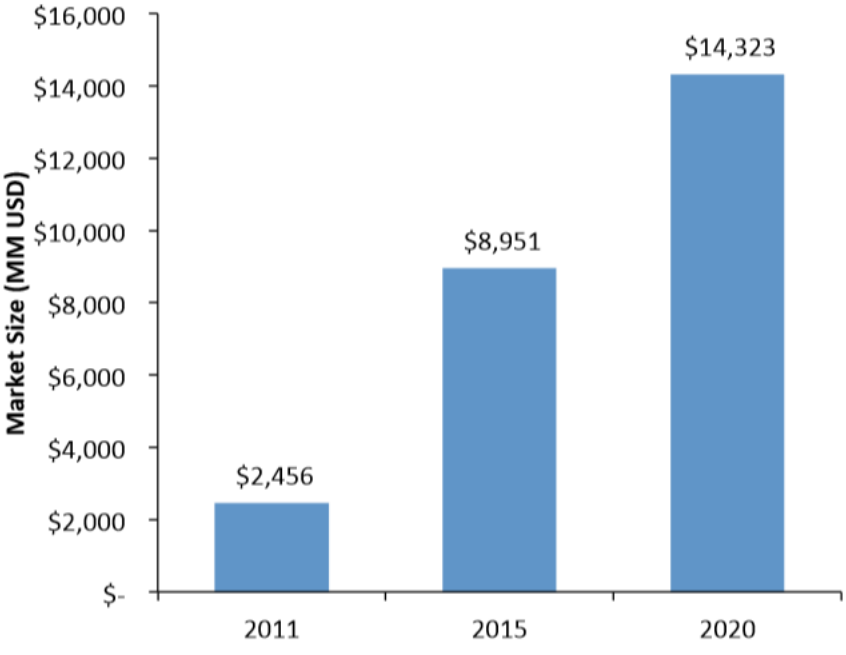

Figure 9 - Global LIB Pack Market (Automotive Applications)

Source: Roland Berger (2012), ABB (2013); Pike Research (2013) CEMAC Analysis

As can be seen from Figure above, the global LIB Pack market for automotive applications is projected to reach $14,323 million in 2020 compared to just $2,456 million in 2011.

2.2.2 Battery Supply Chain

As batteries are such a major component of EVs, this study will explore its supply chain in detail.

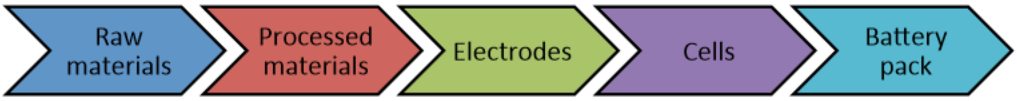

Figure 10 - The Automotive LIB Manufacturing Value Chain

Source: Pike Research (2013); CEMAC Cost Analysis (May 2014)

Battery manufacturing, as can be seen from the battery value chain figure above, comprises several steps which are performed in separate facilities: -

1. Raw materials, which are the basic input materials (such as Graphite, Lithium, Cobalt etc.) are mined;
2. Raw materials are processed to remove impurities and to achieve specific composition. The processed materials are considered “critical to quality” which means that their purity determines the overall cell performance and yield;
3. The processed and purified materials are then used to manufacture electrodes (cathode and anode materials). This stage is also “critical to quality” which means that it determines the overall cell performance and yield;
4. Electrodes are then used to form cells. Cells are the fundamental, functional charge-retaining battery units comprising anode, cathode, separator, electrolyte, and casing. Usually electrodes and cells are manufactured is the same facility. This stage is critical to quality as the cells will determine the battery performance and yield.
5. The final stage involves the composition of packs through the assembly of multiple cells, thermal management, controls and physical protection to form a complete battery pack.

Battery cell production was estimated to be at 70 GW for electric LDVs in 2018. Battery production is concentrated in China, which holds over 50% global market share. The remaining market share is divided between Korea, United States and Japan. Although there are around 60 battery manufacturers in China, the leading two companies, BYD and CATL, account for more than half of the Chinese market. Figure 10 shows the LIB market share of top brands in 2018.

The benefits of economies of scale are encouraging battery manufacturers to increase their production capacity. A major percentage of production is sourced from small plants with a capacity of around 3-8 GWh/year, however, several recent statements by battery manufacturers, of expansions in production capacity, indicate both increases in existing plant sizes and the establishment of new plants by new entrants in the automotive battery market. 21% of the total capacity is recently installed and is located in China, Japan and Korea[21]. This new development of increased production volumes will improve capacity utilisation rates[22], (Refer to Figure 15) which at present are quite low in some of the regions.

2.2.3 Battery Cost and Production

The biggest barrier to EV adoption has been the cost of batteries. In 2007, the price of lithium-ion batteries was well over $1,000/kWh, but has fallen sharply in recent years, primarily due to more cost-effective methods and increased scale of production.

[21] EV Volumes, 2019

[22] Benchmark Minerals, 2018

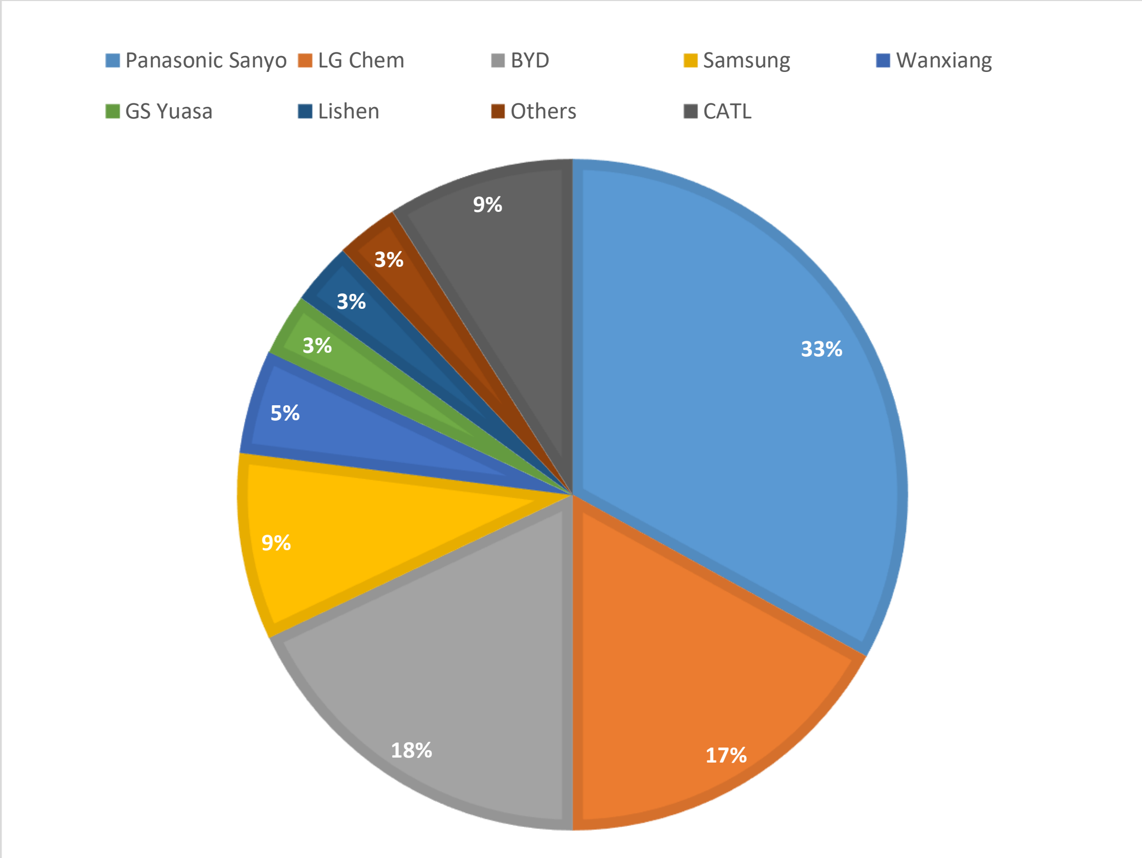

Figure 11 – Company-Wise Lithium-Ion Battery Market Share (2018)

Source: Authors' compilation from various sources

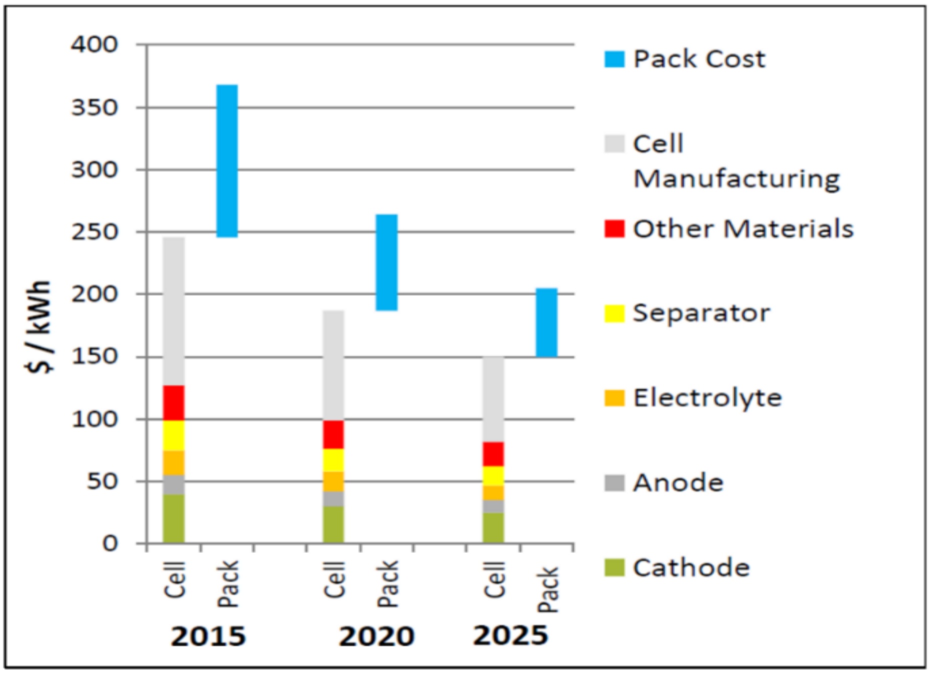

Figure 12 - Component Trends 2015-2025 (Pre-tax prices in Thousand 2016 USD and Percentage)

Source: Bloomberg new energy finance

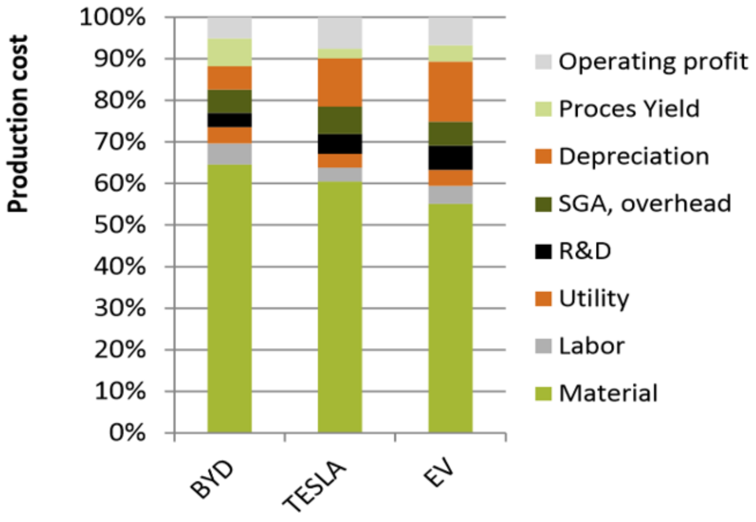

Figure 13 - LIB Cost Structure for Selected Vehicles

Source: AVICENNE Energy 2017

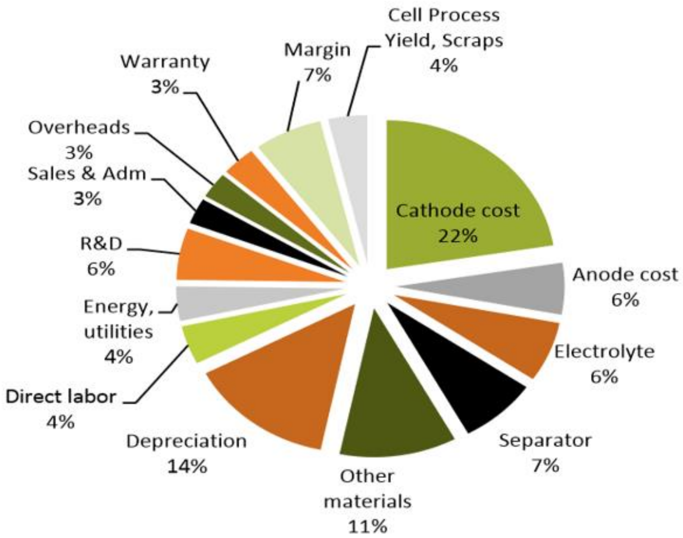

Figure 14 - LIB Cell Cost Structure

Source: AVICENNE Energy, 2017

The EVs introduced in 2010 had an estimated battery pack cost of $1,000/kWh. In contrast, General Motors' Chevrolet Bolt (2017) battery pack had an estimated cost of about $205/kWh and Tesla's Model 3 battery pack cost $190/kWh. This represents a decrease of more than 70% in the price per kWh in six years (Refer to Figure 12, showing reductions are mainly attributable to reduced battery back cost and anode cost).

South Korea, China, and Japan, taken together, currently supply 95% of the world's advanced batteries. Major global battery manufacturers include: LG Chem, Samsung SDI, SK Innovation from Korea; BYD and CATL from China; and Panasonic from Japan. Many automakers including Daimler, BMW and Volkswagen have stressed their need to secure supply of automotive batteries. As GM's

Chevrolet Bolt is equipped with a 60kWh battery pack while other similarly priced vehicles (VW e-Golf, Nissan Leaf and Ford Focus BEV), have a battery size below 40kWh, OEMs are trying to outperform competitors based on battery performance. As the costs of battery systems (cell + pack) fall, automakers will be able to equip their EVs with more powerful batteries. Better batteries will in turn improve the vehicle range (distance covered on a single charge), and this will help address the range anxiety.

Battery size is a key determinant of driving range. A larger battery means improved range (distance covered per charge) as the two have a strong positive correlation. It also means bigger price and increased charge time. To improve range, it makes sense to have bigger/heavier battery (i.e., higher kWh), however, this would also make the vehicle heavier, and thus, reduce the efficiency and increase the charge time for a larger battery. To keep weight down, ideally, a battery's energy density should be enhanced. But a higher energy density creates more heat as does faster charging, and this in turn increases the risk of fire eruption. This interaction between battery size and charge time, efficiency, and cost is tricky and challenging for the manufacturers to balance.

Steady improvements have been seen in battery performance, primarily in the form of improved energy density, through continued R&D aimed at:

- Improving materials,
- Decreasing the amount of non-active materials used,
- Reducing materials' cost (refer to figure 11),
- Improving cell design (refer to figure 11),
- Increasing production speed and yield

These above factors have resulted in lower cell and battery pack costs. Increased production volumes, particularly in China, are bringing economies of scale to lithium-ion battery manufacturing.

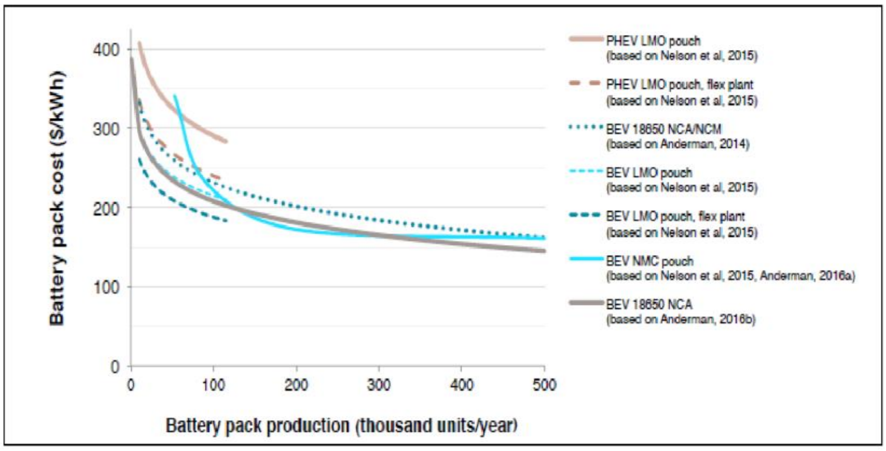

Figure 15 – Relationship between LIB Pack Cost and the Total Production Volume

Source: Steen et al (2017)[23]

From the Figure 15 above, it can be seen that the battery pack cost levels out towards $175/kWh for production volumes surpassing 200,000 packs/year. This pack level cost of $175/kWh reportedly corresponds with a LIB cell cost of $100/kWh. Battery experts consider this cost level as a trigger

[23] Steen, M., Lebedeva, N., Di Persio, F. and Boon-Brett, L., EU Competitiveness in Advanced Li-ion Batteries for E-Mobility and Stationary Storage Applications – Opportunities and Actions, EUR 28837 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-74292-7, doi:10.2760/75757, JRC108043.

point, potentially accelerating the uptake of e-mobility applications. It is said to be achievable by as soon as 2025 or by 2030 and could lead to production capacity falling significantly short of the global demand for LIB cells available at that time. Falling battery costs should alleviate range issues.

2.2.4 Global Production Capacity

Battery plants require huge financial investments (Refer to Table 1). Specific investment costs for new LIB cell production capacity has come down to approximately $ 150/kWh (as can be seen from the average cost in Table 1) and is expected to decrease further as other manufacturing capacities become operational.

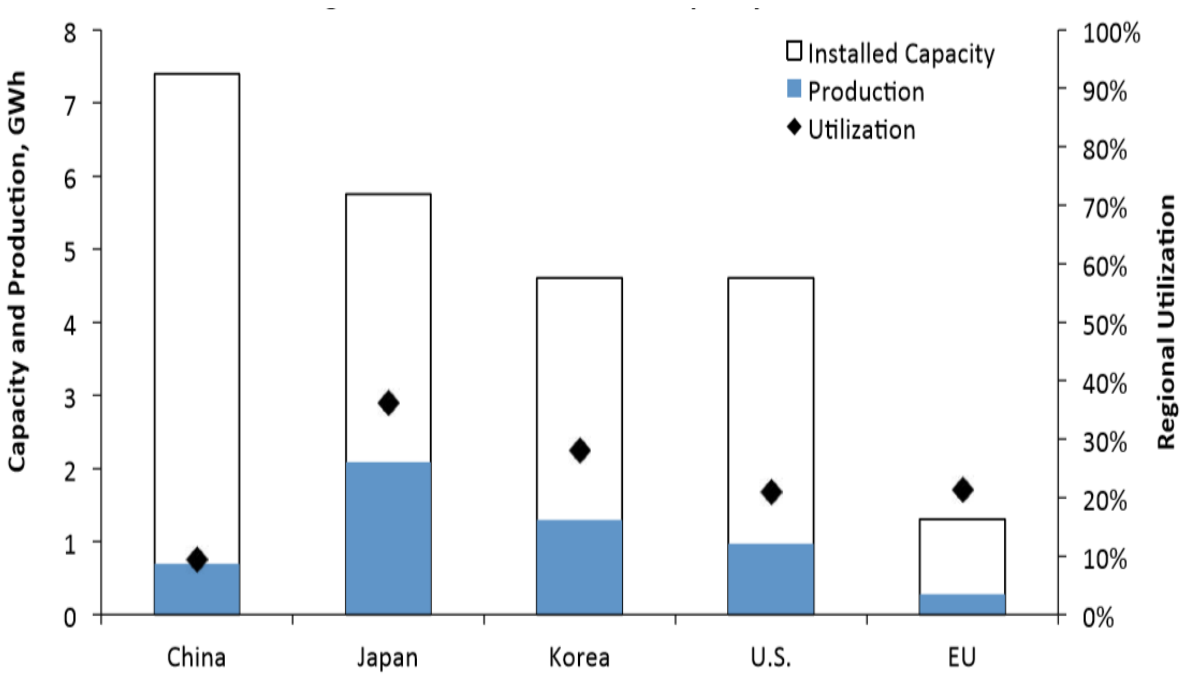

Figure 16 - Global LIB Production, Capacity and Utilization

Source: Bloomberg New Energy Finance (2014); Pike Research (2013); Advanced Automotive Batteries (AAB) (2013); Roland Berger (2012); IEA (2011); CEMAC estimates.

Initially, battery manufacturers and governments overestimated the total EV demand and made huge investments in production capacity. This led to a substantial surplus of LIB cell production capacity for automotive applications as shown in Figure 16. Supply-side governmental supports have also been made available for capacity expansions. For instance, in the United States, the American Reinvestment and Recovery Act of 2009 (ARRA) delivered $1.5 billion in support for the development of domestic battery manufacturing. Similarly, the governments of China, Japan, and Korea have also been aggressively pursuing their goals for domestic LIB production since a long time through tax and other investment incentives. These countries have lately started supporting consumer EV adoption[24]. It is worth noting that the figure shows industry-level utilization, it is likely that on a firm and plant-specific level, utilization is higher, and even more so for established players.

2.2.5 Battery Concerns

As already mentioned, consumer concerns regarding battery life determine their decision to purchase an EV or not. Car makers are addressing these concerns by offering warranties.

[24] Patil 2008, Pike 2013

Table 1 - Investment Cost of LIB Production Capacity Set-Up (in USD and EUR)

LIB Cell Production Plant	Capacity (GWh/y)	Specific Investment Cost	Reported Investment Cost
Panasonic (plant in China)	2.5	200 $/kWh	$ 0.5 Billion
Tesla (plant in Nevada, USA)	35	142 $/kWh	$ 5 Billion
LG Chem (plant in PL)	2	170 $/kWh	$ 340 Million
Samsung SDI (plant in HU)	2.5	120 €/kWh	€ 300 Million
Terra E (plant in DE)	8	125 €/kWh	€ 1 Billion
Energy Absolute (plant in Thailand)	1	88 $/kWh	$ 88 Million
Dynavolt (based in CN)	6	67 €/kWh	€400 Million
NPE	13	100 €/kWh	€ 1.3 Billion

Source: Steen et al (2017)[25]

This measure reinforces confidence in the product (battery) durability and quality. If the battery capacity falls below a certain capacity before a predetermined number of years or a distance travelled, it is considered to have failed and is thus entitled for replacement. EV makers on average offer warrantees which suggest that a battery should retain 70% of its capacity after 8 years or 100,000 miles. However, some manufacturers are offering more than this. For instance, Nissan provides supplementary battery capacity loss coverage for 60,000 miles or 5 years. In USA, states adopting the California emissions warranty coverage periods, require battery manufacturers to offer a minimum of 10-year coverage on partial ZEVs (which include EVs).

Li-ion battery technology's stability and safety need to be enhanced so as to enable better battery resilience in extreme weather conditions. Exploration of new internal components for Li-ion batteries is being encouraged. These new components (such as lithium iron or fuel batteries) will improve the industry, making it greener and more competitive.

EV batteries must undergo thorough safety testing and meet the required safety standards. These standards are designed to ensure that batteries are secure during a crash, chemical spillage from batteries is limited, and the chassis is isolated from the high-voltage system to avert electric shock.

Critical raw materials such as lithium and cobalt, are not only expensive but also dependent on foreign sources for production. The aim of battery recycling is to regain and recycle critical materials from lithium-based battery technology used in various applications (automotive, consumer electronics, energy storage etc.).

[25] Steen, M., Lebedeva, N., Di Persio, F. and Boon-Brett, L., EU Competitiveness in Advanced Li-ion Batteries for E-Mobility and Stationary Storage Applications – Opportunities and Actions, EUR 28837 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-74292-7, doi:10.2760/75757, JRC108043.

2.3 Other BEV Components (Motor, Transmission, battery management system)

2.3.1 Electric Motor

One of the key driving forces of the EV propulsion system is the electric motor. Under normal mode of operation, the motor sets the EV in motion. And when regenerative braking mechanism is applied, it behaves as a generator. Different motors have been designed over the years, on the basis of the driving requirements. The categorization of these electric motors is described below.

- Brushed DC Motor
- Induction Motor (IM)
- Permanent Magnet Brushless DC Motor (BLDC)
- Permanent Magnet Synchronous Motor (PMSM)
- Switched Reluctance Motor (SRM)
- PM Assisted Synchronous Reluctance Motor
- Synchronous Reluctance Motor (SynRM)

Used in earlier EVs, brushed DC motors (Fiat Panda, Renault Express, and Conceptor G-Van), can deliver large torque at low speed levels. However, these motors have become obsolete in EV propulsion systems mainly due to their heavy weight, heating issues (can generate sparks), and low levels of efficiency. The BLDC motors have a higher efficiency than induction motors, a more compact size, reliable output delivery and lesser heating issues. However, the torque is restricted at higher speeds. BLDCs are thus mostly used in smaller vehicles with power output of up to 60 kW. These are used in Toyota Prius, Nissan Leaf, and Soul EV. The PMSM motors are small in size and can drive a vehicle at different speeds despite the absence of a gearing system. They are also highly efficient, and can deliver large torque. However, the motor stability is compromised during in-wheel operation at high speeds. Majority of the recent BEV models use PMSMs. IMs are used in vehicles such as Tesla Model S, Toyota RAV4, Tesla Model X, and GM EV1, and they have been used in both some of the earliest as well as the newest EVs. Induction motors have a commutator-less drive system. SRMs, although more affordable and safer than their counterparts, create noise during operation and are very heavy and even have low efficiency in certain conditions. As these motors do not require permanent magnets, which are made from rare earths, significant research is being conducted to make these more efficient. BMW i3 uses Assisted Synchronous Reluctance Motor and Renovo Coupe uses Axial Flux Ironless Permanent Magnet Motor famous for its lightweight design and good power density.

Electric motor technology can redefine the EV landscape. The motor typically accounts for less than 10% of an electric vehicle’s cost. New research had indicated that motor prices, unlike other EV components will not decrease over time. Certain factors are forecasted to cause EV motors to constitute a greater percentage of the vehicle’s cost, as batteries become smaller. Part of that is explained by the trend of motor proliferation: from one to four traction motors (in-wheel motors, one for each wheel instead of one for the whole vehicle) in certain vehicles. Furthermore, an increasing number of E-buses have doubled the number of motors. Another is the integration of motor with the controller so that the two together represent one unit.

Similarly, just as a more powerful battery increases an electric car’s range, new powertrains can have a comparable impact. For instance, Bosch’s electric axle drive, is a combination of three powertrain components contained in one compact unit. A single unit, comprising the motor, power electronics, and transmission, directly drives the car’s axle. This makes the powertrain far more efficient and a potentially huge business opportunity as the e-axle can be fitted in HEVs, BEVs, SUVs, and even light trucks[26]. These factors are having a multiplier effect for the motor sales.

Automotive manufacturers are already focusing on this emerging trend. Nissan has been trying to sell its battery business[27] while improving motor research and doubling its motor production in its Chinese plant. Tesla 3's new innovation was the motor not the battery[28]. Experts believe that one of the key reasons for Tesla 3's unparalleled volumes in its category is its matchless powertrain efficiency. Tesla has developed its own variant on the switched reluctance motor. Furthermore, Tesla's extremely popular 'Ludicrous Mode' option which enable an acceleration to available is attributable to capabilities of its own reinvented induction motors[29].

Major players in electric motor market include Fukuta Electric & Machinery Co. which produces permanent magnet motors and supplies products to Tesla amongst other companies. Japan's Nidec Corporation plans to invest US$500m for expansion of production capacity for electric traction motors for BEVs in China. Nidec's plant in China already produces 600,000 units every year and this investment will double that capacity. Motor suppliers such as Nidec, Danfoss and Federal Mogul are focusing on the switched reluctance motors. Other suppliers, such as Dana, have invested in advanced permanent magnet motors.

Battery Management System (BMS)

The size of the global BMS market had an estimated value of USD 3.61 billion in 2018. It is projected to increase at a CAGR of 19.0% from 2019 to 2025[30]. Some of the major payers operating in this market include the following:

- Johnson Matthey PLC (U.K.);
- Valence Technology, Inc. (U.S.);
- Nuvation Engineering (U.S.);
- Linear Technology Corporation (U.S.).

EV batteries have modular configuration, and each comprises of hundreds and even thousands of individual battery cells. Each of these cells has a voltage reaching from 1.2 V to 3.6 V, making it high-energy. Battery packs require intricate electronics and software for the management of current levels, temperatures and voltage for each individual cell module. Taken together, the system is known as the Battery Management System (BMS).

When an EV is connected to an electricity outlet, the BMS controls the charging process. Its integration with the battery chemistry and its associated thermal properties, make the BMS a cohesive which regulates the charging rate (subject to the current, input voltage, and the ambient temperature), and the residual charge remaining in the battery. The BMS aims to maximize battery life, both in the total number of life cycles achievable as well as per discharge cycle. Automotive battery management works in real-time in rapidly changing charge-discharge conditions as the vehicle accelerates and decelerates. Furthermore, it has to link with other vehicle processes, such as the engine management, climate controls, communications, and safety systems in order to accomplish the following:

[26] Bosch Press Release. Available at: https://www.bosch-presse.de/pressportal/de/en/the-start-up-powertrain-for-electric-cars-the-bosch-e-axle-offers-greater-range-121216.html
[27] Reuters (2917). Available at: https://www.reuters.com/article/us-nissan-battery-idUSKBN1AO0K1
[28] Electric Motors for Electric Vehicles: Land, Water, Air 2019-2029
[29] https://www.electrichybridvehicletechnology.com/opinion/electric-motors-the-new-ev-battlefield.html
[30] https://www.grandviewresearch.com/industry-analysis/battery-management-system-bms-market

- Control battery charging and discharging
- Measure and forecast the battery state, also known as state of charge (SOC)
- Thermal Management
- Deliver battery status and authentication to a consumer interface
- Interconnect between all battery components
- Acquire and monitor data and ensure protection
- Cell Balancing

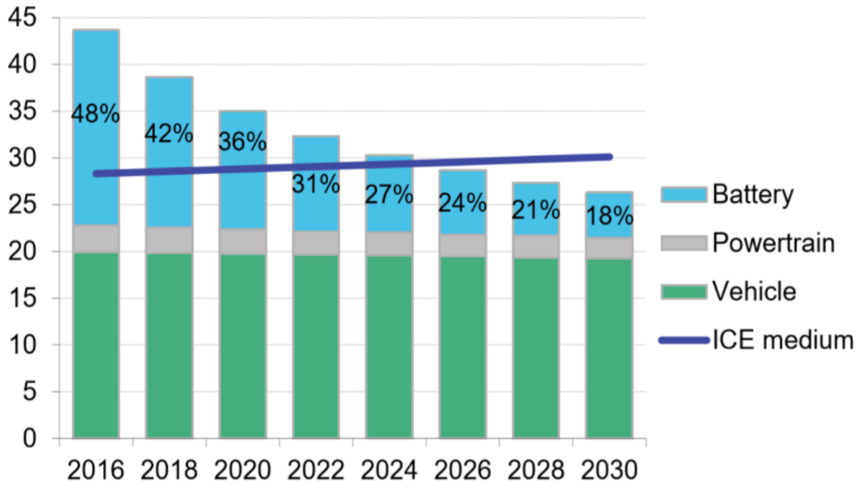

Figure 17 – ICEV VS. EV COMPONENT TRENDS, FOR MEDIUM SEGMENT PRICE, US, 2016-2030

Source: Bloomberg new energy finance[31]

2.4 Innovative technologies

Graphene-Lithium Technology. Graphene was discovered in 2004, at the University of Manchester. Jiangsu NESC Science and Technology Company developed a battery based on a Graphene-Polymer technology (China Daily). The addition of Graphene nano-technology to Lithium batteries is said to bring unprecedented properties as the carbon atoms in Graphene are super-conductive. The absence of chemical reactions ensures that these batteries don't degrade like lithium-ion ones.

Practical applications have revealed that Graphene-Lithium nano-technology in e-bike batteries brings primarily a much-improved energy density (2.5 times better). The price per kWh will initially be at least the same but will decrease (40% cheaper than li-ion batteries by 2021) as time goes on and production numbers grow.

A working prototype is expected to be displayed at the upcoming Eurobike show in Friedrichshafen, Germany. European Union recently announced a €1 billion subsidy program targeting the development of Graphene applications and products. China has founded 'China International Graphene Industry Union' – an organization set-up for the industrialization of Graphene as the country is amongst the most Graphene-rich countries in the world. Other than use in batteries, Graphene is

[31] Available at: https://data.bloomberglp.com/bnef/sites/14/2017/07/BNEF-Lithium-ion-battery-costs-and-market.pdf

already being integrated by a company named Vittoria. This company started working with Graphene in 2013. Vittoria holds distribution rights of Graphene Nano platelets in various countries. These Nano platelets are used in wheel and wheelset production.

Significant cost cuts can also be achieved through other innovative developments. Options include:

- Redesigning vehicle manufacturing platforms.
- Using an uncomplicated and innovative design architecture,
- Making use of new developments such as the compact size of electric motors
- Exploiting the fact that EVs have fewer moving parts than ICEVs. For instance, Volkswagen recently announced the development of a new vehicle manufacturing platform to achieve cost parity between EV and ICEVs.
- Adopting the appropriate BEV technology strategy: ‘energy-saving’ or the ‘new energy’.
- Adapting battery sizes to travel needs (matching the range of vehicles to consumer travel habits) is also critical to reduce cost by avoiding “oversizing” of batteries in vehicles. Close co-operation between manufacturers to design purpose-built EVs are not only relevant for freight transport, but are also pertinent in order to meet range, passenger capacity and cargo space requirements for vehicles used in shared passenger fleets (e.g. taxis and ride-sharing).

Technological improvements in chargers are particularly impressive, as EVs are increasingly being used in heavy-duty applications (primarily buses, but even trucks). Charger standards have been developed for high-power chargers which can charge up to 600 kW. Mega-chargers are now being talked about for use in heavy trucks that could charge at 1 megawatt (MW) or even more. Given the continuing innovation in the assembly and general design of EVs, they are capable of challenging conventional vehicles[32].

[32] https://link.springer.com/article/10.1007/s10098-015-1019-5

3 Competitiveness of Global BEV Supply Industry

3.1 USA: Supply Chain Status and Strengths

3.1.1 OEMs

Major USA Domestic EV Manufacturers include: General Motor Company (automotive division: Chevrolet), Tesla, and Ford Motor Company. The first EV designed and developed from the ground up was EV 1 by General Motors which gained a cult following. GM discontinued EV 1 in 2001 as its high production cost made it commercially unviable. However, the company truly responsible for starting up the EV revolution in U.S. is Tesla Motors. Tesla started as a small Silicon Valley-based start-up. Initially, it set out to produce a luxury electric sports car, one that would have a range of over 200 miles per charge, as opposed to the then-prevailing 80m/charge. In 2010, Tesla received $465 million loan from the Department of Energy's Loan Programs Office to set up a manufacturing facility in California. The company's huge success enabled it to repay the loan nine years earlier than it was due. Tesla has since then, gone on to win international acclaim for its e-cars. It now boasts being the largest auto industry employer in California and manufactures its own battery packs, battery management systems, motors, and power electronics. Tesla's success drove many established automakers to accelerate their own work on EVs.

Tesla is not the only renowned American OEM. Chevrolet, the automotive section of General Motors, introduced its first all-electric car - Chevrolet Bolt, with a range of over 220 miles per charge and a price tag far below that of the other long-range vehicles (including Tesla's current line-up). Other automotive incumbents such as Fiat Chrysler Automobiles and Ford Motor Company have also become prominent EV manufacturers. Ford Motor Company even has a separate division aimed at energy storage strategy and research that studies numerous technologies aiming to deliver a more powerful EV battery.

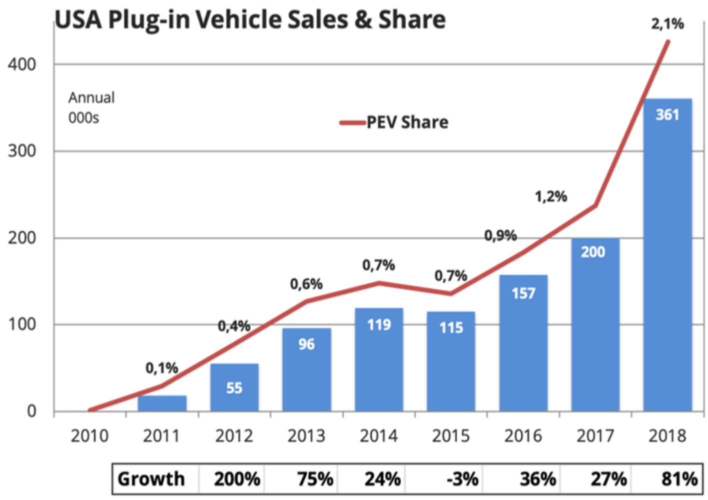

Figure 18 - USA Plug-in Vehicle Sales and Share
Source: EV Volumes.com

3.1.2 Batteries

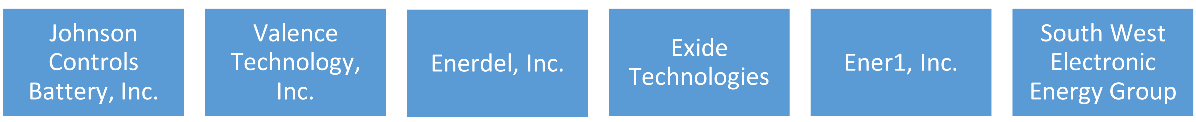

Figure 19 - Major Battery Manufacturers in U.S.A

The United States has managed to establish a foothold in automotive LIB production and secured 17% of global automotive LIB capacity in 2018. It is home to some of the major battery manufacturers as shown in Figure 18. USA's strengths in battery manufacturing is due to early research investments. Cathode materials for rechargeable LIBs were developed by researchers at the University of Texas in the 1980s. R&D investments were made in LIB technology by the U.S. Advanced Battery Consortium starting from the 1990s. Today USA is leading the world in terms of battery technology research. However, compared with China, its battery supply chain is relatively immature. Most cell and battery plant manufacturers in USA are comparatively new to the industry and the country thus lacks regional supply chain advantages as there is little vertical integration across associated processes such as cell production and electrode materials manufacturing. Almost the whole of US LIB capacity is targeted to serve the developing automotive market, as opposed to South East Asian LIB production capacity (current global leaders) which was built to cater to domestic consumption as well as to export markets. The South Asian firms developed their LIB production knowledge and experience by serving and supplying to consumer electronics markets. They have since then created robust supply chains and gathered significant production experience and skills which are transferrable to the LIB cell production for automotive end-markets.

The recycling of lithium-ion batteries is currently done at a rate of less than 5% in USA[33]. About 15% of USA's cobalt consumption is from recycled scrap today. The USA wants 90% of all discarded batteries to be recycled eventually and is targeting investment accordingly. In 2019, the Energy Department announced a $15 million investment to set up a Lithium Battery R&D Recycling Centre. Battery Recycling Prize of 5.5 million is also being offered to find innovative solutions to battery recycling.

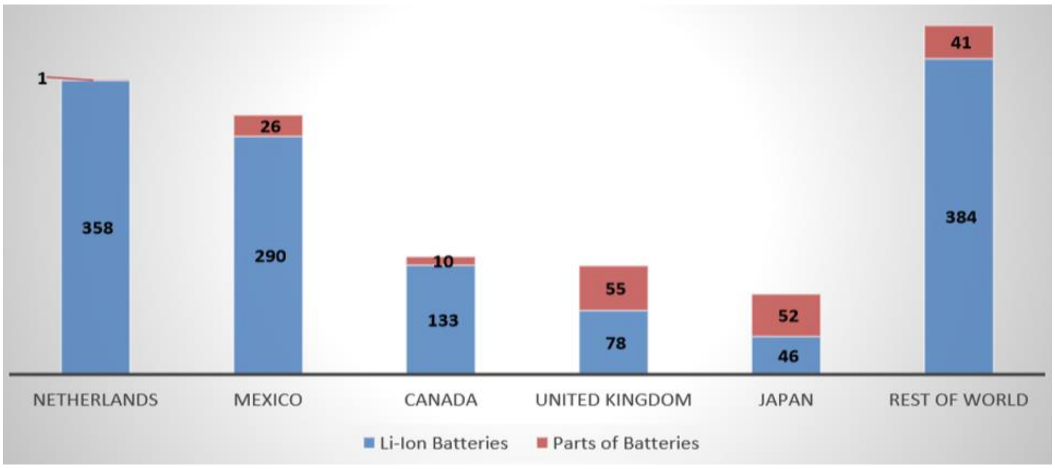

Figure 20 - US Exports of Lithium-Ion Batteries and Components (in 2017, USD million)

Source: USITC, DataWeb

The US trade flow data on lithium-ion batteries appears to be EV-related in some instances. For instance, Tesla's EV plant in the Netherlands, which opened in 2013, gets its batteries imported from USA. This may explain why the Netherlands is the leading destination for U.S. LIB exports. Likewise, Fiat 500e's assembly plant is in Mexico. A significant share of LIB exports to Mexico probably supports that production. USA imported li-ion batteries worth $92 million from Japan, $54 million from China, 64 million from South Korea and 12 million from rest of the world in 2017.

[33] source: https://www.energy.gov/articles/energy-department-announces-battery-recycling-prize-and-battery-recycling-rd-center

Raw Material Mining: USA does not produce or mine any of the major raw materials required for LIB manufacturing. It had no share in the graphite, cobalt and nickel production/mining stage of the global lithium-ion battery supply chain in 2018. The country produced around 1% per cent of the world's lithium in 2018.

Processing Stage: Similarly, USA had no significant share of graphite, nickel and cobalt processing stage of lithium-ion battery supply chain in 2018. However, it had 8% share in global lithium processing stage of lithium-ion battery supply chain in 2018.

CELL MANUFACTURING

LIB cell Cost structure in US (excluding margins) - $278/kWh

Material - $200/kWh
Labor - $30/kWh
Maintenance - $8 /kWh
Equipment - $40 /kWh

USA has LIB Cell Manufacturing capacity of 3,770MWh (fully commissioned), 12,00MWH (under construction) and 35000MWh (announced)

3.1.3 Other BEV Components

USA is home to several major BEV components suppliers. US Companies are amongst the top 20 global automotive suppliers (by revenue in 2018):

1. Lear - €18,444m
2. Cummins - € 17074m
3. Goodyear - € 13,496m

Other notable companies involved in BEV components are:

- Protean Electric specializes in providing in-wheel, electric-drive system for PHEVs, HEVs, and BEVs. The technology creates a permanent magnet e-machine possessing high torque and power density and in which power electronics and controls are packed within the motor itself.
- Rockwell Automation was founded in 1903 with a small investment of US$1,000, has since become one of the global leaders in automation technology, with annual revenues of more than US$90 billion
- TE Connectivity with a revenue of USD $14 billion in 2018
- Dana Incorporated manufactures sealing and thermal products, axles, and drive shafts, for automotive manufacturers had a revenue of over USD 8 billion in 2018

3.1.4 Policy and Regulation

One of the USA's key strengths is the central government's commitment to EV movement. In early 1970s, rising oil prices and gasoline scarcities, worsened with the Arab Oil Embargo of 1973, and renewed government's interest in removing or at least lowering the country's reliance on foreign oil. The Congress passed the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976, under which it authorized the Energy Department to support R&D on EVs and HEVs. This encouraged many established and small entrepreneurial automakers to explore innovative non-gasoline vehicle technologies including electric cars. It was the Department of Energy's Loan Programs

Office that gave Tesla $465 million loan to establish its first manufacturing facility in California, thus setting in motion the world wide large scale adoption of BEVs.

USA makes use of stringent fuel standards to help EV industry. Fuel standards generate demand for clean vehicle technologies, including BEVs. Increased demand drives job growth along the EV value chain in addition to generating fuel savings. New federal and state regulations have passed the following:

- Clean Air Act Amendment of 1990
- Energy Policy Act of 1992
- CAFÉ (Corporate Average Fuel Economy) Standards
- Low Emission Vehicle (LEV) Standards by the California Air Resources Board – vehicles exhausts must meet specified GHG emissions requirements and each manufacturer must conform to the fleet average GHG requirements.
- State Agency Low Carbon Fuel Use Requirement - Of the total amount of transportation fuel bought by the state governments, 3% must come from transportation fuel sources with very low carbon. The required share will increase by 1% per annum until January 1, 2024.

There is a national commitment to build EVs and key EV components in the United States. The goal is to "DEVELOP, DEPLOY, LEAD". Keeping this in view, the federal government has invested millions of dollars all over their value chain. This includes: $80 million a year investment for electric battery research and development; $2.4 billion support to develop a domestic LIB supply chain for EVs under the American Recovery and Reinvestment Act of 2009[34]. The Obama Administration asserted that these ARRA investments may lead to 70% reduction in the cost of EV batteries by the end of 2015, and enable the production of up to 40% of the world's advanced EV batteries in the US.

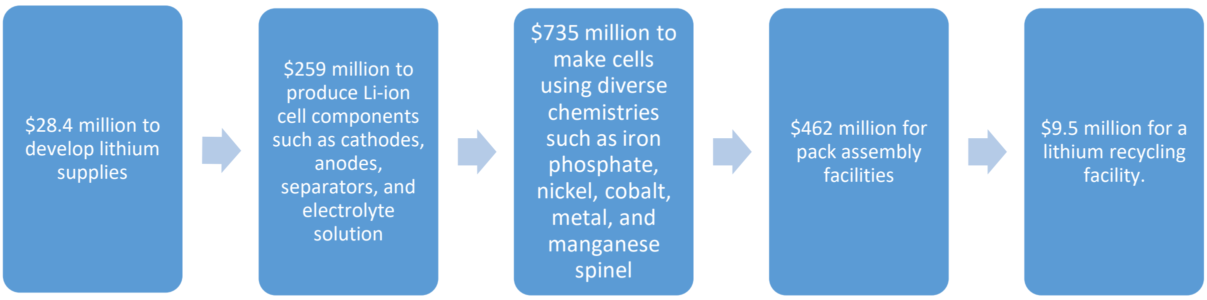

Figure 21 - DoE Investments along domestic battery supply chain ($1.5bn)

In 2019, the State Department of Energy (DoE) announced its plans to fund 48 new projects focusing on advanced battery manufacturing and EV drive in over 20 states. BEV customers receive tax credit rebates of up to $10,000 at the time of purchase. Under the Recovery Act, the Energy Department invested over $115 million to help build countrywide charging infrastructure comprising 18,000 public, residential, and commercial charging stations across the country. Other types of incentives offered include:

- Purchase discounts (Clean vehicle rebate)
- Subsidies
- Utility rebates
- Technical Trainings

[34] ARRA; P.L. 111-5

There are around 25 types of incentives being offered at the local and state levels. The most frequently used type of incentive is a grant (22% of all incentive programs), second being a tax credit (over 20% of all non-federal incentives), tax exemption ranks third (13.2% of all incentive programs), and rebates are fourth (almost 10% of all non-federal incentives).

3.1.5 Research and Development

USA has a long history of investing in research and development along the EV value chain. As already stated, researchers at the University of Texas developed cathode materials for rechargeable lithium batteries back in the 1980s, and the U.S. Advanced Battery Consortium made R&D investments in lithium ion battery technology beginning in the 1990s.

Table 2 - Research and Development Initiatives in USA

Organization	Research Focus	Organization Description
Quantum Scape	Solid state and lithium-ion batteries.	The organization is a Stanford spin-off, Volkswagen paid $100 million in 2018 to increase stakes in the organization.
Solid Energy Systems	Developed lithium-metal rechargeable battery technology. Engineered the Apollo™ which has half the size (1200 Wh/L) but double the energy density (450 Wh/kg) of conventional Li-ion cells.	The organization is an MIT spin-off and which delivers energy density characteristics and cycling performance in its products. Suitable for battery-weight and dimension constrained applications such as EVs.
Ionic Materials, Incorporation	Solid-state rechargeable battery cells.	Uses polymer science, electrochemistry and battery science. An advanced materials supplier, sells to battery industry. the ecosystem of cell manufacturers for various markets
UQM Technologies, Incorporation	Non-rare earth magnet motors.	Work is being done under the US Department of Energy (DoE) Advanced Research and Development Grant ($4 million). UQM is cost-sharing 25% of the total effort.
National Renewable Energy Laboratory	Development and application of non-rare-earth magnets in a high-performance permanent magnet motor.	A Congress-funded, government-owned organization which specializes in R&D in energy efficiency.
Oak Ridge National Laboratory	Development and application of non-rare-earth magnets in permanent magnet motors.	A national science and technology laboratory focusing on multiple areas sponsored by the U.S. Department of Energy (DoE)

Organization	Research Focus	Organization Description
Cairn Energy Research Advisors	Provision of strategic insight and data to enable clients to thrive in the dynamic international energy marketplace.	A global research and consulting firm focusing on energy storage
Solid Power Incorporation	Solid-state rechargeable batteries	Improving performance and manufacturing scale of batteries.

USA is now focusing on solid-state battery technology that eliminates the liquid found in batteries with a solid polymer, thus giving high energy density. This could potentially reduce charging time to as low as 10 minutes and also improve the safety of batteries by eliminating their potential for flammability, make cells thinner and packs smaller. Table 2 gives an overview of the companies focusing on solid-state and other technologies in USA. Up to $50 million of DoE funding is being made available for research projects supporting the EV Everywhere Grand Challenge.

US is focusing on improvements needed in batteries, motors, power electronics, lightweight materials, vehicle designs, and fast-charging infrastructure technology. The efforts have paid off as in 2007 lithium-ion batteries were running over $1,000 per kWh, but the price of batteries have gone down by 70% since then.

The DoE is the main body in the USA which finances EV related research. Its aim is to speed up the development of U.S. manufacturing capacity for electric drive components and batteries, and the deployment of electric vehicles to “help establish American leadership in developing the next generation of advanced vehicles”. DoE planned to provide funding to 48 new projects dealing with advanced battery manufacturing and EVs in more than 20 states in 2019.

U.S. also funds capital expenditures on qualified research projects by issuing bonds subsidized by the state government. Government bodies may also issue tax credit bonds and subsidize the borrowing costs through direct payment bonds to finance research on EV related technologies (e.g. Alternative Fuel and Advanced Vehicle Technology Research and Demonstration Bonds). Financial assistance is also available to transportation providers; private and non-profit organizations; and higher education institutions for R&D and deployment projects involving zero emission vehicles such as BEVs.

Case in point: Incentives in California

California has the following incentives in place:

- Alternative Fuel Vehicle (AFV) Technical Training gives incentives for personnel education on the operation safety, mechanics, and maintenance of AFVs, and implementation of associated systems.
- Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP) administered by the California Energy Commission (CEC) - provides financial incentives to vehicle and technology manufacturers, businesses, workforce training partners, consumers, fleet owners, and academic institutions which aim to develop and deploy advanced transportation technologies
- The Motor Vehicle Registration Fee Program (Program) funds projects that reduce air pollution from vehicles.

- Pacific Gas & Electric (PG&E) offers discounts on residential time-of-use rates for electricity used in EV charging. Numerous other power utilities also offer charging rebates for domestic and commercial users and businesses as well.
- Zero Emission Vehicle (ZEV) Production Requirements - In California, manufacturers whose annual sales exceed 60,000 vehicles, must meet ZEV requirements for at least 14% of the vehicles.
- Obligatory Electric Vehicle Supply Equipment (EVSE) Building Standards are in place.

California ZEV Plan – Future Targets
By 2020, the state will have established adequate infrastructure to support one million ZEVs;
By 2025, there will be 1.5 million ZEVs on the road in California and clean, efficient vehicles will displace 1.5 billion gallons of petroleum fuels annually;
By 2025, there will be 200 hydrogen fueling stations and 250,000 PEV chargers, including 10,000 direct current fast chargers, in California;
By 2030, there will be 5 million ZEVs on the road in California; and
By 2050, greenhouse gas emissions from the transportation sector will be 80% less than 1990 levels.

3.1.6 Key Takeaways

- U.S.A.'s major strength in EV value chain is in Research and Development where it leads the world. Rising oil bill → state intervention → R&D Funding →automakers' interest
- U.S.A is a new entrant in Li-ion battery supply chain and lacks the competitive advantages enjoyed by South East Asian manufacturers (Japan, Korea). However, it has established footholds in this industry and holds 17% share of global LIB supply industry.
- California has the highest number and share of EVs amongst all U.S. states.

3.2 China: BEV Supply Chain Status and Strength

Recent years have seen China taking significant steps to aid its transition from an ICE-based vehicle fleet to New Energy Vehicles – NEVs - (a term used in China to refer to PHEVs, BEVs and fuel cell EVs) in recent years. Chinese industry is the world's biggest manufacturer of EVs and the Chinese market for EVs is the world's largest as more than half of the world's new electric cars are bought in China[35]. China's electric car market is almost 3 times the size of the US electric car market. In 2018, the country had 1.26 million electric cars to United States' 361,000 electric cars. Although, China has the largest volume of EV in absolute terms, relatively, NEVs hold only a small share of the automotive market (4.4% in 2018).

The EV value chain in China is the most comprehensive. The EVs (especially electric cars) produced in China are equipped with a high percentage of domestically produced components[36]. Despite being in its early stages, the EV industry has firmly secured its position on the global map in terms of key raw material extractions, battery production, vehicle manufacturing and infrastructure provision. With this

[35] BBC News, Available at: https://www.bbc.com/news/business-46745472
[36] Wang and Kimble, 2011

foundation, China has built a value chain of EVs that is very similar in structure to that of traditional vehicles.

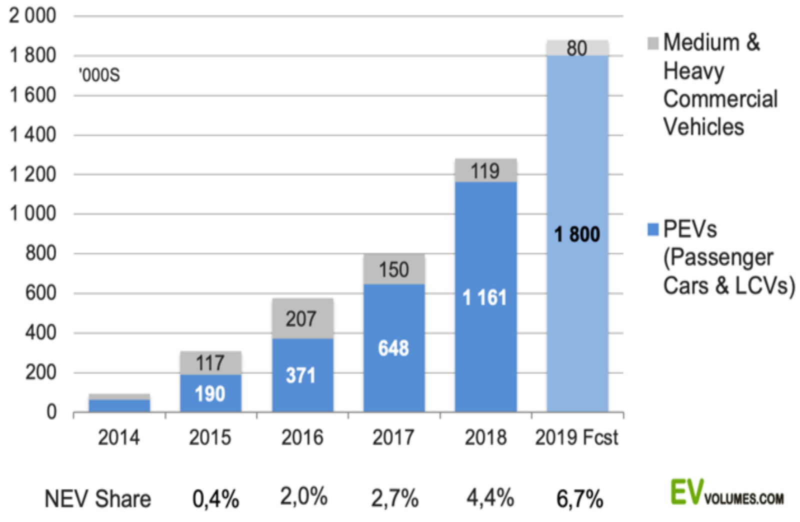

Figure 22 - China New Energy Vehicle Sales Development

Source: EV Volumes, 2019

3.2.1 OEMs

Chinese OEMs produced 43 percent of the world's electric vehicles in 2016. The domestic OEMs hold a dominant position and have a sales share of approximately 94% of the Chinese EV market. Almost Around 500 manufacturers hold registration to make EVs in China[37]. It is estimated that China's total EV production capacity will go up to about 3.9 million units per annum, which is three times the current levels.

Foreign brands' presence in China's EV market, is small with a share of about 5% and imports account for about 3% of the total sales. NEV sales of domestically-produced vehicles have risen 58% in China in the first five months of 2019 compared with the year-ago period[38]. In 2018, EV Sales Volume increased 79% while all other types decreased by 16%. There are 1.1m NEV passenger cars in addition to 60 000 LCVs, making their market share in the light vehicle sector around 4.2%.

China has the highest BEV penetration rate in electric LDV sales in all major global markets. The share of electric two-wheelers is anticipated to reach 90% in 2030. The uptake of electric buses in China, particularly in urban areas, is the fastest worldwide. Strong market dynamics have resulted in Chinese BEB expansion to international markets[39]

Yutong: Officially known as Zhengzhou Yutong Group Co., Ltd., Yutong started as a bus repair plant in 1963. It has since become a manufacturer of electric buses headquartered in Zhengzhou, Henan. Global market share of 15% and Chinese Market share of 30%. It was world's leading bus manufacturer by sales volume in 2016. Yutong exports electric buses all over the world: North America, UK, France,

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[37] https://www.electrive.com/2019/06/05/china-tightens-regulations-for-ev-startups/

[38] https://www.forbes.com/sites/jimcollins/2019/06/14/chinas-electric-car-boom-is-already-running-out-of-gas/#637bb3dadcb5

[39] Global mass transit, 2018

Australia, Cuba, South Africa, Chile and Venezuela, Yutong was granted Ecology Label of BusWorld Award in 2017 for its work on new energy vehicle technology

Geely: One of the most prominent Chinese brands***,*** Geely, has launched pure electric mid-size car brand "Geometry A", and plans to have 10 models by 2025. It is targeting 1m EV sales in 2020***.*** Their first electric model "Geometry A" has a range of 500 km (310 miles) on a single charge, a maximum power of 120 kW and an acceleration to 100 km/h (62 mph) in 8.8 seconds***.*** The company acquired Volvo Cars in 2010[40] and following this acquisition established a new Geely's Innovation Center Europe at Lindholmen Science Park in Gothenburg. Plans are in place to employ approximately 200 engineers from China and Sweden. Geely held 6.5% market share and RMB106.6 billion in revenue in in 2018. The company has also announced to set up a complex for new energy vehicles (NEV) at a cost of more than $5 billion in China's Zhejiang province***.***

BAIC – BJEV Motor: Chinese Auto Giant, BAIC, had a global NEV market share of 3.32%***.*** BAIC has announced a target to achieve a sales level of 0.5 million and 1.3 million electric cars in 2020 and 2025 respectively***.*** BJEV (BAIC's EV division), is working on having six new BEV models by 2021. These will be based on three new BEV platforms. The company has planned an NEV development center worth $770 million with focus on electric motor, battery, electric control unit, intelligent connectivity, lightweight materials and complete vehicle application***.*** As production support for this project, BAIC BJEV commissioned a new $291 million, (538,000 square foot) development facility. It is established in collaboration with other partners, including BAIC investor Daimler, battery manufacturer CATL, Magna (OEM), and Huawei Technologies. This new facility will house 88 laboratories and over 400 testing rooms dedicated to EV testing and development.

3.2.2 Battery

Major Chinese EV battery manufacturers are:

Build Your Dreams (BYD) ***-*** BYD is one of the major Chinese OEMSs manufacturing NEVs. BYD having adopted a strategy of vertical integration, has built 20 GWh of battery cell capacity, making it China's largest battery manufacturer.

CATL – Another top Chinese battery company, CATL has headquarters in Ningde, Fujian province, established in 2011. The company specializes in the production of LIBs and the development of ESS - energy storage systems. It has manufacturing facilities in Jiangsu, Qinghai, and Guangdong provinces and has a capacity of 7.7 GWh with plans to reach battery production capacity of 50 GWh by 2020.

Chinese government wants to support and endorse both BYD and CATL as a national champion. In addition to battery manufacturers, China also has mega cell manufacturing companies:-

Lishen Battery – A Tianjin based company, Lishen, has production plants in Qingdao, Bejing, Suzhou, Wuhan, Shenzhen, Ningbo, and Mianyang, and aims to have 20GWh of battery cell capacity by 2020.

Wanxiang Group - Hangzhou's Wanxiang Group is one of China's leading automotive components suppliers and is amongst the biggest private companies. Wanxiang has acquired over two dozen companies in the United States, with its first acquisition happening in 1994 in Illinois. It has since acquired some of the major companies including A123, a battery maker in 2013, and Fisker Automotive in 2014.

Mining Chinese companies are amongst the world's largest lithium producers. Lithium is a lightweight metal that has become one of the key raw materials for batteries. Chinese companies own mines all

[40] https://norden.diva-portal.org/smash/get/diva2:1180272/FULLTEXT01.pdf

over the world from South America to Australia. Plants are being built in China to make lithium chemicals and batteries. China produced more than 60% of the world's lithium in April 2018, compared with less than 1% by the US. The city of Xinyu is particularly important in the global electric vehicle supply chain as it supplies lithium to Tesla, BMW and VW. China has gained prominence in lithium through private companies rather than state-owned ones. Revenues for two largest producers - Ganfeng Lithium and Tianqi Lithium have increased from around $100m to over $1bn per annum in a decade. China held 58% share in global graphite production stage; 35% share in the nickel mining stage, and 3% share in global cobalt mining stage of LIB supply chain in 2018

Processing

- China held 100% share of graphite processing stage of lithium-ion battery supply chain in 2018
- China had a 33% share in global nickel processing stage of lithium-ion battery supply chain in 2018
- Increases in production volumes in China are bringing about economies of scale to lithium-ion battery manufacturing. This means that cell and battery pack level production costs are amongst the world's lowest.

Ganfeng is the world's largest producer of pure lithium metal, a product that is set to play a key role in solid-state batteries. Ganfeng agreed a 10-year supply deal with VW April 2019. The carmaker aims to launch more than 70 electric car models over the next 10 years — a target of 22m electric vehicles by 2028. In Xinyu, Ganfeng has plans to move up the value chain into battery production. Ganfeng plants have robotic assembly lines to assemble sheets of battery materials to be made into lithium-iron phosphate batteries (used in China's electric buses). China had 80% share in Cobalt processing stage of global lithium-ion battery supply chain in 2018.

CELL Manufacturing

• China had a 62% share in cell manufacturing stage of global lithium-ion battery supply chain in 2018

• China's LIB-cell players have rapidly increased their production capacity and are thus increasing their global supply share reaching 25% in 2016. This was mainly at the expense of Japanese manufacturers,

• China has a larger share of global cell production than Japan. Data projections show that its share is expected to rise to over 70% by 2020.

• Domestically produced lithium-ion cells are used in more than 90% of the Chinese EVs

• Cell manufacturing accounts for 50% of total battery manufacturing costs. As China has the lowest LIB cell cost structure in the world: (excluding margins)- $278/kWh
Material - $200/kWh
Labour - $30/kWh
Maintenance - $8 /kWh
Equipment - $40 /kWh
Chinese cell manufacturing will have a dominant influence in the future value split EV manufacturing.

China has LIB Cell Manufacturing capacity of 16,704MWh (fully commissioned), 3576MWh (partially commissioned), 18,730MWH (under construction) and 12,847MWh (announced).

3.2.3 Policy and Regulation

The Chinese government is targeting the following for the coming years:

- 5 million EVs by 2020 inclusive of 4.6 million passenger light-duty vehicles.
- New Energy Vehicle (NEV) mandate: Passenger car sales must achieve NEV credit to match 12% of the manufacturers' sales.
- NEV sales share targets: 7-10% by 2020, 15-20% by 2025 and 40-50% by 2030.
- Current fuel economy standard to be used till 2020 and proposal for tightened fuel economy standard (4 L/100 km) for cars by 2025.

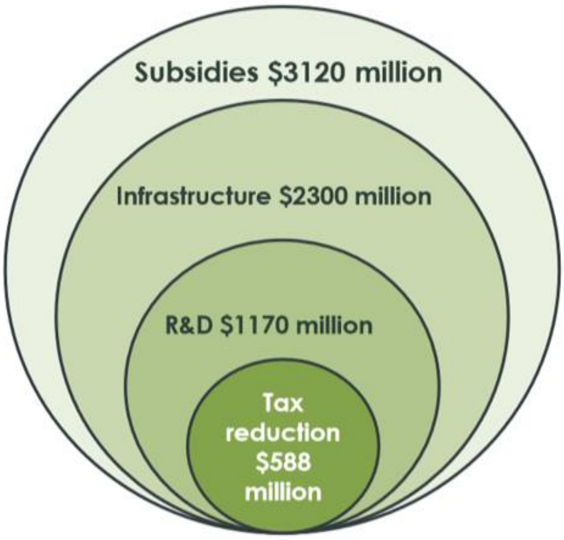

Figure 23 - Breakdown of Government Spending on NEV Development

Source: Feng An. (2016). China's NEV Policies and Market Development Innovation Center for Energy and Transportation

China has put a restriction on investment in new ICE-only vehicle manufacturing plants. As per the National Reform and Development Commission, establishment of new companies that make only combustion-engine cars will not be allowed.

Subsidies and Incentives

The use of differentiated incentives for vehicles based on their battery characteristics (e.g. zero-emissions vehicle credits and subsidies under the New Energy Vehicle mandate) has been in place since 2012. Current subsidies are focused on production side, rather than consumption side

By 2016, the Chinese Government had invested a total of $7.2 billion for EV development. $3120 million of this was given as subsidies to manufacturers at the time of purchase. See figure 22 above. Financial support for purchases has fuelled apprehensions about automakers becoming overly reliant on subsidies., so much so that they are neglecting the development of new technologies and better vehicles. Hence, China is now scaling back subsidies on EVs in order to encourage local manufacturers to depend on innovation rather than assistance and also to consolidate the auto industry amongst competitive players. To qualify for any incentive, the minimum range requirement has been raised to 250 kilometres (up from 150km) and the minimum energy-density requirement has been increased 105 Wh/kg (up from 90). Starting in 2017-18 allowance RMB/car was cut down by 20% of 2016 standard. From 2019-20, it will be cut down by 40% of 2016 standard. At the same time, the subsidies for long-range BEVs (400 kilometres or more) rose by 14 percent, to 50,000 renminbi ($7,900). Thus battery-makers now have more incentive improve their range[41]. The government plans to phase out subsidies entirely after 2020, although no details are given yet.

In major Chinese cities, particularly the congested ones, expensive license plates are used as a tool to curb traffic congestion in big cities. A plate for a traditional ICEV costs as much as $14,000 in Shanghai. However, for EVs, new license plates come for free. This incentive is applicable in the largest and most congested cities, including Beijing, Shanghai, and Shenzhen. In 2017, China's central government spent 6.64 billion Yuan ($1 billion) in 2017 to fund consumers' eligible automobile purchases. About 39 cities have favourable policies in place to encourage EV adoption.

Protectionist Policies

Protectionist policies have helped the domestic EV industry to flourish in China[42]. It is necessary for foreign firms to form a partnership/joint venture with a Chinese company. In order to access the Chinese market (to sell in China), foreign firms must also share their technology blueprints. Foreign investment is limited to 50 percent on PEV technologies in China. For instance, when GM introduced Volt in China, the Chinese government demanded that it must share its engineering technology secrets. Other U.S. companies, like battery-maker A123 Systems, have also chosen to share technology blueprints in the past in order to access the massive Chinese market.

Emission Standards

OEMs' increased attention on EVs in China mainly reflects tougher emissions targets set by government. Automakers have to comply with an obligatory EV credit target. Under the New "cap and trade" system, OEMs which make more than or equal to 30,000 cars need to earn enough credits to match 12% of their output. An NEV can receive 2-6 credits depending upon its range. Any company that fails to reach its quota faces a fine, but manufacturers can in this case, buy credits from those who have a surplus. This system is particularly appealing to foreign manufacturers, who currently making the most efficient NEVs. A Tesla manufactured in China, for instance, will particularly get the highest credit. If Tesla sells a sufficient number of vehicles, it will be able to sell the surplus credit achieved to other manufacturers. This system is proving to be attractive to businesses as several international EV automakers have announced new joint ventures with domestic Chinese brands.

3.2.4 Other BEV Components

The Central Government of China is making an unparalleled $15 billion investment in PEV development. This massive investment is expected to help fund demonstration programs, commercialize powertrain technologies, and introduce funds straight into the country's vehicle, battery and electric motor manufacturing operations.

China also dominates the supply of rare earths, which are critical raw materials in the manufacturing of permanent magnets of electric motors. It thus dominates the supply of permanent rare earth magnets and in turn, the permanent magnet motor supply. Chinese government reportedly threatened to cut off international supplies of rare earth magnets used in motors in 2011-12. This led to dramatic increase in global rare earth prices.

[41] Feng An. (2016) China's NEV Policies and Market Development. Innovation Center for Energy and Transportation (iCET)

[42] https://www.bbc.com/news/business-46745472

China is leading the production of mined rare earth products as well as that of refined rare earth compounds. Chinese production accounted for 86% of the total refined production in world in 2017. A total of six state-owned organizations control rare earth production in China. China North Rare Earth Group (largely from the Bamiyan Obo mine in Baotou, Inner Mongolia) was reported to be the largest producer in 2017. As demand surpasses official production quotas, illegal production in China was a common feature in the Chinese domestic rare earths industry, Frequent government inspections and better material tracking caused illegal Chinese production to decrease sharply in 2017.

3.2.5 Research and Development

China, like the U.S, is now focusing on solid-state battery technology. Numerous organizations are working on this technology. For instance, China's Qingdao New Energy Research Institute is exploring this technology and considers that by 2025, a commercial product is possible. Solid state technology is included in China's biggest cell producer's - Contemporary Ampere Technology Ltd. - advanced-battery research. Besides this technology, work on Graphene technology is also underway. China International Graphene Industry Union (CIGIU) has been established in agreement with the requirements of technological innovation set by the Ministry of Science and Technology. CIGIU is an international non-profit organization and its members include research institutions, universities, major enterprises (with a focus on grapheme domain), and financial and investment groups. CIGIU aspires to create a financial cooperation platform in order to develop graphene technology industrially at a global level.

3.2.6 Key Takeaways

- China is both the biggest manufacturer and the biggest market for cars globally.
- Buys more than half of the world's new electric cars.
- China's electric car market is 3 times larger than the US electric car market. In 2018, China had 1.26 million electric cars to 361,000 electric cars in the US.
- China has the largest volume of EV in absolute terms. But relatively, EVs still hold only a small share of the total market.
- Uses the term New Energy Vehicles which includes BEVs, hybrids and plug-in hybrids.
- China leads the electric two-wheeler market: produced 26 million units and had an estimated stock of 250 million units (1/4th of the global stock) in 2018.
- Has the world's largest fleet of battery electric buses (120,000 medium and heavy commercial vehicles in 2018).
- Domestic OEMs have a 94% market sales share of the Chinese EV market.
- Incentives being phased out in recent years as industry matures and cost of production falls.
- Growth in investment in battery manufacturing is most notable in China.
- China leads the production of rare earth products (mined) and rare earth compounds (refined). In 2017, Chinese production accounted for 86% of global refined production. Rare earths are a key raw material in permanent magnets which are used in electric motor for EVs. China has in the past withheld supply of rare earths to ramp up prices and has the potential to do so again.
- Put together a complete value chain comprising a high percentage of locally produced components which are also incorporated into foreign cars being manufactured in China.
- China has firm foundations in EV industry in terms of key raw material extractions, battery production and infrastructure for vehicle manufacturing.
- Foreign automotive vehicle & components manufacturers must form joint ventures with local firms to enter the Chinese market.

- Research focus on Graphene Technology - China International Graphene Industry Union (CIGIU) for industrial development of Graphene.

3.3 Norway: BEV Supply Chain Status and Strengths

3.3.1 OEMs

1970-1990 was the concept development phase in Norway. EV prototypes and propulsion systems were developed by private organizations such as Strømmens Verksted, Bakelittfabrikken (preceding Think), and ABB, supported financially by from the research council of Norway. Efforts to commercialize Norwegian-made BEVs began in the 1990s, with the government financially and institutionally supporting domestic BEV manufacturing firms. The test phase (1990-1999), as it is often called, saw the first vehicles being tested in public test programs, lobbying activities being launched and Norstart (Norwegian EV association) being established and the first EVs Think Global, Buddy Electric etc being introduced. The earliest users were enterprises and organizations. Kewet Electric Vehicles, imported from Denmark were also introduced. Both Think and Kewet went bankrupt. Think was later bought by some Norwegian investors looking to launch new EV models.[43]

Mass adoption of EVs began with the launch of new Pure Mobility and Think (also called as Buddy or Kewet) models. However, in 2010-2011 leading auto manufacturers including Mitsubishi, Citroën, Peugeot and Nissan launched their electric vehicles in Norway. The subsequent price competition breaks out saw swiftly falling prices and the Norwegian manufacturers went bankrupt.

Being a high per capita income country, Norwegians are today relying majorly on imported vehicles to support burgeoning domestic demand. As can be seen from Figure 23 below, Nissan Leaf is the most sold electric vehicle in the country, followed by Volkswagen Golf and BMW I3.

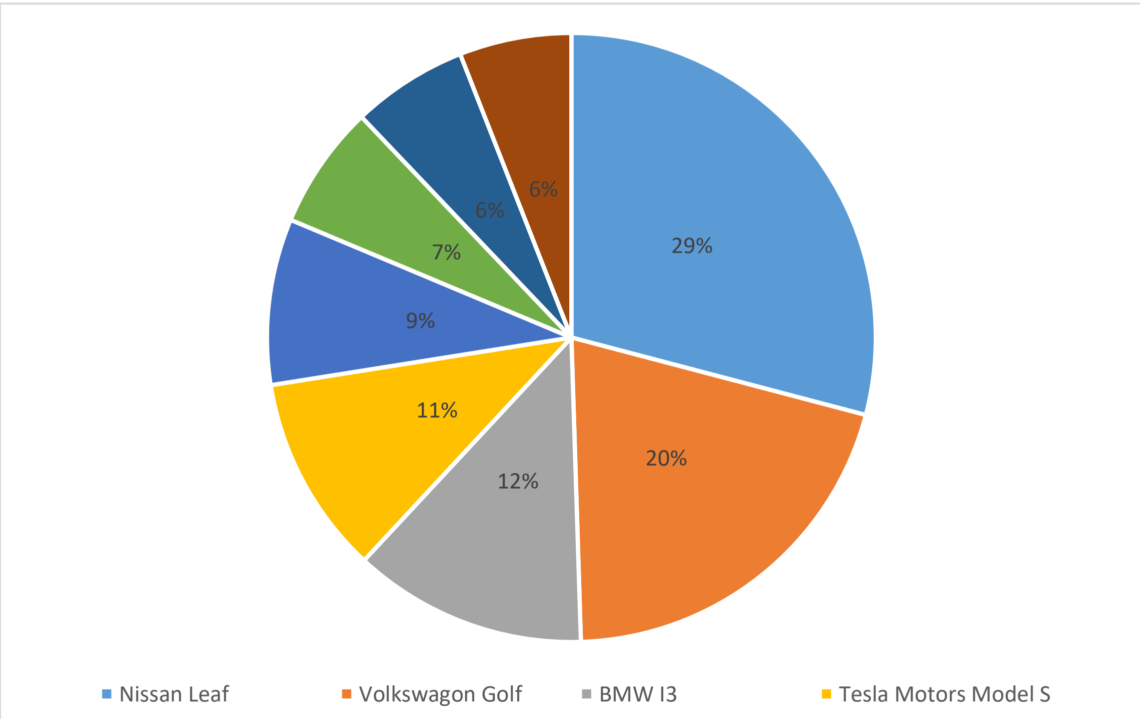

Figure 24 - Total Market Share by Brand in Norway (till 2018)

[43] Figenbaum, E., & Kolbenstvedt, M. (2013). *Electromobility in Norway-experiences and opportunities with Electric Vehicles* (No. 1281/2013).

3.3.2 Battery

At present, Norway doesn't have any significant domestic battery manufacturing and neither does Europe for that matter. Norway intends to capitalize on the European demand for battery cells which is expected to cross 300 GWh by 2025. The high demand mainly comes from European car manufacturers (OEMs). However, as Europe doesn't have any large-scale domestic battery cell manufacturing, the competitiveness of European OEMs is at risk.

Norway intends to build a cluster targeting various research verticals to afford the Nordic region a competitive advantage in energy-efficient battery cells production. For this purpose, they have initiated a leading battery conference in Norway - Oslo Battery Days – held every second year. The participants come from leading public and companies, investors, start-ups, academics and businesses that have a stake in the battery revolution. Attendees include battery users; suppliers, developers, pack assemblers; production equipment manufacturers; test equipment makers; academic members; R&D engineers; researchers; investment companies; battery recyclers; and government officials. This multi-stakeholder partnership further intends to build an alliance of stakeholders willing to join the Norway's emerging R&D cluster based on battery cell production.

FREYR, a major player in battery cells, has announced ambition to develop a Nordic Battery Belt, with potentially four gigafactories in Norway. It has already secured €7.25 million investment from an independent EU body, EIT InnoEnergy, in order to build a battery cell gigafactory in Norway and has developed partnership with leading Norwegian and European institutions and companies[44] such as SINTEF (primarily contributing R&D along the battery value chain including techno-economic assessments); Norwegian University of Science and Technology (NTNU); as the prime partner providing relevant higher-degree education. The aim is to develop a green, ethically responsible and energy efficient battery cell production, that is one of its kind in the world. This ambitious plan will help increase value creation in Norway by shifting to battery manufacturing.

LADAC PRODUCTS AS, is a major company involved in lead acid battery business. Its services are based on product development, production and delivery to professional users.

3.3.3 Other BEV Components

There is no significant manufacturing of motors or other BEV components in Norway.

3.3.4 Policy and Regulation

Norway's long-term policy commitments have helped achieve high growth in BEV market penetration. These commitments have reduced the perceived risk of buying a BEV. The country's considerable budget surplus enables it to give hefty subsidies and incentives to support zero emissions in the transport sector. Despite being an oil producing country, petrol prices are high whereas electricity is comparatively cheap. Even then, supply-side barriers and technological hurdles prohibited significant BEV uptake. In the late 1990s and early 2000s, domestically produced models in Norway could not combine quality and affordability. It was after 2010, that the BEV sales truly picked momentum. Advancements in battery technology and intense competition from global automotive suppliers led to rapidly falling prices. Since Norway already had demand-side incentives in place, BEVs were in a position to compete with ICEs, both economically and practically. This resulted in dramatic growth and today Norway is the world's leading per-capita EV market.

[44] https://news.cision.com/freyr/r/freyr-as-announces-plans-to-build-a-32-gwh-battery-cell-production-facility-in-mo-i-rana-in-norway-a,c2779883
https://www.freyrbattery.com/about

In 1991, Norway became the world's first country to introduce a CO2 tax on petroleum production. Its population is and even was significantly aware of the country's substantial exports of fossil fuels.[45] Norway enjoys popular public support for electro mobility. In the Fifth National Transport Plan (2018-2029) requires all new vehicles to be zero-emission by 2025. Norway is now targeting to halve emissions from transport sector by 2030 (baseline 1990).

Research analysis on Norway finds that electro mobility enjoys high degree of support and acceptability from the general public, political establishment and industry. Norway's broader emissions targets set in the country have been agreed upon with cross-party political consensus since 2008[46]. Furthermore, industry stakeholders are both supportive and supported. For example, Fortum (an electric utility) has become the largest charging infrastructure operator in Norway with the help of government-sponsored grants[47]. Statkraft – the state utility – has managed to acquire a controlling stake in the second largest charging operator - Grønn Kontakt.

Government taxes have made petrol cars more expensive to buy in Norway. The price of Honda CR-V begins at £21,000 in the UK but starts at 486,900 kroner, or £46,000 in Norway. Similarly, imported VW e-Golf 36kWh costs (before taxes) £28,285, whereas a petrol-fuelled Golf 1.2L comes at a cost of £19,867 (before taxes). Under the Norwegian tax system, the petrol model gets £5,866 added in registration tax and £4,966 added as VAT (at 25%). The purchase price thus becomes a hefty £30,699. This makes the petrol version £2,414 more expensive. The electric car is also cheaper to operate, as annual charging costs average only £264 as compared with average fuel cost of £1,293 on petrol. Exemption from road tolls, saves EV owners approximately £1,319 a year, and road-tax reductions save another £267. All things combined; an e-Golf is over £3,000 a year cheaper to operate. Massive subsidies bring small electric cars within the reach of working-class families.

3.3.5 Research and Development

Norway generously funds research and development on EVs. Numerous organizations, both government-owned and private, are researching advancements in this technology. For instance, SINTEF, headquartered in Trondheim, Norway, is an independent research organization. On the government side, research on electro mobility is financed by the Research Council of Norway. Transnova, established in 2009, finances demonstration projects that have the potential of reducing Green House Gas emissions from the transport sector. Innovation Norway funds the commercialization phase. The Norwegian Public Roads Administration also funds some of the research studies. NTNU – The Norwegian University of Science and Technology (Norwegian: Norges teknisk-naturvitenskapelige universitet, NTNU) - has been a regular contributor of knowledge, technology and human resource to the energy industry for over a hundred years. The recently formed NTNU Battery Initiative, will be making contribution to the emerging battery cluster in Norway by providing both qualified candidates and basic research.

3.3.6 Key Takeaways

- Norway saw 49% market penetration for BEVs in 2018[48]. Powers EVs through its 98% renewable electricity (hydro plus some wind power source).
- Early adopters in Norway are primarily individuals belonging to the high-income group and well-educated background who want to save money.
- Vehicle fleet operators (for instance, corporations, car rental agencies, and governments) are amongst early adopters of EVs. As the fleet users intensively use their vehicles, this means

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[46] Norwegian Government, Cross-Party Statement on the Climate Report, 2008
[47] Fortum, Operations in Norway, February 2016 [accessed 17.02.2017]
[48] Global EV Outlook, 2019

that they stand to incur correspondingly lower fuel and maintenance costs in comparison to ICEVs and the high number of total kilometers driven per vehicle per year improves the relative Total Cost of Ownership of EVs.

- Access to Infrastructure - In Norway, 95% of BEV owners have access to home charging, and 60% have access to charging facilities at their work places[49].
- Even in a country like Norway, the key incentives influencing the decision to purchase a BEV are ultimately practical/economic, rather than ethical.

TIMELINE OF EV INCENTIVES IN NORWAY

- Purchase and import taxes removed (1990-)
- 25% VAT on purchase exempted (2001-)
- Annual road tax exempted (1996-)
- Charges on ferries and toll roads removed (1997- 2017)
- Unrestricted municipal parking (1999- 2017)
- For EVs, ferry rates are a maximum of 50% of the total amount (2018-)
- For EVs toll roads is a maximum of 50% of the total amount (2019)
- EVs have access to bus lanes (2005-)
- New rules allow local authorities to limit the access to only include EVs that carry one or more passengers (2016)
- Company car tax is reduced by 50% (2000-2018)
- Company car tax is reduced to 40% (2018-)
- On leasing, exemption from 25% VAT (2015)
- Fiscal compensation is given for scrapping ICE vans when converting to a ZEV van (2018)
- Holders of driver license class B are allowed to drive electric vans class C1 of up to 2450 kg (2019)

[49] Norwegian Vehicle Association (November 2013)

4 Automotive Industry in Pakistan

4.1 Overview

At present there is weak local demand in Pakistan not only for BEVs but also for traditional vehicles. A small percentage of the population can afford to buy cars. People who buy low-end cars (e.g. Mehran) are among the richest people in the country in relative terms. Two-wheeler potential exists. It is thought that many infrastructure projects, especially under China Pakistan Economic Corridor, will help boost the automobile sector.

On the supply side, the sector witnesses ad-hoc changes to the policy environment frequently and is characterized by a poor business climate, highly concentrated industry, low exports, low market size, and limited consumer choice. Still it has managed to create engineering capacity and employment throughout its value chain. Pakistan is tapping export markets for motorcycles, auto parts and tractor to a small extent. But the sad truth is that after decades of tariff protection, Pakistan's passenger car industry still cannot sustain itself without government protection. A "cascading structure" of tariffs is in place. The rates are highest for CBUs and then become gradually lower for inputs to each stage of the value chain. Higher tariffs are set for CBUs with larger engine sizes. In addition, auto parts which are localized face higher tariffs and non-localized parts face lower.[50]

Table 3 - Production of Automobiles

Category	Installed Capacity	No. of Units		
		2018-19 (Jul-Mar)	2017-18 (Jul-Mar)	% change
CAR	240,000	170,118	166,166	2.4
LCV	43,900	19,536	22,713	-14.0
JEEP	5,000	5,745	9,841	-41.6
BUS	5,000	649	555	16.9
TRUCK	28,500	5,027	6,907	-27.2
TRACTOR	100,000	37,457	52,551	-28.7
2/3 WHEELERS	2,500,000	1,342,185	1,424,379	-5.8
Source: Pakistan Automotive Manufacturer Association (PAMA)				

Automobile sector growth declined by 7.6 percent during FY 2018 - 2019. Sub sector growth analysis shows that production of:

- Buses grew by 16.9 percent
- Tractors fell by 28.7 percent
- Trucks fell by 27.2 percent
- LCVs fell by 13.6 percent
- Jeeps & Cars fell by 0.1 percent
- Motor cycles fell by 11.7 percent
- Passenger car sector grew by percent

Low growth rates were reportedly caused by higher registration rates for non-filers (individuals required by law to file their income tax return, but who fail to do so by the required date), and even a ban on non-filers to purchase vehicles of certain engine capacity. The imposition of 10% Federal Excise Duty (FED) on vehicles exceeding 1700cc has severely dented the sales of SUVs, cars, and jeeps in Pakistan. Other expected causes are:

[50] Bari, F., Afraz, N., Mukhtar, N., Khan, U., Hussain, S. T., & Fatima, U. (2016). Regional competitiveness studies: research study on auto sector. *Institute of Development and Economic Alternatives*, *152115*.

- High growth of Buses – attributable to Urban Transport Schemes under which old buses are being replaced.
- Low growth of Trucks - certain government projects halted work, so the supplies of trucks and the respective payments were disrupted.
- Low growth of Tractors – Attributable to massive slow-down in agriculture growth, water shortages and other issues like increase in the prices of agricultural inputs and halting of development projects.
- Low Growth of Two/three Wheelers: This sector offers most preferred and economical means of transport and best alternative in the absence of public transport in the cities. During the Jul-Mar FY2019, the two/three wheelers sector also failed to show normal growth, it reduced production by 5.8 percent. These vehicles cater to lower income group, hence, are extremely price sensitive as compared with passenger cars and trucks. Even a slight change in price can change demand dramatically. The poor economic condition and rapidly devaluating rupee also decreased sales figures of two and three-wheel vehicles. Due to their affordable nature, two and three-wheel vehicles hold great potential for growth in the future.

Automotive Parts Production: There are approximately around 1,600-1,700 companies operating in the automotive parts market in Pakistan. A large number of these are involved in the production of repair parts. 200-240 companies supply parts for OEM (original equipment manufacturer) production. These companies basically supply single unit parts; however, some make components combining multiple parts. Although the auto parts industry does not consist of clear multiple tiers, which may be seen in other various countries, most components are directly supplied to automakers, hence these are considered to be first tier suppliers.

The automotive parts industry originated in the nationalization phase in the 1970s, when automobile production in the country started in the form of CKD (complete knock down) production. Production equipment as well as made parts such as cylinder blocks, castings and gears were introduced by various manufacturers from other countries. Due to privatization, this parts industry expanded strongly, with its growth accelerating in the 1990s, when localization of automotive parts became pervasive and mandatory as the government announced the Product Specific Deletion Program (PSDP) to clearly define localization rules in 1995. PSDP was responsible for protecting and fostering the domestic automobile industry and ensuring the requirement of automakers to achieve local content of over 70%.

Parts industry thus resulted in steady growth in terms of production volume, if not in international competitiveness in terms of quality and various other factors, as it was not subject to competition with foreign products. Thus, the Pakistani automobile industry faced the major issues in terms of improving industry’s competitiveness.

Tariff Based System (TBS) replaced PSDP in 2007. TBS permits imports of parts that are locally available, provided that customs duties are paid. Automakers were thus allowed to expand their sourcing choices. Local parts suppliers in turn faced strong competitive pressure. Under the TBS various automakers switched to imports. However, recently, there has been a tendency of returning back to local procurement due to the Pak Rupee depreciation (making imported parts more expensive).

The Automotive industry of Pakistan is still highly dependent on imports for various components and materials and increasing their local supply is a vital issue facing the automotive parts industry in the country. Exports remain marginal. However, the manufacturers and assemblers of vehicles have learned to develop a lot of parts and components locally over the years.

The main market players in the car market of Pakistan are Honda Atlas, Hinopak, Indus Motors, Mitsubishi, Pak Suzuki, Dewan Farooque, and Sigma Motors. Till 2014, Pakistan had a moderately concentrated car market. Three Japanese firms (Honda, Suzuki and Toyota) made eight models and these accounted for nearly all the car sales in Pakistan. The largest market share of passenger cars belongs to Pak Suzuki, a market share of 56% followed by 28% market share of Indus Motors and 15.7% of Honda Atlas. The remaining 0.3% of market share belongs to other passenger cars[51]. The market structure of the automotive industry is sensitive too. Interventions by the government provide protection, exemptions and specific preferential treatment for production or trade to entities in this sector.

Pakistan falls in the category of the few manufacturers in the world who are producing or assembling all kinds of vehicles, ranging from trucks & buses, 2/3 wheelers, motorcars, prime movers, tractors and LCVs (light commercial vehicles). Recent developments have seen the automotive industry in Pakistan operating under rising urban buying, and technical cooperation and franchise agreements with China, Japan, Korea and Europe. Major international brands such as Hyundai, Renault and Kia motor are anticipated to start production Pakistan. Major allied industries comprise of CNG (compressed natural gas stations), workshops, automobile parts shops and tire shops.

4.2 The Economic and Business Case for BEVs

Pakistan's economy has been declining at an accelerating rate due to the increasing trade deficit (increasing imports and declining exports). Bill for fuel imports currently amounts to USD 13.3 billion, which is estimated to reach a staggering value of USD 30.7 billion by 2025, further exacerbating the already declining economy. Given this high dependence upon oil, mass adoption of BEVs has the potential to improve the trade deficit. Pakistan currently spends USD 13 billion on oil import every year. The burgeoning oil-based transport sector is a key contributor to this bill. As the transport sector continues to grow, so will the oil import bill which is expected to reach USD 30 billion for Pakistan by 2025. Battery based energy storage, as found in BEVs, gives the same mileage with one-third of the cost compared to their ICE counterparts. This means that even if BEVs are charged with coal or gas-based electricity generation sources, almost 25-40% fuel can be saved, thus directly translating into a lower import bill[52].

Burning fossil fuels, including oil, increases carbon emissions along with hazardous compounds such as Sulphur Dioxide, Nitrogen Dioxide and particulate matters, thus leading to environmental degradation. Most industrial cities in Pakistan are well over the threshold of clean air. Poor air quality causes over three hundred thousand deaths every year in Pakistan every year. BEVs are a promising technology for reducing the greenhouse gas emissions and other environmental impacts of road transport. The tail pipe emissions of EVs are zero, and since 37% electricity generation in Pakistan is from renewable sources, the overall impact of EVs is 70-80% reduction in environmental emissions in the overall energy value chain[53].

Historically, the power generation has been besieged with many challenges and has not been able to fulfil the power demand of Pakistan. This situation is set to reverse in the next several years according to some studies and Pakistan will have a surplus of power generation as it has signed up to new projects that will increase its total power generation capacity to 62.184 GW peak generation. Overview of the energy consumption of different vehicle technologies shows that BEVs are less energy

[51] KPGM 2013
[52] Ullah, N. (2019). Electric Vehicles in Pakistan: Policy Recommendations Volume I Cars.
[53] Ibid

intensive than other vehicle technologies. It is estimated that a supply of 1 GW can fully charge 500,000 EVs daily. Even Pakistan will have an excess capacity of approximately 15 GW by 2025 but in case of Pakistan, even if the government does not buy this excess electricity, it will still have to pay exorbitant capacity charge payments as per the contracts[54].

4.2.1 Commercial Viability of BEVs in Pakistan's market

Table 4 - Cost Comparison Between Fuel and Electric Car

Description	Vitz (Petrol)	Swift (Petrol)	Cultus AGS (Petrol)	V9 XR EMV (Electric)	V5 6 KWh (Electric)
Cost of car	21,50,000	20,50,000	19,75,000	21,00,000	18,00,000
Full Tank or full charge cost in PKR	4,181	3,955	3,955	168	120
Fuel/Charge Cost per month in PKR	104,525	98,875	98,875	4,200	3000
Fuel/Charge Cost per year in PKR	1,254,300	1,186,500	1,186,500	50,400	36,000
Total Fuel/Charge Cost in 7 years	8,780,100	8,305,500	8,305,500	352,800	252,000
Total Maintenance Cost in 7 years	210,000	210,000	210,000	42,000	42,000
Total Car Cost+Fuel/Electricity cost+Maintenance Cost	11,140,100	10,565,500	10,490,500	2,494,800	2,094,000

4.2.2 Poor Demand Outlook

The lack of demand for BEVs in Pakistan can be attributed to several distinct factors. The first and the foremost concern of a consumer would be the vehicle cost. The purchase cost of BEVs is much higher than comparable ICEVs, as already stated in the previous section.

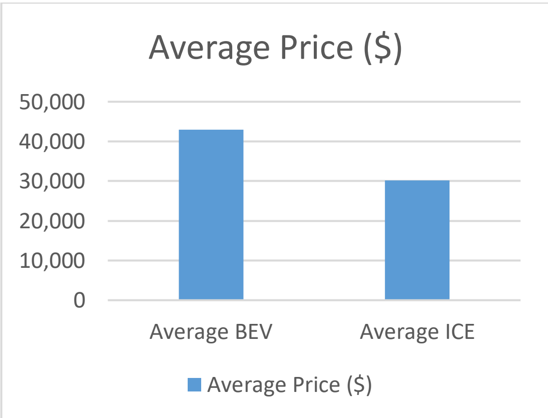

Figure 25 - Average Price Comparison

On the other hand, the operational cost of BEVs is lower than ICEVs. However, due to lack of awareness and financing facilities consumers mostly base their decision on the purchase cost only. Another concern is about the resale value of the vehicle. Even internationally, BEV residuals are weak. Excluding the premium market segment, BEVs' residual values are 6 percentage points lower than

[54] Ibid

their ICE counterparts. Demand in the residuals market can be created by making consumers believe that a BEV's utility is higher than that of an ICEV.

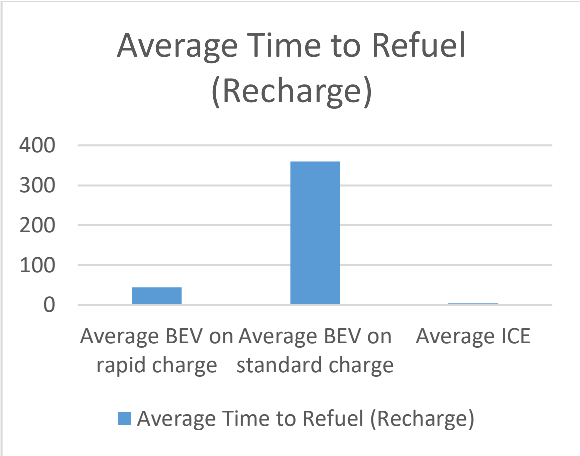

Figure 26 - Average Time to Refuel for Different Vehicles

Lack of infrastructure also raises understandable concerns: it takes significantly longer to recharge a BEV than it does to refuel an ICEV. Consumers need publicly accessible charge points (especially those offering rapid charge) at convenient locations. These facilities are not available at present in Pakistan. In future, it is possible to make use of alternatives such as home charging or workplace charging facilities. In the long-run, a network of charging stations will have to be installed to alleviate the range anxiety. Range anxiety, a consumer's worry whether the vehicle will reach its destination, is a major global barrier to widespread BEV adoption. Since research has also shown that the actual range of BEVs is generally less than the claimed range,[55] it is likely to remain a glaring concern in Pakistan.

Battery concerns are also present as battery degradation is a known feature of BEVs. This is exacerbated by the fact that temperature extremes significantly impact energy consumption (e.g., through cabin climate control) and battery performance. Given the environmental context of Pakistan, consumers are concerned about the required frequency of battery replacement. From the experience of the developed world, it can be seen that most companies offer battery warrantees ensuring 5-10 years of battery life. It remains to be seen whether domestic producers can replicate these practices.

Demand push factors such as government support through the use of taxes and incentives have been missing up till now. Regulations on emissions, which have been used by many countries as a way to make traditional internal combustion engines more expensive, have been non-existent in Pakistan. The government needs to set and enforce such targets.

EV adoption is significantly influenced by consumer characteristics and context specific factors, such as electricity costs, fuel prices, and availability of charging stations (Sierzchula et al., 2014). Research shows that consumers who are affluent, educated, young or middle aged are more likely to buy an EV[56]. If these findings are applied in Pakistan's context, it can be anticipated that the potential market base for BEVs will be limited in early years. Thus, new players in BEVs will need to carefully craft the target customer base and their value proposition.

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[55] Citi Research, LMC

[56] See for instance Plötz et al., 2014, Hidrue et al., 2011, Plötz et al., 2014, Gärling and Thøgersen, 2001, Graham-Rowe et al, Hidrue et al., 2011, Curtin et al., 2009, Ozaki and Sevastyanova, 2011

Table 5 - Key Players Interviewed in Pakistan as Identified through the Value Chain Framework

VEHICLE TYPE	ORIGINAL EQUIPMENT MANUFACTURERS	BATTERY	MOTOR	CONTROLLERS	CABLES	KNOWLEDGE CENTERS	GOVERNMENT
2/3 wheelers	**Omega (Road Prince)**: Shahid Naseem (Director Operations), Shahrukh Naseem (Director) Power Electronics Pakistan: Mawish Ahmad (Director), Wasim Ahmad Khalil (Managing Director) Jolta: Muhammad Azim (Chairman), Usman Sheikh (CEO Auj Group, Irfan Ahmed (CEO Jolta) and management InerZ Automotive: Haider Zaidi (CEO), Murtaza Zaidi and senior managers Sazgar Engineering: Mian Ali Hameed (Director)	Atlas Group: Aamir Shirazi (Director) Treet-Daewoo: Farid Rasheed (GM Sales and Marketing)	Golden Dynamics: Najam Rauf Mughal (Director) Alkhas Industries: Noor Ahmed Diamond Electrical Company: Ghulam Farid	Jolta: Irfan Ahmed (CEO)	Fast Cables: Kamal Amjad Mian (Director)	LUMS Energy Institute: Dr. Naveed Arshad, Dr. Fiaz Ch., Nauman Zaffar NED University: Faculty members in electrical and mechanical engineering	Engineering Development Board (EDB): Mirza Nasir Baig (Head), Khuda Bakhsh (Legal), Asim Ayaz (Policy-Coord) Lahore Chamber of Commerce and Industries: Almas Hyder (President)
Cars	Nishat Hyundai: Sohail Nawaz (Managing Director) Atlas Group: Aamir Shirazi (Director) S. Zia ul Haq & Sons: Shaukat Qureshi						
Buss/trucks	S. Zia ul Haq & Sons: Shaukat Qureshi						

5 Analysis of BEV Supply Industry in Pakistan

Over 100 companies exist in Pakistan that assemble conventional motor vehicles, which include cars, trucks, busses, motorcycles, rickshaws as well as tractors along with 1,700 automotive parts manufacturers. Parts manufacturers are mainly local capital companies whereas the OEM assemblers are led by Japanese companies. This section presents an overview of the insights gained through the interview stage with various organizations (identified through value chain framework) which are currently involved or have the potential to become involved in EV manufacturing and gives a qualitative understanding of the EV perspective and the readiness status of BEV industry in Pakistan.

5.1 OEMS

Hyundai Nishat

Hyundai Nishat is an automobile manufacturer formed as a joint venture between Hyundai and Nishat Mills, a subsidiary of Nishat Group, based in Lahore. Hyundai Nishat is the authorized assembler and manufacturer of Hyundai vehicles in Pakistan. When interviewed, the company was focusing on putting together a production plant in Faisalabad before June 2021 to benefit from Auto Development Policy 2016-21. This production plant is the result of PKR 120m investment project. At present, the company focuses on internal combustion engine (ICE) based vehicles and they see commercial three and four wheelers as their initial demand points. However, it is worthwhile to mention that when Nishat Group first entered an agreement with South Korean Hyundai Motor Company to set up a car assembly plant in Pakistan, it planned to introduce electric and hybrid passenger cars (DAWN, 2017).[57]

Hyundai (a Korean company) wants to move manufacturing out of Korea because of domestic issues such as demands for higher labour wages, strikes, and worker unions. Hyundai is taking initiative in actively looking for other markets to outsource their production and is looking at Pakistan as a potential export hub.

The company agrees that theoretically electric vehicles give huge savings and points out that Pakistan should start with commercial vehicles. However, it also insists that conventional automakers in Pakistan, especially those that are Japanese-owned, are not in favor of introducing EVs very soon as there are lots of issues to be resolved with batteries and motors, and hence insist on going conventional 50 years. Players such as Honda, Toyota and Suzuki have recently made huge investments in transmission and engine parts and established new ICE production plants, so they do not want their investments going to waste by switching to BEV production.

Nishat-Hyundai agrees that mass BEV adoption in Pakistan will require major changes. Existing auto parts manufacturers will be affected, except perhaps engine and transmission as they are sourced from abroad. The company insists that local players in R&D usually do reverse engineering in Pakistan but must also move to testing and field test validation if BEVs are to be adopted. It agrees that the recent policy change direction taken by the EDB is a welcome change for the industry. Under the new policy, EDB restricted the import of cars and encouraged start-ups to establish. The proposed incentives are available for manufacturers establishing production plants before 2021 and are also applicable on as many models launched. Nishat-Hyundai's plant is also established to avail this policy. They are also launching two commercial models: an SUV and a sedan. This is challenging as they are establishing a plant and launching models at the same time. For this reason, they have not been able to focus on introducing BEVs. Nishat-Hyundai believes that there is reasonable potential for the introduction of BEVs and the company also intends to start plans for developing a roadmap soon. They

[57] (https://www.dawn.com/news/1318040)

believe Pakistan's capability is very good, and it has skilled and cheap labour. Government should give clarity and maintain it to foster this industry. Being a firm believer in technology transfer, the company invites Korean vendors and enables local vendors to interact with them. It believes that vending industry is more important than OEMs in this shift to EV and Pakistan has an advantage as main suppliers are located in China. To make a part locally, manufacturers can start with a component and make use of input-output ratio.

Atlas Honda Limited

Atlas Honda Limited is a public listed company, incorporated on October 16, 1962. It is a joint collaboration between Honda Motor Company Limited Japan and Atlas Group, one of Pakistan's renowned business conglomerates. The company is primarily engaged in progressive manufacturing and marketing of motorcycles and spare parts and is the largest motorcycle manufacturer in Pakistan and the brand enjoys a loyal customer base. Often considered as a pioneer of motorcycle industry in Pakistan, Honda Atlas has been leading two-wheeler market for over 50 years and has a current production capacity of over 1.35 million units per annum.

The Principal-led company, however, does not intend to capitalize on its position as an established and strong incumbent, and has no plans at present to enter the EV market and plans to continue its focus on ICE based vehicles. At present the organization believes that the industry is constrained by factors such as lack basic research and prototype, field test and validations, and perceives a somewhat high degree of technological uncertainty and low supplier base for BEV industry to flourish.

The organization believes that the pathway to EV introduction should be: CBU => SKD => CKD => Assembly => Parts. Initial demand point would be from four-wheeler cars as they are the trend setters. At present the organization believes that the industry battery business is OEM driven, once there is proven demand from OEMs, battery manufacturing will pick up pace. Lead acid' which is the available technology in Pakistan is gradually shifting to 'Maintenance free'. Given sufficient time and demand, it will give way to Li-ion naturally.

Sazgar Engineering

The organization currently focuses on ICE based three and two wheelers. Their product portfolio comprises 70cc, 100cc, 110cc, 125cc, 150cc, and 250cc motorcycles. In-house production of basic parts is their major internal core capability as localization has reached 95% in their 70cc category, and 70-75% in 100cc, 110cc and 125cc category. However, Engine remains their major outsourced component and their 150cc and 250cc category motorcycles are imported 100%.

Sazgar has developed a prototype of an electric three-wheeler (lightened body). The business outlook for BEVs according to the organization is complicated. Sazgar sources components and parts from China. At present the two-wheeler EV costs PRK 90, 000. The company says that component prices fall with the passage of time and they did for a while (engine price went down from $98 to $52), but the rising labor costs in China and the depreciating Pak Rupee have led to their increase recently.

According to Sazgar, the chief component influencing the final vehicle price is the battery. Battery costs are high to begin with, over PKR 20,000 for a 20 Amp battery in a two-wheeler. The body costs PKR 25,000. Although the reported life of lead-acid batteries is 3 years by most brands, the harsh weather necessitates frequent battery replacement as the battery performance starts/life starts decreasing after 1.5 years. The replacement cost of PKR 20,000 every two years is too expensive to be borne by the target customers. Lithium-ion batteries give much better performance, but are correspondingly more expensive. They claim that battery cost is as much as half the total cost in electric four wheelers. The running cost of an EV is quite impressive PKR 17-19 per charge. However, an electric scooter covers only 50 km/charge. When considered in the context of lack of infrastructure, this makes EVs unreliable, unattractive and restricted in scope as compared to petrol-fuelled ones in Pakistan.

Sazgar believes that technological improvements in this area are coming from U.S.A and not China. Still, they see technology transfer taking place from China to Pakistan and manufacturing coming to Pakistan. Sazgar predicts the cycle: Business Potential leads to Vehicle and Component Import which in turn leads to Local Development. They believe that the local vendor base is very developed and Pakistan can leverage that to build the BEV industry. The government should give the EV related components the same incentives as those given to ICE components to set the cycle in motion.

AUJ Group, Lahore

AUJ in collaboration with their manufacturing partner in Sahiwal, is converting conventional motorcycles into electric ones in Pakistan. The process design is developed by AUJ itself, along with controller, battery system, charger, motor and battery pack. The E-bike introduced by AUJ follows the product design of Honda (Japanese) motorcycles as their spare parts are easily available in Pakistan. The company also offers customers the choice of getting an electric kit retrofitted into their existing vehicles. It estimates that if a conventional oil-based motorcycle gives 50 km on average at a cost of PKR 4000, an electric motorcycle, will give the same at a cost only PKR 500.

AUJ has established a separate company, JOLTA, to work on BEVs exclusively.

JOLTA Electric, Lahore

Jolta Electric is a specialized solution provider. It is close to launching two-wheeler (70, 100, 125cc) and closed three-wheeler EVs that are lithium-ion based. Controller and battery management system have been developed locally. Its upcoming products are: Jolta Electric Rikshaw JER – 200, Jolta Electric Loader JEL – 150, and Superfast Power Bank. The company also provides EV Kits (battery, battery management system, DC motor, and controller) which can be used to convert ICE vehicle to battery electric. These EV kits can be particularly useful for the smaller players in the industry: 2-wheeler EV providers who are trying to scale up.

Jolta has five years of product designing, development & manufacturing experience in China with special reference to EVs. Their team comprises of electronics engineers, R&D specialists, product scientists, PhDs, mechanical & computer scientists. Their product scientists designed some of the key EV components locally, like Controller and the Battery Management System (BMS) and the products have passed through different phases of R&D and rugged road tests. They hope to start manufacturing these components locally sometime early next year.

Table 6 - Technical Specifications of Selected Products by JOLTA

Technical Specifications	JE - 70	JE - 100	JE - 125
Motor	48v, 1500W	60v, 3000W	72v, 5000W
Motor Power	2 HP	4 HP	6.8 HP
Battery Power	30 Ah	30 Ah	40 Ah
Distance Covered in One full Charge	50-60 km/Hr	70-80km/hr	110-120 Km/Hr
Top Speed (Plain Road)	50 Km/Hr	70 Km/hr	80 Km/Hr
Speed on Inclined Road	25-30 Km/Hr	40-50 Km/Hr	50-60 Km/Hr
Charging Time (To Fully Charge the Battery Bank)	5 Hrs	6 Hrs	8 Hrs
Units Consumed (while charging the battery bank)	1.5 Units	2.5 Units	3.5 Units

Source: Company documents

Jolta is of the opinion that lithium ion technology will soon become obsolete and be replaced with Graphene technology making batteries very cheap. The company is also exploring this avenue and Jolta's R&D team is working on Graphene-based Super Cells formula and intends to have its own patent soon. Currently these Super Cells are being outsourced from China.

Like other companies, Jolta faces the following current challenges: there is no BEV eco system in place; market is not ready; prices are too high to be affordable by the common man, lengthy charging time and fear factor. Despite these setbacks, Jolta Electric is looking forward to be the preferred "Technology Provider" for up to 30% of the total EVs anticipated to be produced in Pakistan by 2030. In Renewable Energy & Storage Technologies, they hope to secure a significant market share in the world by virtue of being in the R&D of Graphene based Super Cells. Jolta plans to play an aggressive role for a pollution free Pakistan and aspires to help other countries control climate & environmental conditions.

Jolta sees itself as more of an EV technology provider/partner as opposed to a manufacturer or assembler. Top management is of the view that the company is of entrepreneurial nature and helps entrepreneurial initiatives establish themselves. The company frequently provides guidance and support to their employees several of whom have gone on to set up their own start-up companies

Omega Industries (Road Prince)

Omega Industries currently focus on ICE based vehicles. They developed a hybrid two-wheeler about four years ago in 2015. The hybrid motorcycle was a novel idea as they were pitched against ICE-motorcycles at a time when petrol prices were exorbitantly high. Nevertheless, their EV failed to capture the market as petrol prices started falling soon thereafter, hampering demand for their Hybrid model (the oil price trend is on the rise again).

The organizations suggest that the country's EV strategy should focus on creating demand and allowing imports. Once the demand is there (for instance, by removing license fees, giving free registration), EVs, especially electric two-wheelers have the potential of becoming popular amongst the school/college/university students. Import of EVs, their components and parts will lead to local firms reverse engineering the design and eventually lead to the design of product domestically. This will lead to development in the BEV industry logically.

Natural Development: Import => reverse engineering => design

They also suggest beginning with three-wheeler commercial electric vehicles and possibly making use of lead acid batteries to reduce cost.

Power Electronics Pakistan (PEP), Lahore

PEP has designed an electric three-wheeler (E-Rickshaw). They converted a standard open rickshaw into electric by replacing the engine and gear box with electric DC motor, selector switch and batteries. Controller and wiring were made in-house by PEP itself. However, these vehicles can only be operated/used in closed premises, since there is no mechanism at present to get them registered. Their EV has reasonable speed, 40-45 km/h and does 4-5 hours per full charge (100% 15A). Customers can choose from various battery types: dry battery/ li-ion battery/lead acid battery.

The product has a strong metallic framework, with reasonable size battery compartment. It is equipped with all the required features such as speed o meter, battery level indicator, head light, tail light, and side indicators. Most importantly, its running cost is only 10 Paisa/Km (PKR 0.1/Km) and if charged on solar panel it is completely free. As the E-Rickshaw has no engine i.e. no clutch or gear, it will incur no oil change or any such maintenance cost. It can be provided in tailored designs according to clients' business needs. Currently three designs are offered: Loader, Theatre and Patient Cart Types.

S. Zia ul Haq & Sons (SZS), Karachi

SZS is a group of companies, with diversified business activities, locally and abroad. They have been involved with oil & gas sector, and for the last 4 years actively working with local and Chinese companies engaged and operating in the coal development and power generation at THAR, the 3rd largest coal deposits in the world. The group has operational facilities in UAE, US, Bangladesh, Yemen and Iraqi Kurdistan. As a part of their expansion program to cater to the future technological requirements and opportunities, SZS decided to enter the high-tech business activity of manufacturing of Electric Cars, Buses/ Vans/ Scooters/ Rickshaws, Batteries, Electric Chargers and other applications with their SZS EV AUTO DIVISION. Their objective is to cater for the upcoming market locally and even have export potential to the Middle East by 2022 and onwards.

SZS is involved in importing and manufacturing of four-wheeler (cars, vans, pickups) and two (scooters) wheeler EVs. They are targeting same prices as ICE-based vehicles and seek to localize battery and charger manufacturing. In addition to this, they are working on motors in Gujrat/Gujranwala and believe the BEV industry progressing through the following pathway:

Complete built unit => Semi knock down => Complete knock down

SZS have established an Electric Vehicle Assembly cum Progressive Manufacturing Plant in Karachi, Pakistan. This plant operates on the basis of MOU’s and technical collaborations with Chinese companies. In addition to this, the company has also started importing electric vehicles from China since December 2018/ January 2019. The company has a diversified product portfolio: E-Cars, E-Vans, E- Pickups, E-Buses, E- Scooters, E-Chargers and E-Batteries. The company claims that their customers can save as much as following by using their products:

Motorcycle -----------------------------------PKR 3,000 – 4,000/ Month
Cars/Vans/Pickup-----------------------PKR 25,000 – 50,000/Month

City/Intercity Buses/Coaches-----PKR 300,000 – 500,000/Month

For instance, they estimate that an E-bike can create a saving of PKR 3,000 – 4,000 PM (on the fuel alone) for a consumer, thus offsetting the purchase cost within a period of 15-18 months depending upon usage. Similarly, an E-Car owner would save PKR 25,000 to 50,000 PM, thus offsetting its purchase cost within 24-36 months depending upon the model and the capacity of EV. E Intercity Bus owner would save PKR 300,000 to 500,000 per month, thus offsetting the cost of E Intercity Bus, within 30-36 months, again depending upon the model and capacity of E Intercity Bus along with other E Buses. Total bus operation cost would be cut down by 50%, this effect will reduce the commuter's fare cost. Furthermore, the repair and maintenance cost of EVs are significantly less as compared to fuel-based Vehicles as EVs have 200 to 475 components compared to 2,000 plus in fuel-based vehicles.

The group foresees the coming 2020 - 2030 as being particularly challenging in terms of manufacturing of innovative products and services, although the company claims to have the credentials, resources and technical support required to setup manufacturing plants in Pakistan and UAE, with reputed partners.

SZS' Sales & Marketing Strategy involves:

- Conducting Road Shows in Karachi, Lahore, Islamabad, Multan, Faisalabad, Peshawar etc.
- Using all mediums for EV promotion like social media, print & electronic media automobile websites etc. for creating public awareness.
- Establishing dealers and after sale services network in all major cities of Pakistan.
- Establishing sales & marketing offices, and maintenance & repair workshops in Karachi, Lahore, Islamabad, Multan, Faisalabad, Peshawar etc. to ensure the availability of spare parts.
- Getting maintenance & repairing technicians trained from China.
- Establishing EV sales network through banks utilizing online booking system (joint marketing) and dealer network to maximize the sales of EVs.

The organization is inducting transparency in the marketing/sales strategy of auto industry in Pakistan. All money for CBU imports, will be deposited and managed through the banking system (establishment of LCs, from the booking and holding the balance till clearance), besides paying off for the imports at due dates (60-90 days supplier credit). Clients would have the option to check their delivery and payment schedule online, besides the choice of category/ color and other features and delivery options.

Like other organizations entering EV industry, SZS faces numerous challenges like negative consumer perception about EVs. There is no transportation ministry in Pakistan at the Federal level to exclusively tackle the transport sector and guide its development towards new technology through adaptation and policy making. SZS says that the duty and tax structure is high on imports of E- vehicles, as opposed to other countries who have encouraged and provided purchase and manufacturing incentives for customers as well as the investors of EV technology.

The organization claims that the ICE automotive manufacturers have a powerful lobby at various levels, which often dredges up the negative aspects of EV and its technology. Due to this lobbying, EV policy (being finalized by the Government), has been delayed multiple times is still pending to be approved. It sees vested interests hindering the implementation of the EV policy by the Government and even asserts that the EDB is playing into the hands of powerful ICE automotive manufacturers.

InerZ, Islamabad

InerZ is a research, design, and engineering company based in Islamabad, Pakistan. Their focus is on building efficient battery pack (space, cost and energy) and they are targeting the specifications and price of a 70cc bike. This is an intelligent move on their part as the motorcycle market is dominated by the 70cc bike segment. Their product is at prototyping and test stage. Their targeted market segment comprises companies with large scale commercial vehicles or fleets, e.g., TCS.

InerZ's design studio is focused on providing services from concept to prototype and further engineering support for manufacturing. Their team of experienced designers & material engineers are developing concepts for manufacturers. The company claims to have in-depth analysis & research on consumer behavior in Pakistan in auto industry, particularly motorbikes, and insists that their clients can use the knowledge to develop their own brands, and sales & marketing strategies to launch EVs. Furthermore, they are also engaged in R&D on the design and manufacturing of Lithium Ion cells and battery packs along with exploring their optimum usage and safety.

5.2 Battery

The battery industry in Pakistan is lead acid-based manufacturing. Although majority of the players are using obsolete technology and production methods, there have been a few examples of innovative firms. The report expounds on one of them:

Treet Daewoo

Treet Batteries is a part of Treet Group of Companies and is a Lead acid-based battery manufacturer. Treet has established a state-of-the-art battery manufacturing plant in the second largest industrial state near Faisalabad and markets its batteries under the brand name Daewoo, hence the name Treet-Daewoo. Treet also has a 2-wheeler EV manufacturing plant which at present produces only small volumes.

Treet is of the view that battery brands develop very slowly over time. It is very difficult to make customers (OEMs and individuals) switch from their existing brand preferences. Treet finds it difficult to generate demand for their batteries, both for automobile production and other purposes, due to this precise reason. The ingrained buying habits compel people to stick with the existing three leading brands. There is not much margin in pricing as battery technology has become standardized and commoditized. Product differentiation is on the basis of advertising and branding.

In an attempt to increase their product market penetration, Treet has started offering Maintenance Free Battery Technology - a segment where other lead acid battery manufacturers were not active. Treet-Daewoo is the only manufacturer of Lead-Acid batteries in Pakistan which offers Maintenance Free Sealed Batteries (MFSB) for automotive needs and Specialized Deep Cycle Batteries for Urgent Power Supply (UPS) and Solar Systems. Their specialized batteries are designed for the Pakistani environment and are manufactured using advanced Korean Technology.

As discussed with their specialists, lead acid batteries can be used instead of lithium-ion in two and three-wheeler EVs. Though admittedly, they do not give the same performance. As Lithium-ion battery introduction will involve establishing a different plant and installing significant capacity, it will need huge financial resources. This is not a viable option for battery manufacturers as of now because of low demand volumes. Hence, initially Lead acid will have to suffice in 2/3-wheeler EVs being introduced in Pakistan. Lithium ion may become feasible in future once demand picks up significantly.

Besides this, some effort towards importing and assembling Li ion cells is also happening in Pakistan. LUMS School of Science and Engineering is experimenting with the assembly of Li-ion battery using imported cells. Their main challenge encountered in doing so is optimization of energy density, charging time, price, temperature, efficiency (temperature sensitive), weight, life cycle parameters.

Globally battery constraints seem to be coming down sharply and new technologies are being introduced, namely, Graphene based technology and ultra-capacitors. Graphene technology has already been discussed in section 2 and as already stated, Jolta is working on Graphene batteries in Pakistan. However, the study couldn't find any organizations working with Ultra-capacitors (an auxiliary power source because of their high-power densities. If combined with batteries, ultra-capacitors produce a hybrid Energy Storage System).

5.3 Other BEV Components

Electric Motor

Motor manufacturing mainly takes place in Gujranwala and surrounding areas in Pakistan. Various types of motors are produced locally, though mostly AC motors. The report draws insights from Golden pumps, Diamond Motors and Akhlas Motors to get an overview of the motor industry. It found sophistication and export orientation is lacking and manufacturing making use of mostly recycled material. For instance, electric sheets are mainly recovered from international scrap; manufacturing of original copper wire requires scale, so second hand copper wires are used; in bearings, several levels of quality (ABCD) are used. Key facilities for research and development such as for testing for international standards are lacking. As for adapting production to accommodate BEV production, most manufacturers believe that they can possibly reverse engineer over time (5-7 years) and designing might take longer. Motors must operate between an optimal temperature range in order to maintain their efficiency. There is also a potential role of fan manufacturing industry in BEV value chain.

Cables

The study interviewed Fast Cables. The company states that the current automobile market size is too small for large companies. Cables basically involve two items: conductor (almost constant) and insulator (varies). In BEVs, unlike ICE based vehicles, temperatures are not very high. BEVs can bring opportunities in 4 wheelers. Though lab equipment is missing it can quickly catch up.

Controller

The study could not find a specific relevant company. Companies like Jolta and InerZ are working to develop their own electric motors.

5.4 Policy and Regulation

The Automotive Industry functions within a rubric of various policies and regulations. These include the:

- Industrial Policy
- Trade Policy
- The Finance Acts which adjust the tariff and fiscal system backed by the SROs (Statutory Regulatory Orders) and the Customs General Orders
- Auto Development Program
- Tariff Based Scheme
- National Environmental Quality Standards.

The Tariff Based System (TBS) replaced the Deletion Program in 2006 and was designed to protect and promote the local auto industry and the promote it. The TBS was established after consultation and dialogue with all the stakeholders of the Automotive Industry including Vendors, OEMs, and manufacturers from the sub-sectors of the Automotive Industry.

- PAMA (Pakistan Automotive Manufacturers Association)
- PAAPAM (Pakistan Association of Automotive Parts and Accessories Manufacturers)
- APMA (Association of Pakistan Motorcycle Assemblers)
- Engineering Development Board (EDB) maintains data about the automotive industry

The Auto Development Policy (ADP 2016-21) represented a paradigm shift in the industry and enabled many new players to join the market and introduce new models. The policy envisioned a **Take off stage** at which huge investments will be made by existing players and tremendous expansion of industry volumes would occur. CPEC – China Pakistan Economic Corridor – is thought to facilitate this development.

In past, there have been few SROs to encourage import of BEVs and related parts by reducing duties. The current Auto Development Policy 2016-21 does not have the needed focus on BEVs as it provides no mechanism to register an all-electric vehicle in Pakistan. On 5th November 2019, the federal cabinet approved Pakistan's first "National Electric Vehicle Policy". This ambitious policy has been developed by the Ministry of Climate Change, Government of Pakistan. Under this policy, 30% of four- and tri-wheelers in the country will be converted into electric vehicles by 2030.

Table 7 - EV Market Penetration Targets by Government of Pakistan

EV Penetration Targets	Medium Term Targets (Five year Cumulative)	Long Term Targets (2030) Per year	Ultimate Target (2040)
Cars (includes vans, jeeps and small trucks)	100,000	30% of New Vehicle Sales (60,000 app)	90% of New Sales
Two/Three Wheelers	500,000	50% of New Vehicle Sales (900,000 app)	90% of New Sales
Buses	1000	50% of New Vehicle Sales	90% of New Sales
Trucks	1000	30% of New Vehicle Sales	90% of New Sales

Source: National Electric Vehicle Policy (2019), Ministry of Climate Change, Government of Pakistan

As an introductory strategy, the following incentives are offered under the new EV Policy:

- 15% duty on import of used EVs (up to three years old) 2019- 2021
- Zero sales tax and no registration fees on CKDs till 2021
- Zero duty and zero sales tax on Completely Built Units (CBUs) of EV-specific parts

- Zero duty and zero sales tax on Completely Built Units (CBUs) of EV components and modules
- Locally manufactured units will be exempt from sales tax for the next 7 years.
- Exemption from registration fees and annual token tax for EVs.

Under this policy, the federal Government will allow import of 100,000 electric vehicles over a period of 5 years. It plans to purchase 1000 all-electric buses and allow these to be operated by commercial operators for a concessionary period. The first 200 BEBs are to be imported and the next 800 are to be manufactured in Pakistan. Metro buses' routes in Lahore, Islamabad, Rawalpindi, Peshawar and Multan are going to be prioritized for electrification of buses. As for the introduction of electric truck, the policy states that 500 electric trucks will be deployed on the CPEC dominated Karakoram Highway routes.

Swappable battery systems are also to be promoted. The government will allow the import of 20,000 CBUs of imported swappable battery based three wheelers along with charging infrastructure at 0% custom duty and 0% sales tax for manufacturers setting up these units. EV parts and Components (of low speed EVs such as three/two wheelers) not being manufactured locally are allowed import at 1% custom duty.

Charging infrastructure plans will be gradually implemented. All Level 2 charger will be imported at 1% duty and 1 % sales tax for the next two years. After two years, Level 2 chargers' components only would be importable at 1% duty and locally manufactured chargers will be sold at 1% sales tax. All entities offering public Level 2 charging will be allowed to show installation cost of facility as Corporate Social Responsibility (CSR) contribution. All Level 1 chargers will be installed with smart meters to control peaks at electricity grid.

To encourage local assembly, manufacturing and export, the following strategy is adopted:

- To promote localization of engineering and design, components and parts for manufacturing conversion kits will be allowed import at 0% duty and will be allowed 0% GST on sales for next 5 years.
- Zero duty and zero GST on import of all batteries, motors and electronics utilized in EV manufacturing (except lead acid batteries) that are not locally manufactured for two years. Applicable to manufacturers intending to pursue domestic development and production only.
- Zero duty and zero GST on import of all components and parts for sale to manufacturers of batteries, motors and electronics utilized in EV manufacturing (except lead acid batteries) that are not locally manufactured for 5 years.

Several government initiatives are set to be launched in near future as stated in the EV Policy. The government intends to establish a National Center for Electric Vehicles, which will help develop business models for attracting national and international investment in EVs; train workforce on EV value chain; evaluate context-specific factors and their impact on EVs such as high temperatures, unpaved roads, altitude variations and weak electric grid; and collect and evaluate data from EV testing. Furthermore, an Inter-Ministerial Committee on Electric Vehicles will be established and EV Model Cities will be designated across Pakistan along with the creation of Special Economic zones.

The EV Policy is developed with an aim to reduce the oil import bill and to reduce air pollution (vehicle emissions being a major contributor to smog) which increasingly reaches hazardous levels in urban cities of Pakistan. It is said that EVs will help save PKR 2 billion in oil import bills. It is also anticipated to lower dependence on Liquefied Petroleum Gas and Compressed Natural Gas stations. Most of these stations shut down in winter due to gas shortages in winter, especially, in Punjab. The policy intends to convert CNG stations into charging docks for EVs.

Although the new policy has only just been approved it has drawn widespread criticism from various stakeholders in the automotive sector. Most term it an "ad hoc decision" and claim that the policy favours the introduction of electric cars at the expense of domestic industry. It is further claimed that the domestic automobile players' consent was not sought by government officials before the finalization of the policy. Hyundai Nishat, a prominent player in the sector, has already expressed its displeasure at the new policy stating that the company being a new entrant into the Pakistan market, it had made huge investment under the Automotive Industry Development Policy 2016-21, but has not yet made profit. Most stakeholders of the traditional auto industry are concerned that this policy would lead to unwarranted external debt accumulation, in addition to shifting jobs from Pakistan to other countries. The auto parts manufacturers, represented by the Pakistan Association of Automotive Parts and Accessories Manufacturers, are of the view that the new EV Policy's introduction, while the auto development policy 2016-2021 is in effect, would create confusion.[58]Pakistan is hoping to become 17th signatory of International Energy Agency's 30%@2030 initiative. The challenge for the government is to proceed with mass EV adoption keeping in view conflicting objectives: new players, existing players, climate change, and localization. The backlash from the new EV Policy is a clear indication of this. Given the country's obsolete transmission and distribution network, it is evident that the system will need upgradation on urgent basis to support the electrification of transport sector. Charging infrastructure will incur both fixed costs (such as installation, transformers, utility service, and equipment) and variable costs (i.e., electricity charges). The eventual electricity tariffs will be determined by the actual operating cost of the EV chargers. Commercial chargers require significant and sustained increase in demand to be economically profitable.

Green Banking Guidelines (GBG) of State Bank of Pakistan have been launched to support sustainable and green developments in Pakistan. Although GBG do not address EVs, it is planned that SBP will develop a policy that should provide financial support for potential EV purchasers.

Some institutions argue energy supply in Pakistan is surplus in next ten years. 2018's numbers: 160TWh (capacity @ PKR 5/kWh) versus 128 TWh (usage). Hence, the provision of electricity for charging BEVs is not an obstacle in the foreseeable future.

5.5 Research and Development

The automotive industry of Pakistan has been traditionally unsupportive of trade liberalization. This has led to inadequate competition in the sector and complacency amongst the auto manufacturers who have a general tendency to eschew research and development. The lack of R&D leads to consumers facing higher prices and low-quality standards.

Still there have been instances of innovative initiatives by some of the country's leading research institutes and universities. For instance, Pakistan's first Formula Electric car was selected for participation in the Formula SAE Lincoln-2016, and was developed by a team of PNEC-NUST students in May 2016[59]. Smart metering to even out extra energy supply by flexible pricing is being explored. Institutions such as SAARC Energy Centre and distribution companies are working on development of charging infrastructure for electric vehicles

LUMS School of Science and Engineering

[58] Express Tribune, 7th November 2019
[59] DAWN News https://www.dawn.com/news/1257957

The LUMS Syed Babar Ali School of Science and Engineering (SBASSE), established in 2008, has a vision to carry out state-of-the-art, multidisciplinary education and research. It is modelled on some of the world's leading universities and it aims for a new focus on science and engineering education in the country. Its mission is to:

- Create globally competitive technology leaders and entrepreneurs.
- Produce multi-disciplinary research of national and international significance.
- Solve the problems and anticipate the needs of domestic and global industry and society.
- Become a model for other high-quality research universities in Pakistan.

SBASSE offers undergraduate, MS and PhD degree programmes in the fields of Chemistry, Chemical Engineering, Computer Science, Electrical Engineering, Mathematics and Physics, all of which are relevant to the BEV industry. Student projects are currently focusing on electric vehicles and are participating in international competitions.

NED University of Engineering and Technology

NED University is another one of Pakistan's flagship engineering institutions approaching its centenary. The university produces high quality graduates has become renowned as a centre of excellence in Pakistan in higher education and scientific research through faculty development, and creativity and innovation. It makes research and development, and innovation a strategic priority for the so as to achieve its vision the sustainable development and economic growth of the country. The university aims to strengthen its existing linkages with other academic institutions, government and industry, and to develop new linkages. Student projects regularly feature innovative technologies such as EVs. It is also working with Mehran fans to develop motors.

LUMS Energy Institute

The Energy Institute at LUMS serves as a center of technical excellence, think tank, capacity building ground, and knowledge network to institutionalize a renewable rich future for Pakistan in a sustainable and cost-effective manner. It is also working with federal government to provide intellectual support in the development of BEVs encouraging policies and setting targets for 2030.

Research being conducted at the institute includes: development of smart grid models and their use in smart power infrastructure distribution in developing countries; energy generation through renewable sources, integration with grid, smart homes, and smart metering infrastructure development. It is also working on the development of Smart Microgrid infrastructure at LUMS. With its strong linkages with local and regional industry partners, it is well positioned for electrical energy conservation, optimization and integration of renewables in smart grids along with

University of Engineering and Technology Lahore

The University of Engineering and Technology (UET) Lahore, is a public university located in Lahore (and Peshawar), Pakistan and specializes in STEM subjects, i.e., science, technology, engineering and mathematics (STEM). The university has around 18 research centers and several of these are relevant to the BEV industry, such as: Automotive Engineering Center; Software Engineering Center; Energy Research Technologies Development Center; Manufacturing Technologies Development Center Nano Technology Research Center; Innovation and Technology Development Center; Engineering Services UET; Center for Energy Research and Development. More specifically, the university is currently focusing on developing test beds of electric motors.

6 Discussion on Competitiveness of BEV Industry in Pakistan

6.1 Readiness Status of the BEV Supply Industry

This section presents a qualitative and a systematic/framework-based assessment results of the supply industry.

Table 8 - Heat Map: Pakistan

Vehicle	Battery		Motor	Body parts	Control system	Cables
	Lead Acid	Lithium Ion				
2 wheeler	Ready	Ready	Somewhat Ready	Ready	Ready	Ready
3 wheeler	Ready	Somewhat Ready	Somewhat Ready	Ready	Ready	Ready
4 wheeler (light vehicles)	Lead acid battery is not practical here.	Not ready	Can be ready in 5-7 years with financial incentive.	Somewhat Ready	Somewhat ready	Ready
4 wheeler (heavy vehicles)		Not ready		Somewhat Ready		Ready

The figure above uses a heat map to illustrate the report's qualitative assessment of the readiness of various value chain players in Pakistan. The categorizations include: "ready", "somewhat ready", "Can be ready in 5-7 years with financial incentive" and "not ready". The construction of heat map represents some inherent difficulties. It should be noted that precise categorization becomes difficult due to considerations of imports, alliances, joint ventures, and joint efforts between international automakers and suppliers of EV components. For instance, all the battery suppliers of the 20 top-selling vehicle models, have battery cell production originating from three countries: China, Japan, and South Korea. Battery manufacturing in Pakistan also relies on availability of imported battery cells. So, it is difficult to assign labels. Other factors such as OEMs' decision to enter the business of battery pack production capture maximum value of the vehicle.

Table 9 - Average Scores for TOE Parameters in Pakistan

Technological Context	
Knowledge base and capabilities	3.5
Basic research and prototype	3.1
Field test and validation	2.7
Supply base	2.6
Procurement processes	2.7
Mass production	2.2
Quality assurance and control mechanisms	2.8
Cost structure	3
Compatibility with existing models of business	2.9
Direct and indirect benefits	3.3
Organizational Context	
Satisfaction with existing processes and technology	3
Organizational size – is it sufficient?	3.1

Top management knowledge, innovativeness, and support	3.5
Championship among employees	3.4
Knowledge absorptive capacity	3.7
Strategic planning	3.2
Perceived financial cost of switching/entering into BEV segment	3.4
Availability of financial resources	2.9
Organizational perception of technological uncertainty	3.3
Managerial obstacles	3.1
Employees' knowledge	3.3
Environmental Context	
Risk and uncertainty about future of BEVs	3.3
Effectiveness of regulatory policy	2.8
Intensity in competition	2.7
Government pressure	2.6
Availability of supplier base	2.3
Availability of customer base	2.5
Trading partners (distribution network)	2.6
Market scope (demand)	2.8
Supporting infrastructure	2.4

The survey was conducted on the basis of a questionnaire developed along the TOE framework. (Exhibit 2).

6.1.1 Technological Context

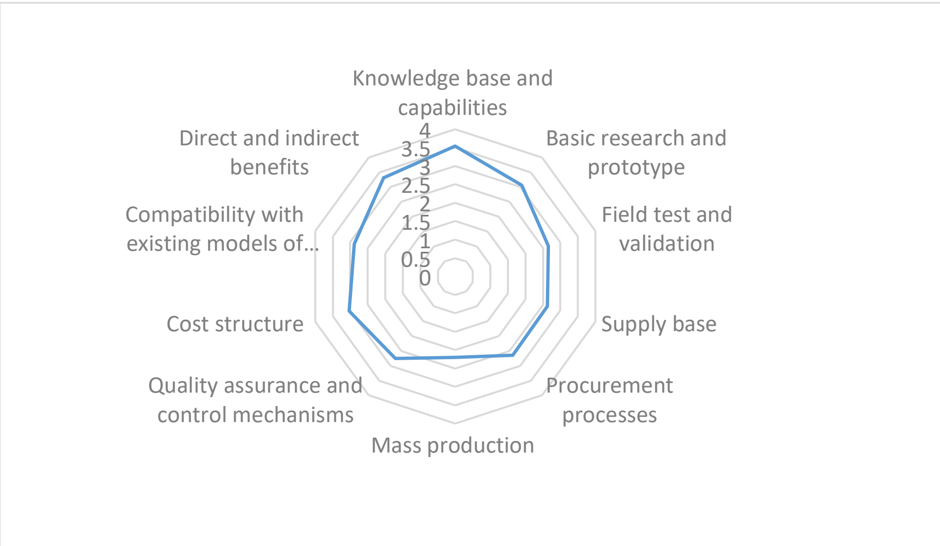

Figure 27 - Industry Average with Respect to Technology

From the survey results (Refer to Figure 24), it can be concluded that Pakistan has reasonably skilled knowledge base and capabilities (average score 3.5), and though they are not at a cutting-edge level, they are sufficient at the moment. Basic research and prototype skills (average score 3.06) are also reasonably developed. However, most organizations judge themselves to be deficient in areas such as Field test and Validation (2.7), Supply Base (2.6), and Procurement Processes (2.7).

A deficient supply base seemingly poses a big hurdle, although an advantage of not having established suppliers and a low degree of localization is that it makes new entry easy[60]. While Pakistan has many local manufacturers, who supply directly to local OEMs, there are none Tier 1 suppliers supplying to global value chains. Local vendors often acquire technology once it is outdated and discarded. For instance, the study shows that local BEV manufacturers are hoping to use lead-acid batteries whereas the world has long moved on to superior technologies (lithium-ion). There is much need for innovation through research and development, especially in the "design" phase of the process, in order to allow the sector to add value to the parts it produces.

Furthermore, the general view is that the process technology is not ready for large scale manufacturing as 'Mass Production' gets an average 2.2 score. The general consumer behavior in Pakistan does not support buying new models/products, thus making demand inelastic for automobiles. Quality assurance and control mechanisms also have a long way to go (average score 2.8).

Most respondents believe Battery Technology to be a key need and so need more improvement on that front. Others quoted battery management systems as area of technology which needs are crucial in maintaining battery life in the country's harsh climate and the vehicle design needs to be developed and adapted to the local context (rugged terrain) accordingly. Software aspect of batteries and BEVs, chemistry of cells, and battery cost, safety and range issues also need further exploration. As stated by a key stakeholder, 'technologies are available; localization is the problem'. As it turns out, various basic components of the vehicle such as motor development, battery manufacturing, control systems, body, drivers are already being developed or have the potential to be developed. What remains to be done is the integration of all these.

The current business models are weak, and BEVs will need strong new models (Compatibility with existing models of business gets a low 2.9). World over, EVs were commercialized by making use of unique models: luxury specific business model; luxury multipurpose business model; economy-specific purpose business model; and the economy multi-purpose business model. For the Pakistan's economy and market, the last two seem more appropriate. Firms using the economy specific purpose business model started out by adding a service component to their product in the form of renting or leasing the battery separately from the vehicle. This has two major advantages: first, battery leasing makes EVs more affordable and secondly, battery management is made easier as the uncertainty about the battery's reliability is shifted from the customer to the firm. The vehicle's residual value is increased (as it depends upon battery). One of the earliest EV producer, Think (Norwegian OEM) sold its car separate from the battery to be able to offer a lower price than its competitors. Many OEMs (incumbents and new entrants) first gained resources and knowledge by serving the luxury market with refitted EVs and then started building purpose-built models. For instance, BMW initially refitted its Mini before designing and producing an EV from scratch. Refitted cars are said to be a sub-optimal fit between the existing technology and features of the new EV technology, mainly because the chassis design is not optimized for EVs[61].

[60] Bari, F., Afraz, N., Mukhtar, N., Khan, U., Hussain, S. T., & Fatima, U. (2016). Regional competitiveness studies: research study on auto sector. *Institute of Development and Economic Alternatives*, *152115*.
[61] Bohnsack, R., Pinkse, J., & Kolk, A. (2014). Business models for sustainable technologies: Exploring business model evolution in the case of electric vehicles. Research Policy, 43(2), 284-300.

The technological context of the BEV value chain is fraught with difficulties in Pakistan. Licensing requirements are a major impediment for parts manufacturers supplying local parts to OEM standards. Technical collaboration is much sought by organizations as many firms at present lack the technical expertise to develop the parts and components in-house without the support provided by technical collaborations. Technical collaborators need a strong incentive to come to Pakistan and this study could identify few international players willing to do so (Songuo Motors being one example we could find) as most prefer a stronger regional market in India, and the relatively small volumes in Pakistan do not present an attractive option to them at the moment. On the downside, technical collaborations often involve mandatory use of equipment imported from the global suppliers. Other factors such as taxes on royalties and licensing fees also inhibit technology acquisition as these limits the profitability and ability of local manufacturers trying to enter the OEM supply chain. It should be borne in mind that the Chinese protect their most strategic assets through capital control over the subsidiary, e.g. by maintaining majority equity stakes. Less strategic assets and older technologies are shared through licensing agreements. An even lower degree of control is maintained through distant trading and technical cooperation[62].

6.1.2 Organizational Context

Figure 28 - Industry Average with respect to Organization

Figure 25 shows the state of BEV industry with respect to organizational parameters. Satisfaction with existing processes and technology is adequate (3) indicating that firms believe that they can switch to BEV technology without majorly overhauling their processes. For instance, Lead acid battery manufacturing base already exists. As discussed earlier, lead acid batteries, even though they don't give the same performance as lithium-ion batteries, can be used in two/three wheelers in the beginning. Manufacturers may decide upon investing in a li-ion plant once demand picks up. Similarly,

[62] Bari, F., Afraz, N., Mukhtar, N., Khan, U., Hussain, S. T., & Fatima, U. (2016). Regional competitiveness studies: research study on auto sector. *Institute of Development and Economic Alternatives*, *152115*.

motor manufacturing can also pick up quickly as existing manufacturers need only develop new moulds.

Most of the survey participants deem their organizational size to be sufficient (neither high nor low) and rank the parameter 'top management knowledge, innovativeness, and support' a bit on the higher side. 'Knowledge absorptive capacity (3.7)', 'employees' knowledge' and 'championship among employees' all receive comparatively better average scores. So does Strategic Planning (3.2). Perceived financial cost of switching/entering into BEV segment (3.4) is also in the moderate range and not as high as one would expect.

Availability of financial resources (2.9) is an area where many firms believe themselves to be lacking. Limited access to finance also hampers technology acquisition. Stand-alone or entrepreneurial firms that are not part of conglomerates have to rely on self-financing since the government neither significantly supports research and development financially nor in the forms of R&D tax breaks or exemptions on technical licensing fees. This implies that local vendors have only able to make incremental improvements in their production processes instead of complete overhauls. Consequently, the BEV vending industry is and is expected to remain small and fragmented in near future.

Organizational perception of technological uncertainty (3.3) a little bit on the higher side. This reflects the dilemma of OEMS and other key value chain players the world over: Either invest today in EVs and the associated technology when the cost is high and demand is uncertain, or wait for costs to fall and demand to rise. Managerial issues do not seem to pose any significant hurdles.

Survey respondents mentioned development needs in the organizational context and required support on development of lithium-ion battery manufacturing, motors, investment funding from public and private sector, cost competitiveness with HEV and FFVs, local manufacturing of related electric parts and help from research institutes.

6.1.3 Environmental Context

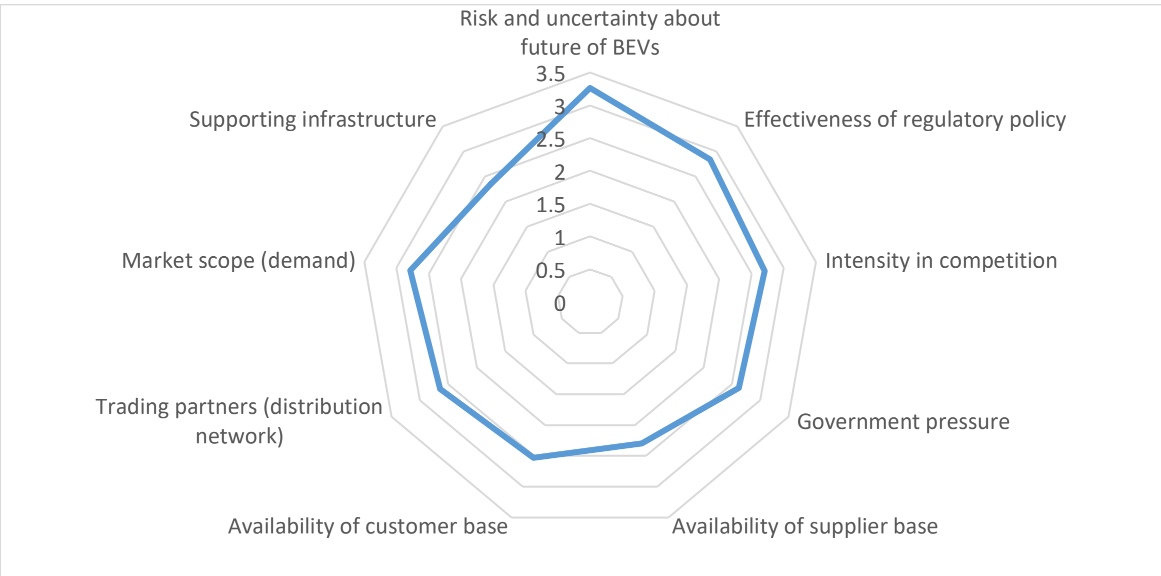

Figure 29 - Industry average with respect to Environment

A cursory view of the Figure 26 on average industry scores with respect to environment, shows that most firms believe the environmental context in which they operate to be the poorest of the three, as all parameters are ranked consistently in the lower range.

Supporting Infrastructure scored only 2.35 in the survey. This itself presents a chicken and egg problem. Widespread provision of supporting EV charging infrastructure only makes sense if there is enough demand and presence of EVs on the roads. At the same time, demand for BEVs will not pick up unless EV charging infrastructure is available. Availability of charging infrastructure solutions (swappable battery system, public chargers etc.) need to be explored.

A promising new development on the BEV front has come to light recently in the form of central government's interest in this area and the subsequent efforts to develop BEV supply industry. Government support is coming in. Government awareness about the potential of BEVs in reducing environmental pollution particularly in Punjab, lessening oil imports and creating new business opportunities in the country. Through the adoption of this technology, Pakistan can save about PKR 2 billion annually through reduced oil imports. In addition, pollution will reduce by up to 70 per cent[63]. However, the business organizations deem these developments insufficient as 'Effectiveness of regulatory policy' averages a low 2.8 score. At present, the automotive industry is not governed by significant regulatory pressures (such as emissions targets etc. set in the developed countries) as Government Pressure is ranked a mere average of 2.6. With regards, to support needed to encourage BEV related manufacturing, majority of the participants called for more EV friendly government policies such as a supportive regulatory system; manufacturing and consumer incentives to build demand; and low customs duty and sales taxes. reduced cost of imported parts. government subsidization, lowering cost of production on vehicles. E.g. DC Motors, batteries, other accessories no Ministry of Transport on a federal level.

The capital cost of purchasing EVs is high at this time but is expected to reach parity with FFVs in the next few years (estimated 2025). The Operating Cost of EVs is quite low in Pakistan. An ICEV runs one kilometer for ten rupees with the 2018 fuel cost, an equivalent EV can cover the same distance using only three rupees at the 2018 domestic electricity rates. Still the market scope or demand is low (2.8). End consumers perceive BEVs to be a risky purchase and manufacturers are constrained by this uncertain behaviour (Risk and uncertainty about future of BEVs rated 3.3). In the environmental context, BEV stakeholders require increased awareness and knowledge of EVs amongst customers. Pakistan does not offer a large market size (like China and India for instance). However, its proximity to a major EV hub – China - should help generate substantial opportunities in the BEV value chain. China has made demonstrated commitments to investing in Pakistani infrastructure and has a well-established EV value chain along with good trading relations with Pakistan. Pakistan could make an attractive partner for Chinese firms looking to outsource, particularly now that China's labour costs are rising.

Another concern is adapting an electric vehicle to the local environment and most stakeholders mentioned the lack of feasibility studies to determine specific demand level and design requirements.

Although the scores for Intensity in Competition (2.7) are low, signifying a lack of local competition, local suppliers in the auto parts sector have to deal with the realities of smuggling which has traditionally crippled the auto parts industry. Smuggled auto parts enter from India, China and Afghanistan. Often these are of poor quality (indiscernible to consumers), thus driving prices down to

[63] PM's Adviser on Climate Change Malik Amin Aslam briefed the meeting on the electric vehicle policy.

the lowest level equilibrium. This is also a contributing factor to another parameter 'availability of supplier base' which is ranked a mere 2.3.

6.2 Recommendations

Table 10 - Skills recommendation by vehicle type

Vehicle Type	Recommended Skill Sets
2 and 3 wheeler	Manufacturing of the frame, body and the interior in EVs is similar to that of ICEVs', so skills are transferable in these categories. Consumer protection: Target consumers are highly price sensitive so customers should be protected from variable market prices by offering innovative models. Provision for EV charging: Enable charging to be done at regulated prices in the short-term. Charging to be done at market prices in long-term to ensure maximum social benefit. Ability to pursue sustainability Integration of EVs in mobility service business models or their valuation as resources for electricity markets. Ability to innovate and compete by achieving higher production scale. Battery reuse and recycling.
4 wheeler (light vehicles)	Ability to change existing production lines. Establishment of a dealership network. Ability to shift from outsourcing to own production in long-term. Ability to make radical changes in the materials usage and production processes, if switching from ICEV to EV manufacturing. Technical assistance and public outreach. Training, education, and marketing on EVs and related technologies. Development of partnerships across multiple stakeholders to advance EV adoption. Business model innovation: Incorporation of new services downstream from the focal OEM's original core business, e.g. through a partnership or joint venture or through vertical integration of new capabilities. Development of strategies for partnerships. Battery reuse and recycling

Vehicle Type	Recommended Skill Sets
4 wheeler (heavy vehicles)	Connect government officials, planners, and other EV stakeholders across provinces to enable and activate valuable channels for procurement partnerships, knowledge exchange and collaboration on inter and intra-regional transportation issues. Communications: programs in order to increase familiarity with BEVs and information dissemination: can take to form of public event organization, workshops, and technology demonstrations; development of print and internet education and marketing resources. Conduction of marketing campaigns (conducting phone, email, and social media); and harnessing local media coverage. Design and implementation of programs to train municipal/government personnel as these agencies are amongst the few first responders. Training to establish automobile dealerships and a skilled base of electricians and automotive technicians, and fleet managers.

6.2.1 Government policy & regulations

Firstly, one of the key needs of the automobile industry at the moment is currency stability. The rapid rupee devaluation has adversely affected the prices of automobiles. Automakers have had to revise the prices several times from 2018 to 2019 to pass the effect of rupee devaluation on to the consumers. This led to declining sales as prices rose multiple times. Economic policy needs to promote domestic demand instead of curtailing it. Price-sensitive potential buyers are refraining from making purchases at the moment. Furthermore, regulatory uncertainty needs to be removed such as that regarding filer versus non filer issue[64].

The regulatory policy framework needs to be overhauled. This needs to be addressed given the substantial air pollution. The BEV Policy should focus on enhancing demand as well as localization of manufacturing. There is a certain concern amongst the industry circles as to the viability and worth of switching to BEVs. The purpose of such a transition in Pakistan's case should be to reduce oil import bill; it wouldn't do to incur the same expenditure by importing huge volumes of BEVs (or related parts) without mobilizing the domestic industry.

6.2.2 Financing

Although the operating cost is quite low, financing the purchase cost of an EV is quite a challenge. There is a need to make loans available for BEVs. New BEV leasing models should be introduced for the purchase of vehicles and batteries. Instead of handing out subsidies for purchasing electric vehicles, incentives should be provided to stimulate demand. This effort will also prove to be less draining for the country's finances. The focus should be on developing a self-sustaining business model for electric vehicles instead of setting specific targets for quantities sold. The government of Pakistan also needs to lead the purchase of electric vehicles through public procurement. Gradually replacing most official vehicles makes sense as the bulk of their journeys are within cities and thus well suited to electric vehicle range. This will set a good example and may build confidence among the general public. Giving hefty subsidies to a select few group of individual consumers would be unwise use of

[64] The government earlier placed in a restriction that only tax return filers could purchase a car, but later withdrew it

limited resources. Other opportunities should be explored such as supporting potential corporate consumers through business tax rebates, interest free loans, and capital allowances.

In the long-run, create an environment that encourages electric vehicle use, including building the necessary infrastructure. The capital cost of purchasing EVs is high at this time but is expected to reach parity with FFVs in the next few years. Until that time, to encourage EV penetration, many countries in their EV policies have slashed the taxes and duties to zero and have provided further tax rebates to encourage large scale adoption of EVs. Pakistan does not have a budget surplus. Hence cannot afford and should not attempt to hand out massive subsidies.

Given the high capital and production costs associated with BEV manufacturing, it is observed that in Pakistan, the incumbent OEMs are hesitant to invest in BEVs. Hence, the manufacturing and innovation will have to come from the start-ups and innovative firms. However, at the battery manufacturing level, it is the incumbents who must take a lead as battery manufacturing requires huge investment in plants and start-ups usually lack the needed financial resources. Furthermore, through BEV value chain analysis (done in Section 2), it can be inferred that the battery value chain contains a transition from cost-dominated to value-dominated segments (Refer to Figure 23). It is clear that Pakistan with its non-existent BEV components and parts supply base cannot compete in the cost-driven segments of the value chain: raw material mining and processing, and cell manufacturing. Hence, it would be more profitable to import the low-cost cells for batteries. However, in the value driven (e.g. battery pack manufacturing) segment, the decisive criterion for a positive business case is the ability to meet the specific requirements of the customer. Hence, competition at global level does not play an important part for LIB pack manufacturing. The industry in Pakistan should, therefore, begin by leveraging and developing these segments: battery pack manufacturing, battery pack integration and battery recycling.

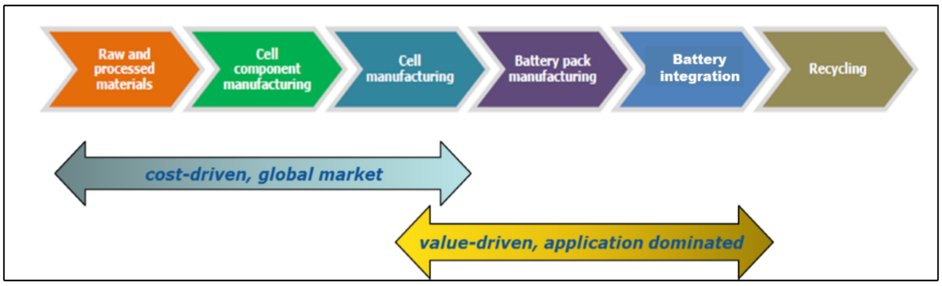

Figure 30 - Characterization of Value Chain Stages

Source: N. Lebedeva, F. Di Persio, L. Boon-Brett: Lithium-ion battery value chain and related opportunities for Europe[65]

The starting target markets should be: two/three wheelers, commercial vehicles, and institutional customers. Instead of focusing efforts on boosting sales to individual consumers, the government should prioritize encouraging EV use in commercial operations which rely on large numbers of vehicles, such as, business distribution networks, taxi companies in city centers, car-rental and sharing services, and as official government vehicles. Public procurement and corporate fleet orders may help establish the electric vehicle market.

Using BEVs in car-rental services in large urban areas like Lahore, Karachi and Islamabad are good options. Electric vehicles used by car rental enterprises could be charged at fixed places when not in use. The government needs to provide support to these car-sharing businesses and help them

[65] Available at: https://ec.europa.eu/jrc/sites/jrcsh/files/jrc105010_161214_liion_battery_value_chain_jrc105010.pdf

gradually expand charging and parking stations. This will also offer more citizens direct experience of electric vehicles, helping to increase acceptance. City taxi services can be a potentially lucrative opportunity especially if a battery-swap model is adopted that requires less than ten minutes of waiting. Furthermore, the industry is relatively easy for the government to manage.

The networks of distribution companies (such as TCS and DHL etc.) and industries in urban areas provide another opportunity. As these companies have high rates of operation, they stand to gain from the low-operating costs of EVs and as they are already likely to have private, centralized places to install charging stations, they are less likely to require finance and infrastructure support from the government.

Electric vehicles could also replace the trucks especially those operating along the CPEC and Karakoram Highway routes, and Buses (e.g. Metro Buses in Lahore, Islamabad and Peshawar) which mostly run on diesel fuel. Since these vehicles are usually used on fixed routes and schedules, their charging infrastructure can be easily established and managed along fixed depots.

6.2.3 Technology

Substantial technological gap exists at present with the auto industry in Pakistan lacking both the expertise and skills. From the experience of China, it can be learned that provision of financial support alone will not be sufficient. This technology gap can be closed only through collaborations with international companies. Technology transfers and cooperation with international leaders during early developmental phases of this technology will be instrumental.

The assessment reveals significant concern about charging infrastructure. However, it is difficult and expensive to install. Two and three wheelers are typically used within a city and could be charged from an ordinary wall socket. On the other hand, cars and especially buses and trucks typically cover longer distances so their introduction requires a completely different strategy. In the short-run, a good starting point for the introduction of BEVs could be to focus on areas where charging infrastructure is already there and/or where it could be managed by users themselves, for instance, at the workplaces and at companies that have in-house utilization systems. Another would be to start with areas where government has direct influence for example metro buses. Battery swapping systems also hold considerable potential until other solutions are made available.

Public-private partnerships can play an important role in facilitation of adoption and spread of EV related technologies. EV charging infrastructure, in particular, can benefit from these partnerships as it may help increase the pace and scale of infrastructure development as the market will have access to government utility expertise, capital, and other resources. Public entities can make use of their existing channels to provide a more equitable access to this technology and the combined resources can be pooled to engage in research efforts (for instance, through establishment of forums and consortiums) Private-public partnerships can also help in the implementation of new business models.

7 Conclusion (Pakistan)

A major conclusion from the study's understanding on Pakistan is that the lack of demand is hindering the BEV industry. In the absence of a proven and established demand base, manufacturers are hesitant to invest and lack funding opportunities. It is understood that the pathway to BEV adoption should focus on creating demand and initially opening up the market to imports of BEV CBUs, components and parts. This will help create a demand base which will in turn promote local manufacturing on BEV components and parts and ultimately vehicles. Customer base can also be generated by encouraging the fleet and logistics – based companies to switch to BEVs, as these organizations have high usage and will hence enjoy substantial reductions in operating costs by switching to BEVs.

OEMs can move forward by following this pathway: CBU => SKD => CKD => Assembly => Parts. From the vendors' side it can be concluded that that the best initial introductory strategy would be to allow the import of parts and components for a few years. The local vendors can reverse engineer the technology and start developing or designing their own products.

The government can start out by prioritizing EV promotion in commercial operations that rely on large numbers of vehicles, such as car-rental and car-sharing services, business distribution networks, taxi companies in city centers, and official government vehicles rather than concentrating on individual consumers. Public procurement and corporate fleet orders will help establish the electric vehicle market and create a substantial demand base. Fleet and logistics – based companies have high usage and will hence enjoy substantial reductions in operating costs by switching to BEVs.

8 Analysis of BEV Supply Industry in India

8.1 Introduction

One of the main drivers of BEV adoption in India in recent years has been the large oil import bill and the associated drain on foreign currency that India incurs every year. For instance, India imported 84% of its crude oil needs in the year 2018-19 and spent nearly $112 billion dollars on oil imports[66]. The second driver is the greenhouse gas (GHG) emissions due to the consumption of petrol and diesel in the transport sector. As of 2019, it is estimated that 22 out of the 30 most polluted cities in the world are in India[67]. Adoption of BEVs and hybrid vehicles in large scale should address both these challenges simultaneously.

However, in order to enable adoption of BEVs by the market that is dominated by ICE vehicles, it is essential to bridge the viability gap between BEVs and ICEVs. Also, given the evolutionary nature of electric vehicle technology and the significant investments needed into this field, both industry and the government need to make investments and work together towards a common goal. Below we first discuss the viability gap in various sectors of the Indian automobile industry, followed by the policy framework that the Indian government has put forth to address this gap and promote the BEVs in each of these segments.

8.1.1 The Two-Wheeler Segment

India has more than 18.8 million registered two wheelers plying on its roads and majority of these vehicles (nearly 85%) belong to the 100 – 125 cubic capacity (cc) engine category. An equivalent BEV that gives comparable performance in terms of speed, acceleration and gradeability, would currently cost at least twice that of an ICE based vehicle. However, the operating and maintenance cost of a BEV is much lower than an ICE based vehicle. Therefore, for the viability analysis, one should consider the total cost of ownership (TCO) estimates. According to the viability analysis carried out by Society of Indian Automobile Manufacturers (SIAM) in their white paper (SIAM 2017)[68], even at TCO level, the personal use two-wheelers (30 to 50km/day) cannot brake-even, even after 5 years of ownership, unless the battery cost falls below $100 per KWh. However, for commercial use vehicles (150 to 200km/day), the payback can happen within 2 to 4 years, if the battery prices fall between $100 to $150 respectively.

8.1.2 The Three-Wheeler Segment

The three-wheeler market in India is the world's largest market and even in this segment, the BEVs cost twice as much as ICE based three-wheelers. Since three-wheelers are used mainly for public and goods transportation purposes, any downtime due to charging related issues will directly lead to revenue losses. Therefore, having adequate charging infrastructure becomes that much more critical in this segment. One option is to have battery swapping facility, which can reduce the range anxiety as well as the down time due to charging. The SIAM (2017) study shows that, since three wheelers are primarily used for commercial purposes, the TCO break-even can happen within 3 to 5 years, if the battery prices fall between $100 to $200 respectively.

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[66] https://economictimes.indiatimes.com/industry/energy/oil-gas/indias-oil-import-dependence-jumps-to-84-pc/articleshow/69183923.cms?from=mdr

[67] https://www.theguardian.com/cities/2019/mar/05/india-home-to-22-of-worlds-30-most-polluted-cities-greenpeace-says

[68] http://www.siam.in/uploads/filemanager/114SIAMWhitePaperonElectricVehicles.pdf

8.1.3 Four-Wheeler, Passenger Car Segment

In India, nearly 99% of passenger cars sold belong to small (<4 meter) or mid-size (4-4.5 meter) segment. Due to the highly competitive pricing of ICE based vehicles in the small segment, which constitutes 88% of the total market, the equivalent BEV costs more than twice that of an ICEV. In terms of TCO, the personal use passenger cars, which travel between 40 – 50 km/day, are not viable even after 7 years, even at a battery price of $50 per KWh. However, for cars that are being used by the taxi fleets (200 km/day), BEVs become viable within 4 to 5 years, if the battery price falls between $100 to $150 (SIAM 2017).

8.1.4 Buses

The capital expenditure needed for BEV buses is the highest amongst all vehicle segments, due to the larger battery packs that are necessary for running the buses. Since majority of buses in India fall under the 7.5 to 12 tonne classification, the optimal capacity for a BEV is 120 KWh. Estimated show that the initial purchase cost of a BEV would be nearly 2.5 times that of a diesel-based bus. Another challenge in this segment is the life of the battery, which will last for only 5 to 6 years, due to harsh operating conditions. Buses, being utilized for public transport, may also need faster charging infrastructure, which will further reduce the life of batteries. According to SIAM's (2017) analysis, assuming a power tariff of INR 7/KWh, the BEVs will have a viability gap of INR 400,000 to 500,000 per annum, for a 10-year operation. If the batteries need to be replaced mid-way, this gap will further increase. Again, battery swapping is another option that should be explored for BEV buses.

8.1.5 Policy Framework for adoption of BEVs in India

The Indian government began pushing for BEVs in earnest from 2015 onwards with the announcement of FAME (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India) policy. Even though a national mission on electric mobility was approved in 2011 itself in India, momentum picked up in the last couple of years (2018-2019), when Indian government made its intentions regarding BEVs clear by allocating significant amount of funds (Rs. 10,000 crore) for Phase-2 of FAME policy (FAME II). The government also began involving major policy thinktanks like NITI Aayog and Department of Heavy Industry, Ministry of Road Transport and Highways to create roadmaps for BEV adoption in India. The objectives of FAME policy were twofold: (i) generation of demand for BEVs in India through demand side incentives, and (ii) creation of ecosystem by establishing network of charging stations. In addition to the central government incentives for demand generation, FAME also enlisted the support of state governments, through non-fiscal incentives, such as waiver/concessional road tax, exemption from permits, waiver/concessional toll tax, waiver/concessional parking fee, registration fee etc.

The total BEV sales in India crossed the 7,50,000-units mark and reached a total of 7,59,600 units in the financial year 2019. Out of this, 6,30,000 BEVs belong to the three-wheeler segment. The electric two-wheelers account for 1,26,000 vehicles, and BEVs in the passenger car segment are about 3,600[69]. There are also a few hundred electric buses plying in cities like Hyderabad, Delhi, Ahmedabad, Pune, etc.

The Society of Manufacturers of Electric Vehicles (SMEV) – is the association of Indian manufacturers of electric vehicles (EV) and electric vehicle components, working closely with the central and state governments for the formulation of policies and processes supporting the EV ecosystem (Refer to

[69] https://www.autocarindia.com/car-news/ev-sales-in-india-cross-75-lakh-mark-in-fy2019-412542

Exhibit 7). Since SMEV does not support uncertified products, many E-Rickshaw players are not its members.

8.2 Analysis of Current BEV market in India

Since nearly 80% of vehicles plying in India belong to two- and three-wheeler segments, Indian government decided to focus on these two segments. There is also focus on public transport through electrification of buses and taxi fleets through subsidies, to reduce pollution and petroleum needs in the transport sector. According to FAME II, which came into existence in March 2019, the target number of vehicles that will be subsidised during the next three years are: One million two-wheelers, half a million three-wheelers, 35,000 cars and 7,090 buses.

FFAME II policy not only brought in more funds, but also aligned the subsidies/incentives to local content requirements and linked them to performance of the vehicles. Since the cost of batteries is the main differentiating factor between BEVs and internal combustion engine (ICE) based vehicles, the demand incentive in FAME II was linked to the battery capacity (kWh or kilowatt-hour). Also, the extent of subsidy is capped to 20% of the cost of the vehicles (40% in case of buses).

Below, we provide segment-wise analysis, followed by the supply chain analysis for all the segments.

8.2.1 Two-Wheeler Segment

The two-wheeler BEV segment in India is interestingly dominated by start-ups, rather than the well-established players. The major players in this segment include Revolt Motors, Ather Energy, Ampere Vehicles, Tork Motors, Okinawa, 22Motors, Hero Electric and Kinetic Motors. While many of these start-ups are in the process of making big strides by developing sophisticated electric vehicles from bottom-up, the incumbents have taken a wait and watch approach. Some of the incumbents have invested in start-ups (e.g., Hero, the largest two-wheeler manufacturer in India, has invested in Ather Energy one of the start-ups, also established a separate subsidiary called Hero Electric, which focuses on electric vehicles). The Indian government is very keen to push only electric vehicles in the two-wheeler segment from 2025 onwards, and is actively engaging with the automobile industry in pursuit of this plan. The industry majors, especially the market leaders who specialize in ICE based engines are pushing back on this plan, and are asking for more time for the transformation.

As part of FAME II policy, an incentive of Rs.10,000 per kWh is given for two wheelers with advanced battery technologies that satisfy certain performance criterion and a minimum percentage of local content requirements (at least 50% of the vehicle parts should be sourced locally). Approximate size of battery to be eligible for the incentive is 2 kWh. Maximum number of vehicles to be supported under this scheme is one million. Maximum ex-factory price of vehicle to avail the incentive is INR 1.5 lakh. In total, INR 2000 crores has been allocated for the two-wheeler segment.

Since the incentives are tied to performance of the vehicles in phase-2 of FAME policy, only five manufacturers have become eligible for incentives: Ather Energy, Ampere, Okinawa, Jitendra Electric Vehicles, and Hero Electric. To receive subsidy, electric two-wheeler makers must get eligibility certificates from vehicle testing agencies as well as meet local content requirements. The FAME benefits are limited to vehicles equipped with lithium-ion batteries.

8.2.2 Three-Wheeler Segment

The story is somewhat similar in three-wheeler segment as well. The last mile connectivity needs of people who make use of public transport modes such as Metro, along with the high pollution levels in cities like Delhi have prompted some entrepreneurs to come up with e-rickshaws, a popular alternative to ICE based auto rickshaws. These e-rickshaws are powered by lead-acid batteries, and in recent times, are being offered with a Lithium-ion battery option. While this segment is also dominated by start-ups, such as GEM, Ecoyan, Saarthi, Mayuri, Kinetic Green, Etron some traditional companies like Mahindra, Bajaj, and Piaggio have also begun to offer electric versions of their 3-wheeler product. However, unlike the two-wheeler segment, where highly sophisticated electric vehicles are being developed by many start-ups with the help of venture capital funding, the start-ups in three-wheeler segment are mainly driven by the market demand and a majority of them import e-rickshaw kits from China, which are then assembled and sold in India.

An incentive of INR 10,000 per kWh is given as part of FAME policy, for three wheelers that meet certain criterion. For instance, the vehicles must be used for public transport purposes only, must be registered as "Motor Vehicle" and must contain advanced battery technologies satisfying certain performance criterion[70]. Maximum number of three wheelers to be supported under this scheme is 500,000. Approximate size of battery to be eligible for the incentive is 5 kWh. Maximum ex-factory price of vehicle to avail the incentive is INR 5 lakh. In total, INR 2,500 crores has been allotted for the three-wheeler segment.

India today has more than 1.5 million battery-powered, three-wheeled e-rickshaws[71]. As mentioned earlier, the demand for e-rickshaws is fuelled by the last mile connectivity needs of the metro cities in India, rather than the government incentives. Also, the auto drivers found that e-rickshaws are quieter, faster, cleaner and cheaper to maintain than a traditional auto rickshaw, which helped with faster adoption in this segment.

8.2.3 Four-Wheeler, Passenger Car Segment

The first battery operated electric vehicle (REVA) was introduced in India nearly 20 years ago by Reva Electric Car Company (RECC), an indigenous firm that collaborated with several US based firms to develop technology and components to produce the BEV. However, the market demand was lukewarm and only few thousand REVAs were plying on Indian roads by 2015, when the FAME policy was introduced by the Indian government. RECC was in the meantime acquired by another domestic automaker, Mahindra in 2011, which launched the upgraded versions of REVA, as Mahindra e2o in March 2013, for approximately USD 11,000.

Only recently, other auto majors of India, such as Tata Motors and Hyundai have launched BEVs in the Indian passenger car market. The market leader Maruti Suzuki has announced its plans to introduce its first BEV in India in the year 2020. In order to spur the demand for BEVs in the passenger car segment, the central government established a joint venture of public sector units under the Ministry of Power, called Energy Efficiency Services Limited (EESL), which is leading the procurement and sale of Electric Vehicles in India.

The phase-II of the FAME policy provides incentives on passenger cars purchased by aggregators that operate taxi fleets, and not to individual buyers. The incentive for four-wheeler passenger vehicles is similar to that of 2&3 wheelers, i.e., INR 10,000 per kWh. Maximum number of vehicles to be supported under this scheme is 35,000. Approximate size of battery to be eligible for the incentive is 15 kWh. Maximum ex-factory price of vehicle to avail the incentive is INR 15 lakh. Total fund support allocated to passenger cars is 525 crores.

In case of hybrid vehicles, an incentive of INR 10,000 per kWh is given and the maximum number of vehicles to be supported under this scheme is 20,000. Approximate size of battery to be eligible for

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[70] https://dhi.nic.in/writereaddata/UploadFile/publicationNotificationFAME%20II%208March2019.pdf

[71] https://economictimes.indiatimes.com/industry/auto/auto-news/india-overtakes-china-with-e-rickshaw-revolution/watt-a-movement/slideshow/66391774.cms

the incentive is 1.3 kWh. Maximum ex-factory price of vehicle to avail the incentive is INR 15 lakh. Total fund support allocated to hybrid passenger vehicles is INR 26 crores.

8.2.4 Bus Segment

The adoption of battery electric buses in India has been very slow, despite the push by the government through FAME policy. This is because, the cost of a BEV in this segment is nearly three to four times that of a diesel bus. As a result, out of the more than 1.6 million buses that are currently registered in India, only a few hundred buses are powered by batteries. However, one must note that, cities like Delhi and Mumbai have been using cleaner fuels like CNG and bio-fuels like ethanol to operate public transport buses[72].

Many metros and tier-1 cities, such as Delhi, Mumbai, Bengaluru, Kolkata, Hyderabad Chandigarh, Lucknow, Mumbai, Dehradun, and Rajkot have already carried out trial runs of battery electric buses and some cities like Delhi, Mumbai, Pune and Ahmedabad are already using a few of these for plying passengers on some city bus routes. One of the major reasons for slower adoption of electric buses is the need for proper planning and techno-feasibility assessment to map out the feasible routes and the intermediate charging points etc. Another reason being, the need to set aside funding by the state governments to purchase these electric buses, in addition to the funds allocated by the central government.

Major players in this segment include Olectra-BYD, a joint venture between India’s Goldstone Infratech Ltd. and Chinese electric vehicle major BYD; Ashok Leyland, Tata Motors and JBM Solaris.

The FAME II policy provides incentives for buses with BEV technology that are used for public transport purposes. To be eligible for incentives, the buses must be registered as "Motor Vehicles" and contain advanced battery technologies satisfying certain performance criteria, and fall under M2/M3 category[73]. An incentive of INR 20,000 per kWh will be provided and a maximum number of vehicles to be supported under this scheme would be 7090. Approximate size of battery to be eligible for the incentive is 250 kWh and maximum ex-factory price of vehicle to avail the incentive is INR 2 crores. Total fund support allocated for buses is 3,545 crores, and the maximum incentive cap is 40% of the cost of the vehicle.

8.3 Electric Vehicle Battery Value Chain

The supply chain for BEVs in India is nascent and evolving as can be seen from Table 9 below:

[72] https://gggi.org/site/assets/uploads/2016/10/2016-08-Electric-Buses-in-India-Technology-Policy-and-Benefits.pdf

[73] https://dhi.nic.in/writereaddata/UploadFile/publicationNotificationFAME%20II%208March2019.pdf

Table 11 - The current supply chains of prominent BEV assemblers in India

EV Type	Manufacturer	Battery	Battery Management System (BMS)	Motors	Motor Controller
Electric Two Wheelers	Ampere Vehicles	Purchased	Own design	makes own motors, chargers and controllers	
	Hero Electric	Cells imported; battery packs assembled in-house	Own design	Imported from Taiwan & China	
	Ather Energy*	Cells imported; battery packs assembled in-house	Own design; locally manufactured	Designed & developed drive train incl. motor controllers	
	TVS Motors	Cells imported; battery packs made in-house	Own design		
	Emflux Motors	Imported from Samsung, Korea	Developed BMS, motor controller and motor		
	Electrotherm	Imported		Designed & developed motors and controllers	
Electric Three Wheelers	Gayam Motor Works	(Local Lead-Acid Battery)	Own design BMS	Imported	Imported
	Lohia Auto	(Local Lead-Acid Battery)		Imported	Imported
	Saera India*	Local Lead-Acid Battery		Imported	
	Goenka Elecric Motor Vehicles*	Local Lead-Acid Battery		Localised	Localised
Electric Cars	Mahindra*	Cells Imported; battery packs assembled in-house	Own Design	Imported	Own design
	Tata Motors	Imported	Outsourced	sourced from Electra EV, a group Co.	
	Hyundai Motors	Imported	Outsourced	Imported; sourced from parent Company	

EV Type	Manufacturer	Battery	Battery Management System (BMS)	Motors	Motor Controller
	Toyota Kirloskar	All Items (designed & developed Toyota Japan) by imported from parent company			
Electric Buses	Ashok Leyland*	Imported	Imported/Outsourced		
	Olectra*	Imported from BYD China			
	JBM Solaris*	Cells imported; battery packs (own design) outsourced	own design; outsourced	Outsourced	Outsourced

Source: based on http://www.eai.in/blog/2018/12/electric-vehicles-supply-chain-india.html - Energy Alternatives India (EAI) and additional inputs from our interactions with OEMs (*)

There is adequate capability to build drive and electronics components for EVs within the country; specialized electronic design and software development firms are supporting OEMs in their efforts to develop complex electronic controllers for manufacturers' requirements and for developing local sources.

Several BEV assemblers that we interviewed mentioned about the difficulties they faced in developing local manufacturing and supply base because of the small volumes. Manufacturers also face the problem of higher costs for items involving imported inputs especially items involving rare earths such as permanent magnet motors. The Government policy of lowering import duties for EV components to encourage faster adoption have only exacerbated the difficulties of potential local component manufacturers. However, one leading OEM expressed that though local supplies could be developed for almost all items, it is currently more economical to import. The Industry would have to continuously work towards improving efficiencies of systems and components. The current designs and specifications of EV systems and components are likely to undergo significant changes in future.

Several news reports have appeared on BEV Battery manufacturing plans of auto firms based in India. These are summarized below in Table 10:

Table 12 - Announcements of battery manufacturing plans in India

Manufacturer	Technology Partner	Plant Location	Capacity MW/Year	Items to be made
Delta	Taoyuan Taiwan	Krishnagiri, TN	50 MW	Battery Module & Assembly
BHEL	LIBCOIN, Australia		1 GWh	LI-Ion Cells
Mahindra Electric	LG Chem Skorea	Chakan Maharashtra	RINR 1000 Crs	Battery Module & Assembly
Exide	Leclanche Switzerland	Gujarat		Battery Module & Assembly

Manufacturer	Technology Partner	Plant Location	Capacity MW/Year	Items to be made
RAASI Solar - CECRI	CECRI	Krishnagiri Dist., TN	RINR 1,000 Crs	Li-Ion Battery
CECRI		Taramani, Chennai, TN	100 MWhr	Li-Ion Battery
Acme		HP	300 MW	Battery Assembly
Adani		Gujarat		Integrated Li-battery mfg
EON Electric		Haridwar, Utt		Battery Module & Assembly
Exicom		Gurugram	500 MW	Battery Module & Assembly
HBL Power Systems		Hyd Telengana		Li-Ion Cells & Batteries
Suzuki Toshiba Denso		Hansalpur Gujarat	RINR 1150 Cr ($180m)	Battery Module & Assembly
Zhuhai Yinlong New Energy		Punjab		EV
Amara Raja Batteries Limited	ISRO	AP	100 MWhr $300bn	Battery Module & Assembly
Tata Chemicals Limited, Mumbai	ISRO	Dholera Gujarat	Rs 40 bn ($600m) 10 GWh	Li-Ion Cells & Batteries

Source: Compiled from published news reports and discussions with manufacturers

In addition, several firms have reported interest in Li-Ion Battery Manufacturing Projects. These include: Bharat Electronics Limited (BEL), Carborundum Universal Limited, Exicom Tele-Systems Limited, Gurgaon, GOCL Corporation Limited, Hyderabad, NALCO Bhubaneswar, Sukhbir Agro Energy Limited, New Delhi, Thermax Limited, Pune (ISRO licensees); Reliance Industries; BYD, Panasonic, Saft France, Foxconn; Coslight India, Greenfuel Energy Solutions, JSW Energy, Napino Auto & Electronics, Trinity Energy Systems, Trontek Versatile Auto Components.

All the battery manufacturing projects envisage importing Lithium-ion Cells to manufacture battery modules and packs to customers' requirements. Some of the large manufacturers have also planned manufacturing of Lithium-ion Cells. Even though many projects have been announced, the progress on the ground seems to be slow, especially in light of 'the wait and watch' approach of Indian automotive manufacturing industry towards introduction of electric vehicles and the uncertainty regarding the demand for BEVs.

8.4 Other BEV Components

The supply chain for BEVs in India is nascent and evolving as can be seen from Table 9 above.

There is adequate capability to build drive and electronics components for EVs within the country; specialized electronic design and software development firms are supporting OEMs in their efforts to develop complex electronic controllers for manufacturers' requirements and for developing local sources.

Several BEV assemblers that we interviewed mentioned about the difficulties they faced in developing local manufacturing and supply base because of the small volumes. Manufacturers also face the problem of higher costs for items involving imported inputs especially items involving rare earths such as permanent magnet motors. The Government policy of lowering import duties for EV components to encourage faster adoption have only exacerbated the difficulties of potential local component manufacturers. However, one leading OEM expressed that though local supplies could be developed for almost all items, it is currently more economical to import. The Industry would have to continuously work towards improving efficiencies of systems and components. The current designs and specifications of EV systems and components are likely to undergo significant changes in future.

8.5 Policy and Regulation

Rising carbon footprint and other environmental impacts of the fuel-based vehicles have nudged policymakers the world over to look seriously at BEVs.

India made its first concrete decision to incentivize BEVs in 2010, when, the government announced financial incentives for manufacturers of electric vehicles sold in India under a INR 95-crore scheme of the Ministry of New and Renewable Energy (MNRE). The scheme provided incentives of up to 20% on ex-factory prices of the vehicles, subject to a cap.

Since then, the central government has taken several steps to get more Indians to adopt EVs.

In March 2012, The Ministry of New & Renewable Energy (MNRE) discontinued the INR 95-crore subsidy scheme which caused a 70% drop in BEV sales, besides closure of several dealerships.

In 2013 India unveiled the 'National Electric Mobility Mission Plan (NEMMP) 2020' to make a major shift to electric vehicles and to address the issue of national energy security, vehicular pollution and growth of domestic manufacturing capabilities. The scheme offered subsidies for EVs and incentives for creating supporting infrastructure.

However, in 2014, the Government discontinued subsidy on EVs, as a result, electric two-wheeler sales crashed to a mere 21,000 units a year (from 100,000 two years earlier) and closures of as many as 960 distributors and 26 of the 35 major electric two-wheeler makers.

In 2015, in a move to boost electric vehicle sales in the country, the government allocated INR 1,000 crore for the NEMMP for the next two financial years. The amount was intended for setting up of infrastructure, technology development, incentives and pilot projects.

In 2015, the Government earmarked INR 75 crore under the Faster Adoption and Manufacturing of Electric vehicles (FAME) policy which was welcomed by the Industry.

Phase I of the FAME scheme, which was initially for a period of two years from April 1, 2015, was extended for six months until September 30, 2017, with a slight modification. The benefits available to the Mild Hybrid technology under the scheme were discontinued with effect from April 1 2017.

Under FAME Scheme Phase-I, the demand incentive amount was determined for each category (vehicle - technology - battery type) taking into account the principles of Total Cost of Ownership (TCO), Pay-back Period on account of fuel savings, cost of maintenance etc.

A review of FAME Scheme noted that the overall phased implementation plan has taken off but at the very slow pace and recommended the subsidy structure needed to be revised to incentivize cleaner technologies and to establish parity across technologies.

Based on the experience gained during Phase 1 of FAME Scheme and suggestions of various stakeholders including industry associations, the Department of Heavy Industry announced in March 2019, Phase-II of the FAME Scheme, with an outlay of INR 10,000 Crore for a period of 3 years commencing from 1st April 2019.

In March 2019, the government announced a plan to set up a National Mission on Transformative Mobility and Battery Storage to "drive clean, connected and shared mobility" initiatives. The mission envisages a five-year phased manufacturing programme (PMP) till 2024 for a few large-scale, export-competitive integrated batteries and cell-manufacturing Giga plants in India. The programme would also work towards localization of production across the entire electric vehicle value chain. Domestic products would enjoy a 5%-15% tariff protection vis-à-vis imports. The plan would thus encourage the industry to make the necessary investment in capacity to localize the value chain.

In July 2019: The Goods and Services Tax (GST) on EVs was reduced from 12 per cent to 5 per cent and on electric chargers from 18 per cent to 5 per cent. The rate cut gives a clear signal that the government proposes to forge ahead with its target of reducing urban pollution and crude oil import bill. Both rate cuts considerably narrow the price differential between EVs and petrol and diesel vehicles.

In August 2019, faced with recessionary trends in the Auto Industry, the government softened its stance on the timeframe for transition to EVs (i.e. 100 per cent electric cars by 2030). The Ministry of Heavy Industries, the Ministry of Road Transport and Highways, the Power Ministry, and NITI Aayog — the Policy Think Tank tasked with policymaking and implementation of the government's e-mobility plan — agree to a "softer, pragmatic, phase-wise approach". Under the revised plan, highly-polluted urban cities are to be targeted first. The change in stance follows automakers' strong opposition of the government's proposed plan to ban two-wheelers (below 150cc) and three-wheelers by 2023 and 2025, respectively, and replace them with battery-operated EVs.

Considering the slow rate of offtake of Electric Vehicles and concerns raised by the automobile industry to move to, the government revised its plans for electric passenger cars from 100 per cent to 30 per cent.

Various initiatives have been taken by the Government to promote electric mobility in the country. Some of them are summarized hereunder:

(i) Under new GST regime, the rates of GST on Electric Vehicles have been kept in the lower bracket of 12% (with no Cess) as against the 28% GST rate with Cess up to 22% for conventional vehicles.

(ii) Ministry of Power has allowed sale of electricity as 'service' for charging of electric vehicles. This would provide a huge incentive to attract investments into charging infrastructure.

(iii) Ministry of Road Transport Highways ha announced exemption of permit in case of battery operated vehicles.

(iv) Energy Efficiency Services Limited (EESL), a joint venture of PSU's of Ministry of Power, Govt. of India is procuring 10,000 nos. of Electric Vehicles from reputed manufacturers for distribution to Government Departments on rental model and upfront sale model. EESL's tender of 10,000 nos. of EV's has reduced the cost of EV's substantially.

(v) Issue of Expression of Interest (EoI) for deployment of 5000 electric buses by State Transport Departments/Undertakings etc.

The Automobile which made significant investments in meeting the stringent BS-VI Emission Norms is strongly advocating a technology-agnostic (technology-neutral) policy that accommodates both conventional ICE and Electric Vehicles, at least for the immediate future.

8.6 Research and Development

Automotive Research Association of India (ARAI) is co-operative industrial research association by the automotive industry with the Ministry of Industries, Government of India established in 1966, to provide services to the industry in the fields of applied research and product development in automotive engineering. The **Automotive Research Association of India, (ARAI)** is located at Pune, India is located in the western part of Pune, Maharashtra. Its two main wings are the Research & Development Division, the Homologation Division.

Centre for Battery Engineering and Electric Vehicles (C-BEEV), IIT-Madras setup under professor Ashok Jhunjhunwala, has a major research focus on Electric Vehicles. CBEEV houses two centres of excellence: Centre for Battery Engineering (CoBE) and Centre for Electric Vehicles (CoEV). It has collaborated with several car and two/three-wheeler makers, battery manufacturers and motor makers to crack the e-vehicle market.

In addition, all the other IITs and numerous Engineering Colleges are engaged in research on various aspects of technologies and processes of automobile industry and electric vehicles.

Since past 5-6 years leading automotive manufacturers in India have initiated R&D work on Electric Vehicles and have established well equipped in-house R&D facilities manned by technical domain experts.

Department of Science and Technology (DST) began its scoping exercise for R&D activities in the BEV space by participating in FAME discussions, conducting a series of stakeholder discussions on EV R&D Programs and BEV charging standards. DST also held workshops and project development meetings by inviting participation from various stakeholders in industry and academia, to finalize a detailed R&D plan. As a result of some of these efforts, DST came up with the following focused areas for R&D: (i) technologies for Rare Earth Permanent Magnet Motors (ii) Energy Storage Systems which are temperature tolerant and (iii) Control & Power Electronics Devices[74].

Indian Space Research Organization (ISRO) has been actively supporting the Indian industries through technology transfers since its inception. In recent times, ISRO has offered to transfer space grade Lithium ion cell technology, which was developed for its satellite and launch vehicle applications, to competent public/private sector units and start-ups on a non-exclusive basis. ISRO's technology and production facilities are capable of producing cells of different size, capacity, energy and power density, and can cater to a wide spectrum of power storage requirements. Bharat Heavy Electricals Limited (BHEL), a leading public sector unit in India has entered into a technology transfer agreement with ISRO, to produce Lithium ion cells for both space as well as automotive sector needs[75].

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[74] https://dst.gov.in/heading-electric-transformation

[75] https://www.isro.gov.in/update/23-mar-2018/isro%E2%80%93bhel-tie-production-of-space-grade-lithium-ion-cells

9 Competitiveness of BEV Industry

9.1 Readiness Status of BEV Industry

The competitiveness of BEV industry can be measured using the following three dimensions:

(i) Technological capabilities
(ii) Organizational Capabilities
(iii) Support from Policy and External Environment

In order to understand the various challenges being faced by the BEV industry on the above dimensions and to assess its competitiveness, we carried out primary and secondary data/information collection as well as conducted in-depth interviews with industry stakeholders from across various sectors of the industry. Table 11 below lists the companies we interviewed from various sectors of BEV industry.

Table 11 - Key Players Interviewed in India as Identified through the Value Chain Framework

VEHICLE TYPE	ORIGINAL EQUIPMENT MANUFACTURERS	BATTERY	BATTERY MANAGEMENT SYSTEMS	MOTORS	CONTROLLERS	START UPS
2/3 wheelers	• Ather Energy • Mahindra Electric • Ecoyan	• BHEL • Amara Raja Batteries • Exide Batteries	• BHEL • Bosch • Toyota • Pulse propulsion	• Bosch • Pulse propulsion • BHEL	• Bosch • Pulse propulsion • BHEL	• Ather Energy • Pulse propulsion • Ecoyan
Cars	• Toyota Kirloskar • Mahindra Electric					
Buses	• Ashok Leyland • JBM Solaris • Olectra-BYD					

Our insights based on the interviews and data analysis are summarized below (see Table 12 for average industry scores across the three dimensions).

Table 12 - Average Scores for TOE Parameters in India

Technological Context	
Knowledge base and capabilities	4.18
Basic research and prototype	4.24
Field test and validation	4.53
Supply base	3.94
Procurement processes	4.29
Mass production	4.00
Quality assurance and control mechanisms	4.53
Cost structure	4.24
Compatibility with existing models of business	3.00

Direct and indirect benefits	4.56
Organizational Context	
Satisfaction with existing processes and technology	3.94
Organizational size – is it sufficient?	3.18
Top management knowledge, innovativeness, and support	4.53
Championship among employees	4.35
Knowledge absorptive capacity	4.19
Strategic planning	4.35
Perceived financial cost of switching/entering into BEV segment	4.06
Availability of financial resources	4.0
Organizational perception of technological uncertainty	2.59
Managerial obstacles	1.59
Employees' knowledge	3.94
Environmental Context	
Risk and uncertainty about future of BEVs	2.65
Effectiveness of regulatory policy	3.71
Intensity in competition	3.35
Government pressure	3.88
Availability of supplier base	3.18
Availability of customer base	3.18
Trading partners (distribution network)	3.44
Market scope (demand)	3.94
Supporting infrastructure	2.59

The survey was conducted on the basis of a questionnaire developed along the TOE framework. (refer to Exhibit 2 for more details).

9.1.1 Technological Capabilities

Compared to ICE based technology, BEV technology is relatively simple, and allows new entrants into the market. i.e., entry barriers are low from a technology angle. While there is scope for high-tech firms such as Tesla and Toyota to differentiate themselves with technologically superior products, there is enough space for low-tech and relatively newer firms to garner significant market share with simpler products, especially in emerging markets like India and Pakistan. Also, the modular nature of electric drive train allows companies to source various sub-systems (controllers, motors, batteries) from different players and assemble final products with relatively low know-how and investments, compared to ICE drive train, which is much more integrated in nature.

As a result, start-ups seem to have more advantage in BEV space compared to incumbent players. Incumbents also come with a lot of baggage, in terms of significant investments into ICE based product platforms, dedicated production and tooling equipment, well entrenched manpower, long standing supplier networks etc. While the same aspects work towards their advantage if the technology continues to develop in the same trajectory, since BEV is creating a break in the trajectory, these become roadblocks to change course. This somewhat explains the strong resistance by many established Indian automakers in shifting to BEVs completely by 2025 in the 2/3-wheeler segment, as proposed by Indian government. The reasons cited include the investments made by the automakers into ICE based technologies, in order to meet the Bharat VI norms, which are coming into effect from April 2020 onwards.

While some start-ups, especially in the two-wheeler segment seem to have invested in R&D of vehicle technologies and the electric drive train technologies, the battery technology is posing major challenges that need to be addressed quickly to enable faster adoption of BEVs in India. Battery cells and higher power Motors are being imported currently. One major challenge is to do with the cost of the batteries, which accounts for nearly 40% of the total cost of the vehicle and makes it prohibitively expensive for buyers. The second challenge is the suitability of existing battery chemistries to Indian conditions. The extreme temperatures of hot and cold in several parts of India are not very conducive to use of Lithium-ion battery chemistries that are under use in western countries. The technology needs to be developed further to ensure battery packs are not overheated during hot summer days, and batteries do not get discharged during cold winter days. Similarly, the existing motor technologies predominantly make use of permanent magnets which are rare earth metals, and are not easily available in abundance. There is a need to come up with motors that can be manufactured locally and without rare earth materials, to make motors available for large scale adoption of BEVs in India.

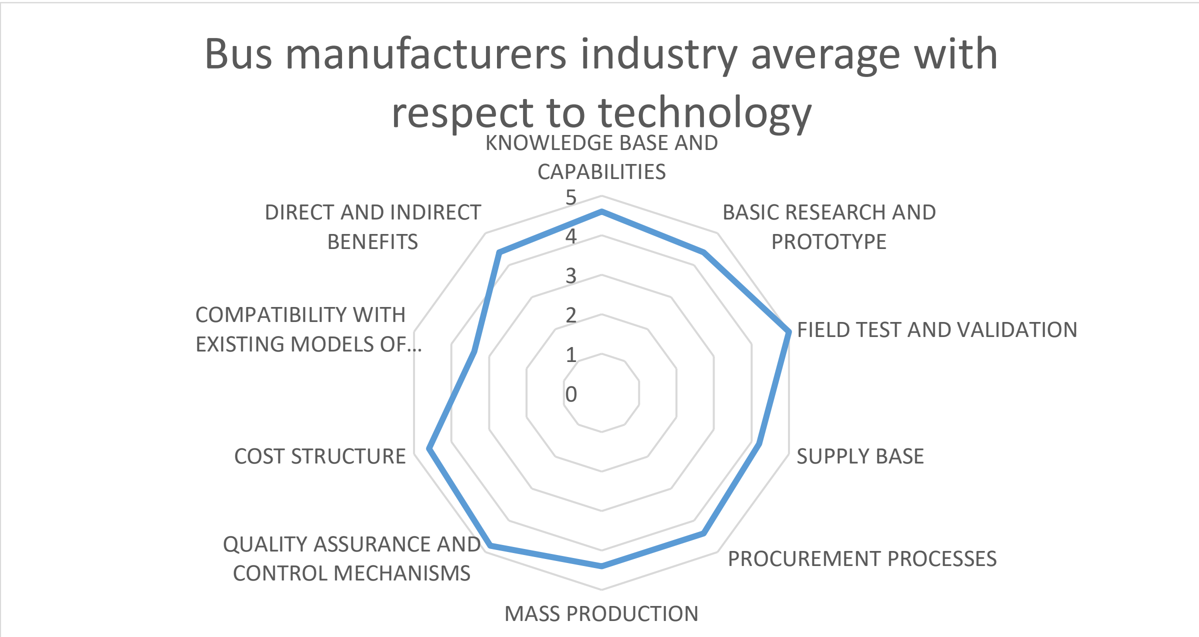


Figure 31 - Industry average with respect to Technology in India

The interviews with the industry practitioners revealed that, lack of compatibility with existing businesses (with a score of 3 out of 5) is a major drawback, when it comes to BEV technology (refer to Figure 31). Since BEV technology is very different from ICE technology, the incumbents are not able to find synergies from their well established ICE based technical capabilities. This could be one reason why companies like TESLA and BYD, which are new to the automobile manufacturing, are able to garner significant market share in the BEV market, compared to the industry leaders. Also, lack of supply base (3.94) seems to be one of the bottlenecks for all automakers; Lack of mass production opportunities (4.00) are cited as reasons for not making investments into the supply base by the established auto firms. However, all the firms we interviewed mentioned that they have basic research and prototypes (4.24) and reasonably sufficient knowledge and capabilities (4.18) to introduce products in the BEV segment, and find the testing and validation facilities (4.53) in the country to be adequate (especially the component suppliers). While the companies find the cost structure for BEVs to be on the higher side (4.24), they felt there are many direct and indirect benefits (4.54), which encourage them to take the BEV segment seriously. Many also stated that they have established in-house processes such as procurement (4.29), quality assurance and control mechanisms (4.53) and plan to scale up the production as and when the demand in the market picks up.

9.1.2 Organizational Capabilities

Organizational capabilities are typically built over time, and are entrenched in firm-specific processes, resources, and routines. The firm's age, size, culture and diversity of a firm's product portfolio to a large extent define their maturity and ability to adopt new technologies and introduce new products. There are both advantages and disadvantages that incumbents have vis-à-vis start-up firms. For instance, incumbents would have easy access to capital, higher risk taking ability, well-established R&D function, which helps them to experiment with new technologies. Whereas, start-ups might be more focused, come without too much overheads/expectations, and hence are more agile in new product introductions. Therefore, it is interesting to note that, very few incumbents are making first moves in the BEV market in India, whereas, the start-ups seem to be making major strides, especially in the two and three wheeler segments.

Figure 32 - Industry average with respect to Organization in India

Also, one would think that multinational enterprises (MNEs) with their access to global markets and wider product portfolios are better placed to take leadership than indigenous firms in the emerging markets. However, what we observe in India, is that it is the indigenous companies which are taking the lead on the BEV front, which is interesting and needs further investigation. Based on our interviews with the industry practitioners, we find that perceived cost of switching or entering into the BEV business is felt to be quite high (4.06) for Indian auto companies (refer to Figure 32). They also find that their current organizational size is not sufficient (3.18) when it comes to assembling and/or supplying of BEV components. Both component suppliers and vehicle assemblers felt that their employee knowledge in the BEV related aspects, while is high, it could be further improved (3.94). None of them however find the technological uncertainty (2.59) to be a major obstacle and are happy with the top management support and commitment towards the BEV business (4.53). However, while availability of financial resources on an average seems to be high (at 4.00), bus assemblers found it as one of the major challenges, due to high cost of capital investments that need to be made into the BEV business (based on discussions during the interviews). It is also interesting to note that all players from different segments mentioned that, managerial obstacles for entering into BEV business are very low (1.59).

9.1.3 Support from Policy and External Environment

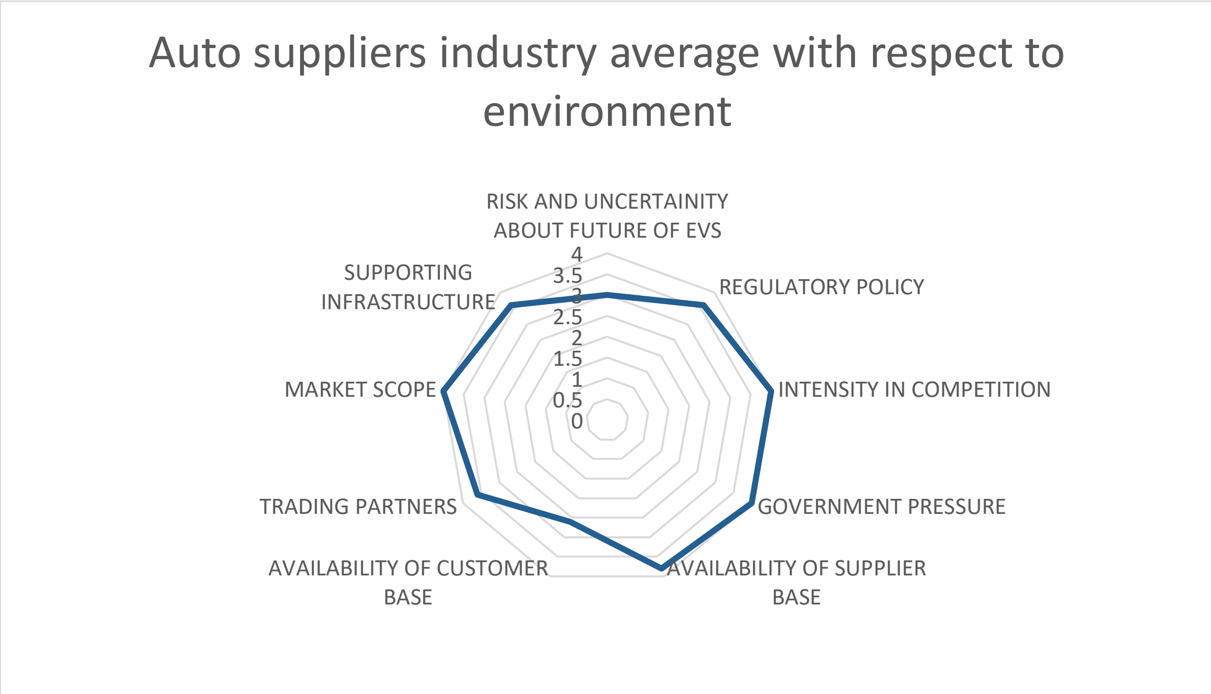
Clearly in countries like China and Norway, where the adoption of BEVs has been the highest, the regulations imposed by the government, incentives and aggressive push for taking leadership in new technologies etc. seems to have paid off, in terms of faster and larger adoption of BEVs. While Indian government too started a major push towards BEVs in recent times, the incentives are nowhere near that of China. The second phase of FAME brought in greater clarity and significantly higher amount of funds, which is in the right direction. Indian government is also planning to offer sops for investments into battery plants and cell manufacturing, as well other electric drive train related production investments, to encourage localization.

In addition, to generate more demand from the customer side, in the 2019 budget, Indian government announced income tax rebates of up to ₹1.5 lakh to customers on interest paid on loans to buy electric vehicles, with a total exemption benefit of ₹2.5 lakh over the entire loan period. Also, customs duty exemption was announced on lithium-ion cells, which will help lower the cost of lithium-ion batteries. Makers of components such as solar electric charging infrastructure and lithium storage batteries can avail investment-linked income tax exemptions and other indirect tax benefits. Even state governments are coming forward and announcing state-level incentives to encourage BEV adoption in their respective states. Delhi government for instance recently announced an EV policy for Delhi with slew of incentives mainly targeting two wheelers and commercial vehicles, as well as public charging and battery swapping facilities[76].

All these measures seem to have created reasonably conducive external policy environment for the assemblers as well as suppliers of BEV components as can be seen from Figure 33, with industry practitioners showing medium appreciation towards the regulatory policy and overall external environment for the BEV industry in India. For instance, the data analysis shows that while the risk and uncertainty about future of BEVs is low (at 2.65); regulatory policy framework is reasonably good (3.71) and at the same time industry players are feeling pressure from the government (3.88) to enter into the BEV segment. However, players from all segments are finding the supporting infrastructure in terms of charging stations, testing facilities etc (2.59) as well as supply base (3.18) to be lacking; whereas suppliers are finding customer base to be lacking (3.18). This clearly shows a chicken and egg problem, wherein both suppliers and customers are waiting for each other to develop, before making significant investments into this segment. However, the fact that the industry is finding the market

[76] https://auto.economictimes.indiatimes.com/news/industry/delhi-rolls-out-electric-vehicle-policy-targets-5-lakh-ev-registration-by-2024/72939676

scope to be reasonably high (3.94) and competitive intensity to be reasonably low (3.35) is a good news for India. Along with the recent monitory incentives announced by the government, if the infrastructure improves and trading partners come onboard (which is currently at 3.44), things should start improving and both suppliers of components and auto assemblers will start making investments, which should augur well for the Indian BEV market.



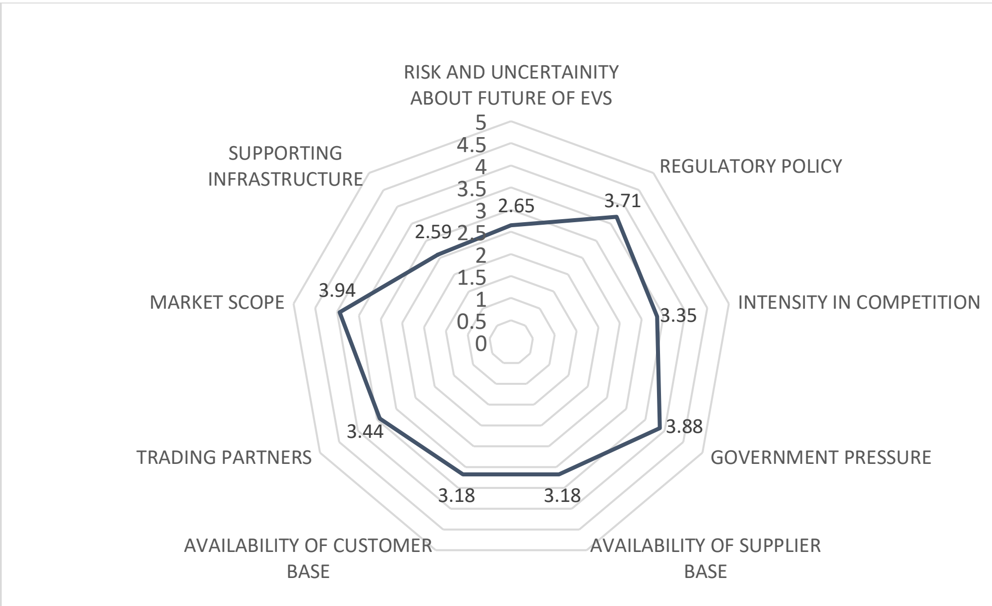


Figure 33 - Industry Average with respect to Environment in India

9.2 Recommendations to improve BEV business environment

Battery cells and higher power motors are being imported currently, as manufacturing of cells in low volumes is not economical. However, as volumes increase, it is important to develop local supplier networks for these components for the following reasons. Firstly, the Indian market is highly price sensitive. The cost of a BEV is nearly twice that of an ICE based vehicle, and a significant chunk of this cost is due to the electric drive train, which includes the battery pack. As discussed earlier, nearly 75%

of the cost of the battery pack is due to the cells. Therefore, unless there are continuous cost reductions in cells and these savings are captured, which is only possible if the cells are manufactured locally, the BEVs will not become cost competitive. Therefore, it is necessary to increase the availability locally, in order to penetrate into mass market, which is where economies of scale will kick in. Similar logic applies to motors as well. Therefore, until the market demand picks up and makes local production a viable business proposition, the government should help manufacturers by providing subsidies on raw material imports, capital investments, production volumes etc. Incentives on capital investments, especially for manufacturing of cells, is necessary since it is a highly capital intensive activity. The recent customs duty exemption on lithium-ion cells by India's Finance Minister is the right step in this direction. Other investment-linked income tax exemptions and indirect tax benefits were also announced for makers of components such as solar electric charging infrastructure and lithium storage batteries.

Electronics manufacturing in the country also needs to develop further. Similarly, there is dearth of raw material availability in the country. Currently there is a lot of dependence on countries like China for raw materials like Lithium-ion, cobalt, nickel etc. The only way to reduce dependence on other countries is by developing technologies for recycling of used batteries and cells, and by developing closed loop supply chains for all rare earth materials. Also, there is a need for more testing and validation facilities. Currently, only ARAI and i-CAT are the only two automotive related testing facilities available in the country.

The next challenge is related to availability of talented workforce. The BEV start-ups pointed out that it is not easy to get highly skilled manpower in this field. This seems to be a challenge even for established companies. According to a senior executive from one of the established MNE suppliers in India:

"*We need to improve our bandwidth to diversify into emerging technologies and markets. Second challenge is to train our manpower in these new domains. Finally, we need to figure out how to reuse our existing facilities and distribution channels for the EV business*"

Another important challenge is standardization of charging technology and infrastructure. While electric two-wheelers need simple infrastructure like creating of plug points in malls, office and residential parking lots, bigger vehicles will need more complex and faster charging infrastructure. Government needs to work towards standardization of swapping stations and charging infrastructure to facilitate faster adoption of three-wheelers and passenger vehicles. All automakers and charging infrastructure creating companies should be encouraged to use Bharat standards. The current estimates suggest that there will be 100 fold increase in charging infrastructure by 2030. Better clarity in policy and regulations would help in reaching these targets in an efficient and cost-effective manner.

Some firms felt that, in addition to the incentives for capital investments into EV production, the government should also have a minimum cap on BEVs on all OEMs. Say similar to China, 25 - 30% of all automaker capacity should be dedicated to BEVs. Demand will pick up further, if the government also mandates, for instance that all new fleets of buses should be EVs only. Focus of the policy should be on shared mobility and public transport, as most pollution and oil usage can be reduced here.

In case of public transport vehicles, such as three-wheelers, buses and taxi-fleets, more clarity is needed in tendering processes by the state governments. E-rikshaws do not figure in any of the government initiatives, such as Start-up India or in state government plans and platforms. Also, there is very little clarity regarding e-rikshaw regulations, even at the Regional Transport Offices of various states. There is a need to educate and create more awareness, both for government organizations, as well as customer organizations. There is also need for financing and funding opportunities for e-rickshaw manufacturers. According to the executives operating e-rickshaw start-ups, even banks do not provide any funding currently. Also, FAME-II policy does not provide any incentives for lead acid battery-based e-rikshaws and two-wheelers. These limitations need to be addressed quickly and a greater clarity in policy framework and a roadmap for the near future would help companies chalk out their investments and strategies for BEV related businesses.

9.3 Lessons from the Indian Experience

The Indian experience shows that, it is important to generate market demand and a conducive regulatory and policy environment for BEV entry, to ensure faster adoption of BEVs in any market. This is one of the reasons why India failed to adopt BEVs in a big way despite being one of the first markets that saw introduction of a BEV in the 4-wheeler segment way back in 2001-02[77]. The recent push by the Indian government through FAME policy has finally provided the impetus for the growth at least in the two & three-wheeler segments. The key take-aways based on Indian experience for Pakistan and other SAARC countries are summarized below:

- There is a need to ensure that the cost of BEVs is on par with traditional ICE based vehicles. While the variable cost of operating and maintaining a BEV is comparatively very low, the fixed cost of owning a BEV with equivalent performance to an ICE based vehicle is at least two times or more. Only when this initial cost of ownership is more comparable, will the personal use customers be willing to explore BEVs. Whereas, TCO is the right comparison for the commercial use vehicles. However, at current battery prices, even the TCO calculations make BEVs unviable in almost all segments. Which means, there is an urgent need to greatly reduce the cost of battery, to ensure faster adoption of BEVs in highly competitive auto markets of SAARC countries.
- The next important challenge is to address other performance metrics, starting with range. Range anxiety has been cited as one of the major obstacles to BEV adoption across the world. This will require not only technological advancements, in terms of higher battery density, increased speed of charging etc., but also charging infrastructure and/or battery swapping stations. Once the range issue has been tackled, automakers need to focus on other performance metrics, such as speed, acceleration, battery life etc.
- Given the challenges involved in establishing the charging infrastructure, the government has to play a key role in enabling and encouraging various players, including private parties, regulatory agencies, state electricity boards and automakers to come together to work out standards and create charging and/or battery swapping infrastructure. Standardization of charging technology and infrastructure will be essential to ensure maximum coverage can be achieved across the segments.
- On the supply side too, it seems government intervention is needed to facilitate establishment of BEV supply chains. Depending on the size of the market, there is a need to identify appropriate components, systems and sub-systems that need to be manufactured locally, and provide sufficient incentives to induce private investments into these facilities. This is to ensure that cost of the vehicle becomes affordable, which should ultimately help with the faster adoption.

[77] https://timesofindia.indiatimes.com/business/india-business/Reva-launched-in-Delhi/articleshow/6591776.cms

- From creation of man power with appropriate skill-sets, government and industry need to enter into a partnership and work with technical institutions such as ITIs, engineering colleges and IITs to introduce appropriate programs and course structures. Associations such as Confederation of Indian Industry (CII) and Automotive Component Manufacturers Association (ACMA), SMEV should proactively create appropriate training programs for the current industry workforce, so that the industry transition to BEVs and scaling up can take place smoothly.
- We also learn from the Indian experience that, e-rickshaw segment is perhaps best placed for faster adoption of BEVs, due to the viable economics and market demand. The government need not make too much investment here, other than playing a facilitator role by putting in place appropriate regulatory norms and by enabling access to capital resources. Wider adoption of e-rickshaws will also create charging infrastructure, which, if planned properly, can also be used for charging of other vehicles.
- The fact that not many incumbent automakers have made serious foray into the BEV segment in India also shows that, perhaps some caps on minimum production of BEVs are necessary, especially in the two and four-wheeler segments. However, without addressing all the above factors, creating minimum caps alone may not be fair from automakers' perspective. Therefore, one needs to think through this strategy carefully and should introduce these caps only after the market has matured a little and charging infrastructure has been put in place.

10 Conclusion (India)

From the government side, there is a need for greater clarity in terms of policies and regulations. All our discussions with the industry practitioners revealed that once that clarity comes, companies will start investing, especially in assembly of vehicles and battery pack facilities. However, scaling up might take a few months. Therefore, production at large scale should become possible in the next one or two year time frame. From a battery pack manufacturer's point of view, the supporting infrastructure seems to be adequate. While more testing and validation facilities are needed for vehicle assemblers, it seems they are not a bottleneck for battery manufacturers.

Our study results also indicate that, the government must play a key role to encourage adoption of electric vehicles in the Indian subcontinent. While there have been some incentives to induce demand for BEVs in various segments, there is a need for supply side incentives, to encourage investments into key component manufacturing within the country. There is also a need for standardization of technologies, charging and swapping infrastructure, to reduce inefficiency and unnecessary duplication of investments and efforts. While electric three wheelers and e-rickshaws dominate the BEV segment in India due to higher demand in this segment, greater clarity in regulations and some amount of handholding by creating funding opportunities and quality improvement initiatives can give further boost to this sector.

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EXHIBIT 1

LAHORE UNIVERSITY OF MANAGEMENT SCIENCES

Suleman Dawood School of Business

Venue: Room # 104 First Floor

Seminar on Manufacturing of Battery Electric Vehicles (BEVs) in Pakistan

Friday, August 30, 2019

02:30 - 03:00 pm	**Registration of participants**
03:00 - 04:15 pm	**Welcome note**
	Sharing of understanding of BEVs manufacturing – Global trends, China, India, and Pakistan Dr. Syed Zahoor Hassan (Lahore University of Management Sciences) Dr. Haritha Saranga (Indian Institute of Management Bangalore) - Skype Dr. Shakeel Sadiq Jajja (Lahore University of Management Sciences)
	Questions and answers
04:15 - 4:45 pm	**Networking tea**
04.45 - 6:00 pm	**Panel discussion and conclusion** Panel consists of leaders in organizations progressing in manufacturing of BEVs in Pakistan Panel is supported by domain experts in the audience Moderated by Dr. Syed Zahoor Hassan

EXHIBIT 2

QUESTIONNAIRE BASED ON TOE FRAMEWORK FOR THE BEV SEMINAR

Subject: **Request for Participation in Research on Readiness of Battery Electric Vehicles (BEVs) Manufacturing**

Dear Sir/Madam,

Suleman Dawood School of Business (SDSB) of Lahore University of Management Sciences (LUMS) and Indian Institute of Management Bangalore (IIMB) are research driven leading business school in South Asia.

At SDSB and IIMB, we are conducting a research funded by SAARC Energy Center (SEC) to assess readiness of manufacturing understand of battery electric vehicles in Pakistan and India.

In this regard, we request you to please spare your valuable insight by filling out the attached questionnaire.

We assure you that the information sought in this questionnaire will be treated with complete confidentiality. The research results will not base on individual business data but on aggregate level understanding of the industry.

You might find some questions lacking direct relevance to you. Please ignore them and respond to as many as you can.

Please attach your business card with your response so that we can share findings of the research with you.

Thank you very much. If you have any questions please do not hesitate to contact me on the below information.

Sincerely,

Dr. Shakeel Sadiq Jajja

Faculty Director, Rausing Executive Development Center
Assistant Professor, Suleman Dawood School of Business

Lahore University of Management Sciences
Direct: +92 42 3560 8435
Email: ssj@lums.edu.pk

And on behalf of:

Dr. Syed Zahoor Hassan
Professor and Former Vice Chancellor
Lahore University of Management Sciences

Dr. Haritha Saranga

Professor

Indian Institute of Management

Lahore Bangalore

SECTION 1: Respondent's Information

Name of your organization:

____

Your organization's potential role in BEV manufacturing:

____

Address:

____

____

Your name, designation, phone number and email address:

____

____

How useful was this session in enhancing your understanding of BEVs manufacturing readiness in Pakistan?

☐ Not useful ☐ Slightly useful ☐ Moderately useful ☐ Useful ☐ Very useful

Note: Based on your understanding, please respond to questions on behalf of your organization if the question is applicable to your organization. Alternatively, please respond from on behalf of BEV manufacturing industry in Pakistan.

Section 2: Key Players in Battery Electric Vehicles (BEVs)

In your awareness who are the key players in this area of manufacturing in Pakistan?

Original equipment manufacturers:

____

Vendors (e.g., body parts, batteries, motors, battery management system, and controller):

____

Distributors:

____

Supporting service providers:

____

Others (Please specify):

____

Section 3: Technology

With regards to BEVs technology what is state of following factors in your organization (or industry if this is not relevant to your organization):	Low	Somewhat Low	Neither High	Somewhat High	High
Knowledge base and capabilities	1	2	3	4	5
Basic research and prototype	1	2	3	4	5
Field test and validation	1	2	3	4	5
Supply base	1	2	3	4	5
Procurement processes	1	2	3	4	5
Mass production – Is the process technology ready for large scale manufacturing?	1	2	3	4	5
Quality assurance and control mechanisms – are they in place?	1	2	3	4	5
Cost structure – Is it too high/low vis-à-vis other traditional (IC) technologies	1	2	3	4	5
Compatibility with existing models of business – are there any synergies?	1	2	3	4	5

Direct and indirect benefits – how does entry into BEVs affect your new product portfolio, sales & market share (direct); and brand name (indirect) etc.?	1	2	3	4	5

Section 4: Organization

With regards to BEVs technology what is state of following factors in your organization (or industry if this is not relevant to your organization):	**Low**	**Somewhat Low**	**Neither High Nor Low**	**Somewhat High**	**High**
Satisfaction with existing processes and technology	1	2	3	4	5
Organizational size – is it sufficient?	1	2	3	4	5
Top management knowledge, innovativeness, and support	1	2	3	4	5
Championship among employees	1	2	3	4	5
Knowledge absorptive capacity	1	2	3	4	5
Strategic planning	1	2	3	4	5
Perceived financial cost of switching/entering into BEV segment	1	2	3	4	5
Availability of financial resources	1	2	3	4	5
Organizational perception of technological uncertainty	1	2	3	4	5
Managerial obstacles	1	2	3	4	5
Employees' knowledge	1	2	3	4	5

Section 5: Environment

With regards to BEVs technology what is state of following factors in your organization's environment (or industry if this is not relevant to your organization):	**Low**	**Somewhat Low**	**Neither High Nor Low**	**Somewhat High**	**High**
Risk and uncertainty about future of BEVs	1	2	3	4	5
Effectiveness of regulatory policy	1	2	3	4	5
Intensity in competition	1	2	3	4	5
Government pressure	1	2	3	4	5
Availability of supplier base	1	2	3	4	5
Availability of customer base	1	2	3	4	5
Trading partners (distribution network)	1	2	3	4	5

Market scope (demand)	1	2	3	4	5
Supporting infrastructure	1	2	3	4	5

Section 6: Future Outlook

What are your organization's (industry's) intentions and plans regarding BEVs?

____

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What does your organization (or industry) need to make you (or industry) manufacture BEVs or related parts?

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What areas of technology (as mentioned in Section 2) need improvement/development?

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____

What areas of organization (as mentioned in Section 3) need improvement/development?

____

____

____

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____

____

What support or development (as mentioned in Section 4) will make your organization (or industry) manufacture BEVs or related parts?

____

____

____

____

____

____

I filled out this questionnaire on behalf of:

☐ My organization ☐ BEV manufacturing industry in Pakistan

EXHIBIT 3

Organization	Role in BEV Industry	Name and Designation
Sharif College of Engineering & Technology	student and faculty R&D research projects	Dr. Akhtar Rasool, Asst. Professor
CORE group	Policy and Academic	Dr. Ahmed Kiani Director
Engineering Development Board	Policy/ Road map	Mirza Nasir Baig CEO
Power Electronics	3 wheelers manufacturing	Mawish Ahmad M.D.
General Fan Company Pvt. Ltd.	Motor manufacturing (any type)	Mobin Ilyas, director 03008620026
Gas and Oil Pakistan limited	infrastructure potentially for charging docks (OMC)	M. Mamnoon Hamid Business Development Officer
Pakistan Accumulators pvt. Ltd.	Battery manufacturing	Faisal Mehboob Plant Manager
AUJ Technologies pvt ltd	Solution and Technology provider to industry	Usman Sheikh CEO
Jolta Technology limited	we are doing biz? Share in Pakistan	Muhammad Azim
47 Ventures Investments	Investor	Khurram Zafar
GFC Fans	Motor manufacturing	Nabeel Ilyas Head of Sales and Marketing
EV Technologies and S Zia ul Hasan	Input and local manufacturers	CEO
BARQBOX	local assembly of batteries, li-ion	Mansoor Lashari
BARQBOX	local assembly of batteries, li-ion	sohail lashari chairman
Toyota Indus Motor Co.	manufacturing of cars/LCV/HEV/BEV	Babar S Khan CRO
Treet Corporation Ltd		Hammad Malik GM Sales
Jolta Technology limited	developing electric kits for two wheelers and three wheelers	Irfan Ahmed CEO Hi Tech Systems Int'l
GO	battery packs/swapping station/chargers	Ammar Talaat CSO
Honda Atlas Cars Pakistan Ltd.	not started, planning at the time	Muhammad Akmal Dar GM Import, Purchase and Logistics
M/S Power Electronics	3-wheelers (rickshaws) at present	Engr. Wasim Ahmed Managing Director
Fast Cables Ltd	Cable manufacturer	Kamal Mian director
LUMS Energy Institute	R&D and Policy making	Dr. Naveed Arshad
FTMM-Daewoo Batteries		Farid Rasheed GM Sales& Marketing

Millat Equipment Limited	Exploring potential	Arif Ahmed Abbasi General Manager
Dost Steels	None at the moment	Saad Zahid Director
Millat Equipment Limited	Gears and Transmission Manufacturing	Muhammad Adnan Akram Manager Technical
Jawad Corporation (SUNRA)	Already doing CBU since 2017	Adeel Gohar Partner,
INER-Z	Developing 2 wheeler EV	Director
TRYDAN	Redesigning the four-wheeler tramp for optimized weight and work in regenerative technology	Saddam Akhtar CEO
LUMS Energy Institute	Policy manufacturing for Evs	Abu Bakr research associate
LUMS Energy Institute	Policy manufacturing for Evs	Malik Arslan Research Associate
Golden Dynamics Pvt. LTD.	DC/AC Motor Manufacturing	Khurram Rauf Mughal (Director)
INER-Z	Design engineering studio aiming to capture the EV market	Murtaza Zaidi CEO
VPL Limited	Currently dealing in CBUs for Eurpoean and Chinese brands. Could potentially be local assemblers in future	AbuBakr Rashid (Product and Application Engineer)
VPL Limited	We are automotive suppliers (trucks and buses); possible manufacturer of vehicles based on financial viability	Uzair Shahid Country Manager, Bus. Division,
Fast Cables Ltd	supply of electrical cables and harness	Adeel Raheel, Business Development Head
Ignite	Funding for R&D	Yasir Ahmed Manager Project Evaluation
Imran Saeed	In 2015, we worked on hybrid bike	Manager R&D

EXHIBIT 4

Cathode Component of Battery Cells in Various Electric Vehicles

Manufacturer	Battery Supplier	Cathode Chemistry	Designation
Renault-Nissan-Mitsubishi	AESC, LG Chem	*nickel-rich layered oxide cathodes*	$LiNi_{1-x-y}Mn_xCo_yO_2$ (NMC) $LiNi_{1-x-y}Co_xAl_yO_2$ (NCA)
Tesla	Panasonic Tesla	*Lithium-nickel-cobalt-aluminum oxide (NCA)*	$LiNi_{1-x-y}Co_xAl_yO_2$ (NCA)
BMW **VW**	Panasonic Samsung	*Lithium Manganese*	$LiMn_2O_4$
Zhengzhou Yutong	CATL, Lishen, CALB, etc. China	*Lithium Nickel, Manganese Cobalt Oxide Lithium Nickel Cobalt Aluminium Oxide*	$LiNi_{1-x-y}Mn_xCo_yO_2$ (NMC) $LiNi_{1-x-y}Co_xAl_yO_2$ (NCA)
BYD	BYD	*Lithium Iron Phosphate*	$LiFePO_4$ (LFP)
BHEL, Ashok Leyland, Tata Motors, etc.	BYD, etc.	*Lithium Nickel, Manganese Cobalt Oxide*	$LiNi_{1-x-y}Mn_xCo_yO_2$ (NMC)

Source: Dmitry V. Pelegov and José Pontes; 2018; Main Drivers of Battery Industry Changes: Electric Vehicles—A Market Overview; *Batteries* 2018, *4*(4), 65 and Coffin, David, and Jeff Horowitz. "The Supply Chain for Electric Vehicle Batteries." *Journal of International Commerce and Economics*, December 2018. https://www.usitc.gov/journals.

EXHIBIT 5

Comparison of important parameters of various electric buses in the Indian market

Segment	Diesel Buses		CNG	Hybrid Electric Bus	Pure Electric Bus
Model	Volvo 8400 [16] (AC)	Tata STARBUS SLF 44 [17] (AC/non-AC)	Tata STARBUS LE CNG 18 [18] (AC/non-AC)	Tata Starbus Hybrid[19] (AC/non-AC)	BYD K9[20] (AC)
Seats	32	44	18	32	31
Length	12.3 m	12 m	12 m	12 m	12 m
Width	2.5 m	2.5 m	2.55 m	2.55 m	2.55 m
Height	3.2 m	3.2 m	3.35 m	3.35 m	3.49 m
Gross weight	16,200 kg	16,200 kg	16,000 kg	16,200 kg	18,500 kg
Costs (INR)	88 lakhs	33 lakhs	30 lakhs	1.2–1.4 crores	2–3 crores
Fuel efficiency	2.2 km/L	3.5 km/L	2–3 km/kg	2.2–4km/kg	1.5 kWh/km
Fuel cost	INR 23/km	INR 15/km	INR 13–19/km	INR 10–17/km	INR 10/km
Range (km)	484	560	260–390	286–520	249
Fuel tank size	220 L	160 L	720 L	720 L	-
Charging time	–	–	–	–	3–6 h
Max power	290 BHP	177 BHP	230 BHP	230 BHP engine 44 kW battery	180 kW
Max torque	1,200 Nm	685 Nm	687 Nm	678 Nm	700 Nm
Battery type	–	–	–	Li-ion batteries	Li-ion Iron (300 kWh)
Emission standard	EURO III	BS III	BS IV	EURO III	Zero tail pipe emission

Source: Global Green Growth Institute and Center for Study of Science, Technology and Policy (2015). Electric Buses in India: Technology, Policy and Benefits, GGGI, Seoul, Republic of Korea

EXHIBIT 6

Manufacturers of E-Rickshaw Models Certified by ICAT, Manesar, Haryana

Name of the Manufacturer
1. 3S Industries
2. A. K. Gupta & Co
3. A. V. Automotives Pvt. Ltd.
4. A3T Incorporated
5. Aadhya Enterprises
6. Aaditya Emotors India Pvt.
7. Aaditya Garbage Products Pvt Ltd
8. Aargee Electric
9. Accretion Power Autos
10. Adapt Motors Pvt. Ltd.
11. Adidev Technoa Pvt. Ltd
12. Aditya Sai Industries
13. Aksmd Rechargeable Vehicles Pvt. Ltd
14. Allfine Industries Private
15. Altier Electric Vehicles Pvt. Ltd.
16. Altius Technologies
17. Aman Electric Vehicles
18. Ambika Industries
19. Anish Powertech Pvt. Ltd
20. Anjali Auto Components
21. Anjali Traders
22. Ankush Auto Deals
23. Aparna Industries
24. API Motors Pvt. Ltd
25. APM Auto Sales
26. Apsara Enterprise
27. Archit Enterprises

Name of the Manufacturer
28. Arihant Enterprises
29. Arman Green Vehicles
30. Arna Electric Auto Pvt. Ltd
31. Arrow Automotive
32. Asha Tilak Ventures Pvt Ltd
33. Ashwa Electric
34. Asia Body Builders and Manufacturers
35. Attolent Autogroup Pvt Ltd
36. Atul Auto Ltd
37. Atut Sangam
38. Avl Electric Vehicles
39. AVON Cycles Ltd
40. Axceed Industries (OPC) Pvt. Ltd.
41. BABA E Vehicles
42. Baghwan Rikshaw Udyog
43. Bajaj Implements Private Limited
44. Bajaj Implements Private Limited
45. Bal Gopal Wheels Private Limited
46. Bali Auto Industries
47. Bareja Automotive
48. Battery Rickshaw Sangh
49. Bentinck Industries Private Limited
50. Bestway Agencies Pvt. Ltd
51. Bestway Banarash
52. Bharat Manufacturing & Assembling E Riksha

Name of the Manufacturer
53. Big Bull Trader Pvt. Ltd.
54. Bijnor Enterprises
55. Bright Autozone Pvt. Ltd
56. Caparo Autotech Ltd
57. CART INDIA
58. CEEON INDIA
59. Champion Poly Plast
60. Chandak E Automobiles LLP
61. Charuvikram Automobile Pvt. Ltd
62. Chauhan Auto Industries
63. Chehak Batteries
64. Chirag Enterprises
65. Citadel Enterprises (OPC) Private Limited
66. Classic (India) Motors
67. Classic Engineers & Fabricators
68. CLH Gaseous Fuel Applications Pvt Ltd
69. Creative Engineering
70. D S F Industries Pvt. Ltd
71. Dashmesh Traders
72. Datang Evahaan Pvt. Ltd.
73. Dave Exim (P) Ltd
74. DD Auto Private Limited
75. Deep Drawn Technologies
76. Delta Autocorp LLP
77. Deltek Enterprises Pvt Ltd
78. Desmoto Electrics Pvt. Ltd.

Name of the Manufacturer
79. Dhar International
80. Dhatri Infrastructure Pvt.
81. Diamond E Vehicles
82. Dilli Electric Auto Pvt. Ltd
83. Divansu Automobiles Ltd
84. Divya Automobiles
85. Diwa Green Technology Private Limited
86. Duke Auto India
87. Dukemoto Motors Pvt. Ltd
88. Durable Flanges Pvt. Ltd
89. Dynavolt Technology (India) Limited
90. DYS Impex Pvt Ltd
91. E Guru Auto Energy
92. E Xtra Fast Solution
93. E-Ashwa Automotive Private Limited
94. Eco Smart Vehicles Pvt. Ltd.
95. Eco-Friendly Electric Vehicle Pvt. Ltd.
96. Ecogreen Hi-Tech Products
97. Edmrc Mannschaft LLP
98. Electra International
99. Electreca Vehicles
100. Electrotherm India Ltd
101. Elephanta Industries Pvt.
102. Elite Auto Engineers Pvt Ltd
103. E-Motion Automotive Industry LLP
104. Energy Electric Vehicles
105. Enigma Automobiles Pvt. Ltd.

Name of the Manufacturer
106. Epower Vehicles Pvt. Ltd
107. Eusi Motors Pvt. Ltd
108. EVEX India
109. Five Elements
110. G & G Automotive
111. G K Rickshaw
112. G- Kon Electric Motor
113. G Williams Fabrications Ltd
114. Gauri Auto India Pvt Ltd
115. Gayam Motor Works Pvt.
116. Gayatri Electric Vehicles
117. General Agencies
118. Geo Alliance
119. Gobind Industries (P) Ltd.
120. Godawari Techno Solutions Pvt Ltd.
121. Goenka Electric Motor Vehicles Pvt. Ltd
122. Goodenergy India
123. Goodwill HI Precision Works Pvt Ltd
124. Gram Tarang
125. GRD Motors
126. Green Fuel Alternatives Pvt Ltd
127. Green Impex
128. Green Kaiketsu Automotive India Pvt. Ltd
129. Green Star Motors
130. Green Technologies
131. Green Technologies Namah Industries Pvt. Ltd.
132. Green Valley Motors

Name of the Manufacturer
133. Green Way Eco Ride
134. Green Wheelz (India)
135. Greenwheels Automobile Pvt. Ltd
136. Greenworld Motors Pvt. Ltd.
137. GRG Smart Vehicle Pvt. Ltd
138. Gurukirpa Industries
139. H.D. Automotives
140. Haarish Automotives (OPC) Pvt. Ltd.
141. Hanuman Udyog
142. Harsh Trading Company
143. Hero Electric Vehicles Pvt. Ltd.
144. Him Teknoforge Ltd
145. Hindustan Motor Corporation
146. HI-TECH Industries
147. Hitech Mechanical Works
148. HITEK Electric Auto Co.
149. Hooghly Motors Pvt. Ltd
150. HOP Motors Pvt. Ltd
151. Hotage Corporation India
152. Hovel Cylinder Pvt. Ltd
153. Hundal Industries
154. I – Moto Greens Pvt. Ltd.
155. Indian Motors
156. J.S. Auto (Pvt) Ltd
157. Jade Korea Spine Life
158. Jaidka Power Systems Pvt.

Name of the Manufacturer
159. Jajodia Commodities Pvt
160. Jajodia Exports Pvt. Ltd
161. JAL Enterprises
162. Jay Ace Technologies Ltd
163. Jaydev Enterprise
164. Jemco Engineering Pvt. Ltd.
165. Jessun Techno Private Limited
166. JHL Motors Pvt. Ltd
167. JIJO Electric wheels pvt
168. Jindal Electric Vehicles
169. Jitendra New EV Tech Pvt.
170. Jitendra Tempo Parts
171. JS Mobileon Private Limited
172. JSS Engineering Company
173. Juno Castings Pvt. Ltd
174. JVC Bharat
175. K T Enterprises
176. K. V. Industries
177. KABMAX Electric Automobiles Pvt. Ltd
178. Kalika Vahan Private Limited
179. Kalpvriksh Electromobiles
180. Kamaz Industries.
181. Kanha Electric Vehicles
182. Kaptech India
183. KGN Industries
184. Khalsa Agencies
185. Khemraj Automotive

Name of the Manufacturer
186. Kirti Solar Ltd
187. KLB Komaki Private Limited
188. Knight Queen Industries Pvt. Ltd.
189. Kranti International
190. Krishna Engineering Works
191. Krishna Vehicals
192. Kuku Automotives
193. Lakshya Auto Sales Corporation
194. Launcher Material Handling Industries
195. Lawat Motors
196. Laxmi E Rickshaw Company
197. Lohia Auto Industries
198. M G Industries
199. M.K Enterprises
200. M2J E Vahan Pvt. Ltd
201. MAA Shakti Exim Pvt Ltd
202. Mac Auto India
203. Macneill Engineering Limited
204. Mahi Enterprises
205. Mahindra & Mahindra Ltd
206. Mali Enterprises
207. Manmohan Kaur
208. Mehar Dattey Group Motors Private Limited
209. Mini Metro EV LLP
210. MK Brothers
211. Mohan General Trading Company
212. Mondal Trading

Name of the Manufacturer
213. Motor and General Sales Private Limited
214. Mullick Three Whellers
215. Multi Dimensional Solutions
216. Nabh Motors Pvt Ltd
217. Nanya Airconn Pvt. Ltd
218. Naraindass and Sons
219. NB Turned Components Pvt. Ltd
220. Needle Eye Plastic Industries Pvt Ltd
221. New Arcana India
222. Nextstep Engineering (P)
223. Ngage Impex Pvt. Ltd.
224. NHD Motors
225. Nibe Motors Pvt Ltd.
226. Nipun Sanyantra Pvt. Ltd
227. Nirmal Utility Services Pvt
228. Nova Automotive Technologies Pvt. Ltd
229. OK Play India Ltd
230. Olympus Industries Private Limited
231. Om Balajee Automobile (India) Pvt. Ltd
232. OM Industries
233. Om Raj Autotech LLP
234. Omega Sales and Agro Industries
235. Original Fuel System Pvt. Ltd.
236. Pace Agro Pvt Ltd
237. Pansen Engineering India Private Limited

Name of the Manufacturer
238. Panther Electric Vehicles
239. Pari E - Vehicles
240. Pari Metro E Rickshaw
241. Parveen Auto
242. Pats Motor Corp
243. Plaudit Techno India Pvt Ltd
244. Praakram Auto & Construction Equipments
245. Prag Motors
246. Prakash Enterprises
247. Premier Esol Technologies
248. Prestantia Creations Private Limited
249. Pubang Etron Electric Motor Pvt. Ltd
250. Punjab Body Builders
251. Purva Udyog Pvt. Ltd.
252. PVR Petro Chemicals Pvt.
253. Pythox Motors Pvt. Ltd.
254. Qoogo Motors Private Limited
255. R3 Enterprises
256. Raccoon Motors Pvt. Ltd
257. Radha Raman Electric Vehicles
258. Rahul Agro Exports Pvt. Ltd.
259. Rajesh Steel & Wire Industries
260. Rajiv Raj Vehicle Pvt. Ltd
261. Ramon Industries
262. Rasandik Engineering Industries India Ltd
263. Rayon Engineers

Name of the Manufacturer
264. Riteset Industries
265. Riya Enterprise
266. S and J Industries
267. S N C Udyog
268. S. V. Automotive
269. S.P. Electronics
270. Saera Electric Auto Pvt. Ltd.
271. Saksham Tech Automobiles
272. Saksham Trading Company
273. Sanchal Automobiles Pvt.
274. SAS Motors Ltd
275. Sathi Motors Electric Vehicle Pvt. Ltd
276. Sauryaa Sharyo Corporation
277. SE Asia CO.
278. Sealion Automobile Pvt. Ltd.
279. Sen and Pandit Voltage Control Pvt. Ltd
280. Seth Industrial Corporation
281. Shakti Auto Green
282. Shine Metal Udyog Pvt Ltd (Unit II)
283. Shinme Electrical Vehicle Private Limited
284. Shiv Om India
285. Shree Siddhivinayak International
286. Shree Siridi Sai Mineral & Exports Pvt. Ltd
287. Shreya Engineers
288. Shri Namo Electric Automotive
289. Shri Ram Astral Motors Co

Name of the Manufacturer
290. Shri Ram Autotech Pvt. Ltd
291. Shriraj Electric Vehicles
292. Siarsa Electricals Private Limited
293. Simplex Electrical Engineering Pvt Ltd
294. Singhal Enterprises
295. Sirf India Vehicle Pvt. Ltd
296. Siwach Steel Pvt Ltd
297. Six Senses Automotive Pvt.
298. SKS Trade India Private Limited
299. Skyride Automotive
300. SN Solar Energy
301. Soni E Vehicle Pvt. Ltd
302. Speedways Electric
303. Speego Vehicles Company Pvt Ltd
304. SRD Renewables
305. Sritech Energy Pvt. Ltd
306. SSB Industries
307. Star Bull E Motors
308. Successpath Marketing Pvt. Ltd
309. Suganji Rara Electric Vehicles Pvt. Ltd
310. Sumfonl Auto Traders Pvt.
311. Sunglow Fab LLP
312. Sunshine Technologies
313. Sunultra Power Solutions Private Limited
314. Super Metro Industries
315. SuperEco Automotive Co. LLP

Name of the Manufacturer
316. Supertech Inc
317. Sutlej E-Motive LLP
318. Swadeshi Industries (India)
319. Swastik
320. Swastika Polymers Pvt. Ltd
321. Syndicate Auto Components
322. Taurus Electric Vehicles
323. Tejasgreen Automotive
324. Terra Motors India Pvt. Ltd
325. Thukral Electric Bikes Pvt.
326. Top Team Machines Pvt
327. Trishika Industries
328. Trupart Automotive India Pvt. Ltd.
329. Truz Industries
330. TSM Engineering Pvt. Ltd

Name of the Manufacturer
331. TSR Trade COM
332. Twashtre Automotive Private Limited
333. Twinkle Tradecom Private Limited
334. Two Friends Auto Electric Co.
335. U.P. Telelinks Ltd
336. UMA Motors
337. Unique Enterprises
338. Unique International
339. United Transmovers Pvt.
340. Universal Auto Enterprises
341. V. T. Engineering
342. Vani Electric Vehicles Pvt
343. Various Innovative
344. Veeto Automobiles
345. VGLAN Buildcon Private Limited
346. Victory Electric International

Name of the Manufacturer
347. Vinci Industrial Corporation
348. Vishwakarma GNG Industry
349. Vishwarup Enterprise
350. Volmac Engineering Pvt. Ltd
351. Vrinda Enterprises
352. VSL Industries
353. VVA Auto Industries Pvt.
354. Walkman Motors Pvt. Ltd
355. Welkin Healthcare Pvt. Ltd.
356. Wox Coolers Pvt. Ltd.
357. Xxplore Automotive Private Limited
358. Y C Electric Vehicle
359. Yuvraj International
360. Zeniak Innovation India Ltd

EXHIBIT 7

E-Rickshaw Models Certified by ICAT, Manesar, Haryana[78]

Name of the Manufacturer	Category	Model
1. 3S Industries	E-Rickshaw	BHARAT
2. A. K. Gupta & Co	E-Rickshaw	TUSKAR
3. A. V. Automotives Pvt. Ltd.	E-Rickshaw	Diamond SHAKTI
4. A3T Incorporated	E-Rickshaw	BIJALEE
5. Aadhya Enterprises	E-Rickshaw	JUGNOO
6. Aaditya Emotors India Pvt.	E-Rickshaw	DIXN
7. Aaditya Garbage Products Pvt Ltd	E-Rickshaw	E Aaditya
8. Aargee Electric	E-Rickshaw	MN-ONE
9. Accretion Power Autos	E-Rickshaw	ACCRETION Dx
10. Adapt Motors Pvt. Ltd.	E-Rickshaw	Sweekar
11. Adidev Technoa Pvt. Ltd	E-Rickshaw	BLESS
12. Aditya Sai Industries	E-Rickshaw	Suprio A-1
13. Aksmd Rechargeable Vehicles Pvt. Ltd	E-Rickshaw	LONG WAY
14. Allfine Industries Private	E-Rickshaw	AF-7
15. Allfine Industries Private	E-Rickshaw	AF-7 ECO
16. Altier Electric Vehicles Pvt. Ltd.	E-Rickshaw	RAJHANS
17. Altius Technologies	E-Rickshaw	BULBUL
18. Altius Technologies	E-Rickshaw	ALTIUS
19. Aman Electric Vehicles	E-Rickshaw	A STAR 900
20. Ambika Industries	E-Rickshaw	JAGRAN DLX
21. Anish Powertech Pvt. Ltd	E-Rickshaw	INDO CHEETAH
22. Anjali Auto Components	E-Rickshaw	POWERTECH-1850
23. Anjali Traders	E-Rickshaw	Musafir Eco
24. Ankush Auto Deals	E-Rickshaw	MAHARATHI
25. Aparna Industries	E-Rickshaw	SHREE SHAKTI
26. API Motors Pvt. Ltd	E-Rickshaw	API PUSHPAK
27. APM Auto Sales	E-Rickshaw	APM

[78] The International Centre for Automotive Technology (ICAT) is India's premier Homologation and Testing centre developed under NATRiP by Govt. of India. It is one of the agencies notified under CMV rule no 126 for issuance of "TYPE APPROVAL CERTIFICATE (TAC)" and "CONFORMITY OF PRODUCTION (COP) Certificate".
National Automotive Testing and R&D Infrastructure Project (NATRiP), is a joint initiative between the Government of India, a number of State Governments and Indian Automotive Industry to create a state of the art Testing, Validation and R&D infrastructure in the country. Other Testing Centres established under NATRIP are: GARC Chennai, NATRAX Indore, NIAIMT Silchar and VRDE Ahmednagar

Name of the Manufacturer	Category	Model
28. Apsara Enterprise	E-Rickshaw	V 15
29. Archit Enterprises	E-Rickshaw	TEZ
30. Arihant Enterprises	E-Rickshaw	SHUBH YATRA
31. Arman Green Vehicles	E-Rickshaw	JOYRIDE
32. Arna Electric Auto Pvt. Ltd	E-Rickshaw	ARNA 100
33. Arrow Automotive	E-Rickshaw	EV 11
34. Asha Tilak Ventures Pvt Ltd	E-Rickshaw	ARG ELECTRIC
35. Ashwa Electric	E-Rickshaw	ASHWA RATH
36. Asia Body Builders and Manufacturers	E-Rickshaw	AGWAN
37. Attolent Autogroup Pvt Ltd	E-Rickshaw	ATUT SHAKTI
38. Atul Auto Ltd	E-Rickshaw	ATUL Elite
39. Atut Sangam	E-Rickshaw	Atut Sangam DLX
40. Avl Electric Vehicles	E-Rickshaw	CAPTAIN
41. Avl Electric Vehicles	E-Rickshaw	CAPTAIN INDIA
42. AVL Electric Vehicles	E-Rickshaw	CAPTAIN POWER
43. AVON Cycles Ltd	E-Rickshaw	AVON E-Rick 306
44. AVON Cycles Ltd	E-Rickshaw	AVON E-Rick207
45. AVON Cycles Ltd	E-Rickshaw	GREENWAY
46. Axceed Industries (OPC) Pvt. Ltd.	E-Rickshaw	AX-SUPER
47. BABA E Vehicles	E-Rickshaw	BABA 800

Name of the Manufacturer	Category	Model
48. Baghwan Rikshaw Udyog	E-Rickshaw	BAGWAN
49. Bajaj Implements Private Limited	E-Rickshaw	RF-100
50. Bajaj Implements Private Limited	E-Rickshaw	RF-RANGER
51. Bal Gopal Wheels Private Limited	E-Rickshaw	E-ROJGAR
52. Bali Auto Industries	E-Rickshaw	Cheetah
53. Bareja Automotive	E-Rickshaw	BAREJA
54. Battery Rickshaw Sangh	E-Rickshaw	BRS 10 (Mayuri)
55. Battery Rickshaw Sangh	E-Rickshaw	BRS 20 (Yufang)
56. Bentinck Industries Private Limited	E-Rickshaw	INDIAN BUGGY
57. Bestway Agencies Pvt. Ltd	E-Rickshaw	ele
58. Bestway Agencies Pvt. Ltd	E-Rickshaw	ele 1000
59. Bestway Banarash	E-Rickshaw	VERDE O-R
60. Bharat Manufacturing & Assembling E Riksha	E-Rickshaw	ADARSH GOLD
61. Big Bull Trader Pvt. Ltd.	E-Rickshaw	B-1
62. Bijnor Enterprises	E-Rickshaw	JANTA

Name of the Manufacturer	Category	Model
63. Bright Autozone Pvt. Ltd	E-Rickshaw	CITY CAB
64. Bright Autozone Pvt. Ltd	E-Rickshaw	GARIB RATH
65. Caparo Autotech Ltd	E-Rickshaw	E-VAHAN
66. Caparo Autotech Ltd	E-Rickshaw	E-VAHAN Green
67. Caparo Autotech Ltd	E-Rickshaw	RAKSHAK
68. CART INDIA	E-Rickshaw	ENERGY MAX
69. CEEON INDIA	E-Rickshaw	EASY WAY-ERX
70. Champion Poly Plast	E-Rickshaw	SAARTHI
71. Champion Poly Plast	E-Rickshaw	Saarthi E Cab
72. Champion Poly Plast	E-Rickshaw	SAARTHI PLUS
73. Chandak E Automobiles LLP	E-Rickshaw	nunu
74. Charuvikram Automobile Pvt. Ltd	E-Rickshaw	e-YU
75. Charuvikram Automobile Pvt. Ltd	E-Rickshaw	e-YU 1.1
76. Chauhan Auto Industries	E-Rickshaw	VIRAAT
77. Chehak Batteries	E-Rickshaw	BABA
78. Chirag Enterprises	E-Rickshaw	GURU JI DLX
79. Chirag Enterprises	E-Rickshaw	BOBBY DLX
80. Citadel Enterprises (OPC) Private Limited	E-Rickshaw	SIYARA
81. Classic (India) Motors	E-Rickshaw	CIM CLASSIC INDIA

Name of the Manufacturer	Category	Model
82. Classic Engineers & Fabricators	E-Rickshaw	CLASSIC SUPER
83. CLH Gaseous Fuel Applications Pvt Ltd	E-Rickshaw	Green Rick
84. CLH Gaseous Fuel Applications Pvt Ltd	E-Rickshaw	Green Rick Super
85. Creative Engineering	E-Rickshaw	RUNNER
86. D S F Industries Pvt. Ltd	E-Rickshaw	DSF 1000 DLX
87. Dashmesh Traders	E-Rickshaw	SWARAN
88. Datang Evahaan Pvt. Ltd.	E-Rickshaw	ETO
89. DAVE EXIM (P) **LTD**	E-Rickshaw	NAHATA-PA
90. DD Auto Private Limited	E-Rickshaw	e-Rick1
91. DD Auto Private Limited	E-Rickshaw	e-Rick 1 Eco
92. Deep Drawn Technologies	E-Rickshaw	E-KRANTI
93. Delta Autocorp LLP	E-Rickshaw	STAR
94. Delta Autocorp LLP	E-Rickshaw	VISTA
95. Deltek Enterprises Pvt Ltd	E-Rickshaw	YUGO
96. Deltek Enterprises Pvt. Ltd	E-Rickshaw	DDIXN
97. Desmoto Electrics Pvt. Ltd.	E-Rickshaw	ANDAAZ
98. Dhar International	E-Rickshaw	BHALO DI-125

Name of the Manufacturer	Category	Model
99. Dhatri Infrastructure Pvt.	E-Rickshaw	GREEN GO K5
100. Diamond E Vehicles	E-Rickshaw	Diamond E-Smart
101. Dilli Electric Auto Pvt. Ltd	E-Rickshaw	CITY LIFE ECO CAB
102. Dilli Electric Auto Pvt. Ltd	E-Rickshaw	City Life XV-850
103. Dilli Electric Auto Pvt. Ltd	E-Rickshaw	CITYLIFE E-FORCE
104. Divansu Automobiles Ltd	E-Rickshaw	PARAS ECO
105. Divya Automobiles	E-Rickshaw	KOBRA
106. Divya Enterprises	E-Rickshaw	TURBO SMART
107. Diwa Green Technology Private Limited	E-Rickshaw	DIWA
108. Duke Auto India	E-Rickshaw	DUKE AUTO
109. Duke Auto India	E-Rickshaw	TYSONN DELUXE
110. Dukemoto Motors Pvt. Ltd	E-Rickshaw	DUKEMOTO
111. Durable Flanges Pvt. Ltd	E-Rickshaw	MY RIDE
112. Dynavolt Technology (India) Limited	E-Rickshaw	Hohomer Knight MK-2
113. DYS Impex Pvt Ltd	E-Rickshaw	BASANTEE SONAR BANGLA
114. DYS Impex Pvt Ltd	E-Rickshaw	BASANTEE ECO DRIVE
115. E Guru Auto Energy	E-Rickshaw	SHIV SHAKTI

Name of the Manufacturer	Category	Model
116. E Xtra Fast Solution	E-Rickshaw	Extra Fast
117. E-Ashwa Automotive Private Limited	E-Rickshaw	e-riksa1
118. Eco Smart Vehicles Pvt. Ltd.	E-Rickshaw	ECO SMART
119. Eco-Friendly Electric Vehicle Pvt. Ltd.	E-Rickshaw	EVE
120. Ecogreen Hi-Tech Products	E-Rickshaw	BHAWAK
121. Edmrc Mannschaft LLP	E-Rickshaw	YUVA
122. Electra International	E-Rickshaw	ELECTRA
123. Electreca Vehicles	E-Rickshaw	SAWARE
124. Electreca Vehicles	E-Rickshaw	SAWARE SUPREME
125. Electrotherm India Ltd	E-Rickshaw	E-TAXE
126. Elephanta Industries Pvt.	E-Rickshaw	Elephanta
127. Elite Auto Engineers Pvt Ltd	E-Rickshaw	GARUD
128. E-Motion Automotive Industry LLP	E-Rickshaw	E-Vahini
129. Energy Electric Vehicles	E-Rickshaw	UDAAN
130. Enigma Automobiles Pvt. Ltd.	E-Rickshaw	MARUT
131. Epower Vehicles Pvt. Ltd	E-Rickshaw	POWER 1000

Name of the Manufacturer	Category	Model
132. Eusi Motors Pvt. Ltd	E-Rickshaw	EURASIA
133. EVEX India	E-Rickshaw	RANGER
134. Five Elements	E-Rickshaw	HANS
135. G & G Automotive	E-Rickshaw	THOR
136. G & G Automotive	E-Rickshaw	SHAHENSHAH
137. G K Rickshaw	E-Rickshaw	ER India G-7
138. G- Kon Electric Motor	E-Rickshaw	VEER
139. G Williams Fabrications Ltd	E-Rickshaw	GWF SILVER
140. Gauri Auto India Pvt Ltd	E-Rickshaw	E-GARUD PASSENGER
141. Gayam Motor Works Pvt.	E-Rickshaw	SMART URBAN
142. Gayatri Electric Vehicles	E-Rickshaw	DABANG
143. General Agencies	E-Rickshaw	PANTHER GOLD
144. Geo Alliance	E-Rickshaw	GEO GREEN
145. Gobind Industries (P) Ltd.	E-Rickshaw	MY CAB
146. Godawari Techno Solutions Pvt Ltd.	E-Rickshaw	G-ONE
147. Goenka Electric Motor Vehicles Pvt. Ltd	E-Rickshaw	PRINCE
148. Goenka Electric	E-Rickshaw	PRINCE TURBO

Name of the Manufacturer	Category	Model
Motor Vehicles Pvt. Ltd		
149. Goenka Electric Motor Vehicles Pvt. Ltd	E-Rickshaw	Queen
150. Goodenergy India	E-Rickshaw	E-BIRD
151. Goodwill HI Precision Works Pvt Ltd	E-Rickshaw	G9000
152. Goodwill HI Precision Works Pvt Ltd	E-Rickshaw	Queen Deluxe
153. Gram Tarang	E-Rickshaw	STAG
154. GRD Motors	E-Rickshaw	DAVRATH
155. Green Fuel Alternatives Pvt Ltd	E-Rickshaw	EKO TEJAS
156. Green Impex	E-Rickshaw	Galaxy
157. Green Kaiketsu Automotive India Pvt. Ltd	E-Rickshaw	VAAYU
158. Green Star Motors	E-Rickshaw	GREEN STAR
159. Green Technologies	E-Rickshaw	BAAZ
160. Green Technologies Namah Industries Pvt. Ltd.	E-Rickshaw	SWASTIK
161. Green Valley Motors	E-Rickshaw	GVM PREMIUM
162. Green Way Eco Ride	E-Rickshaw	RHINO
163. Green Wheelz (India)	E-Rickshaw	INTERCITY

Name of the Manufacturer	Category	Model
164. Greenwheels Automobile Pvt. Ltd	E-Rickshaw	E-RANGER
165. Greenworld Motors Pvt. Ltd.	E-Rickshaw	E CAB 0933
166. Greenworld Motors Pvt. Ltd.	E-Rickshaw	e-cab
167. GRG Smart Vehicle Pvt. Ltd	E-Rickshaw	GOWEL ER+
168. GRG Smart Vehicle Pvt. Ltd.	E-Rickshaw	GOWEL ECO
169. Gurukirpa Industries	E-Rickshaw	E-HAWK
170. H.D. Automotives	E-Rickshaw	Savari Pro
171. Haarish Automotives (OPC) Pvt. Ltd.	E-Rickshaw	eSAFAR
172. Hanuman Udyog	E-Rickshaw	PRAGTI
173. Harsh Trading Company	E-Rickshaw	NAVRANG
174. Hero Electric Vehicles Pvt. Ltd.	E-Rickshaw	RAAHII+
175. Him Teknoforge Ltd	E-Rickshaw	KAG CHEETAH SUPER PREMIUM LX
176. Hindustan Motor Corporation	E-Rickshaw	e-maggic
177. HI-TECH Industries	E-Rickshaw	HI-TECH
178. Hitech Mechanical Works	E-Rickshaw	UTTAM

Name of the Manufacturer	Category	Model
179. Hitech Mechanical Works	E-Rickshaw	UTTAM DLX
180. HITEK Electric Auto Co.	E-Rickshaw	e-RAJDOOT
181. Hooghly Motors Pvt. Ltd	E-Rickshaw	BUTTERFLY
182. HOP Motors Pvt. Ltd	E-Rickshaw	HOP 900
183. Hotage Corporation India	E-Rickshaw	BADSHAH
184. Hovel Cylinder Pvt. Ltd	E-Rickshaw	HOVEL
185. Hundal Industries	E-Rickshaw	SAMRATH
186. I – Moto Greens Pvt. Ltd.	E-Rickshaw	Belleza
187. Indian Motors	E-Rickshaw	Rocket
188. J.S. Auto (Pvt) Ltd	E-Rickshaw	JSA E Rickshaw
189. Jade Korea Spine Life	E-Rickshaw	SMART
190. Jaidka Power Systems Pvt.	E-Rickshaw	ARJUN DLX
191. Jaidka Power Systems Pvt. Ltd.	E-Rickshaw	ARJUN
192. Jajodia Commodities Pvt	E-Rickshaw	SODYCO EXPRESS
193. Jajodia Exports Pvt. Ltd	E-Rickshaw	SODYCO
194. JAL Enterprises	E-Rickshaw	Passenger
195. Jay Ace Technologies Ltd	E-Rickshaw	JAY

Name of the Manufacturer	Category	Model
196. Jay Ace Technologies Ltd	E-Rickshaw	JAY VX
197. Jaydev Enterprise	E-Rickshaw	JAYDEV
198. Jemco Engineering Pvt. Ltd.	E-Rickshaw	JEMCO
199. Jessun Techno Private Limited	E-Rickshaw	JESSUN
200. JHL Motors Pvt. Ltd	E-Rickshaw	JHL-Falcon
201. JIJO Electric wheels pvt	E-Rickshaw	AutoPark Charlee Deer
202. Jindal Electric Vehicles	E-Rickshaw	JINDAL
203. Jitendra New EV Tech Pvt.	E-Rickshaw	JET 650
204. Jitendra Tempo Parts	E-Rickshaw	UMANG
205. JS Mobileon Private Limited	E-Rickshaw	e–JS1000
206. JSS Engineering Company	E-Rickshaw	JMJ PATHER SATHI
207. Juno Castings Pvt. Ltd	E-Rickshaw	e-KutKut Rikki
208. JVC Bharat	E-Rickshaw	CITY LIFE SYN01
209. K T Enterprises	E-Rickshaw	KT E-Vahan Smart
210. K. V. Industries	E-Rickshaw	DIGITAL
211. KABMAX Electric Automobiles Pvt. Ltd	E-Rickshaw	JANRATH
212. Kalika Vahan Private Limited	E-Rickshaw	KALIKA RAINBOW
213. Kalpvriksh Electromobiles	E-Rickshaw	ELECTRIKO
214. Kamaz Industries.	E-Rickshaw	Zikroma
215. Kanha Electric Vehicles	E-Rickshaw	E-RAFTAAR
216. Kaptech India	E-Rickshaw	AUTO EVX
217. Kaptech India	E-Rickshaw	PRATHAM ERX
218. Kaptech India	E-Rickshaw	PRIME
219. KGN Industries	E-Rickshaw	DANGAL A-ONE
220. Khalsa Agencies	E-Rickshaw	KHALSA
221. Khemraj Automotive	E-Rickshaw	KHANAK
222. Kirti Solar Ltd	E-Rickshaw	ELECTECA ECO
223. Kirti Solar Ltd	E-Rickshaw	Electeca PRIME
224. KLB Komaki Private Limited	E-Rickshaw	KOMAKI
225. Knight Queen Industries Pvt. Ltd.	E-Rickshaw	SHAURYA ER-005
226. Kranti International	E-Rickshaw	ECOREAN MARK-1
227. Krishna Engineering Works	E-Rickshaw	Ashvashakti
228. Krishna Vehicals	E-Rickshaw	DOLPHIN
229. Kuku Automotives	E-Rickshaw	KUKU Greens

Name of the Manufacturer	Category	Model
230. Kuku Automotives	E-Rickshaw	MARS
231. Kuku Automotives	E-Rickshaw	VICTORIA
232. Lakshya Auto Sales Corporation	E-Rickshaw	LAKSHYA
233. Launcher Material Handling Industries	E-Rickshaw	LAUNCHER ERICKSHAW
234. Lawat Motors	E-Rickshaw	MARCO
235. Laxmi E Rickshaw Company	E-Rickshaw	NANDI
236. Limited	E-Rickshaw	CARRAVA
237. Lohia Auto Industries	E-Rickshaw	Comfort
238. Lohia Auto Industries	E-Rickshaw	COMFORT F2F
239. Lohia Auto Industries	E-Rickshaw	COMFORT F2F LI
240. Lohia Auto Industries	E-Rickshaw	Humrahi
241. M G Industries	E-Rickshaw	TEJAS
242. M.K Enterprises	E-Rickshaw	SAGUN
243. M.K Enterprises	E-Rickshaw	SAGUN SDLX
244. M2J E Vahan Pvt. Ltd	E-Rickshaw	M2J
245. MAA Shakti Exim Pvt Ltd	E-Rickshaw	SAARTHAK
246. Mac Auto India	E-Rickshaw	MAC 900
247. Macneill Engineering Limited	E-Rickshaw	MACNEILL
248. Mahi Enterprises	E-Rickshaw	MAHI POWER
249. Mahindra & Mahindra Ltd	E-Rickshaw	Mahindra e-Alfa Mini
250. Mali Enterprises	E-Rickshaw	e parivahan
251. Manmohan Kaur	E-Rickshaw	ABHIRAAJ
252. Mehar Dattey Group Motors Private Limited	E-Rickshaw	ABBI-R
253. Mini Metro EV LLP	E-Rickshaw	Mini Metro
254. Mini Metro EV LLP	E-Rickshaw	Mini Metro V2
255. MK Brothers	E-Rickshaw	MKB MOTORS
256. Mohan General Trading Company	E-Rickshaw	E-RAHI
257. Mondal Trading	E-Rickshaw	FIREFOX XM
258. Motor and General Sales Private Limited	E-Rickshaw	DHOOM
259. Mullick Three Whellers	E-Rickshaw	MTW
260. Multi Dimensional Solutions	E-Rickshaw	UNIRICK
261. Nabh Motors Pvt Ltd	E-Rickshaw	e-Yuga
262. Nanya Airconn Pvt. Ltd	E-Rickshaw	SAWAARI TREND
263. Naraindass and Sons	E-Rickshaw	VASUDEV-A1
264. NB Turned	E-Rickshaw	CHANDNI

Name of the Manufacturer	Category	Model
Components Pvt. Ltd		
265. Needle Eye Plastic Industries Pvt Ltd	E-Rickshaw	ESTAR – ECAB
266. New Arcana India	E-Rickshaw	BYBY
267. Nextstep Engineering (P)	E-Rickshaw	e-Rocket-Shuttle
268. Ngage Impex Pvt. Ltd.	E-Rickshaw	LIVGUARD BATTERIES PVT. LTD
269. NHD Motors	E-Rickshaw	NHD SUPER
270. Nibe Motors Pvt Ltd.	E-Rickshaw	SAHASTRA
271. Nipun Sanyantra Pvt. Ltd	E-Rickshaw	E-VAHAAN
272. Nirmal Utility Services Pvt	E-Rickshaw	TOOKTOOK
273. Nova Automotive Technologies Pvt. Ltd	E-Rickshaw	NOVA SUPREME
274. OK Play India Ltd	E-Rickshaw	E-RAAJA
275. Olympus Industries Private Limited	E-Rickshaw	SAFAR
276. Om Balajee Automobile (India) Pvt. Ltd	E-Rickshaw	DMW
277. OM Industries	E-Rickshaw	ECO WHEELS
278. Om Industries	E-Rickshaw	PRAKASH
279. Om Raj Autotech LLP	E-Rickshaw	SUVIDHA

Name of the Manufacturer	Category	Model
280. Omega Sales and Agro Industries	E-Rickshaw	OMEGA SUPER
281. Original Fuel System Pvt. Ltd.	E-Rickshaw	UNIX 1000
282. Pace Agro Pvt Ltd	E-Rickshaw	PACE STAR
283. Pansen Engineering India Private Limited	E-Rickshaw	MILEAGE KING
284. Panther Electric Vehicles	E-Rickshaw	e-PANTHER
285. Pari E - Vehicles	E-Rickshaw	PARI
286. Pari Metro E Rickshaw	E-Rickshaw	E-TIGER
287. Parveen Auto	E-Rickshaw	USTAD
288. Pats Motor Corp	E-Rickshaw	Flamingo
289. Plaudit Techno India Pvt Ltd	E-Rickshaw	PLAUDIT 100
290. Praakram Auto & Construction Equipments	E-Rickshaw	DAMINI DXI
291. PRAG MOTORS	E-Rickshaw	PRAG
292. Prakash Enterprises	E-Rickshaw	PRAKASH-LKO
293. Premier Esol Technologies	E-Rickshaw	ESOL
294. Prestantia Creations Private Limited	E-Rickshaw	PRESTA AP
295. Pubang Etron Electric Motor Pvt. Ltd	E-Rickshaw	ATOM

Name of the Manufacturer	Category	Model
296. Pubang Etron Electric Motor Pvt. Ltd	E-Rickshaw	SMART V
297. Pubang Etron Electric Motor Pvt. Ltd.	E-Rickshaw	JADE
298. Punjab Body Builders	E-Rickshaw	HVL
299. Purva Udyog Pvt. Ltd.	E-Rickshaw	e-PURVA
300. PVR Petro Chemicals Pvt.	E-Rickshaw	PVR VICTORIA
301. Pythox Motors Pvt. Ltd.	E-Rickshaw	PYTHON
302. Qoogo Motors Private Limited	E-Rickshaw	Q1
303. R3 Enterprises	E-Rickshaw	PHOENIX
304. Raccoon Motors Pvt. Ltd	E-Rickshaw	RE-7
305. Radha Raman Electric Vehicles	E-Rickshaw	Bahubali
306. Rahul Agro Exports Pvt. Ltd.	E-Rickshaw	e Yatra
307. Rajesh Steel & Wire Industries	E-Rickshaw	BAAJ P200
308. Rajesh Steel & Wire Industries	E-Rickshaw	BAJORIA EV-P280
309. Rajiv Raj Vehicle Pvt. Ltd	E-Rickshaw	RVR-BULBUL
310. Ramon Industries	E-Rickshaw	MONU SONU
311. Ramon Industries	E-Rickshaw	RM-1000

Name of the Manufacturer	Category	Model
312. Rasandik Engineering Industries India Ltd	E-Rickshaw	SAMRAT Chief-R02
313. Rayon Engineers	E-Rickshaw	ROCKY
314. Riteset Industries	E-Rickshaw	VIHARI
315. Riya Enterprise	E-Rickshaw	RE007
316. S and J Industries	E-Rickshaw	SONA CHANDI
317. S N C Udyog	E-Rickshaw	SNC
318. S. V. Automotive	E-Rickshaw	SUPPER
319. S.P. Electronics	E-Rickshaw	ELECTRON
320. Saera Electric Auto Pvt. Ltd.	E-Rickshaw	MAYURI DELUX
321. Saera Electric Auto Pvt. Ltd.	E-Rickshaw	MAYURI PRO
322. Saksham Tech Automobiles	E-Rickshaw	ActivA
323. Saksham Trading Company	E-Rickshaw	SAKSHAM E20
324. Saksham Trading Company	E-Rickshaw	SAKSHAM E10
325. Saksham Trading Company	E-Rickshaw	SAKSHAM E20
326. Sanchal Automobiles Pvt.	E-Rickshaw	GATIMAN
327. SAS Motors Ltd	E-Rickshaw	ANGAD eBuggy
328. Sathi Motors Electric Vehicle Pvt. Ltd	E-Rickshaw	E'SATHI

Name of the Manufacturer	Category	Model
329. Sauryaa Sharyo Corporation	E-Rickshaw	exito
330. Sauryaa Sharyo Corporation	E-Rickshaw	EXITO CUATRO
331. Sauryaa Sharyo Corporation	E-Rickshaw	EXITO CUATRO
332. SE Asia CO.	E-Rickshaw	SMART ASIA
333. Sealion Automobile Pvt. Ltd.	E-Rickshaw	7 STAR
334. Sen and Pandit Voltage Control Pvt. Ltd	E-Rickshaw	UMEED
335. Seth Industrial Corporation	E-Rickshaw	neelam DEXTER
336. Shakti Auto Green	E-Rickshaw	SHAKTI GREEN
337. Shine Metal Udyog Pvt Ltd (Unit II)	E-Rickshaw	Sunshine
338. ShineIMetal Udyog Pvt. Ltd	E-Rickshaw	SUNSHINE DELUXE
339. Shinme Electrical Vehicle Private Limited	E-Rickshaw	VIJETA
340. Shiv Om India	E-Rickshaw	SANWRA
341. Shiv Om India	E-Rickshaw	TARA
342. Shree Siddhivinayak International	E-Rickshaw	CHIRPY 100
343. Shree Siridi Sai Mineral & Exports Pvt. Ltd	E-Rickshaw	RR1

Name of the Manufacturer	Category	Model
344. Shreya Engineers	E-Rickshaw	SHREYA
345. Shri Namo Electric Automotive	E-Rickshaw	EWA ECO FRIENDLY
346. Shri Namo Electric Automotive	E-Rickshaw	EWA–G7
347. Shri Ram Astral Motors Co	E-Rickshaw	JAPANESE METRO
348. Shri Ram Autotech Pvt. Ltd	E-Rickshaw	DLX ADVANCE
349. Shri Ram Autotech Pvt. Ltd	E-Rickshaw	Jangid Deluxe
350. Shri Ram Autotech Pvt. Ltd.	E-Rickshaw	DLX PRIME
351. Shriraj Electric Vehicles	E-Rickshaw	ELEPHANT
352. Siarsa Electricals Private Limited	E-Rickshaw	AMAAN
353. Simplex Electrical Engineering Pvt Ltd	E-Rickshaw	ZENITH GOLD
354. Singhal Enterprises	E-Rickshaw	MAGNUM
355. Sirf India Vehicle Pvt. Ltd	E-Rickshaw	LALA
356. Siwach Steel Pvt Ltd	E-Rickshaw	Shakti Auto Deluxe
357. Six Senses Automotive Pvt.	E-Rickshaw	TANNU
358. SKS Trade India Private Limited	E-Rickshaw	Arzoo DLX
359. Skyride Automotive	E-Rickshaw	SKYRIDE ERN

Name of the Manufacturer	Category	Model
360. SN Solar Energy	E-Rickshaw	SN ELLECTRICO
361. Soni E Vehicle Pvt. Ltd	E-Rickshaw	SONI
362. Speedways Electric	E-Rickshaw	MUSAFIR
363. Speego Vehicles Company Pvt Ltd	E-Rickshaw	SPEEGO
364. SRD Renewables	E-Rickshaw	SRD
365. Sritech Energy Pvt. Ltd	E-Rickshaw	Sritech Anjana
366. SSB Industries	E-Rickshaw	BHAVI
367. Star Bull E Motors	E-Rickshaw	STAR BULL
368. Successpath Marketing Pvt. Ltd	E-Rickshaw	Shikara
369. Suganji Rara Electric Vehicles Pvt. Ltd	E-Rickshaw	Rainbow
370. Sumfonl Auto Traders Pvt.	E-Rickshaw	WB01
371. Sunglow Fab LLP	E-Rickshaw	Marshal
372. Sunshine Technologies	E-Rickshaw	SURYA
373. Sunultra Power Solutions Private Limited	E-Rickshaw	SU-5000
374. Super Metro Industries	E-Rickshaw	SUPER 100
375. SuperEco Automotive Co. LLP	E-Rickshaw	TUM TUM

Name of the Manufacturer	Category	Model
376. Supertech Inc	E-Rickshaw	PILOT
377. Sutlej E-Motive LLP	E-Rickshaw	4-Leaf
378. Swadeshi Industries (India)	E-Rickshaw	Swadeshi
379. Swastik	E-Rickshaw	INDIAN
380. Swastika Polymers Pvt. Ltd	E-Rickshaw	URBAN RIDE
381. Syndicate Auto Components	E-Rickshaw	SYNDICATE
382. Taurus Electric Vehicles	E-Rickshaw	TOOFAN
383. Tejasgreen Automotive	E-Rickshaw	ABHIRATH
384. Terra Motors India Pvt. Ltd	E-Rickshaw	TERRA X1
385. Terra Motors India Pvt. Ltd	E-Rickshaw	Y4A
386. Thukral Electric Bikes Pvt.	E-Rickshaw	THUKRAL Er1
387. Thukral Electric Bikes Pvt.	E-Rickshaw	THUKRAL™ DLX
388. Thukral Electric Bikes Pvt.	E-Rickshaw	THUKRAL™ DLX Li
389. Top Team Machines Pvt	E-Rickshaw	HAWA HAWAI
390. Top Team Machines Pvt	E-Rickshaw	HAWA HAWAI XL
391. Top Team Machines Pvt Ltd	E-Rickshaw	SANGAM AUTO
392. Top Team Machines Pvt. Ltd.	E-Rickshaw	RAJEEV AUTO
393. Trishika Industries	E-Rickshaw	KAIZEN M10

Name of the Manufacturer	Category	Model
394. Trupart Automotive India Pvt. Ltd.	E-Rickshaw	NANAK
395. Truz Industries	E-Rickshaw	TRUZ DLX
396. TSM Engineering Pvt. Ltd	E-Rickshaw	BAGGI
397. TSR Trade COM	E-Rickshaw	BOLT
398. Twashtre Automotive Private Limited	E-Rickshaw	OTTO
399. Twinkle Tradecom Private Limited	E-Rickshaw	ANANT
400. Two Friends Auto Electric Co.	E-Rickshaw	SAH YATRI
401. U.P. Telelinks Ltd	E-Rickshaw	Singham
402. U.P. Telelinks Ltd	E-Rickshaw	Singham Cargo
403. UMA Motors	E-Rickshaw	TARZAN
404. Unique Enterprises	E-Rickshaw	RIHAN
405. Unique International	E-Rickshaw	Panther
406. United Transmovers Pvt.	E-Rickshaw	VARDAAN
407. Universal Auto Enterprises	E-Rickshaw	ULTRA
408. V. T. Engineering	E-Rickshaw	JAISWAL
409. Vani Electric Vehicles Pvt	E-Rickshaw	J1000
410. Various Innovative	E-Rickshaw	BHARAT VIDYUT BV1
411. Veeto Automobiles	E-Rickshaw	ODDY S-7

Name of the Manufacturer	Category	Model
412. VGLAN Buildcon Private Limited	E-Rickshaw	V CART
413. Victory Electric International	E-Rickshaw	VICTORY
414. Victory Electric International	E-Rickshaw	VICTORY SUMFONL
415. Victory Electric International	E-Rickshaw	VICTORY VIJETA
416. Vinci Industrial Corporation	E-Rickshaw	E MUDIT
417. Vishwakarma GNG Industry	E-Rickshaw	SULTAN
418. Vishwarup Enterprise	E-Rickshaw	HAANS
419. Volmac Engineering Pvt. Ltd	E-Rickshaw	TIGER
420. Vrinda Enterprises	E-Rickshaw	BATRICK
421. VSL Industries	E-Rickshaw	YATHARA
422. VVA Auto Industries Pvt.	E-Rickshaw	JUNO
423. Walkman Motors Pvt. Ltd	E-Rickshaw	Walkman
424. Welkin Healthcare Pvt. Ltd.	E-Rickshaw	E RATH
425. Wox Coolers Pvt. Ltd.	E-Rickshaw	SIMBA
426. Xxplore Automotive Private Limited	E-Rickshaw	XX
427. Y C Electric Vehicle	E-Rickshaw	e Chetak

Name of the Manufacturer	Category	Model
428. Y C Electric Vehicle	E-Rickshaw	YATRI
429. Y C Electric Vehicle	E-Rickshaw	YATRI DLX
430. Yuvraj International	E-Rickshaw	YUVRAJ
431. Zeniak Innovation India Ltd	E-Rickshaw	INDO WAGEN Q8
432. Zeniak Innovation India Ltd	E-Rickshaw	INDO WAGEN Z1
433. Zeniak Innovation India Ltd	E-Rickshaw	INDO WAGEN Z8

EXHIBIT 8

SMEV MEMBERS

The SOCIETY OF MANUFACTURERS OF ELECTRIC VEHICLES (SMEV)

Organization	Manufacturer Profile
Ajanta Manufacturing Ltd. (E-Bike Division)	EV-2W
Ather Energy	EV-2W
Avan Motors Pvt ltd	EV-2W
EV Techo Electra Motors Pvt Ltd	EV-2W
Lectro E-mobility Pvt. Ltd.	EV-2W
Micromax Electric Pvt Ltd.	EV-2W
NDS Eco Motors Private Limited	EV-2W
Okinawa Autotech Pvt Ltd	EV-2W
Tork Motors Pvt Ltd	EV-2W
Tunwal Electronics	EV-2W
Velev Motors India Pvt Ltd	EV-2W
Ampere Vehicles Private Ltd.	EV-2W/3W
Champion Poly Plast	EV-2W/3W
Etron Electric Motor Pvt Ltd	EV-2W/3W
J S Auto Pvt Ltd	EV-2W/3W
Jitendra new EV tech pvt ltd.	EV-2W/3W
Kinetic Green Energy & Power Solutions	EV-2W/3W
Lohia Auto Industries	EV-2W/3W
Mirakle-5 Automobiles pvt ltd	EV-2W/3W
Piaggio Vehicles Pvt Ltd	EV-2W/3W
Shema E-Vehicle & Solar Pvt. Ltd	EV-2W/3W
SuperEco Automotive	EV-2W/3W
Terra Motors India Pvt. Ltd	EV-2W/3W
YC Electric Vehicle	EV-2W/3W
Electrie-One Auto Pvt Ltd	EV-2W/3W/4W
Smart Dreams Pvt Ltd	EV-2W/4W/Buses
Atul Auto Limited	EV-3W/4W
Pixy Electric Cars Pvt Ltd	EV-4W

Organization	Manufacturer Profile
ACME Cleantech Solutions Private Limited	EV-Component
Advance Cable Technologies (P) Ltd	EV-Component
Bharat Petroleum Corporation Limited	EV-Component
Delta Electronics (India) Pvt. Ltd.	EV-Component
Elektrisola India Pvt Ltd	EV-Component
Fusion Power System	EV-Component
Global Powersource India Pvt. Ltd	EV-Component
Greenfuel Energy Solution Pvt Ltd	EV-Component
Henkel Adhesives Technologies India Pvt Ltd	EV-Component
Kabra Extrusiontechnik Limited	EV-Component
LORD India Pvt. Ltd	EV-Component
LPS Bossard Pvt Ltd	EV-Component
Lucas-TVS Limited	EV-Component
Marsilli India Pvt. Ltd.	EV-Component
Napino Auto & Electronics Ltd	EV-Component
Nitto Denko India Private Limited	EV-Component
PPAP Automotive Ltd	EV-Component
Roots Industries India Limited	EV-Component
Schaltbau India Pvt Ltd.	EV-Component
SEG Automotive India Private Limited	EV-Component
Sehgal Elmoto Ltd.	EV-Component
Sunbeam Auto Pvt Ltd	EV-Component
Sundram fasteners ltd.	EV-Component
Trinity Energy Systems (P) Ltd	EV-Component
Trontek Group	EV-Component
Versatile Auto Components Private Limited	EV-Component
BASF Catalysts India Pvt. Limited	EV-Component
Bosch Group of companies	EV-Component
Exicom Tele-Systems Ltd	EV-Component
GAIL (India) Ltd	EV-Component

Organization	Manufacturer Profile
Greaves Cotton Limited	EV-Component
Infineon Technologies India Pvt. Ltd	EV-Component
Minda Corporation Ltd	EV-Component
Okaya Power	EV-Component
Shigan Evoltz Ltd	EV-Component
Tata Chemicals Ltd	EV-Component

Associations /Institutions Members		
S.NO	**Organization**	**Manufacturer Profile**
1	International Copper Association India	Copper Alliance
2	University of Petroleum and Energy Studies (UPES)	Institution
3	Federation of Automobile Dealers Associations (FADA)	Association
4	Centre for Battery Engineering and Electric Vehicles- IIT- Madras	Institution
5	The Energy and Resources Institute	Institution