Understanding Investment, Trade, and Battery Waste Management Linkages for a Globally Competitive Ev Manufacturing Sector

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FOREWORD

Creating a globally competitive electric vehicle manufacturing sector is India's response to translating the climate crisis into a growth opportunity. The impact of the changing climate is profound, as it affects the lives of thousands around the globe. A critical step towards fighting such an imperative problem is by decreasing emission in one of the largest emitting sectors, i.e., transportation. In this regard, the introduction of Electric Vehicles (EVs) is a boon for the transportation sector. Currently, India has implemented many policies to accelerate the adoption of EVs. Some of these policies include Faster Adoption and Manufacturing of Electric Vehicles (FAME) I & II, Production Linked Incentive (PLI) Scheme for the manufacturing of Advanced Chemistry Cell, etc. These policies form the centrepiece of India's commitment to decarbonising its transportation sector, showcasing its commitment of mitigating global climate change.

It, therefore, gives us great pleasure to introduce our readers to the report on ***Understanding Investment, Trade, and Battery Waste Management Linkages for a Globally Competitive EV Manufacturing Sector***, a joint production between the Indian Council for Research on International Economic Relations (ICRIER) and the International Institute of Sustainable Development (IISD). The report makes an attempt to comprehend various challenges in trade, investment and battery waste management of EVs in India and identifies diverse solutions to aid India's EV transition. This summary captures, in brief, the major findings of the larger study aimed towards policy makers, and technology enablers.

It discusses detailed stylized facts on trade and tariffs of goods involved in the EV value-chain as well as on investment, addressing regulatory barriers to trade and investment in the EV value-chain and identifying key barriers such as charging infrastructure, supply chain concerns, and skill gaps. At the same time, deliberating on the far end of the EV value chain, the results also focus explicitly on the effective management of EV battery waste. The three critical pillars for battery waste management i.e., technology, employment opportunities, policy and regulations are discussed in detail to draw attention to the crucial role the battery waste sector can play in the economy. Both ICRIER and IISD are committed to playing a constructive part in this transition towards a cleaner economy by providing bold and crucial inputs on the platform of greener policies discussion.

This report is a necessity towards understanding the current EV landscape. It helps to fill in the crucial gap of information to ensure an effective framework in place, to then aid the process of making informed decisions for efficient policymaking. We would like to commend the report's authors for putting this summary version together in the current format. At the same time, we would also like to express our gratitude towards the stakeholders who have generously contributed to the report.

Sincerely,

Deepak Mishra
Director and CE
ICRIER

Peter Wooders
Senior Director, Energy
IISD

Acknowledgement

This report is the result of multi-level consultations with several stakeholders without whom it would have been a difficult task to complete and compile our results. We would like to acknowledge the inputs provided by these stakeholders and their immense contribution in making this report a reality.

We would also like to thank Dr Deepak Mishra, *Director and CE, ICRIER and Mr. Peter Wooders, Senior Director, Energy, IISD* who inspired, encouraged, and motivated the team in the entirety of this project. We are thankful to the administrative and events team at ICRIER and IISD for their unfailing support with logistics, event management, organisation, and other associated tasks. We would like to acknowledge the pivotal role played by our knowledge partners, Shakti Sustainable Energy Foundation, for helping us throughout the journey with their keen insights, active networks, and overall guidance.

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Introduction

The Indian automobile industry is expected to be the third largest globally by 2030; during FY 2018-19, it contributed 7.1 per cent of India's GDP and employed more than 37 million people (Department of Heavy Industry, Government of India, 2019). The government provided an extra policy push to ensure the accelerated and sustained growth of the automobile industry under its Automotive Mission Plan (AMP) 2006-2016, followed by an updated plan for the period of 2016-26 (AMP 2016-26) launched in 2015. It aimed to 'propel the Indian Automotive industry to be the engine of the "Make in India" programme' as well as increase the net exports of the industry (SIAM, 2016).

Along with AMP 2006-16, the 'National Electric Mobility Mission Plan (NEMMP) 2020' was launched in 2012 due to high demand for environmentally friendly vehicles. It was the first policy support to electric vehicles (EVs) in India and targeted the deployment of around 2-3 million EVs in the country by 2020. This involved specific incentives to encourage investment in and manufacture of EVs. AMP 2016-26 too focuses on technologies in EV manufacturing (EM) and related network needs. This is because the dynamics of mobility in the country is expected to change dramatically as old systems of mobility and infrastructure may not suffice to meet the requirements of the growing population and changing environment. Thus, India is looking to actively pursue EVs under its transformative mobility initiative, which will help reduce its dependence on imported crude oil and ensure a greener future (Innovation Norway, 2018).

At the global level, several countries are already emphasising the deployment of EVs in order to combat air pollution and mitigate climate change. This is because road transport was the second most important source of carbon emissions in 2014 (nearly 23 per cent of global emissions) (IPCC, 2014). There is also increasing awareness of the other economic benefits of EVs, including increased energy storage, creation of "green jobs" along its value chain, etc. EV deployment has also been linked to the attainment of various United Nations Sustainable Development Goals (SDGs), viz., "*ensuring healthy lives and promotion of wellbeing for all at all ages (Goal 3), promotion of sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all (Goal 8), the building of resilient infrastructure, promotion of sustainable industrialisation and fostering of innovation (Goal 9) and taking urgent action to combat climate change and its impacts (Goal 13)*" (ICTSD, 2017). Thus, the number of EVs has been growing rapidly – the sale of global electric cars reached 7,50,000 in 2016 (with 3,36,000 recorded in China alone). On the flip side, there are environmental concerns about what the unregulated disposal of spent batteries from EVs could lead to. The leaching of chemicals from these batteries could lead to both land degradation and water pollution due to surface runoffs. The policies seeking to provide a fillip to EVs need to take a holistic look at all aspects of the EV supply chain and their environmental externalities.

EV value chains are quite diverse (see, ICTSD, 2017, 2018); they not only include cars, but also electric bikes and heavy-duty vehicles like trucks and buses. The finished vehicles category of EVs includes battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) and hybrid electric vehicles (HEVs). While the production of EVs requires various components, production facilities along these value chains (particularly in the case of batteries) are largely concentrated. For instance, almost the entire global production of electric light-duty vehicles and batteries is in China (50 per cent), followed by Europe (21 per cent), US (17 per cent), Japan (8 per cent) and South Korea (3 per cent).

Notably, government policies and regulations of various countries have been major drivers in promoting EV demand and sales through appropriate "market-pull" and "technology-push" incentives (ICTSD, 2017). Many of them have pledged targets to support the diffusion of EVs on their roads. For instance, China targeted deploying 2 million electric cars in 2020 and Germany targets 6 million EVs by 2030; France and UK seek to completely ban the sales of petrol and diesel cars by 2040, while Norway plans to do that earlier by 2025. The EU targets setting up of charging stations in 10 per cent of its buildings by 2023.

The Indian government has also been active in promoting the EV industry and facilitating its greater diffusion on Indian roads. For instance, Phase I of the Faster Adoption and Manufacture of Hybrid and Electric Vehicles (FAME) scheme was launched in 2015 to fast track the goals laid out under NEMMP. The scheme targeted spending INR 14,000 crore as incentives to manufacturers and consumers for R&D on EVs and for their purchases respectively, and as investment in necessary charging infrastructure (Innovation Norway, 2018). FAME II was launched in April 2019 and entails a budgetary support of INR 10,000 crore to promote the sale and manufacture of EVs. This new phase targets "*electrification of public and shared transportation and aims to support through demand incentives approximately 7,000 e-Buses, 5 lakh e-3 Wheelers, 55,000 e-4 Wheeler Passenger Cars and 10 lakh e-2 Wheelers*" (PIB, Government of India, 2020c) besides seeking to support the setting up of charging infrastructure.

Different states/UTs have taken different approaches to scale up EV deployment. For instance, Delhi's policies are driven by the need to tackle air pollution and create more jobs for battery swapping operators. Karnataka plans to undertake R&D investment and develop itself as a technology hub while Kerala's focus is on using energy-efficient systems. Tamil Nadu is looking to develop EV venture capital funds, tax incentives for manufacturers, subsidies for land and parking spaces for EVs (Sahay, 2019).

Many Indian companies are also taking initiatives to increase EV manufacturing and penetration in the country. For instance, NTPC, Indian Oil, and Tata Power plan to set up more charging stations across India, and Amara Raja looks at enhancing its R&D capabilities to develop battery packs, etc. (Sahay, 2019). Mahindra & Mahindra and Tata Motors are the major Indian manufacturers of EVs. The former has been the pioneer of electric mobility in India and had introduced their first e-car in 2001. Mahindra has also launched various products, such as an electric sedan car, passenger and cargo van, and e-rickshaw (Innovation Norway, 2018). Tata Motors launched two cars for personal buyers recently – Tigor EV in 2019[1] and Nexon EV in 2020.[2] It has also launched electric and hybrid buses in India (Innovation Norway, 2018).

[1] See, The Economic Times article on "Tata Motors launches its first electric car for personal buyers", available at: https://economictimes.indiatimes.com/industry/auto/cars-uvs/tata-motors-launches-its-first-electric-car-for-personal-buyers/articleshow/71502648.cms?from=mdr

[2] See, Mint's article on "Tata Motors launches electric Nexon, says open to fleet sales if it enhances brand", available at: https://www.livemint.com/companies/news/tata-motors-launches-electric-nexon-says-open-to-fleet-sales-if-it-enhances-brand-11580234123923.html

However, India's move to EVs until now has been led mostly by initiatives in public transport. According to the latest release by the PIB, Government of India (2020c), "*about 14,160 Electric Vehicles have been supported till 26.02.2020 by way of Demand Incentive amounting to about INR 50 crores and5,595 electrical buses have also been sanctioned to various State/ City Transport Undertakings under Phase-II of the Scheme. This involves Government incentive of around INR 2,800 crores (sic)*". Along with e-buses, some states/ UTs such as Delhi have also seen a greater deployment of e-rickshaws on their roads, and the Delhi government too mentioned incentives worth INR 30,000 for the purchase of e-rickshaw and a 5 per cent interest subvention on loans taken to buy e-rickshaws, as per the new draft of Electric Vehicle Policy 2019.[3]

Going ahead, Indian states/UTs will need to strategically target private transport too. The role of private cab aggregators will also remain crucial in this regard as "*they generate more km on their vehicles*", leading to greater economies of scale in operations (Arora and Raman, 2019). In fact, India-based Ola Cabs launched the country's first electric mobility project in Nagpur in 2017 and, by January 2019, they were able to serve over 3,50,000 customers via their electric fleet in the state, saving more than 1,230 tonnes of carbon emissions (Raman et al. 2019). Ola Cabs also deployed various fast charging stations in the state. The company has further "*committed to bring 1 million EVs for everyday mobility on Indian roads by 2022*" (Arora and Raman, 2019). While the app economy comprising fleet-based mobility such as Ola and Uber are being considered as one of the key drivers that has an effect on the transition from public to private transport to facilitate the diffusion of EV on Indian roads, the global Covid-19 pandemic is likely to be a major setback, at least in the short run.

Disposal of Spent Batteries

Despite the short to medium-term impact of COVID, mobility needs will result in high demand for EVs in the coming future. This high EV demand will, in turn, lead to a rise in the demand for lithium-ion batteries (LiBs) that are the best-suited storage technology for EVs and will lead to a commensurate expansion of the market for spent EV batteries. Experts have predicted a generation of around 14 lakh tonnes of LiB waste by the year 2030 in India with a substantial amount coming from the EV sector. India is already struggling to cope with existing e-waste. An addition of such a copious amount would pose a great challenge to the envisaged goal of building a circular economy, where waste is reduced, resources are conserved and are fed back to the supply chain for new products. If not solved, this may prove to be a stumbling block for policies encouraging greater EV adoption as well.

A 2019 report on e-waste by the United Nations (UN) cites that one recycler in China already produces more cobalt by recycling than the amount the country mines in one year. Since India is highly deficient in the precious mineral resources required for battery manufacturing, recycling becomes all the more important. Besides, if left unchecked, dumping of spent batteries of such magnitude might lead to chemical leaching and contamination of water sources nearby, as well as land degradation. Therefore, understanding the recycling industry in its entirety to be able to devise an appropriate recycling or exit strategy for spent batteries is of paramount importance.

[3] See, The Economic Times article on "AAP govt. unveils sops, targets 25% new EVs in Delhi by 2024", available at: https://economictimes.indiatimes.com/news/politics-and-nation/aap-govt-unveils-sops-targets-25-new-evs-in-delhi-by-2024/articleshow/72948247.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

Further, battery recycling can prove to be an important new source of manufacturing growth, job creation and wealth generation in the country. To fulfil this objective, getting a closer look at the numerous health and environmental risks that recycling poses also becomes important. Currently, more than 95 per cent of e-waste is being recycled by the informal sector through rudimentary recycling techniques that pose great risk to human health and release toxic pollutants. To save the battery recycling industry from sharing the same fate, India must equip itself sufficiently. While identification of business models for investment in the sector would be critical, setting up institutional frameworks to formalise the largely informal process will also be crucial and should be the first step.

The Draft Battery Waste Management (BWM) Rules, 2020, recently released by the Ministry of Environment, Forest & Climate Change (MoEF&CC) emphasise the significance of the principles of Extended Producer Responsibility (EPR). They highlight the fundamental role that manufacturers, dealers, customers, and recyclers would play in attaining a smooth battery recycling system in the country. The establishment of Producer Responsibility Organisations (PROs) that work with battery manufacturers and take on the responsibility of collecting and channelizing battery waste was also proposed. Although the draft rules rightly take the first step towards formalising the collection of waste, they fail to throw light on the recycling mechanisms after the collection of the spent battery, the environmental impact of recycling and the viability of setting up of battery recycling industries in the first place.

It has also been indicated by the 2019 UN report on e-waste that due to the adoption of poor extraction techniques globally, the current recovery rate of precious metals such as cobalt stands at a mere 30 per cent. A detailed analysis of recycling technologies would not only assist in identifying efficient extraction and recovery techniques but would also be crucial in ensuring the sustainability of EVs. Further, the analysis would facilitate efficient handling of toxic battery waste such as metal oxides, organic electrolytes, graphite, manganese, cobalt, plastic etc. The recovery of precious metals from spent batteries could also potentially reduce the import of battery components, which in turn would strengthen India's energy security.

Addressing all these needs and challenges, this study also aims to holistically understand the existing recycling mechanisms along with the developments made in the battery recycling industry in India.

Implications of Covid-19 on the EM market in India

One positive spillover of the stalling of economic activity and lockdowns resulting from Covid-19 has been the impact on the environment. Coronavirus is expected to trigger the largest ever annual decrease in global CO_2 emissions (Evans, 2020). The air quality indices of different countries have improved following "*reduction in factory and road traffic emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x) and related ozone (O_3) formation, and particulate matter (PM)*" (Hamwey, 2020). For instance, there was a reduction in Nitrogen dioxide (NO_2) emissions in some major Spanish cities such as Barcelona (55 per cent) and Madrid (41 per cent) and 51 per cent in Lisbon as well, compared to the emissions in 2019 (European Environment Agency, 2020).

In India too, PM2.5 levels dropped by 46 per cent and PM10 by 50 per cent as production facilities were shut down and construction activities were put on hold. NO_2 and CO emissions are mainly from the transportation sector and thus, declined by 56 per cent and 37 per cent respectively during the lockdown period. In fact, during this period it was found that "*more cities have their air quality within National standards*" (CPCB, Government of India, 2020).

At the same time, the government's priorities are also likely to be strongly influenced by the pandemic over the next few years, which will have a bearing on the allocation of time, effort and resources to other subjects including EM in India. Moreover, Covid-19-induced macroeconomic shocks will also have an impact on the EM market, both in India and across the world. Notably, the outbreak has already forced many countries, including India, to move towards strengthening their domestic markets and value-chains in different manufacturing segments to attain self-sufficiency or '*Atma-nirbharta*'. This is likely to have a bearing on the policies of the Indian government for the EV industry.

This said, the pandemic could also provide an opportunity for co-ordinated global action to address climate change, and EM provides a clear possibility in this regard. This study has explored these different dimensions in detail.

Main Components

This study on Understanding Investment, Trade, and Battery Waste Management Linkages for a Globally Competitive EV Manufacturing Sector has delved into the aspects of trade, technology and investment, and battery waste management of EV manufacturing and related industries for both public and private transport. There were five components of this study:

- ***Component 1: Stylised facts on trade and investment in EM for both public and private transport and on the use of technologies***
- ***Component 2: Value chains in EM: which are the products and services, what are the skills required and where are the skill gaps in India?***
- ***Component 3: Barriers to trade and investment in the EM market in India***
- ***Component 4: Other demand and supply-side issues related to EV Manufacturing***
- ***Component 5: Battery Recycling: Technology, Barriers, and Opportunities***

Methodology and Tactics

The study has adopted the best research practices in its methodology. It has pursued a top down, as well as a bottom-up approach. The top-down aspect focuses on the macro picture in the EV sector. On a broad scale, it studies trade and investments in EV manufacturing, examining the barriers to investment and trade, and analyses value chains in the sector to gain an understanding of the skill availability and shortfalls proportions as well as the gaps. The bottom-up approach was utilised to look at the recycling component of the study – individual EV manufacturers were approached to understand ground realities and drawbacks of investment in the EV sector. The aim was to understand battery recycling and the vital role that it will play in the scaling up of EVs in the country. Different stakeholders including battery recyclers and policy makers like NITI Aayog, etc., were interviewed to gain a holistic picture of the recycling industry in India.

It needs to be highlighted that the objective of the study was to inform all involved stakeholders throughout the process and not just facilitate an end of product approach. From EV manufacturers to individual battery recyclers to policymakers, the intent was to provide inputs that help to reduce gaps in the connecting chain to help strengthen the overall EV policy of the country. Due to the current pandemic, stakeholder consultations were held in hybrid mode through either technological or physical means, whichever was appropriate.

The methodology to achieve these objectives has been discussed in every intermediate step for each component (as previously mentioned). To summarise, the findings of the study are based on an extensive review of existing literature, stakeholder consultations, and detailed analysis of secondary data at a disaggregated level. The databases used included the following:

- Trade data using a number of databases such as UN COMTRADE, Export-Import Data Bank of the Department of Commerce, Government of India, as well as those available on ITC's Trade Map, and verification of the information available on private datasets such as Trade Data Monitor, etc. (for Components 1 and 2)
- Investment data using FDI Markets and other available GoI and private sector datasets such as CMIE Prowess, etc. (for Component 1)
- Data on GVCs using the OECD-WTO TiVA database, UNCTAD-Eora GVC database, etc. (for Component 2)
- Data on barriers to services trade using the OECD STRI database (for Component 2)

In sum, we followed a four-pronged approach for each of the research components. This involved the following:

- Assessment of secondary data to prepare information gathering (for Components 1 and 2)
- Semi-structured in-depth interviews[4] with a select group of India-based and international market participants to identify existing barriers and gaps in investment and skillsets related to both EV manufacturing and battery sectors (for Components 2, 3, 4 and 5)
- Semi-structured interviews and primary data collection from recyclers and dismantlers from select Indian states (for Components 5)
- A Delphi Analysis[5] with a broader set of India-based and international market participants to come to a consensus on the key barriers and how policy interventions might help overcome them (for Components 2, 3 and 4)

[4] It was proposed that around 15 would be conducted during the project.

[5] A Delphi Analysis relies on multiple rounds of surveys with a group of participants with an interest in EV market creation. Each round, we propose to review and summarise participant feedback and share it with the whole group of participants together with the next survey, in which participants are able to adjust their answers according to their new knowledge. This method is aimed at creating a shared understanding across several stakeholder groups, and therefore will contribute to a more actionable EV policy plan.

Summary for Policymakers

Chapter 1: Investment perspectives on accelerating growth in the Indian EV Ecosystem

With a rapidly growing economy and a population of almost 1.4 billion people, India's transition to Zero Emission Vehicles is as much a strategic global goal as a national goal since it is expected that an additional 300 million vehicles will be added to Indian roads between now and 2040, leading to an increase of India's oil demand by 4 million barrels per day, the largest of any country in the world (IEA 2021b). In response, India has pledged that 30 per cent of new vehicle sales will be electric by 2030 to stay aligned with its goals of reducing carbon intensity per unit of GDP by 45 per cent by 2030 (PTI 2021). For that to happen, the electric vehicle market will need a considerable inflow of foreign direct investment.

While investment in EVs and batteries are rapidly scaling up, much more is needed. It is estimated that USD 2.5 trillion in global public and private investments will be needed to shift to 100 per cent EVs. This is about five times the current investment levels (Assis 2021). A recent study has estimated that OEMs are currently planning to spend about USD 500 billion on EVs and batteries through 2030 (Lienert and Bellon 2021), which is a significant increase from pre-pandemic levels of USD 300 billion. The main investment destination is China, which receives almost half of global investment, followed by European countries (Lienert and Bellon 2019).

This chapter will draw on an investor consultation exercise, conducted by a consortium of IISD, ICRIER, Columbia University, Invest India, WRI, and WBCSD. According to CEEW, investment needs in EVs and charging infrastructure in the 2020s alone would amount to USD 180 billion (Singh et al. 2020). NITI Aayog, the premier policy think tank of the Government of India, believes that cumulative investment in India's EV transition could even be as large as USD 266 billion between 2020 and 2030 (NITI Aayog et al. 2022). Total EV investment announcements in 2021 in India reached USD 6.5 billion (NITI Aayog et al. 2022b), highlighting the need for additional FDI inflow.

The in-depth stakeholder consultation found the following nine main takeaways:

1. Policies have been successful in incentivising consumer demand for electric 2W and 3W, with electric 4W and buses also picking up scale.
2. Financing challenges remain, but solutions exist and are under development.
3. The availability of sufficient charging infrastructure is of high concern, despite government subsidies.
4. Battery swapping can alleviate considerable demand side concerns.
5. India is a young player in battery manufacturing, but the growth potential is enormous.
6. Supply chain challenges can derail the rapid upscaling of EV and battery investment, highlighting the need for stronger policy support.
7. India has taken sound steps to incentivise EVs and battery manufacturing since COVID-19, but international competition to attract investment is stark.

8. Complementarity between state and federal policies is crucial, with some states ahead of others.

9. In the medium term, some skill gaps remain to be addressed to ensure smooth transformation to a healthy EV ecosystem.

Recent policy initiatives in India are preparing the country to leverage its market size to become a global EV investment destination. Consulted experts and investors believe that India will first do so by supplying the domestic market, specifically with regards to EVs and EV non-battery components. Within 3-5 years, investors and companies will also make strides into battery assembly, while battery cell manufacturing is not expected to reach the country's full potential just yet.

It should not come as a surprise then that India's EV market is projected to be worth USD 150 billion by 2030 (Invest India 2022). Federal policies such as FAME II, PLI ACC and PLI Auto have together created a strong enabling environment for a globally competitive EV ecosystem in India. Several state policies are also already in place (18 states as of report finalization) to provide additional incentives. This will allow India to also bolster demand in other segments, such as 4W and electric busses, as well as its ability to host mega factories.

Like in other countries, legacy issues such as concerns over capital costs and public awareness about total cost of ownership and incentive mechanisms remain important. India is working actively on improving financing options, but results will need to be shown fast to pave the way for a larger uptake of EVs and subsequent investment. Especially first-loss risk sharing instruments and adding EVs to the Reserve Bank of India's priority sector lending show potential. Investors also believe that lessons can be learned from experiences in other countries, particularly in moving from an enabling policy environment to specific targets and other regulatory instruments to incentivise demand and supply chains.

Certain new barriers that come with India's growing EV market penetration and battery development ambitions are on the rise. These are not specific to India but found across the world. However, countries that can find ways to reduce those barriers will improve their status as investment destinations. On the one hand, new barriers include supply chain worries related to the price and availability of semiconductors, metals and minerals, and battery cells. Battery recycling as well as more active government involvement in sourcing primary materials can reduce, though not eliminate, some of these concerns.

On the other hand, insufficient charging infrastructure and electricity grid readiness are an infrastructure bottleneck to accelerated EV adoption. While several projects are on the way to rapidly add public and private charging stations, concerns remain over the policy framework, from FAME II requirements to install 2W and 3W charging infrastructure and the ability to cap charging fees, to lack of clarity of grid accreditation costs and land availability.

▶ Chapter 2: The Challenge of Skill gaps in the Indian EV sector

As the transition from traditional automobiles to electric vehicles is underway in India, concerns regarding the skill differential in these two segments have surfaced. The skills required in the traditional and electric vehicle industries differ, necessitating re-skilling or re-training of workers to preclude the possibility of job loss while transitioning. This issue assumes particular importance because of the number of jobs the automotive sector provides directly as well as indirectly. As per PIB (2019), the employment number, direct as well as indirect, for the automobile industry has been pegged at 37 million.

This chapter analyses the skill gaps facing the Indian electric vehicle sector. The analysis brings together insights received from consultation with different stakeholders. Overall, the following key points emerge from our analysis:

- The issue of skill gaps is a nuanced one, varying in degree and extent across the EV supply chain. Through our stakeholder consultation, we found that there are almost no skill gaps in the chemistry of anode and cathode cell manufacturing. However, problems in securing workforce for research and development were reported.

- There are various layers to the issue of the skill gaps. This issue is construed by many as being limited to only the workforce engaged in manufacturing or assembling EV or EV components. However, there are issues relating to the skills gap among workers outside the EV supply chain such as those servicing and repairing EVs, in particular skills needed to ensure to operational safety. Closing these skill gaps becomes particularly crucial since many of these individuals are part of the informal sector and have experience in handling only internal combustion engine (ICE) vehicles.

Different economic actors in the sector such as the government, industry, and academia have taken different measures to address the challenge of skill gaps. However, there is need for more effort to resolve the skills gap issue. Ideally, the central government should undertake a comprehensive skill mapping exercise and draw up a concrete action plan to overcome skill deficiencies.

▶ Chapter 3: Green Industrial Policy: An Appraisal of Three State EV Policies

This chapter traces the evolution of India's industrial policy, focusing on the policy towards the EV industry, one of the newly developing industries in India. India's steady transition towards EVs is being fuelled by government policies both at the central and state level. The chapter analyses the EV policies of three states namely Karnataka, Maharashtra, and Tamil Nadu in depth. The state level policy analysis reveals the distinct nature of each of these policies as they address a different mix of incentives in their policies. Further, the degree and extent of incentives offered also differ. The metric of progress selected in the paper, EV registrations, reflects the positive influence of the EV policies in these states. However, caution may need to be exercised in dealing with these findings as there may be several factors affecting EV registrations with an EV policy being one.

▶ Chapter 4: Trade and tariffs along the EV value-chain: literature review and stylized facts

Several studies have explored value chains in the EV industry but not much work has been done in the Indian context. Existing literature also suffers from the lack of a consolidated list of goods and services that are traded along the EV value chain, partly due to the lack of appropriate HS codes to account for the technological shift in manufacturing automobiles and partly due to lack of effort.

Against this background, this chapter presents detailed stylised facts on trade and tariffs on goods that form a part of the entire EV value chain, using data from UN COMTRADE and UNCTAD TRAINS, respectively. The HS codes for these goods have been compiled from existing literature, additional sources, and based on the authors' own assessment of the parts and components likely involved in different segments of the EV value chain. This results in a far more comprehensive analysis of trade and tariff patterns relative to extant work. In another significant departure from existing literature, we also examine regulatory barriers to trade in those services that perform complementary and enabling functions in the EV value chain, using data from the OECD's Services Trade Restrictiveness Index (STRI).

Total exports and imports of goods used in the EV value chain (EV goods or EVGs) increased from USD 1.6 and 1.5 trillion, respectively, in 2010 to USD 2.7 and 2.6 trillion, respectively, on average over 2018-19, registering 73.8 per cent and 80.4 per cent increase in the respective values. As a share of total merchandise trade, the importance of EVGs increased from 10.2 per cent, 9.4 per cent in 2010 to 14 per cent, 13.4 per cent in 2018-19 for exports and imports respectively. Germany, Japan, USA, and China were the top four exporters of EVGs in 2010 and in 2018-19, accounting for over 40 per cent of global exports in EVGs. Notably, India does not figure amongst the top 20 exporters or importers of EV goods in the world, which points to ample scope for improvement along both dimensions, especially in a world integrated in regional and global value chains.

Much like global EVGs trade, India's EVGs trade is also dominated by the broad sector comprising manufacturing of vehicles, which accounted for 76.8 per cent and 51.8 per cent of India's EVGs exports and imports during 2018-19, respectively. The US was by far the largest destination for Indian EVGs exports, accounting for 23.9 per cent of India's total EVGs exports during 2018-19. China was the largest source by far of India's EVGs imports during 2018-19, accounting for 28.6 per cent of India's total EVGs imports.

India's exports and imports of EVGs are not just important from supply and demand perspectives. In fact, there are several EVGs where India exhibited a potential for value chain integration during 2018-19 as observed from the relatively high values of the Grubel-Lloyd index (GLI) of intra-industry trade (IIT),[6] indicating that India was intensive in both exporting and importing disaggregated products within the same HS code. From a policy perspective, it would thus be prudent to liberalise tariffs and non-tariff barriers (NTBs) in India on these HS codes. Cost reductions emanating from liberalising imported EVGs intermediates would be especially beneficial to the domestic EVGs industry as well as EVGs-exporting firms.

[7] RCA = (Xik/Xik)/ (Xwk/Xwk) where X = exports, i = country i, k = product and w = world. Thus, the RCA calculates the share of a product in a country's total exports relative to the share of that product in global exports. An RCA value exceeding one denotes comparative advantage in exporting.

This also assumes salience given that India does not seem to be very competitive in exporting EVGs. India exhibited a revealed comparative advantage (RCA[7]) in exporting EV goods in only 9 of the 65 constituent HS codes; in contrast, the US and Germany showed a revealed comparative advantage in over 50 HS codes.

India imposes amongst the highest tariffs on imports of EVGs, especially on imports used in battery storage and manufacturing of vehicles. Moreover, for manufacturing of vehicles, India's simple average tariffs more than doubled from 22.5 per cent in 2010 to 51 per cent in 2018. India also increased tariffs on both battery storage and battery components in 2018 relative to 2010, which again provides evidence of India's import-substitution policies followed in EVGs of late.

Chapter 5: Barriers to trade in services providing complementary and enabling functions to EV manufacturing

Amongst other factors, foreign investment in EVs also depends on the ability of firms to invest and operate in the importing country in the presence of tariff and non-tariff barriers and regulatory restrictions on service providers of complementary (services that are closely bound in supply with the EVs, either bundled with them or as inputs to them such as computer, distribution, engineering, logistics, transport) and enabling services (that include financial – banking and insurance – and professional – accounting and legal – services).

According to WTO GATS parlance, services trade can be transacted in four different ways, known as the modes of supply. Mode 1 ("cross-border trade") includes all services that can be traded remotely without the need for physical proximity between the buyer and seller, e.g., call centre services. Mode 2 ("consumption abroad") includes services that require the consumer to travel to the country of the buyer for the service to be transacted, e.g., tourism. Mode 3 ("commercial presence") involves transactions between foreign affiliates of an MNC in the host country, e.g., foreign bank operations in the domestic economy. Mode 4 ("movement of natural persons") includes services that require the supplier to travel to the country of the consumer for the service to be transacted, e.g., onsite software programmers.

In this chapter, the analysis of barriers to services trade in terms of modes of delivery is based on our understanding of how trade in complementary and enabling services is transacted and the associated regulatory constraints. For instance, barriers specific to Mode 3 trade in these services include restrictions on licence approvals pertaining to fulfilment of technical standards, limited foreign ownership, type of legal entity, scope of activity, local content requirements, nationality or residency requirements to partake in the provision of certain services including public utilities and professional services, government procurement favouring domestic suppliers, public monopolies restricting entry of private service providers, restrictions on acquisition of real estate, security regulations on data transfer and demands to hire domestic staff (Andrew and

[7] RCA = (Xik/Xik)/ (Xwk/Xwk) where X = exports, i = country i, k = product and w = world. Thus, the RCA calculates the share of a product in a country's total exports relative to the share of that product in global exports. An RCA value exceeding one denotes comparative advantage in exporting.

Thompson, 2000; UNEP, 2018). Similarly, professional qualification requirements, cumbersome visa application procedures, and focus on immigration rules can delay or fully restrict the entry of qualified professionals via Mode 4. In other cases, specialised foreign personnel may be discriminated against due to non-recognition of professional qualifications or the requirement to pass local exams or have domicile to be eligible to practice their trade.

While India has become slightly less restrictive in terms of barriers to complementary services between 2014 and 2021, it is way more restrictive than the OECD countries and several non-OECD economies including Brazil, China, Peru, and South Africa. India's high STRI value in complementary services emanates largely from the restrictiveness of its transport services. India is also the most restrictive country in terms of barriers to enabling services (driven largely by its high STRI values in legal and accounting services).

More disaggregated analysis for India at the individual sector level by type of restriction shows considerable heterogeneity. In fact, India is amongst the more restrictive economies, irrespective of the type of restriction, in the case of enabling services, both accounting and legal, driven by barriers to foreign entry and those on Mode 4. Restrictions on regulatory transparency and other discriminatory measures are the least constraining across sectors in India, while those on competition are also generally low barring transport and insurance.

This analysis suggests that both domestic EV manufacturers and potential foreign investors in the EV-space in India are also subject to restrictions on the services side, which need to be liberalised, given the well-recognised complementarities between goods and services and the increasing servicification of economic activity in countries across the world (WTO, 2019).

Chapter 6: Electric Vehicles: Supply, Demand, and Investment Challenges

The Indian government's push towards widespread adoption of EVs has underlined some of the demand and supply side challenges as well as barriers to investment that are likely to disrupt the commercialisation of EVs (De, 2017). This chapter first examines factors *restricting the supply of EVs in India, followed by an examination of factors influencing the demand for EVs by domestic consumers and finally, discusses barriers to investment faced by domestic and international investors*. The answers to these questions cover global issues specific to EVs that also apply to the Indian context; issues faced by EV manufacturers and consumers only in India as well as general investment side issues that will affect EV production in India.

Chapter 7: Exploring the techno economic viability of lithium-ion battery recycling in India

The LiB market in India is projected to grow exponentially owing to increased demand from the automotive and energy storage sectors. India has taken several steps (Production Linked Incentive scheme for Advance Chemistry Cell, Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME I) and FAME II) to promote the use of

EVs and LiBs. Recently, India, in its net-zero pledge, has increased the target of renewables to 500 GW, and aims to make renewables account for 50 per cent of the total energy mix by 2030.[8] These ambitious targets will certainly make India a significant consumer of LiBs. However, to make the supply chain of EV batteries sustainable, India needs to work on multiple aspects, especially recycling, to achieve sustainability and strengthen energy security.

This chapter aims to present the financial and technological viability of LIB recycling in India. A scoping study was conducted to collect data through a survey of both lead-acid and LiB recyclers distributed across three states (Maharashtra, Haryana, and Karnataka). Primary data on recycling capacity, technology used, and costs related to the installation of the recycling facility and its operation was collected through one-on-one meetings with identified stakeholders. Detailed analysis of stakeholder inputs from consultations and a review of comments suggests the following:

- LiB recycling is highly expensive as compared to recycling of lead-acid batteries (LAB).[9] Analysis shows that installation of LiB recycling infrastructure is highly capital intensive. A recycling plant with an annual capacity of 1 GWh requires more than USD 10 million in total capital expenditure (CAPEX).[10] The annual cost involved in the operation of the plant (OPEX) is estimated at around USD 5.25 million.[11]
- Hydrometallurgy is found to be the prevalent recycling method since this is a more sustainable process as compared to pyrometallurgy. With cobalt and lithium recovery greater than 95 per cent and, in some cases, even higher than 99 per cent, recycling firms would prefer only the hydrometallurgical method but the equipment in hydrometallurgy are cost intensive. The cost involved in installing hydrometallurgical technology equipment alone is projected to be around USD 5 million for a recycling plant of annual capacity of 1 GWh.
- There is a need for more research and development (R&D) on sustainable technologies (such as hydrometallurgy) to bring down recycling costs. An individual recycling unit in India does not recycle more than three types of LiBs.[12] This suggests that the LiB recycling industry should develop into a technology agnostic system for greater coverage of spent batteries. Given the ever-evolving nature of batteries in terms of chemistry and technology, only a standardised technology can make a recycling unit more profitable while continuously increasing its recycling coverage and capacity.
- Further, the collection and transportation cost of spent batteries is a major component in the recycling cost, which affects the profitability of recycling firms. In the absence of localisation, a spent battery has to traverse an

[8] Available at: https://pib.gov.in/PressReleasePage.aspx?PRID=1768712 Accessed on February 3, 2022

[9] ICRIER survey findings

[10] ICRIER survey findings

[11] ICRIER survey findings

[12] ICRIER survey findings

average distance of more than 800 km before it reaches a recycling plant.[13] To reduce transport and collection costs, there is a need to localise recycling activities. Setting up of recycling plants in a strategically distributed manner will bring down the need for long-range transportation and, hence, costs. Localisation will also generate local economic activity. The recycling landscape in the country needs highly efficient logistical improvements in collection and transportation of spent LiB packs, which are hazardous in nature, to make recycling more profitable.

- Limited supply and low volumes of waste collection hamper the achievement of scale economies in recycling plants. However, going forward with large-scale transition to EV, the recycling needs would increase. Increasing recycling capacity in this scenario may result in achieving economies of scale, and eventually higher profitability.

The LiB recycling industry will require more funds in the coming decades to achieve higher national recycling capacity. Therefore, the policymakers should draw up a roadmap to secure sufficient financing for the sector. Central government agencies (such as CPCB) may take steps to conduct a techno-economic analysis of LiB recycling in different parts of the country and make this information available in the public domain. It is suggested that policymakers develop market mechanisms that support financing for and technology adoption by LiB recycling units while taking steps to improve the efficiency of logistics and transportation systems to achieve higher collection efficiency.

[13] ICRIER survey findings

Chapter 8: Understanding employment potential of battery recycling in India

There is a need to look ahead of the expected EV growth and tap the opportunity to increase employment potential in the battery recycling segment of the sector. Batteries form an essential corollary of EVs, and the stock of end-of-life batteries will be a reality in the future. The huge battery market segment will require proper recycling facilities to ensure batteries do not end up in landfills and become an environmental and health hazard. Apart from the environmental benefits, battery recycling could also offer several social benefits. Battery recycling presents opportunities not only ensure a complete and successful EV transition, but also to set up new businesses and provide employment by creating new skilled jobs in recycling units.

This chapter looks at the employment potential of the battery recycling industry in India through a two-step analysis. The first step involves an analysis of secondary data on employment in the broader hazardous waste segment to gauge the number of jobs and skill requirements in waste management related activities, of which management of battery waste is a significant part. The idea is to document the current landscape of employment in the waste sector to begin the conversation on the productivity potential with respect to job creation. The second step in the analysis involves the matching of the results of the previous exercise with primary data as obtained in the on-ground survey results of battery recycling firms. This caters to the understanding of the employment potential and skill requirements of the battery recycling segment to guide policy decisions, particularly with respect to skilling requirements.

Secondary data analysis indicates the following:

- Material recovery accounts for the maximum employment in hazardous waste sector management, followed by remediation activities (pollution-control activities).
- Overall skill structure indicates a significant proportion of low skilled workers in the sector, i.e., population with elementary level education.
- The functional range of occupations in the waste management sector is limited. This can be attributed to the predominance of the informal sector in waste management.
- Significant share of employment in the hazardous waste management sector is constituted by the informal sector.
- Maximum employment in hazardous waste management is in Maharashtra, in the three sample states of Maharashtra, Karnataka, and Haryana.
- Workers do not receive adequate social security benefits, reflecting a disregard for the quality of jobs created in the sector.

Primary data analysis based on the survey results reveals the following:

- About 53.3 per cent of battery recycling units employ 11-30 workers on the premises.
- Most of the employed labour consists of labourers (76.4 per cent) with management (12 per cent) and technical staff (2.6 per cent) accounting for a much smaller share. In fact, the housekeeping, and others (incl. guards, etc.) (5.4 per cent) categories form a larger share than the high skill technical category of workers.
- The skill level among workers is low and is reflected in the dominance of workers with an educational level of Pre-University Course (PUC) (11th and 12th) (48.6 per cent).
- Among the three sample states, employment in the battery recycling segment is the maximum in Karnataka.

The likelihood of a rapid rise in hazardous wastes including battery waste indicates the need for a push towards strong and directed policy decisions. With a focus on harnessing the strengths inherent in the dominant informal share of employment in the sector, this will require among other things, a programme to reskill workers employed in the industry to expand horizons and develop a more capable and better prepared sector for the future. One advantage of this is that it will ensure their employability when the transition to electric mobility is completed. Another issue that is likely to becoming increasingly relevant is whether the skewed access to social security benefits within the sector will remain unchanged. An enlightened approach to the above programme will then also ensure that workers in the whole industry receive social security benefits. This would help the economy as a whole to avoid the health costs that are likely to arise because of unsafe disposal and management of hazardous waste. Greater collaborations will form a key aspect on the agenda as well. A collaborative approach at the level of key players in the sector such as battery manufacturers and original equipment manufacturers (OEMs), at the level of state and these key stakeholders, as well as at the level of formal and informal workers will help address multiple issues and concerns.

Chapter 9: Waste to Wealth: Extended Producers Responsibility for Effective Electric Vehicle Battery Waste Management in India

The impacts of climate change and increasing pollution have necessitated a shift towards the adoption of electric vehicles globally. However, while this will help reduce transportation-based emissions, it is also likely to pose the challenge of managing EV battery waste. To effectively manage the growing quantum of Li-ion waste, the policy approach of Extended Producers Responsibility (EPR) is being increasingly adopted.

This chapter surveys academia, policymakers, recyclers, Producer Responsibility Organisations (PROs) and other important stakeholders in battery waste management, and a few international case studies. The collected data is analysed and arranged to provide policy makers with the information needed to design an effective EPR policy in the country. The key insights from the inputs provided by stakeholders include the following:

- Current waste collection targets under the draft battery waste management rules 2020 are ambitious and need to be aligned with existing recycling and waste collection capacities. Nearly 60 per cent of the respondents were dissatisfied with the current published targets and called for revised practical targets.
- Transportation cost is a major part of the recycling cost. Hence, it is necessary to understand the waste flow dynamics and optimise transportation cost.
- There is acute shortage of skilled labour in the waste recycling industry. Most stakeholders said that finding skilled labour is difficult and that they often have to settle for inadequately skilled workers.
- Incentives play a critical role in the success of market-based policies. More than 60 per cent of the stakeholders wanted better incentives for recycling battery waste.

The rest of this report is organised as an arrangement of all working papers due under the project as different chapters, following the same order as under the *Summary for policymakers*.


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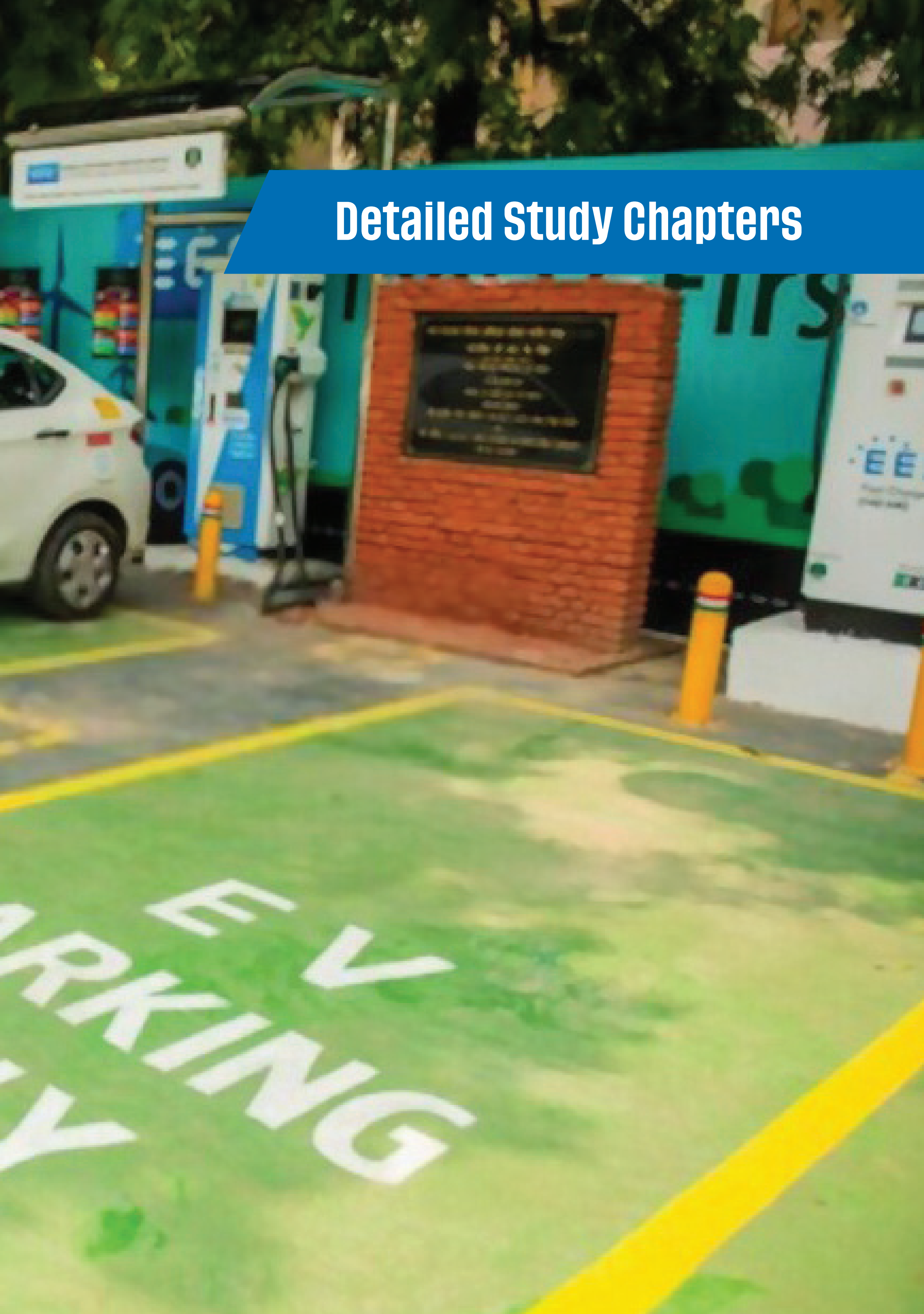

Chapter 1

Investor perspectives on accelerating growth in the Indian EV Ecosystem

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Note: The research on investor perspectives and the associated report was prepared through a joint collaboration of Invest India, IISD, ICRIER, and Columbia University Center on Global Energy Policy. The official version of this report is published here: https://www.iisd.org/publications/report/investor-perspectives-accelerating-growth-indian-ev-ecosystem

1. Introduction

The decarbonization of the transport sector is vital to preventing global warming of more than 1.5°C above preindustrial levels, a central component of net-zero ambitions worldwide, and the most important carbon emission reduction measure aside from greening the power sector (Moerenhout 2021a; 2021b). With 24 per cent of global greenhouse gas emissions coming from the transport sector and more than 40 percent of those emissions caused by passenger road vehicles, the electrification of passenger transport has become a central focus of global efforts to decarbonize the sector (IEA 2022). Indicatively, at the 26th Conference of the Parties (COP26) summit held in Glasgow in 2021, 38 national governments, 47 city and regional governments, 11 automotive manufacturers, 28 fleet owners, and several investors and financial institutions committed to a pledge that by 2035 all new sales of cars and vans sold in leading markets will be zero-emission vehicles (ZEVs; COP26 2021).

Amid the global transition to ZEVs, the case of India is particularly important. Given its rapidly growing economy and its population of almost 1.4 billion people and counting, the country is expected to add an additional 300 million vehicles to its roads by 2040—the largest car market growth of any country in the world, leading to a four million barrel per day increase in its oil demand (IEA 2021b). In response, the Indian government has pledged that by 2030, 30 per cent of all new vehicle sales in India will be electric. This attempt to make the uptake of EVs a strategic objective aligns with India's goal of reducing carbon intensity per unit of gross domestic product (GDP) by 45 per cent by 2030 (PTI 2021). It can also act as a green industrial policy to support a post pandemic economic recovery; reduce oil imports and strengthen energy security; and lessen air pollution and mitigate climate change.

For India to follow through on its pledge, the Indian EV market will need a considerable inflow of foreign direct investment (FDI). Although investment in EVs and batteries is rapidly scaling up around the world, much more is needed. It is estimated that USD 2.5 trillion in global cumulative public and private investments will be required to shift to 100 per cent EVs, which is about fivefold the current investment levels (Assis 2021). A recent study has estimated that original equipment manufacturers (OEMs), also known as automakers, are planning to spend about USD 500 billion on EVs and battery production by 2030 (Lienert and Bellon 2021), a significant increase from pre-pandmic levels of USD 300 billion by the same year. The main destination for this investment is China, which receives almost half, followed by several EU countries, most notably Germany (Lienert and Bellon 2019).

According to the Council on Energy, Environment, and Water, India's EVs and charging infrastructure investment needs will amount to USD 180 billion in the 2020s alone (Singh, Chawla, and Jain 2020). Meanwhile, total EV investment announcements for 2021 in India reached only USD 6.5 billion (NITI Aayog, RMI, and RMI India 2022a), leaving a significant gap between required and actual investment. Nevertheless, the National Institution for Transforming India (NITI Aayog), the Indian government's premier policy think tank, believes that cumulative investment in India's EV transition between 2020 and 2030 could be as large as USD 266 billion, reflecting growing optimism for the sector (NITI Aayog, RMI, and RMI India 2022a).

The purpose of this chapter is to analyse India's present EV ecosystem with a focus on drivers of and barriers to investment. Based on in-depth consultations with experts, policymakers, investors, and companies, as well as results from an online survey with 59 EV experts and companies, it presents nine takeaways highlighting (1) the state of play of India's EV market and policies, (2) the main challenges to further improving its EV ecosystem, (3) government and investor initiatives to alleviate those challenges, and (4) additional challenges to and solutions for accelerating investment.

Takeaway 1: India's recent policies have been successful in incentivizing consumer demand for electric two-wheelers (2W) and three-wheelers (3W), with electric four-wheelers (4W) and buses also scaling up.

India's flagship EV scheme, FAME has been critical to incentivizing EV demand in the country. The government's commitment to electrifying its transport sector is particularly clear in its move from the first phase of the program (2015–2019), which cost USD 128 million, to the second phase (2019–2024), which increased government subsidies tenfold to USD 1.35 billion. Whereas phase I aimed at supporting 280,000 EVs, phase II scaled up vehicle sales by 1 million 2Ws, 500,000 3Ws, 55,000 passenger cars, and 7,090 buses.

In support of this ambitious goal, the FAME program's demand-side incentives effectively lower the upfront purchasing price of EVs through a government subsidy to OEMs. FAME II started with an EV purchase subsidy of USD 134 (INR 10,000) per kilowatt hour (kWh). In 2021, the Indian government increased that subsidy by 50 per cent for 2Ws to USD 201 (INR 15,000) per kWh, bringing the ratio of subsidy to total vehicle cost from a maximum of 20 per cent to a maximum of 40 per cent (Government of India Department of Heavy Industry 2019, 2021c). This measure, in combination with state-level incentives in Delhi, Maharashtra, Gujarat, and elsewhere, has sharply reduced the up-front cost of EVs, especially in the 2W and 3W segments, accelerating the electrification of last-mile mobility.

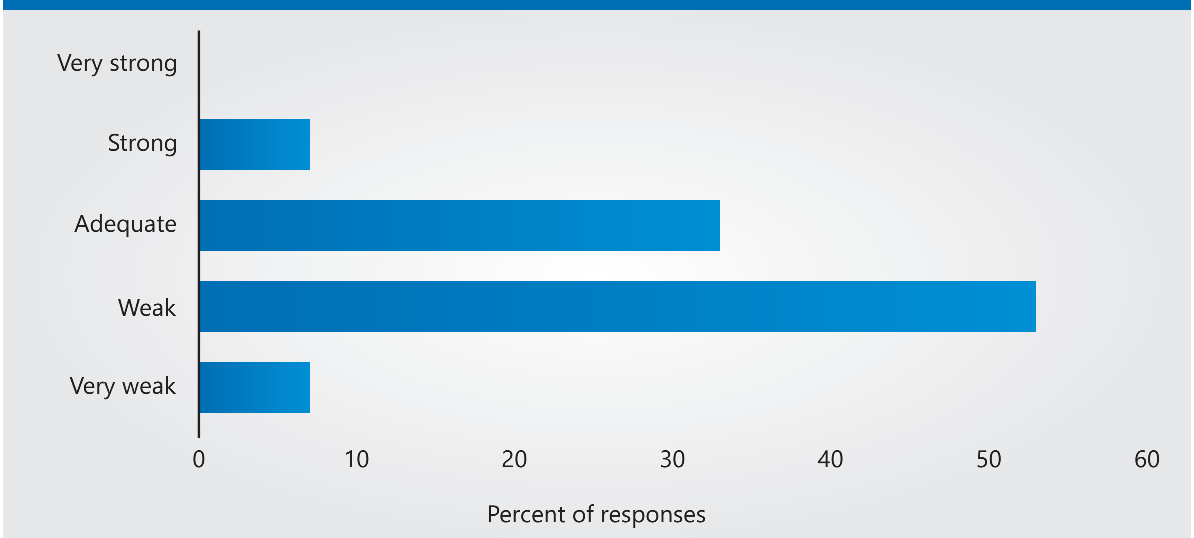
Two other policies have likewise incentivized EV demand. In 2019, the Indian government reduced the goods and services tax (GST)—an indirect tax levied on the supply of goods and services that came into effect in 2017 and replaced many indirect taxes such as excise duties and value-added tax—on EVs and chargers from 12 per cent to 5 per cent (Reuters Staff 2019), while internal combustion engine (ICE) vehicles maintain a GST rate of 28–43 per cent. Additionally, it offered tax deductions for first-time buyers of EVs to the level of USD 2,000 on loans concluded between 2019 and 2023. Importantly, this scheme includes 2Ws (Government of India Income Tax Department 2021), which make up about 75 per cent of the total vehicle fleet in India (Statista 2022).

The impact of these policies has been reflected in EV sales. Whereas in FY 2020–21, India's EV penetration rate (i.e., EV sales as a percentage of total sales) was less than 1 per cent, by the close of FY 2021–22, it was up to 2.5 per cent (Invest India 2022). Many consulted stakeholders believe that the FAME II scheme amendment played a major role in this shift, though this is difficult to verify without user surveys. From the OEMs' side, major companies believe their marketing efforts have helped to increase public awareness of EVs. The success of demand-side incentives has been especially significant in the 2W segment, where sales more than quintupled from FY 2020–21 to FY 2021–22. Other segments such as 3Ws, buses, and PVs tripled in size in that same period. Certain metro cities, such as New Delhi, have witnessed EV penetration of over 9 per cent in new vehicle sales compared to the national average of 2.5 per cent (ibid.). The Indian government is expecting to achieve a 16 per cent EV penetration rate in the 2W segment and a 20 per cent EV share in the 3W segment (in addition to a 13 per cent EV share of transport buses) by 2025. By comparison, the government expects 4W passenger cars to electrify at a slower pace, reaching only a 5 per cent penetration rate by the same year (ibid.).

Takeaway 2: Financing challenges remain, but solutions are being developed.

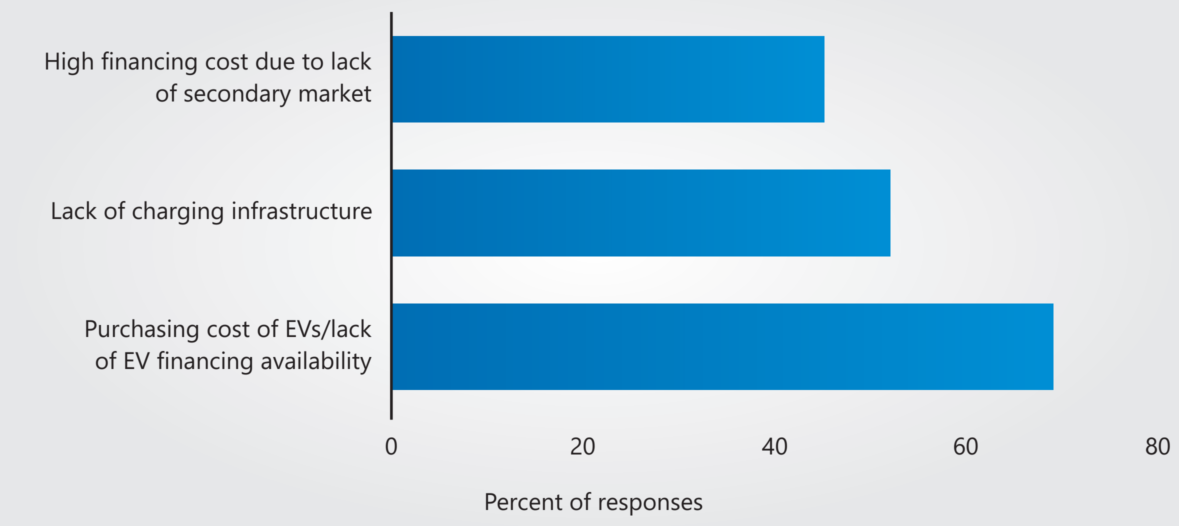
The FAME scheme has been instrumental in improving the affordability of EVs. If India's goal is to exponentially increase EV adoption, however, it will need further policy innovations that address financing challenges for consumers. For example, electric 2Ws currently incur higher interest rates and down payments as well as shorter loan periods than equivalent ICE vehicles. To date, reputed OEMs have offered relatively few electric 2Ws and 3Ws, making it more difficult for financiers to understand the lifespan and depreciation of these vehicles. The limited availability of dedicated financing options keeps up-front costs high for consumers, despite an already low total lifetime cost of ownership (TCO) in certain EV segments compared with ICE vehicles. Reflecting this point, most of the investors consulted for this report saw current financing models to be between weak and adequate (see Figure 1) and ranked the high purchasing costs of EVs as the foremost consumer demand barrier to upscaling investment in electric mobility in India (see Figure 2).

Figure 1: Respondents' evaluation of current financing models available to EV users in India



(Source: Authors)

Figure 2: Respondents' three most frequently cited consumer demand barriers to upscaling investment in electric mobility in India



(Source: Authors)

(Note: Survey participants selected up to 3 barriers from a list of 11)

Aware of the purchasing cost challenge of EVs, the Indian government recently proposed two initiatives intended to improve financing for the sector. The first, set up by the Indian government think tank NITI Aayog and the World Bank, is a USD 300 million, first-loss risk-sharing instrument that protects banks from EV-related loan defaults and effectively lowers the interest rate for consumer loans from 20–25 per cent to 10–12 per cent. It is estimated that under the program the total financing of the State Bank of India—which will act as a program manager—could reach USD 1.5 billion (Bhardwaj 2021; Philip and Shukla 2021).

The second, recommended by NITI Aayog and the Rocky Mountain Institute (RMI), involves including EVs in the Reserve Bank of India's priority sector lending (PSL), a policy that obliges banks to allocate a certain percentage of their lending to priority sectors. This step would bolster investor confidence in two ways. First, like the World Bank facility, it would increase the availability of capital for EV purchasing, including for segments that are economically rational but where consumers struggle with credit. Second, it would send a clear signal to investors that the government is committed to EVs in the long term (NITI Aayog, RMI, and RMI India 2022a). At the time of writing, this measure has not yet been formally approved.

Addressing the financing of EVs at the federal and state levels can yield significant results across EV segments. One survey found that 90 per cent of consumers would consider paying a premium for an EV if the supportive infrastructure was available, including for electric 4Ws (Bureau 2021). This consumer interest could be further bolstered by more transparent data on vehicle performance and the expansion of industry-led buyback programs.

Takeaway 3: The availability of sufficient charging infrastructure is of high concern to all stakeholders despite government subsidies.

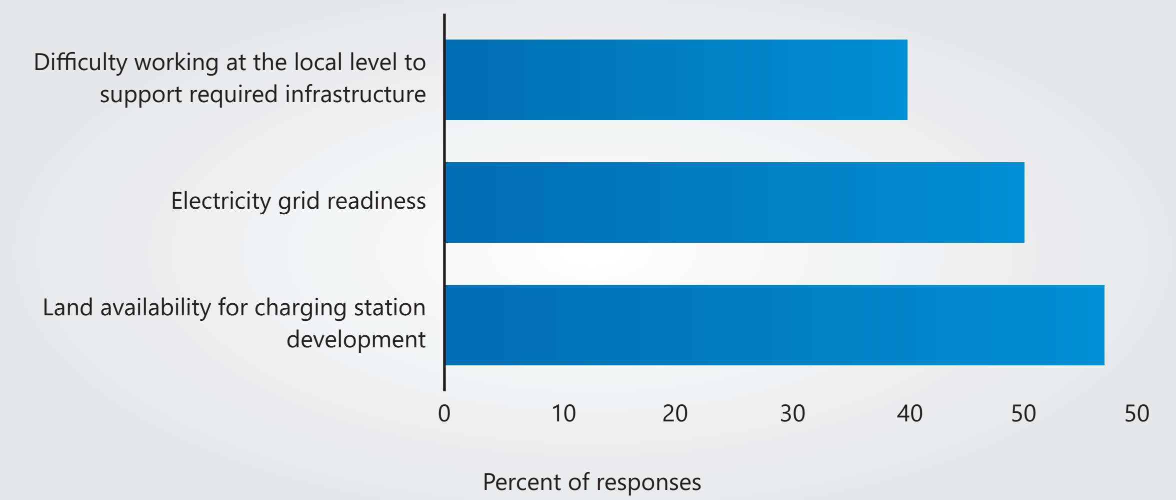
Infrastructure bottlenecks often stall technology adoption, and the case of EVs is no different. Today, charging infrastructure availability is considered as much of an EV-adoption bottleneck as up-front costs (Foster et al. 2021). The global number of chargers is expected to increase from about 10 million in 2020 to 120 million in 2030, though 210 million are needed to stay on track with the goal of limiting global warming to less than 1.5°C above preindustrial levels (IEA 2021a).

Reaching that volume of chargers would require governments around the world to offer public subsidies for charging infrastructure to the level of billions of dollars. Some countries have already adopted this measure. As part of green Keynesian policies since the start of the COVID-19 pandemic, the United States has committed USD 7.5 billion, Germany USD 2.9 billion, China USD 1.5 billion, and Italy USD 850 million (Energy Policy Tracker 2022). However, many more countries, especially those with large auto markets, will need to follow suit.

Currently, India has a total of only about 1,800 public charging stations (Gadkari 2022). 2Ws will require 634 chargers by 2025 and 3,866 chargers by 2030, about 10 per cent of which are expected to be public; 3Ws will require 2,557 chargers by 2025 and 9,826 chargers by 2030, about 20 per cent of which are expected to be public; passenger 4Ws will require 32 chargers by 2025 and 306 chargers by 2030, about 10 per cent of which are expected to be public; and commercial 4Ws will require 262 chargers by 2025 and 2,303 chargers by 2030, about 25 per cent of which are expected to be public. In total, this additional charging capacity will require 0.45 GWh of extra power by 2025 and 2.4 GWh by 2030 (NITI Aayog et al. 2021).

India's current level of public investment in charging infrastructure also lags behind major EV ecosystems around the world. Under FAME II, India committed INR 10 billion (equivalent to USD 134 million) to support the progressive installation of EV charging infrastructure (Government of India Department of Heavy Industry 2019). This amount is in line with the commitment level of Canada, which pledged USD 112 million for charging infrastructure (Energy Policy Tracker 2022). Like in other countries, achieving deep EV penetration in India will require additional subsidies for and investment in charging in the short term. Indicatively, consulted experts and investors viewed the second-largest EV consumer demand barrier to be a lack of charging infrastructure, behind only the high purchasing cost of EVs and much more important than charging time or range anxiety (see Figure 3). Meanwhile, they identified land availability for charging station development and electricity grid readiness as the two largest charging infrastructure barriers (see Figure 4).

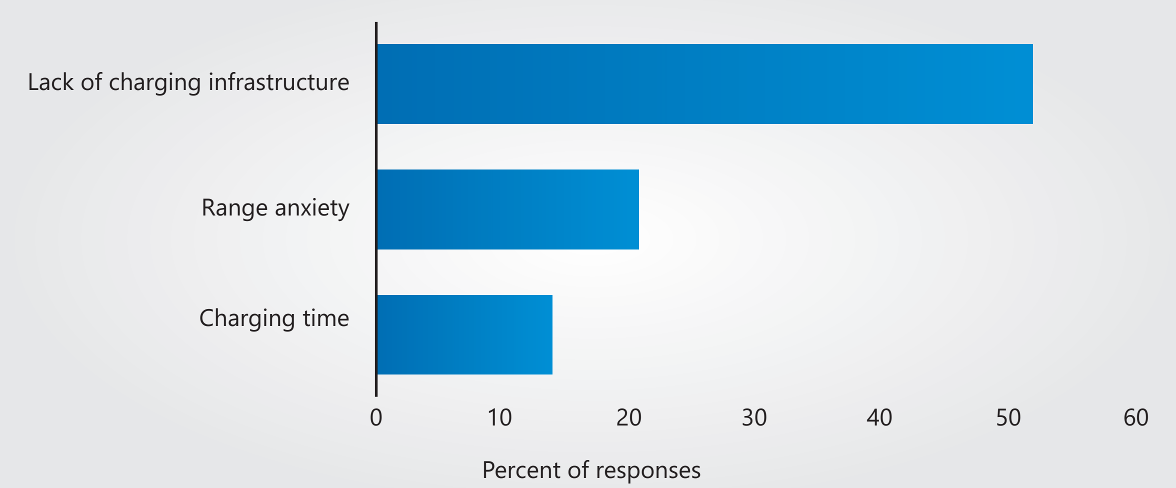
Figure 3: Select a maximum of three infrastructure demand barriers to upscaling investment in electric mobility in India



(Source: Authors)

(Note: Survey participants selected up to 3 barriers from a list of 9)

Figure 4: Respondents' perceptions of barriers to consumer demand: prevalence of concerns regarding charging infrastructure, range, and charging time



(Source: Authors)

(Note: Survey participants selected up to 3 barriers from a list of 11)

Despite concerns over charging availability, the installation of EV charging stations is accelerating in India. Under FAME I, the Indian government sanctioned 520 public charging stations; under FAME II, it has sanctioned 2,900 stations, with another 1,600 in development or being planned. The Indian government also reduced GSTs levied on EV chargers from 18 per cent to 5 per cent (NITI Aayog, RMI, and RMI India 2022b). In an attempt to facilitate the further development of public and private EV charging infrastructure, the Ministry of Power issued consolidated guidelines and standards for it in January 2022.

Several plans for adding charging infrastructure in India are underway. If implemented effectively and supported with public and private investment, they could help incentivize EV adoption:

- Nine megacities in India more than doubled the number of public charging stations between October 2021 and January 2022. These stations were installed following the Indian government's decision to prioritize charging infrastructure in cities with a population of over four million people. The installation effort fits within the goal of India's Department of Heavy Industry to double the number of public charging stations in the country (Gadkari 2022).
- The National Highway Authority of India is aiming to set up EV charging stations every 40 to 60 kilometers along India's national highways to further boost 4W EV penetration in the country (Chauhan 2021). India's largest EV charging station, with a capacity of 100 charging points for 4Ws, was opened in early 2022 along the Delhi-Jaipur National Highway in Gurugram. India's previously largest EV charging station, with 16 AC and 4 DC charging ports for EVs, was situated in Navi Mumbai. In general, the official government target is to have one public charging station every 25 kilometers and one fast charging station every 100 kilometers along major highways (Government of India Ministry of Power 2022b).
- State-owned oil marketing companies in India plan to install 22,000 EV chargers in prominent cities and on major highways over the next few years, indicating a potentially rapid growth in charging infrastructure in the near future (Government of India Ministry of Power 2022a).
- Many startups in India's online delivery space (grocery, food, and e-commerce), such as Zomato and Flipkart, have started transitioning their vehicle fleets to EVs. Some of these players have already committed to the Climate Group's EV100 initiative. The players in this group are setting up their own captive charging stations in large cities.
- Mobility services players, such as BluSmart, in collaboration with JioBP, are setting up mega charging stations in the heart of large cities for their own captive needs.
- The Indian government has attempted to facilitate charging by offering EV bus purchasers one slow charger per bus and one fast charger for every 10 buses that fall under the scheme (Government of India Department of Heavy Industry 2019).

Consulted investors identified four policy concerns that need to be addressed to accelerate charging infrastructure deployment:

- First, charging subsidies under FAME II are limited to high-capacity chargers primarily used for 4W passenger cars, which is at odds with the overall scheme supporting a much heavier market penetration of 2Ws (1 million units) and 3Ws (500,000 units). Meanwhile, the subsidy program effectively puts the burden of expanding 2W and 3W charging infrastructure on charging point operators by requiring the installation of 2W and 3W chargers for eligibility. Consulted investors wanted to see greater government investment in dedicated 2W and 3W charging infrastructure.

- Second, in previous guidelines, the government indicated that state governments had the right to cap the charging fee of any charging point operator that benefited from a subsidy. In updated guidelines, they extended this rule to any operator that received an electricity connection from the distribution company, which encompasses nearly all operators in India. The new guidelines forced operators to assess risk and calculate return on investment, both of which are inevitably linked to charging fees. While consulted investors understand that distribution companies must charge for electricity connections and the government must charge operators for certain provisions such as land, they reported concerns regarding the uncertainty that comes with the potential capping of charging fees.
- Third, it remains unclear who is supposed to pay for grid accreditation—often, charging point operators do—which can cost as much as the equipment. Consulted investors identified the need for clear market rules around setting up charging infrastructure.
- Fourth, like elsewhere in the world, India's charging infrastructure land needs are concentrated in premium locations, making the availability and cost of land a paramount concern, including among consulted investors. The Indian government has already taken critical steps to address this concern, such as allowing state-owned entities to offer land to private charging point operators through a bidding process that values state-owned land at a minimum of one rupee per kWh (and exactly one rupee per kWh for state-owned charging point operators; Economic Times 2022). By using this revenue-sharing agreement, local governmental bodies can accelerate the installation of charging stations.

In addition to these four concerns, some of which federal, state, and local governments are already working to address, investors indicated a broader concern about the financial viability of Indian distribution companies and thus their capacity to invest the capital needed for charging infrastructure.

Across the world, electricity supply will need to be upgraded to accommodate EV charging (Moerenhout 2021a). Distribution companies can facilitate EV adoption by embracing forward-looking business and management approaches, having single points of contact for charging point developers, communicating clearly about hosting capacity on distribution networks, making siting processes easier and faster, encouraging demand-side management, so charging happens at the time of day when power demand is low, and linking up chargers with renewable energy (Arora and Korsh 2021). Consulted investors and government officials agree that addressing this potential technology adoption bottleneck would further enhance trust in India's EV ecosystem.

Much progress has been made to reduce the time it takes to obtain charging connectivity from distribution companies. Whereas this process used to take up to six months, India's Ministry of Power recently published revised guidelines that encourage utilities to complete it within 15 days (though these have not yet been implemented in many states). However, improving charging connection times will require investment on the electricity supply side. Whereas in 2018 EV batteries demanded 2.9 GWh, by 2030 they are expected to demand 158 GWh, with over 50 per cent of that coming from 2Ws (Invest India 2022). Once again, this highlights the importance of distribution companies to EVs, which can be a challenge given the financial stress these companies are under, with total losses amounting to almost USD 23 billion in 2021 (Regy et al. 2021). The Indian government is currently suggesting that distribution companies use the recently launched Rooftop Solar Scheme, which aims to install a cumulative capacity of 40 GW from rooftop solar projects by 2022, to provide less expensive upstream infrastructure to charging point operators.

Takeaway 4: Battery swapping can alleviate considerable demand-side concerns.

The up-front costs of EVs are largely determined by the price of the battery. This makes battery swapping, which allows consumers to purchase an EV at a lower cost without the battery and then use swapping stations to load full batteries and unload empty ones, a potentially attractive incentive option—one that can also help to address other constraints such as insufficient charging infrastructure and lack of dedicated parking space in urban settings. Although users would need to pay for battery swapping services, these costs would be incurred across the lifespan of the vehicle. Currently, discussions of battery swapping in India are focused on 2Ws and 3Ws.

Battery swapping in India could resolve additional obstacles to EV adoption, all linked to the fact that the initial traction for EV adoption is in major cities, including state capitals: the lack of parking space in urban centers due to land availability issues; the use by urban high-rise buildings of diesel-based generators, which are costly and polluting, to satisfy part of their electricity demand; and the need to add EV chargers to urban residential buildings, which could increase load requirements on the grid, especially during peak demand hours. These factors, in combination with India being the largest 2W market in the world, could make battery swapping a viable solution in India's large cities.

Many challenges still need to be overcome, however, for battery swapping to flourish. Currently, major vehicle manufacturers do not share their battery technology information with each other and are not required to do so by intellectual property regulations. This means that different battery designs may not work for different EVs, limiting the potential economies of scale of the battery swapping model. Moreover, taxation of swappable batteries in India is significantly higher (18 per cent) than that of fixed batteries (5 percent; Charan 2022), making them cost prohibitive.

Experts believe that swapping could contribute to 30 to 40 per cent EV growth in India if several conditions are met, including the introduction of government mandates and subsidies, policy frameworks that guarantee interoperability and safety, and battery swapping roadmaps for different segments, from 2Ws and 3Ws to e-commercial fleets. They also believe that swappable batteries would be half the size, require less lithium, last longer, and allow for better grid management compared with batteries individuals charge at home (Charan 2022). Moreover, experts consulted for this study suggested that swapping stations could reduce the sizable land requirements of charging infrastructure because they can be set up in stores and lengthen the lifetime of the batteries because they would be charged in a controlled environment.

Several recent announcements in India indicate progress in the battery swapping realm:

- The EV manufacturer Mahindra and the oil company Reliance Industries will develop battery swapping technology for food delivery fleets of the online food ordering and delivery company Swiggy (Mishra 2021).
- The motorcycle company Hero MotoCorp and scooter company Gogoro will open a network of swap stations (Gogoro 2021).
- The energy company Sun Mobility and Honda will set up a battery sharing and swapping business (Balasubramanyam 2022).
- The electric 2W company Bounce and parking solutions platform Park+ will set up 3,500 battery swapping stations (Economic Times 2021).
- Yulu is expanding its battery swapping network in Bengaluru, Mumbai, and Delhi NCR (Livemint 2021).

The Indian government has started to develop a policy framework to facilitate battery swapping. The current finance minister announced that the government will formulate interoperability standards for EV batteries, focusing specifically on electric 2Ws and 3Ws and targeting the last-mile delivery and ridesharing segments. Recent media reports suggest that the government is also likely to offer EV owners an incentive of up to 20 per cent of the total subscription or lease cost of the battery and is considering cutting taxes from the aforementioned 18 per cent rate to the 5 per cent that is applicable to fixed batteries (Shah 2022).

Takeaway 5: India is a young player in battery manufacturing, but its growth potential in this space is enormous.

The global LiB market is expected to grow from about USD 41 billion in 2021 to at least USD 116 billion in 2030 (Invest India 2021). The battery represents the largest share of an EV's value, at around 40 per cent (Invest India 2021). Within the battery, the battery cell has the highest value (see below). In a rapid growth scenario, India expects an annual battery market of approximately USD 15 billion by the end of the decade, of which about USD 12 billion would come from cell manufacturing and USD 3 billion from battery pack assembly and integration. Even in a conservative scenario, the Indian domestic manufacturing market would be worth USD 6 billion annually (NITI Aayog, RMI, and RMI India 2022b).

The volume of LiB manufacturing among the countries leading this sector is likely to change. Currently, China holds about 78 per cent of battery manufacturing capacity, followed by the US (8 per cent) and the EU (7 per cent). But high levels of demand growth are opening up new initiatives and production capacity worldwide, which will inevitably increase competition. By 2025, it is expected that China's share of LiB manufacturing will fall to 65 per cent, while the EU's share will increase to 25 per cent (NITI Aayog, RMI, and RMI India 2022b). Other countries such as India are also expected to increase their share.

NITI Aayog, RMI, and RMI India (2022b) expect that by 2025 the price competitiveness of electrified 2Ws, 3Ws, and buses will reach parity with ICE vehicles. By 2030, they expect the same to be true of electric 4Ws. Whereas today the 2W and 3W segments have the most potential in India, by the end of the decade, other segments will have grown rapidly too. EV sales penetration of commercial 4Ws, for instance, is expected to be between 30 per cent and 40 per cent by 2030, while in an accelerated scenario, as high as 70 per cent of new sales could be electric. Electric buses are expected to be third, with a conservative sales penetration rate of almost 20 per cent and an accelerated penetration rate of 40 per cent. Currently, state transport agencies are incentivizing intracity electric buses through tenders, while intercity bus routes are often covered by private companies that may delay electrification due to the large distances they cover. The sales penetration rate of private 4Ws is expected to be 5–10 per cent in a conservative scenario and 10–15 per cent in an accelerated scenario (NITI Aayog, RMI, and RMI India 2022b).

These EV numbers imply very strong demand growth for batteries. NITI Aayog and the Rocky Mountain Institute believe that with a high penetration of EVs India could capture 13 per cent of worldwide LiB demand by 2030 (NITI Aayog, RMI, and RMI India 2022b). While it is true that 2W and 3W batteries are smaller and have somewhat less value than 4W batteries, the scale of electrification of 2Ws in India, in combination with the uptake in commercial 4Ws and buses (which require much larger batteries), will spur demand growth.

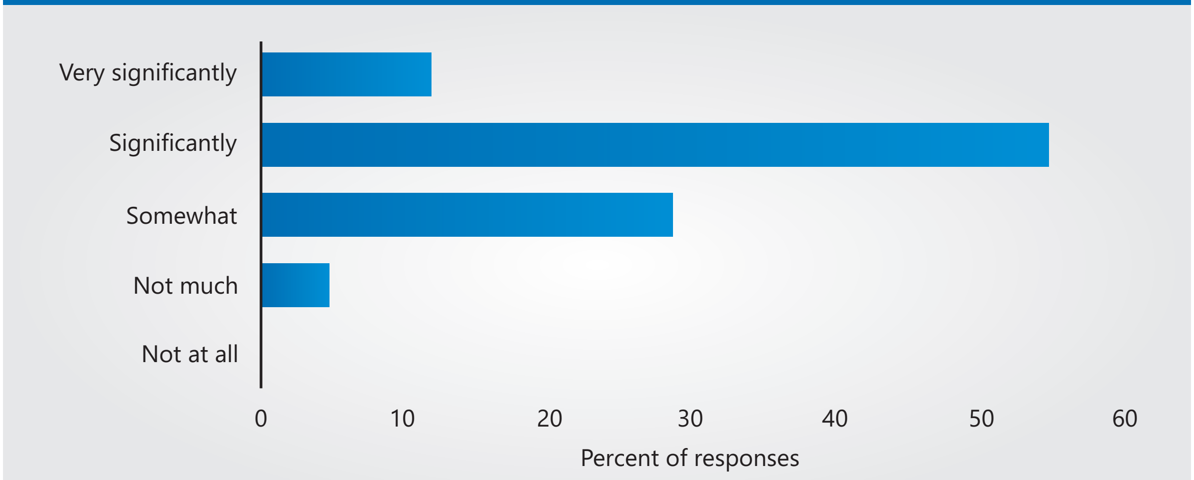
To meet that demand with locally sourced manufacturing, India would need to install two 10 GWh battery-cell gigafactories by 2022, five by 2025, and 26 by 2030. In a conservative scenario, the country would need 10 such factories by 2030 (NITI Aayog, RMI, and RMI India 2022b). Currently, India is not yet a large player in battery manufacturing, but the market potential for this manufacturing is enormous, and the sheer size of future demand should allow for economies of scale.

India's core industrial policy measure to incentivize battery manufacturing is its Production Linked Incentive Scheme for Advanced Chemistry Cell Batteries (PLI-ACC). Launched in 2021, the PLI-ACC is intended to incentivize domestic battery manufacturing. The scheme foresees USD 2.5 billion of subsidies over five years, which will be awarded to battery manufacturers through a competitive bidding process with the ultimate goal of establishing 50 GWh of local manufacturing capacity.

The subsidy amount is determined based on the amount of kWh, the percentage of local value addition achieved, and the actual sale of batteries (Invest India 2022). Within the first two years, winning bidders will need to set up at least 5 GWh of capacity, source 25 per cent of value domestically, and undertake an investment of USD 31 million per GWh. The domestic content requirement then increases to 60 per cent within five years (Government of India Department of Heavy Industry 2021a). While initially companies will be able to enjoy the subsidy by localizing battery assembly, the 60 per cent domestic content requirement makes it mandatory for the manufacturing of battery cells to happen in India within five years.

Experts and investors strongly believe the PLI-ACC and PLI Auto schemes (see below for more detail on the latter) will accelerate the EV ecosystem in India (see Figure 5).

Figure 5: Respondents' assessment of the PLI-ACC and PLI Auto schemes' ability to accelerate the EV ecosystem in India



(Source: Authors)

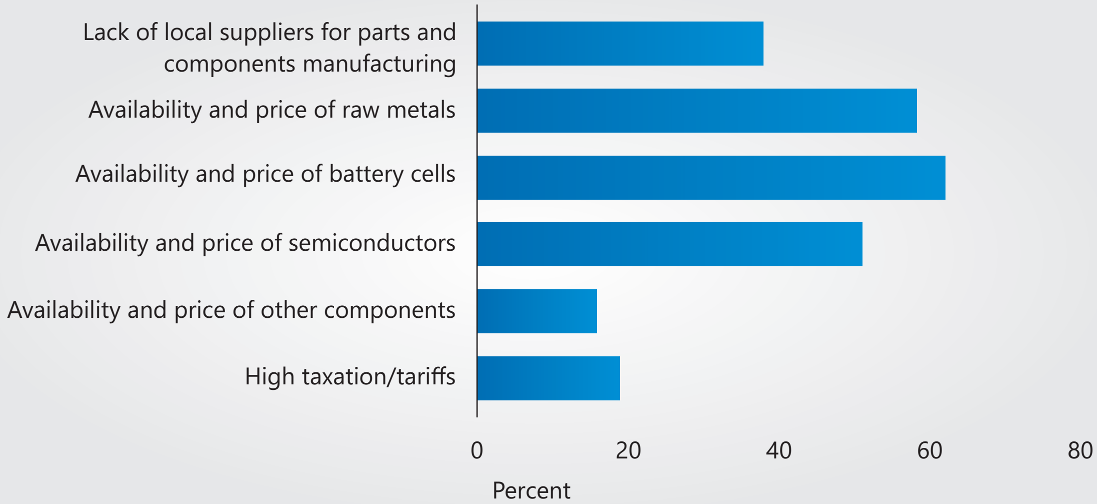
The cost of a battery can be divided into cell manufacturing (65 per cent) and assembly (35 per cent) (Invest India 2021). Within the cell, 35 per cent of the value comes from the cathode, 15 per cent from the anode, 25 per cent from cell assembly, and 25 per cent from other activities and parts, specifically the separator (ibid.). The cathode is cast on aluminium foil and requires raw minerals such as manganese, nickel, cobalt, and lithium. The anode, by contrast, is cast on copper foil and requires graphite. Given that India has plenty of graphite, domestic production of anodes is not at risk from a material supply perspective (ibid.). Investment is needed, however, to build industrial capability and know-how to process graphite into the high-purity graphite used in anodes. The domestic production of cathodes, meanwhile, faces considerable supply chain challenges (see below).

The first bidding round after the initiation of the scheme requested bids for a total of 50 GWh of ACC manufacturing. Companies had to bid for at least 5 GWh and a maximum of 20 GWh of manufacturing capacity. The scheme received an encouraging response from both local and global investors. The tender was oversubscribed, and the government received bids of 130 GWh for a PLI-ACC tender size of 50 GWh. Three companies were finalized to boost local battery cell production: Reliance, Ola Electric, and Rajesh Exports (Invest India, July 2022).

Takeaway 6: Supply chain challenges can derail the rapid upscaling of EV and battery investment, highlighting the need for stronger policy support.

Beyond concerns about competition, India faces considerable energy security and supply chain challenges related to importing automobile components, battery cells, and other components such as semiconductors. Currently, China holds around 75-80 per cent of raw battery material refining and global battery cell manufacturing capacity, and Taiwan accounts for well over half of global semiconductor manufacturing capacity (Nee Lee 2021). Given India's geopolitical tensions with China, a rapid uptake of EVs in the country (and worldwide) would require a more diversified supply base. Consulted experts and investors highlighted that the top three supply chain concerns in India are indeed linked to the availability and price of battery cells, raw metals, and semiconductors (see Figure 6).

Figure 6: Respondents' concerns regarding current supply chains in the Indian EV ecosystem



(Source: Authors)

(Note: Participants indicated agreement or disagreement with each statement as a concern in the current Indian EV ecosystem; the percentage noted here corresponds to agreement)

Battery raw materials

India's ambition to become a battery cell manufacturer has been thwarted by global supply-side constraints that affect Indian producers. As mentioned, cathode manufacturing requires aluminium, cobalt, lithium, premium grade nickel, and manganese. There are considerable supply-side challenges for each of these critical minerals.

The most well-known of these supply-side challenges is linked to cobalt. More than half of the worldwide reserves of cobalt and more than two-thirds of its production are in the Democratic Republic of the Congo (DRC). Cobalt production in the DRC has been plagued by corruption, fraud, and human rights violations. As a result, many battery manufacturers have been cutting the proportion of cobalt they use in batteries and have even been omitting the metal altogether (Moerenhout 2021a).

Unlike cobalt, lithium is likely to remain a key battery ingredient for the foreseeable future (Castelvecchi 2021). As with other key metals, lithium supply is not expected to meet demand over the next few years, specifically owing to the uptake of EVs (Yue Li and Attwood 2021). Lithium resources are also concentrated in a handful of countries, specifically Australia and the lithium triangle in South America. Bolivia and Chile hold among the largest lithium resources worldwide—21 million tons and 10 million tons, respectively, out of a global total of 86 million tons. Nevertheless, the processing of lithium is not well advanced in either country. For example, Chile holds 44 per cent of the commercially viable lithium reserves worldwide but produces only about 22 per cent of the world's lithium (USGS 2021). Despite having more resources, Bolivia mines and processes even less lithium, with its reserves not yet considered economically viable.

Nickel is used in batteries because of its high energy density, which allows for a lower share of cobalt. Although nickel is abundant worldwide, the class-one, high-grade nickel that is comprised of more than 99.8 per cent nickel and allows a battery to be more durable and deliver a longer range (Assay 2021) will be more difficult to supply in the coming decade, especially given the demand competition from the stainless-steel industry (Azevedo, Goffaux, and Hoffman 2020). Already in 2021, there were concerns that the high-grade nickel supply could be insufficient to meet demand (Baratti 2021). This gap is expected to grow due to insufficient high-grade nickel-mining projects to keep up with forecasted demand (Liedtke 2021a; Rystad Energy 2021). Given that Russia supplies 20 per cent of EV battery-grade nickel, the Russian war in Ukraine is putting additional pressure on nickel supply and prices (Finley 2022).

In response to insufficient nickel supply, evolving battery chemistries seek to lower the nickel content of batteries and increase the manganese content (from 10 per cent to around 30 per cent) or use iron phosphate batteries made available by improvements in energy density over the last few years (Rystad Energy 2021). While mining for manganese is relatively simple and supply is found in more than 10 countries considered politically stable, refining it to battery-grade manganese sulphate is both expensive and technologically complex (Liedtke 2021b). Currently, 90 per cent of the global capacity for the production of high-purity manganese sulphate is in China. While some processing plants outside of China are underway, many more will be needed to diversify supply (ibid.).

The Indian government's response to battery mineral supply challenges has been twofold. On the one hand, some government-affiliated experts have suggested that beneficiaries from the PLI-ACC scheme should pass on benefits to raw material suppliers (Iyengar 2021). On the other hand, the government is developing forward-looking policies and incentives to promote "urban mining," which involves recycling LiBs to retrieve and reuse key metals.

Battery recycling can help secure raw material supplies and protect against cost escalation in the medium term. Besides China, which is the leader in LiB recycling, the United States and Europe are enacting policies and incentives to encourage this practice. For example, the EU has proposed a new battery directive that specifies minimum recycled content requirements for battery minerals. Given the success of the PLI-ACC scheme, the Indian government is well positioned to follow suit. Consulted experts suggest that Indian cell makers can be potential joint venture partners for the global recycling companies that access the Indian market.

Nevertheless, many consulted investors believe that the Indian government should also play a more active role in helping secure semiconductors and primary metals for cathode manufacturing. Battery reuse as cheap energy storage can delay battery availability for recycling, and in any case, it will take time to get battery recycling processes up and running. Simultaneously, localization requirements in the PLI-ACC scheme require cathode manufacturing within five years. As a result, investors want the government to engage more actively in setting up international collaborations that can get strategic components and metals to India. For example, some experts have suggested that India could acquire stakes in lithium mines in Bolivia (Dash 2021). The state-owned company KABIL is already working with the biggest lithium-supplying countries (Australia and Chile) and lithium resource-rich countries (Bolivia, Chile, Argentina, and Australia) to take the first steps toward such international cooperation (Hector 2021).

Semiconductors and non-battery components

Like many other countries, India is seeking to capitalize on the global semiconductor shortage by constructing a mega semiconductor cluster. At the end of 2021, the cabinet approved the Semicon India Program, which sets up packages of upwards of USD 10 billion over the next six years to incentivize domestic semiconductor and display manufacturing in India. By mid-February 2022, the government had already received five proposals representing a total potential investment of around USD 21 billion (Bhardway and Cyrill 2022). Reportedly, the government is also in talks with Taiwan to facilitate international cooperation on semiconductor-manufacturing capacity (Rajagopalan 2022).

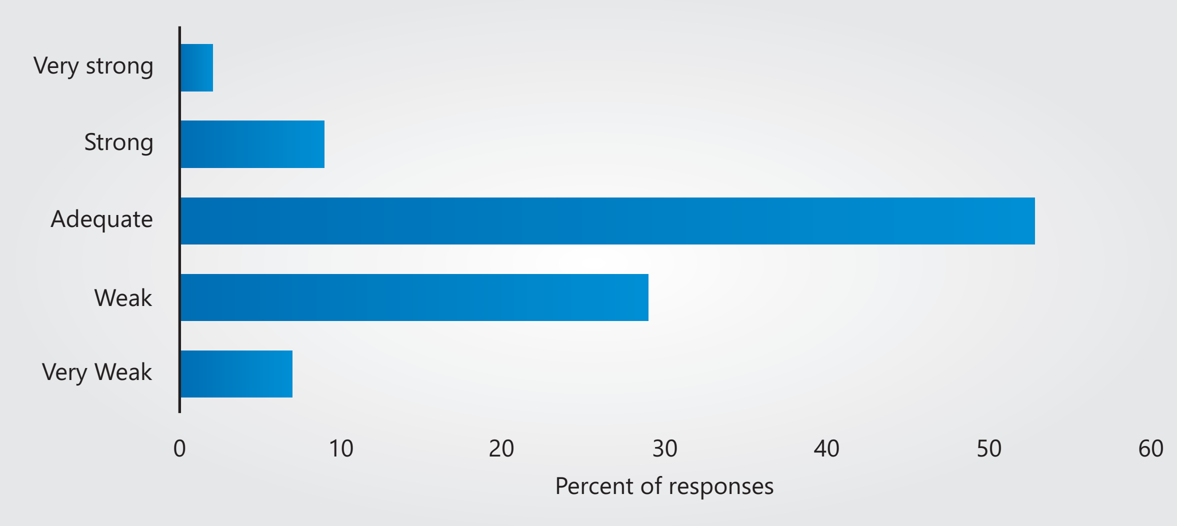
To minimize supply chain challenges beyond batteries and semiconductors, the Indian government approved the PLI Scheme for Automobile and Auto Components Industry (PLI Auto) in 2021 with a budgetary outlay of USD 6.5 billion. This production-linked incentive scheme focuses on non-battery components (with batteries being covered by the aforementioned PLI-ACC scheme) and includes incentives for green vehicles (electric and hydrogen) and high-value advanced automotive technology products. In addition to incentivizing auto OEMs and auto components, the PLI Auto supports non-automotive companies that seek to foray into green mobility (Government of India Department of Heavy Industry 2021b). The scheme is estimated to bring fresh investments of over USD 10.5 billion that will assist in rapidly building a local EV and EV-component manufacturing ecosystem in India (Mukherjee 2022).

In January 2022, the Indian government received a clear signal that investors were ready to participate in the PLI Auto when 115 companies responded to its call for proposals. The Ministry of Heavy Industries approved 20 Auto OEMs as eligible for incentives. Of these 20 OEMs, 10 are incumbent 4W manufacturers, and 6 are non-auto companies that plan to begin manufacturing EVs under the PLI Auto scheme (Mukherjee 2022).

Takeaway 7: India has taken sound steps to incentivize EVs and battery manufacturing since the start of COVID-19, but the competition is stark.

The EV ecosystem in India has space to be competitive globally, but the competition is stark. Several governments around the world have used the COVID-19 crisis as an opportunity to extend fiscal policies that incentivize EV uptake and battery manufacturing. India's key programs, FAME -II and the PLI-ACC, compare favorably with these policies in terms of fiscal incentives for EV purchases and battery manufacturing. As mentioned earlier, they lag behind, however, on charging infrastructure, even as FAME II has allocated USD 130 million to developing it. Despite this challenge, half of the experts consulted for this study believe that India's EV ecosystem policies are now adequate compared with other major EV ecosystems, indicating that the country is ready to receive more FDI and is on track to becoming a mature EV ecosystem (see Figure 7).

Figure 7: Respondents' assessment of the competitiveness of India's EV investment-oriented policies compared to other major EV ecosystems (e.g., Europe and China)



(Source: Authors)

Some of the largest approved commitments outside of India are (Energy Policy Tracker 2022):

- China: USD 1.6 billion for EV purchase subsidies and USD 1.5 billion for charging infrastructure
- US: USD 7.5 billion for charging infrastructure, with several states adding more on top
- Canada: USD 1.1 billion for zero-emission buses and charging infrastructure
- EU: USD 750 billion recovery fund that allows member states to request charging infrastructure support, plus USD 3.2 billion for pan-European research and development (R&D) along the entire battery value chain
- Germany: USD 2.7 billion to double EV purchasing premiums and USD 2.9 billion to extend charging infrastructure
- UK: USD 1.7 billion for charging infrastructure, USD 800 million for zero-emission vehicles purchase subsidies, and USD 700 million for battery manufacturing
- France: USD 600 million for EV purchasing subsidies and USD 800 million for battery manufacturing
- Italy: USD 800 million for charging infrastructure

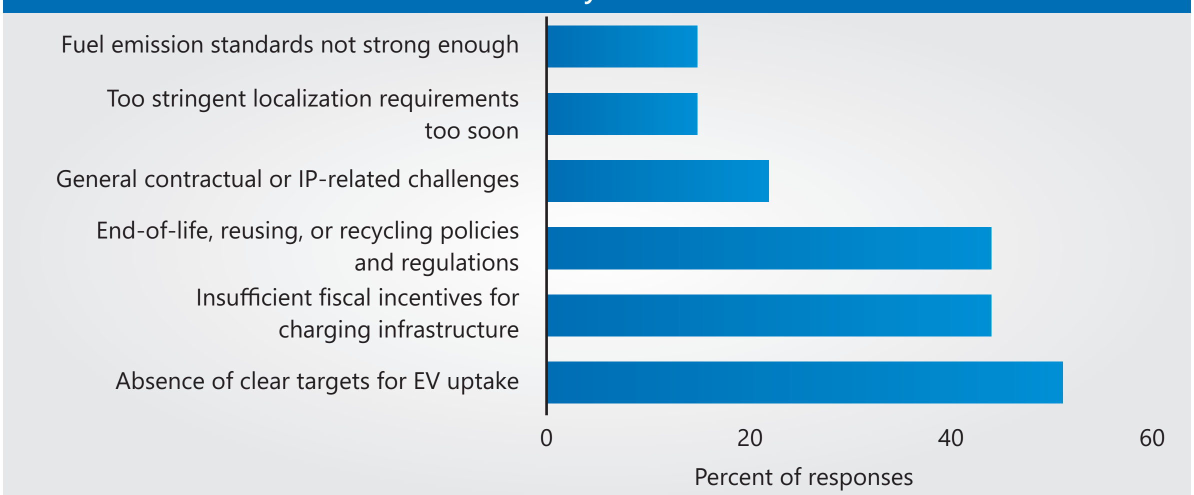
India has certain advantages over these countries, including its sheer domestic market size, its digital competitiveness, the size of its skilled workforce, and its wage competitiveness. Consulted investors suggested that India could further improve its competitiveness by moving from enabling policies to binding targets. Localization targets are included in the PLI-ACC scheme, and failure to achieve them will invoke penalties. Extending targets to include binding EV penetration targets and vehicle emission standards would demonstrate the government's commitment to electrification over the long run and help leverage India's market size (see Figure 8).

The world's major EV ecosystems have begun to adopt strong targets—most importantly for market penetration. At COP26, 28 governments announced the goal of 100 per cent zero-emission car and van sales by 2040, or even 2035 in the case of leading markets (COP26 2021). In its Fit for 55 program, the EU proposed a 100 per cent zero-emission car and van sales target for 2035 (European Council 2022). In the United States, certain states, such as New York and California, are adopting similar targets (Moerenhout 2021b). China has already implemented zero-emissions vehicle credit targets for manufacturers as a share of their total annual vehicle production. By 2023, manufacturers in China will need to ensure that 18 per cent of their sales in the country correspond to so-called new energy vehicles, such as battery EVs or plug-in hybrids. China has also banned ICE versions of 2Ws and 3Ws in numerous cities.

Another frequently used policy to incentivize EVs is the gradual tightening of fuel economy standards. India still lags somewhat behind the other major EV manufacturers on this front. Similar to Japan, it has a 134 g CO2/km cap. By comparison, China, the United States, and Canada have a 114–117 g CO2/km cap, and the EU has an average 95 g CO2/km cap among its member countries (IEA 2021a).

Other measures to incentivize demand include car plate restrictions with EV direct access, traffic restrictions with EV waivers, and low cost or free parking for EVs. These measures have been used in several major Chinese cities and are being considered in multiple countries (IEA 2021a). In India, they could amplify demand in heavily dense urban settings while simultaneously showing investors that certain deployment bottlenecks can be overcome. Currently, while 59 per cent of consulted experts and investors believe that there is near- and long-term ambition for EV adoption and ICE phase out, about half still see an absence of clear targets for EV uptake, which they suggest is the largest policy barrier alongside insufficient fiscal incentives for charging infrastructure to upscaling investment in electric mobility in India (see Figure 8). The investors appear to believe that such targets are far more important than fuel emission standards and stringent localization requirements.

Figure 8: Respondents' three most- and least-cited policy barriers to investment in electric mobility in India



(Source: Authors' survey)

(Note: Survey participants selected up to 3 barriers from a list of 9)

Takeaway 8: Complementarity between state and federal policies is crucial, with some states ahead of others.

If India wants to develop its EV ecosystem, complementarity between federal, state, and local policies is key. As of February 2022, about 18 Indian states have developed final EV policies, with eight more states in the process of doing so. About two-thirds of consulted experts and investors do not believe that coordination between state and federal policies is a particularly urgent policy barrier. However, 39 per cent believe that difficulties at the local level to support required infrastructure (e.g., land for charging and local permits) do represent a key infrastructure barrier. If the goal is to alleviate those concerns, linking local policies to state and federal EV policies can be effective.

The question of which states in India are leading the EV charge has no clear answer. For instance, on the adoption front, northern states such as Uttar Pradesh are ahead of the curve, though Delhi is quickly catching up with a very comprehensive state EV policy that focuses heavily on EV adoption. The picture is completely different for manufacturing, however, where the key is the investor checklist rather than large demand-side incentives alone. This checklist includes the status of the manufacturing ecosystem, state proactiveness in handling investor queries and continuous investment facilitation support, political stability, and long-term sanctity of contracts (promised incentives), dedicated EV policies and incentives as well as capital subsidies from the state, access to port infrastructure for importing raw materials and exports, and the availability of a skilled workforce. Some consulted investors also ask for access to renewable energy to make batteries and vehicles even stronger from an ESG perspective.

Based on these factors, states in southern India, such as Telangana, Karnataka, and Tamil Nadu, in addition to Maharashtra and Gujarat in the west, appear to be at the forefront of the EV manufacturing race. These states are also proactively and regularly engaging with centZral government bodies, such as NITI Aayog and Invest India. That many of these state governments have also taken the initiative to start engaging with bidders in the previously mentioned PLI Schemes is a testament to their hands-on approach. If states wish to build competitive industries, they will also need to focus on their competitive advantage in the EV value chain. For example, Karnataka accelerates the R&D ecosystem that it is already known for, whereas Maharashtra could build on its sizable manufacturing advantage.

Some states are using new approaches to incentivize the creation of an EV ecosystem, such as the exceptional step of investing directly in EV companies. One example is the recent joint venture partnership between the Kerala state government and Lord's Automotive to manufacture EVs in the state. Other states, such as Telangana, are offering a full suite of options to promote technology-development startups, from financing to prototyping centers to business incubators.

Takeaway 9: If the goal is to ensure a smooth transformation to a healthy EV ecosystem, some skill gaps still need to be addressed in the medium term.

As the transition from ICE automobiles to EVs accelerates in India, there is growing concern about the skill differential between these two segments, especially given that the automotive sector is one of India's largest employers for both direct and indirect employment. If the goal is to avoid job losses due to this transition, initiatives to retrain the labor force are required.

The skill gap issue varies in degree and extent across the EV supply chain. For instance, there is almost no skill gap for workers with an understanding of chemicals. On the other hand, companies face problems in securing workers skilled in R&D. Issues surrounding labor in the EV sector are also not limited to the manufacturing and assembly of EV components and vehicles. Since EVs require safety precautions, certain professionals outside of the periphery of the conventional EV supply chain are likely to come in contact with EVs, including shopfloor workers and individuals servicing and repairing EVs. These professionals, many of whom are part of the informal sector and only have experience with ICE vehicles, will need training too. It is important to recognize, though, that even with measures to close the skill gap, some job losses may occur because EV mechanics and maintenance are simpler than their ICE vehicle equivalents. Averting these losses will likely require a more elaborate, just transition pathway.

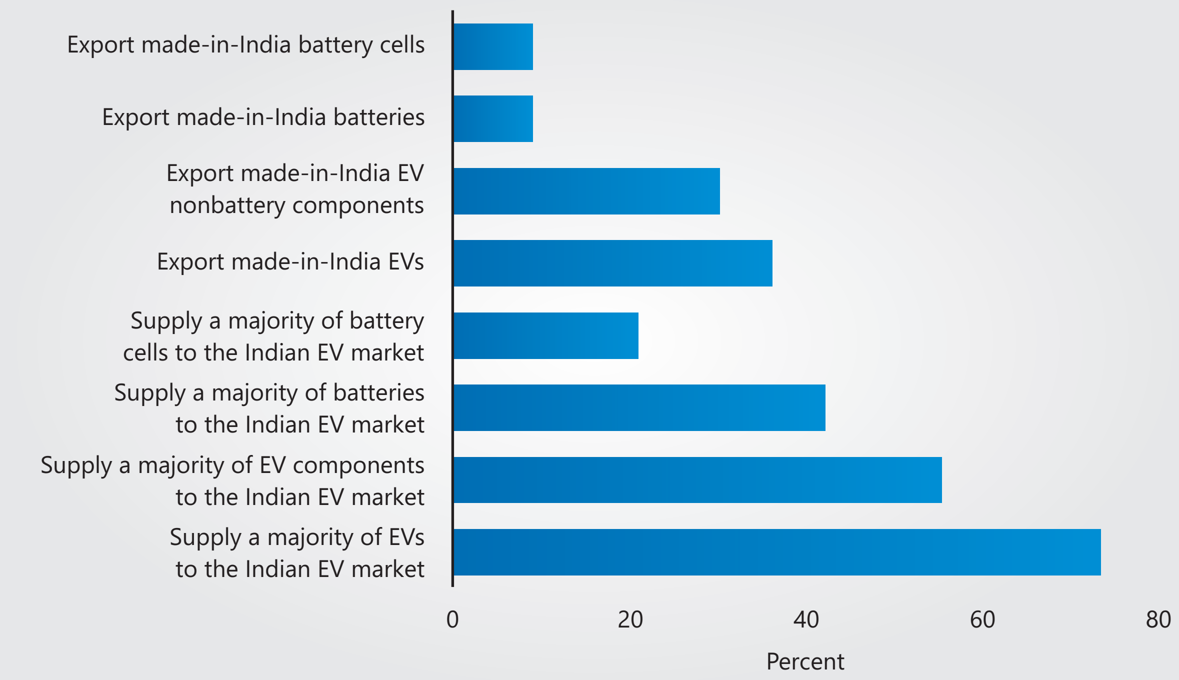
Government, industry, and academia in India have each responded to the skill gap problem. Industry and academia have sought to retrain the workforce and launch education courses, while state governments have sought to support them. For example, Maharashtra introduced a policy that supports amending existing courses or creating new courses on EV ecosystems. In collaboration with OEMs and EV service providers, the state government plans to develop skill enhancement centers to deliver vocational courses linked to the EV ecosystem. Specifically, these centers would train ICE mechanics to repair and service EVs and charging stations. Similarly, Karnataka aims to establish EV skill development centers that, in addition to technical training, will offer a stipend for workers to gain experience at EV manufacturing plants, and Tamil Nadu aims to introduce EV engineering courses in partnership with OEMs that will provide internships to students (Ray et al. forthcoming).

Conclusion

If India (and the rest of the world) seeks to meet its decarbonization goals, expanding the country's EV penetration rate is crucial. Even when powered by coal-fired electricity, EVs produce fewer carbon emissions per kilometer than their ICE counterparts. Additionally, India's timescale for the deployment of EVs is well aligned with plans to deploy 500 GW of renewable energy by 2030.

As this report has shown, recent policy initiatives in India are preparing the country to leverage its market size to become a global EV investment destination. Consulted experts and investors expect that India will do so by, first, supplying the domestic market with EVs and EV non-battery components, and then, within three to five years, making strides in battery assembly at the initiative of investors and companies. The experts and investors do not expect battery cell manufacturing to reach its full potential in the country just yet (see Figure 9).

Figure 9: Respondents' expectations for India-based manufacturing in three to five years



(Source: Authors)

(Note: Participants indicated agreement or disagreement that each outcome was likely to occur in the next three to five years; the percentage noted here corresponds to agreement)

It should come as no surprise, then, that India's EV market is projected to be worth USD 150 billion by 2030 (Invest India 2022). As discussed in this report, federal policies such as FAME II, PLI-ACC, and PLI-Auto have created a strong environment for a globally competitive EV ecosystem in India, specifically in the 2W and 3W segments. Eighteen Indian states have also added new incentives to the mix that can help India bolster demand for 4Ws and electric buses as well as host mega factories.

This chapter also highlighted that, like in other countries, legacy issues such as concerns over the high purchase costs of EVs and limited public awareness about the total cost of ownership and available incentive mechanisms remain important in India. Although the country is working actively to improve financing options, if it seeks to pave the way for broader EV uptake, it will need to accelerate these efforts. Consulted investors believe that lessons can be learned from experiences in other countries, particularly those that have moved from an enabling policy environment to specific targets and other regulatory instruments to incentivize demand and supply chains. India's growing EV market penetration and battery-development ambitions also introduce new barriers, including supply-chain worries related to the price and availability of semiconductors, metals and minerals, and battery cells, as well as concerns about insufficient charging infrastructure and electricity grid readiness.

References

Aditi, Shah. 2022. "India Close to Finalising Incentives under New Battery Swap Scheme." Reuters. February 3, 2022. https://www.reuters.com/world/china/india-close-finalising-incentives-under-new-battery-swap-scheme-source-2022-02-03/.

Arora, Nitish, and Jessica Korsh. 2021. "Utilities and EV Dreams in India." Natural Resource Defense Council (NRDC). October 21, 2021. https://www.nrdc.org/experts/anjali-jaiswal/distribution-companies-discoms-power-indias-ev-dreams.

Assay. 2021. "The Importance of Class One Nickel for the EV Markets." January 12, 2021. https://www.theassay.com/articles/in-discussion/the-importance-of-class-one-nickel-for-the-ev-markets/.

Assis, Claudia. 2021. "Billions Poured into Electric-Vehicle Companies, but Much More Will Be Needed before the Auto Industry Changes." MarketWatch. March 20, 2021. https://www.marketwatch.com/story/billions-poured-into-electric-vehicle-companies-but-much-more-will-be-needed-before-the-auto-industry-changes-11615834509.

Azevedo, Marcelo, Nicolas Goffaux, and Ken Hoffman. 2020. "How Clean Can the Nickel Industry Become?" McKinsey & Company. September 11, 2020. https://www.mckinsey.com/industries/metals-and-mining/our-insights/how-clean-can-the-nickel-industry-become.

Balasubramanyam, K. R. 2022. "Honda to Kick off EV Battery Swapping in Bengaluru by June, First in 3-Wheeler Space." Economic Times. January 14, 2022. https://economictimes.indiatimes.com/industry/renewables/honda-to-kick-off-ev-battery-swapping-in-bengaluru-by-june-first-in-3-wheeler-space/articleshow/88887837.cms?from=mdr.

Baratti, Gianluca. 2021. "Nickel Miners Need to Increase Class 1 Output to Meet Steel, EV Demand: Bank of America." S&P Global Platts. August 23, 2021. https://www.spglobal.com/platts/en/market-insights/latest-news/metals/082321-nickel-miners-need-to-increase-class-1-output-to-meet-steel-ev-demand-bank-of-america.

Bhardwaj, Naina, and Melissa Cyrill. 2022. "What Is the Semicon India Program and How Does It Work?" Dezan Shira & Associates. February 21, 2022. https://www.india-briefing.com/news/semicon-india-program-investment-incentives-manufacturing-design-semiconductors-industry-23860.html/.

Bhardwaj, Sapna. 2021. "NITI Aayog Submits Proposal for Inclusion of EV under PSL." Opportunity India. December 6, 2021. https://opportunityindia.franchiseindia.com/article/niti-aayog-submits-proposal-for-inclusion-of-ev-under-psl-34430.

Bureau, FE. 2021. "Around 90% of Consumers in India Ready to Pay Premium to Buy EV: EY Survey." Express Drives. July 27, 2021. https://www.financialexpress.com/auto/electric-vehicles/around-90-of-consumers-in-india-ready-to-pay-premium-to-buy-ev-ey-survey/2298312/.

Castelvecchi, Davide. 2021. "Electric Cars and Batteries: How Will the World Produce Enough?" Nature 596, no. 7872 (August 17, 2021): 336–39. https://doi.org/10.1038/d41586-021-02222-1.

Charan, Parth. 2022. "Swappable Batteries Will Be Half the Size of a Regular Battery, Require Less Lithium and Last Longer." Moneycontrol. January 18, 2022. https://www.moneycontrol.com/news/business/swappable-batteries-will-be-half-the-size-of-a-regular-battery-will-require-less-lithium-and-will-be-designed-to-last-longer-chetan-maini-co-founder-and-vice-chairman-sun-mobility-8124891.html.

Chauhan, Yatharth. 2021. "Indian Highways to Get EV-Charging Stations Every 40–60 km." 91Wheels. October 18, 2021. https://www.91wheels.com/news/ev-charging-stations-indian-highways.

COP26. 2021. "COP26 Declaration on Accelerating the Transition to 100% Zero Emission Cars and Vans." UN Climate Change Conference UK 2021. November 10, 2021. https://ukcop26.org/cop26-declaration-on-accelerating-the-transition-to-100-zero-emission-cars-and-vans/.

Dash, Dipak. 2021. "Niti Aayog Member Urges Govt to Create Infra for Recycling of Li-Ion Batteries, Acquire Lithium Mines Abroad." Times of India. October 26, 2021. https://timesofindia.indiatimes.com/business/india-business/niti-aayog-member-urges-govt-to-create-infra-for-recycling-of-li-ion-batteries-acquire-lithium-mines-abroad/articleshow/87288271.cms.

Economic Times. 2021. "Bounce Partners with Park+ for Battery Swap Infra." November 27, 2021. https://economictimes.indiatimes.com/industry/renewables/bounce-partners-with-park-for-battery-swap-infra/articleshow/87949613.cms.

———. 2022. "Govt Allows PSUs to Offer Land to Set up EV Public Charging Stations." January 15, 2022. https://m.economictimes.com/industry/renewables/govt-allows-psus-to-offer-land-to-set-up-ev-public-charging-stations/articleshow/88921849.cms.

Energy Policy Tracker. 2022. "Energy Policy Tracker." https://www.energypolicytracker.org/.

European Council. 2022. "Fit for 55." https://www.consilium.europa.eu/en/policies/green-deal/eu-plan-for-a-green-transition/.

Finley, Allysia. 2022. "Russia Can Hold Nickel Hostage." Wall Street Journal. March 14, 2022. https://www.wsj.com/articles/russia-can-hold-nickel-hostage-metals-mining-environment-china-class-domestic-electric-vehicles-11647287911.

Foster, Vivien, Shanjun Li, Binglin Wang, Muxi Yang, and Fan Zhang. 2021. "If You Build It, They Will Come: Lessons from the First Decade of Electric Vehicles." World Bank. https://blogs.worldbank.org/transport/if-you-build-it-they-will-come-lessons-first-decade-electric-vehicles.

Gadkari, Nitin. 2022. "India Has over 1 Million EVs, 1742 Public Charging Stations." Business Standard. April 1, 2022. https://www.business-standard.com/article/economy-policy/india-has-over-1-million-evs-1-742-public-charging-stations-gadkari-122040100303_1.html#:~:text=As%20per%20Vahan%204%20data,(BEE)%2C%20are%20operational.

Gogoro. 2021. "Hero MotoCorp and Gogoro Announce Strategic Partnership to Accelerate the Shift to Electric Transportation in India." April 20, 2021. https://www.gogoro.com/news/gogoro-battery-swapping-india-hero/.

Government of India Income Tax Department. 2021. "Deduction in Respect of Purchase of Electric Vehicle." Pub. L. No. Section-80EEV, Income-Tax Act. https://www.incometaxindia.gov.in/_layouts/15/dit/mobile/viewer.aspx?path=https://www.incometaxindia.gov.in/acts/income-tax%20act,%201961/2021/102120000000076971.htm.

Government of India Ministry of Heavy Industries. 2019. "Corrigendum in Partial Modification of the Scheme for Faster

Adoption and Manufacturing of Electric Vehicles in India Phase II (FAME India Phase II).” Pub. L. No. S. O. 1300(E). https://fame2.heavyindustries.gov.in/content/english/11_1_PolicyDocument.aspx.

———. 2021b. “Notification: Production Linked Incentive (PLI) Scheme for Automobile and Auto Component Industry.” Pub. L. No. S. O. 3946(E), September 23, 2021. https://heavyindustries.gov.in/UserView?mid=2482.

———. 2021a. “Notification: Production Linked Incentive (PLI) Scheme, ‘NATIONAL PROGRAMME ON ADVANCED CHEMISTRY CELL (ACC) BATTERY STORAGE.’” Pub. L. No. S. O. 2208(E), June 9, 2021. https://heavyindustries.gov.in/UserView/index?mid=2487.

———. 2021c. “Notification: Scheme for Faster Adoption and Manufacturing of Electric Vehicles in India Phase II (FAME India Phase II).” Pub. L. No. S. O. 2258(E). https://fame2.heavyindustries.gov.in/content/english/11_1_PolicyDocument.aspx.

———. 2022. “Allotment Made for 50 GWh of Battery Capacity to 4 Successful Bidders for Incentive under (PLI) Scheme for Advanced Chemistry Cell (ACC) Battery Storage.” March 24, 2022. https://pib.gov.in/PressReleasePage.aspx?PRID=1809037.

Government of India Ministry of Power. 2022a. “Government of India to Expand Public Electric Vehicle Charging Infrastructure across the Nation.” February 19, 2022. https://pib.gov.in/PressReleseDetail.aspx?PRID=1799464.

———. 2022b. “Revised Consolidated Guidelines & Standards for Charging Infrastructure for Electric Vehicles (EV) Promulgated) Promulgated by Ministry of Power.” January 15, 2022. https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1790136.

Hector, Darlington. 2021. “India Working to Cut Lithium Imports, Boost EV Sector, Says NITI Chief Amitabh Kant.” Moneycontrol. December 16, 2021. https://www.moneycontrol.com/news/automobile/india-working-to-cut-lithium-imports-boost-ev-sector-says-niti-chief-amitabh-kant-7832501.html.

International Energy Agency. 2021a. “Global EV Outlook 2021.” https://www.iea.org/reports/global-ev-outlook-2021/prospects-for-electric-vehicle-deployment.

———. 2021b. “India Energy Outlook.” https://www.iea.org/reports/india-energy-outlook-2021.

———. 2022. “Transport: Improving the Sustainability of Passenger and Freight Transport.” March 7, 2022. https://www.iea.org/topics/transport.

Invest India. 2021. “A Brief Look at Value Chain of Lithium-Ion Battery.” August 24, 2021. https://www.investindia.gov.in/team-india-blogs/brief-look-value-chain-lithium-ion-battery#:~:text=The%20primary%20raw%20materials%20required,Nickel%2C%20Lithium%2C%20and%20Manganese.

———. 2022. “Electric Mobility Sector.” Presentation at the Stakeholder Roundtable on Understanding Investment Opportunities, Barriers, and Priorities for a Globally Competitive EV Manufacturing Sector in India, New Delhi, India, February 15, 2022.

Iyengar, Suresh. 2021. “Industry Demands Incentives for Raw Material Suppliers to Develop India’s Battery-Making Ecosystem.” Hindu BusinessLine. October 9, 2021. https://www.thehindubusinessline.com/economy/policy/industry-demands-incentives-for-raw-material-suppliers-to-develop-indias-battery-making-ecosystem/article36913423.ece.

Liedtke, Simone. 2021a. “Battery-Grade Nickel Demand to Grow as World Sets Sights on Low-Carbon Future.” Mining Weekly. November 19, 2021. https://www.miningweekly.com/

article/battery-grade-nickel-demand-to-grow-as-world-sets-sights-on-low-carbon-future-2021-11-19.

———. 2021b. “Manganese Expert Warns of Sulphate Supply Deficit for Battery EVs.” Mining Weekly. October 5, 2021. https://www.miningweekly.com/article/manganese-expert-warns-of-sulphate-supply-deficit-for-battery-evs-2021-10-05/rep_id:3650.

Lienert, Paul, and Tina Bellon. 2019. “A Reuters Analysis of 29 Global Automakers Found That They Are Investing at Least $300 Billion in Electric Vehicles, with More Than 45 Percent of That Earmarked for China.” Reuters. April 4, 2019. https://graphics.reuters.com/AUTOS-INVESTMENT-ELECTRIC/010081ZB3HD/index.html.

———. 2021. “Global Carmakers Now Target $515 Billion for EVs, Batteries.” Reuters. November 10, 2021. https://www.reuters.com/business/autos-transportation/exclusive-global-carmakers-now-target-515-billion-evs-batteries-2021-11-10/.

Livemint. 2021. “Yulu to expand its 2W EV charing and battery swapping network”. Livemint. 17 November 2021. https://www.livemint.com/auto-news/yulu-to-expand-its-2w-ev-charging-and-battery-swapping-network-read-more-11637138221819.html

Mishra, Twesh. 2021. “Mukesh Ambani Ups Bet on Battery-Swapping under Agreement with Mahindra.” Business Standard. December 9, 2021. https://www.business-standard.com/article/companies/mukesh-ambani-ups-bet-on-battery-swapping-under-agreement-with-mahindra-121120801098_1.html.

Moerenhout, Tom. 2021a. “Are We Ready for the Electric Vehicles Revolution?” Columbia University Center on Global Energy Policy. December 15, 2021. https://www.energypolicy.columbia.edu/research/interview/are-we-ready-electric-vehicles-revolution-qa-dr-tom-moerenhout.

———. 2021b. “Evaluating Electric Vehicle and Transport Sector Decarbonization Commitments from COP26.” Columbia University Center on Global Energy Policy. December 7, 2021. https://www.energypolicy.columbia.edu/research/interview/qa-evaluating-electric-vehicle-and-transport-sector-decarbonization-commitments-cop26.

———. 2021c. “Is India Ready for an Electric Vehicle Revolution?” International Institute for Sustainable Development. July 28, 2021. https://www.iisd.org/articles/india-electric-vehicle-revolution.

Mukherjee, Sharmistha. 2022. “PLI Scheme for Auto Sector: List of Applications Approved under Champion OEM Incentive Scheme.” Economic Times. February 11, 2022. https://economictimes.indiatimes.com/industry/auto/auto-news/pli-scheme-for-auto-sector-list-of-applications-approved-under-champion-oem-incentive-scheme/articleshow/89502328.cms.

Nee Lee, Yen. 2021. “2 Charts Show How Much the World Depends on Taiwan for Semiconductors.” CNBC. March 15, 2021. https://www.cnbc.com/2021/03/16/2-charts-show-how-much-the-world-depends-on-taiwan-for-semiconductors.html.

NITI Aayog, Government of India Ministry of Power, Department of Science and Technology, Bureau of Energy Efficiency (BEE), and WRI India. 2021. “Handbook of Electric Vehicle Charging Infrastructure Implementation.”2021.https://www.niti.gov.in/sites/default/files/2021-08 Handbookfor EV Charging Infrastructure Implementation 081221.pdf.

NITI Aayog, RMI, and RMI India. 2022a. “Banking on Electric Vehicles in India.” https://static.investindia.gov.in/s3fs-public/2022-01/Banking-on-EV_web_2.0a.pdf.

———. 2022b. “Need for Advanced Chemistry Cell Energy Storage in India.” https://rmi.org/insight/the-need-for-advanced-chemistry-energy-storage-cells-in-india/.

Philip, Lijee, and Saloni Shukla. 2021. “Niti Aayog, World Bank Ready Electric Vehicles Financing Push.” Economic Times. November 1, 2021. https://economictimes.indiatimes.com/industry/renewables/niti-aayog-world-bank-ready-electric-vehicles-financing-push/articleshow/87448054.cms.

PTI. 2021. “Govt Intends to Have EV Sales Penetration of 30% for Private Cars by 2030: Gadkari.” Economic Times. October 8, 2021. https://auto.economictimes.indiatimes.com/news/industry/govt-intends-to-have-ev-sales-penetration-of-30-for-private-cars-by-2030-gadkari/86864948.

Ray, Saon, Vasundhara Thakur, and Samiha Singh. 2022. “Green Industrial Policy: An Appraisal of Three State EV Policies.” ICRIER working paper (forthcoming).

Rajagopalan, Rajeswari. 2022. “India’s Semiconductor Pursuit.” Diplomat. January 28, 2022. https://thediplomat.com/2022/01/indias-semiconductor-pursuit/.

Regy, Prasanth, Rakesh Sarwal, Clay Stranger, Garrett Fitzgerald, et al. 2021. “Turning Around the Power Distribution Sector.” NITI Aayog, RMI, and RMI India. https://www.niti.gov.in/sites/default/files/2021-08/Electricity-Distribution-Report_030821.pdf.

Reuters Staff. 2019. “India Cuts Tax Rate on Electric Vehicles to Boost Uptake.” Reuters. July 27, 2019. https://www.reuters.com/article/us-india-autos-electric-idINKCN1UM08R.

Rystad Energy. 2021. “Nickel Demand to Outstrip Supply by 2024, Causing Headaches for EV Manufacturers.” October 11, 2021. https://www.rystadenergy.com/newsevents/news/press-releases/nickel-demand-to-outstrip-supply-by-2024-causing-headaches-for-ev-manufacturers/.

Singh, Vaibhav, Kanika Chawla, and Saloni Jain. 2020. “Financing India’s Transition to Electric Vehicles.” Council on Energy, Environment and Water. December 2020. https://cef.ceew.in/solutions-factory/publications/CEEW-CEF-financing-india-transition-to-electric-vehicles.pdf.

Statista. 2022. “Two-Wheelers as a Percentage of Vehicles in Operation in India from Financial Year 1951 to 2019.” https://www.statista.com/statistics/664691/share-of-two-wheelers-india/#:~:text=Two%2Dwheelers%20made%20up%20a,India%20in%20financial%20year%202019.

United States Geological Survey. 2021. “Lithium.” https://pubs.usgs.gov/periodicals/mcs2021/mcs2021-lithium.pdf.

Yue Li, Yvonne, and James Attwood. 2021. “EVs Have Lithium Booming—And This Time, There Is No Bust in Sight.” Bloomberg. October 27, 2021. https://www.bloomberg.com/news/articles/2021-10-27/lithium-s-rally-isn-t-slowing-as-costs-rise-for-electric-vehicles-batteries.

Chapter 2

The Challenge of Skill gaps in the Indian EV sector

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1. Introduction

As the transition from traditional automobiles to EVs is underway in the Indian case, the concern of skill differential in the case of these two segments has surfaced. The skills required in both the industries differ thereby creating the requirement of re-skilling or re-training the labour force for precluding the possibility of job loss while transitioning. This issue holds more gravity due to momentous employment that the automotive sector provides directly as well as indirectly. As per PIB (2019), the employment number, direct as well as indirect, for the industry has been pegged at 37 million.

This chapter analyses the skill gaps facing the Indian EV sector. The analysis in this chapter is enriched by bringing together insights received from consultation with different stakeholders.

2. The issue of skill gaps

The transition to EVs has been expected to bring about job gains in some sectors while job losses in others. The NITI Aayog and World Energy Council report underscores the employment generation that is anticipated to be seen in EV-related sectors such as battery charging and battery swapping with the transition from ICE to EVs. A concern that the report highlights is that of the impact of EV adoption on small and medium auto-component industries that are also a significant source of employment and recommends providing them support through the transition. Overall, the report holds that the net impact on employment is expected to be balanced out.

Soman et al. (2020) note that skilling will be key as jobs in the electric vehicle segment and power sector will be created and those in the petroleum sector and ICE will be lost. They estimate that 1.2 lakh jobs are likely to be generated "in EV powertrain, battery and charger manufacturing and electricity generation sector" under the scenario wherein the electric vehicles are able to account for 30 per cent of the new sales in the year 2030 for India. Further, Soman et al (2020) ascertain that a job loss of 1.6 lakh jobs is likely to result "in oil production and ICE powertrain manufacturing activity". There will be a reshuffling of jobs. While manufacturing jobs are likely to be in decline, the areas where employment is expected to grow are: "chemical engineering, electronics, IoT, AI, robotics, 3D printing, mechatronics, deep learning, data modelling, material science and e-waste recycling" (Mandal, 2020).

ASDC and EY (2019) discuss how the emerging trends in the automotive sector are likely to impact the employment scenario in the automotive sector. The report underscores that the movement to electric vehicles will have an impact on the type of jobs across the value chain and that there may be loss of employment owing to the fact that the electric vehicles have relatively less parts. It notes that the auto component manufacturers will be affected since there will be a sea change from their current manufacturing output of ICE vehicle components to EV components. Further, it notes that a significant impact on the mix of auto workers at OEMs and auto component manufacturers is anticipated Given the changing dynamics in the national and international automotive industry owing to the upcoming trends such as IoT, automation, and electric mobility, the report finds that the industry is concerned with regards to skilling of the labour force and their adapting capability in face of the mercurial scenario in the automotive sector. In the Indian case, a shortfall of skilled labour force particularly of engineers is being experienced in the electric vehicle segment (Verma, 2018). Furthermore, it is anticipated that this demand is likely to multiply in the coming years (Verma, 2018). The workforce in India lacks the technical skills and knowledge required in the R&D segment in the automotive sector (Deloitte and CII, 2020).

Extant studies have also discussed the future trends such as Industry 4.0 that the automotive sector is likely to witness or is witnessing and the impact that these trends are likely to exercise on the employment scenario of the industry. Studies have also linked this concern to skill development of the labour force employed in the sector.

Bajpai et al. (2018) report highlights the shifts that Industry 4.0 is likely to bring in the employment scenario of the Indian automotive sector. In the report, skill gaps present in the labour market, inter alia, have been underlined as one of the hurdles in adoption of Industry 4.0 technology. The report notes the government viewpoint of putting greater stress on developing basic skills such as logic skills, empathy, advanced problem solving, and emotional intelligence that can assist in adapting to the mercurial work atmosphere. It underlines the crevasses in data that make it difficult to forecast changes in the employment scenario. It also highlighted the skill gaps and low technical training that is present in the sector. It indicates the requirement for remodelling the measures for skill development in the Indian case. The report includes an array of recommendations including that of improving the skilling ecosystem and diverting greater attention to education at primary as well as tertiary levels.

According to PwC and SIAM (2019) India's automobile sector is likely to experience demand for labour skilled in areas including IoT, mechatronics, 3D printing, and machine and deep learning for catalysing movement to EVs. However, it notes that this transition is likely to render the present skills and jobs superfluous and indicates the need for the industry to focus efforts towards skilling. Some of these effects are being witnessed as the firms in the automotive industry in particular the start-ups are employing workforce which is higher up the skill spectrum such as IT professionals and software engineers[14].

The issue of skill gaps is a nuanced one, varying in degree and extent across the EV supply chain. Through our stakeholder consultation, we found that there are almost no skill gaps in the chemistry of anode and cathode cell manufacturing. However, problems in securing workforce for research and development were reported. In general, it has been noted that there exists a research and development and technology gap in India.[15]

There are various layers to the issue of the skill gaps. This issue is construed by many as being limited to only the workforce engaged in manufacturing or assembling EV or EV components. However, there are issues relating to the skills gap among workers outside the EV supply chain such as those

[14] Inputs from the stakeholder interaction.

[15] Inputs from the stakeholder interaction.

servicing and repairing EVs, in particular skills needed to ensure to operational safety. While there is an acute need to train technicians and repair workers, this an area where there has been lack of government attention. Further, since the voltage that will be dealt with in relation to electric vehicles is higher, there is a need to improve awareness regarding the fundamentals of electricity for ensuring safety while working. There is a high possibility of electric shocks due to lack of precautions. This underlines the need to inform everyone dealing with electric vehicles, even the consumers.[16]

Closing these skill gaps becomes particularly crucial since many of these individuals are part of the informal sector and have experience in handling only ICE vehicles[17].

3. Initiatives and measures taken by various actors

Different economic actors in the sector such as the government, industry, and academia have taken different measures to address the challenge of skill gaps. Following are some of the initiatives taken by various stakeholders for bridging the skill gap (Table 1):

Table 1: Measures for bridging the skill gap by different economic actors

Economic Actor	Measures
Industry	• A Chennai-based startup Skill Lync has collaborated with Ansys for providing knowledge of electric vehicles to Indian undergraduate engineering students (Basu, 2021). • MakerMax, a Canada-based startup announced that it will provide skilling and training regarding electric vehicles to Indian students and engineers (Express Drives, 2019). • In partnership with an online learning platform, DIYguru, ASDC has rolled out its Electric Mobility Nanodegree Programme (Sanghi, 2021). • Together with MG Motor and ASDC, Autobot Academy has launched a new electric mobility programme 'EV Engineering: Architecture and Components' (Sanghi, 2021).
Government	• Several state governments have recognized and incorporated skills issue in their EV policies.
Academia	• A new post graduate programme, M. Tech in Electric Mobility, has been launched by IIT-Delhi[18]. • Indian Institute of Technology Guwahati has introduced MS (Research) programme in E-mobility (Kalita, 2020).

(Source: Authors' compilation from various sources)

[16] Inputs from the stakeholder interaction.

[17] Inputs from the stakeholder interaction.

[18] Source: https://home.iitd.ac.in/show.php?id=39&in_sections=News

These developments underline an important observation that the industry acknowledges the presence of a skilling gap and is taking different measures to bridge it. Further, academic institutions are also supporting the shift to electric mobility.

Recognising the significance of the automotive sector for employment generation in India and the skill set required for employment in the automotive sector, the Final Draft document of the Automotive Mission Plan 2016-26 acknowledges the need for skilling and bridging skill shortages. It also lays out the objective of making "the Indian Automotive Industry a significant contributor to the "Skill India" programme and make it one of the largest job creating engines in the Indian economy". State EV policies lay emphasis on creation of employment, their stress on formal job creation is a notable feature (Kanuri et al., 2021). Bihar's offer of providing funds of R&D for a specified investment amount and a floor on the employment generated (Kanuri et al., 2021) is a good example of rolling in investment, employment generation, and R&D incentives in one. Several state governments including Delhi, Tamil Nadu, and Karnataka have included skill development measures and/or incentives in their respective EV policies.

4. Bridging the skills gap

Bringing together the inputs from the literature and our stakeholder consultations, we find that the following measures or a mix of measures can be deployed for bridging the skills gap:

- ***Stakeholder collaboration***: Collaboration between different stakeholders in the EV sector such as the government, industry, and academia has been recommended as an instrument for closing the skills gap (Deloitte and CII, 2020; Yadav and Mulukutla n.d.; Sanghi, 2021; Mandal, 2020).

- ***Role of the government***: Government has been viewed as playing a crucial role by providing incentives, assisting in setting up international centres for R&D, and forging global ties for decreasing the skill gap (Deloitte and CII, 2020).

  It has been suggested that ITIs need to develop EV-specific courses[19]. A further recommendation here is linking the subsidy under government policies to skill development[20].

- ***Setting up of centres***: Centres for R&D that help bring international talent along with local and establish centre of excellence (Deloitte and CII, 2020 and Arora and Raman, 2019).

- ***Strategies and measures***: Putting in place a strategy for skill development and national level measures (Yadav and Mulukutla, n.d.; The Energy and Resources Institute and Society for Development Studies, 2019). The Energy and Resources Institute and Society for Development Studies (2019) indicate that measures need to be adopted at the national level for imparting the requisite training to the labour force since the transition to electric vehicles is likely to threaten employment of many workers.

[19] Inputs from the stakeholder interaction.

[20] Inputs from the stakeholder interaction.

- ***Role of Academia***: It has been noted that engineering curriculum is likely to become obsolete and needs to be updated[21]. Academica's role in updating the course curriculum has been underlined (Sanghi, 2021).

- ***Labour market developments***: Monitoring the development of the labour market for keeping the policies effective in terms of fulfilling the present as well as future labour demand (Aznar et al., 2021).

- ***Apprenticeship programs***: Apprenticeship has been forwarded as the solution for fulfilling the demand for skilled labour (ASDC and EY, 2019). The report highlights that apprenticeship programs have been enforced by the OEMs and auto component manufacturers (tier 1 and tier 2). and notes that these have been implemented in isolation and do not share any connection with the government apprenticeship promotion schemes. As per the report's analysis, the automotive players in the sector fulfil their labour demand through three channels: Higher education sector, Technical and vocational education segment, and Not in education and employment (NEET) segment. It underlines that while graduates from the higher education and technical and vocational education segment are likely to form the pool of labour force available for OEMs and tier 1 auto component manufacturers and also to some degree for OEM-owned and/or larger vehicle sales dealerships Given this, it highlights that dealership services, tier 3, and tier 4 auto component manufacturers are rendered dependent on the NEET segment for their labour force requirements. The report also highlights the concerns of the auto component manufacturers in lower tiers, dealership sales, and service players and transport fleet owners have voiced concern regarding the inadequacy of skilling infrastructure. Hence, the report recommends that the sector should focus attention on building skilling capacity for the NEET segments. The report also outlines recommendations for the three key stakeholders in the automotive industry in the matters of labour force, government, industry, and academia.

5. Conclusion

The above discussion highlights the significance of this issue facing the EV sector. It is extremely crucial to identify gaps in skilling and to put in place mechanisms for re-training and re-skilling of the labour force engaged in various activities in the electric vehicle space. Though individual firms are resorting to tools such as internal training of workers for circumventing labour supply shortages and skill training is being provided to the labour force via different routes, a streamlined approach to the challenge of skill gaps posed by the electric vehicle transition is necessary for ensuring a smooth transition.

Different economic actors in the sector such as the government, industry, and academia have taken different measures to address the challenge of skill gaps. However, there is need for more effort to resolve the skills gap issue. Ideally, the central government should undertake a comprehensive skill mapping exercise and draw up a concrete action plan to overcome skill deficiencies.

[21] Inputs from the stakeholder interaction.

References

ASDC and EY. (2019). Human resource and skill requirements in the automotive sector (2026).

Arora, N. and Raman, A. (2019). Lessons From India's First Multimodal E-Mobility Project Beyond Nagpur: The Promise of Electric Mobility.

Aznar, A., Belding, S., Bopp, K., Coney, K., Johnson, C., & Zinaman, O. (2021). Building Blocks of Electric Vehicle Deployment: A Guide for Developing Countries. www.nrel.gov/publications.

Bajpai, H., Tandon, A., and Sinha, A. (2018). "Future of Work" in India's Automotive Sector-Perspectives from the Ground. Working report.

Deloitte, and CII. (2020). Future of Mobility in India: Envisioning the future of the Indian mobility ecosystem.

Express Drives. (2019, January 29). MakerMax to offer skill development,training courses in Electric Vehicles in India. The Financial Express. Retrieved from https://www.financialexpress.com/auto/car-news/makermax-to-offer-skill-developmenttraining-courses-in-car-news-in-india/1450480/.

Kalita, K. (2020, June 12). IIT Guwahati becomes the first IIT to introduce MS (Research) programme in E-mobility. The Times of India. Retrieved from https://timesofindia.indiatimes.com/home/education/news/iit-guwahati-becomes-the-first-iit-to-introduce-ms-research-programme-in-e-mobility/articleshow/76340561.cms.

Kanuri, C., Rao, R., and Mulukutla, P. (n.d.). A Review of State Government Policies for Electric Mobility. WRI India Ross Center report

Mandal, S. (2020, March 18). Can India's Current Engineering, Tech Courses Cope With EV Skills Demand? Inc42. Retrieved from https://inc42.com/datalab/can-indias-current-engineering-courses-cope-with-ev-skills-demand/

NITI Aayog and World Energy Council. (2018). Zero Emission Vehicles (ZEVs): Towards a Policy Framework.

PIB. (2019, December 20). Year Ender 2019 Ministry of Heavy Industry. Retrieved from https://pib.gov.in/PressReleseDetailm.aspx?PRID=1597099

PwC and SIAM. (2019). Indian automotive sector: Creating future-ready organisations.

Sanghi, N. (2021, May 24). Why India needs to revise its course curriculum to address EV skill demand. ET Auto. Retrieved from https://auto.economictimes.indiatimes.com/news/industry/why-india-needs-to-revise-its-course-curriculum-to-address-ev-skill-demand/82906986

Soman, A., Kaur, H., Jain, H., and Ganesan, K. (2020). India's Electric Vehicle Transition - Can Electric Mobility Support India's Sustainable Economic Recovery Post COVID-19? CEEW and Shakti Sustainable Energy Foundation Report.

The Energy and Resources Institute and Society for Development Studies. (2019). Faster adoption of electric vehicles in India: Perspective of consumers and industry

Verma, P. (2019, September 16). Electric vehicle makers face shortage of engineers. The Economic Times. Retrieved from https://economictimes.indiatimes.com/industry/auto/auto-news/electric-vehicle-makers-face-shortage-of-engineers/articleshow/65816392.cms?from=mdr

Yadav, N. and Mulukutla, P. (n.d.). Tracking India's Industrial Evolution with Electric Mobility.

Chapter 3

Green Industrial Policy: An Appraisal of Three State EV Policies

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1. Introduction

The automobile sector in India is growing at a CAGR of over 15 per cent in the last 5-7 years and is described as the next sun rise sector of the Indian economy. The sector contributed to India's GDP in 2019 and is likely to reach a market size of USD 512 billion by the year 2026 (Grant Thornton, 2021). India is steadily moving from traditional automobiles to EVs. Both at the central and state government levels, several policy initiatives have been introduced to promote the transition to EVs. While the central government is formulating various schemes at the national level, several state governments have devised their EV policies.

In this chapter, we analyse in detail the EV policies of three states, namely, Karnataka, Maharashtra, and Tamil Nadu. We first set the stage by examining the specific provisions made in the EV policies of these states. We classify the incentives and measures provided in these EV policies under the following broad categories: supply-side incentives and measures; demand-side incentives and measures; labour force-related incentives and measures; research and development-related incentives and measures; and charging stations and other network infrastructure-related incentives and measures. We then attempt to take stock of the progress that these policies have achieved, in terms of EV registrations. We also study the impact of these policies on the adoption of EVs.

The chapter is structured as follows: Section 2 discusses the concept of a green industrial policy and its evolution in some countries that have adopted such a policy. Section 3 discusses the evolution of India's industrial policy at the central and state levels. In subsequent sections, we limit our focus to India's electric vehicles sector. Section 4 provides an overview of EV policies in India. Section 5 analyses the EV policies of Karnataka, Maharashtra, and Tamil Nadu. Section 6 sheds light on the progress of these state EV policies in terms of vehicle registrations. Section 7 presents the suggestions and recommendations based on the analysis.

2. Green Industrial policy

The concept of green growth includes the promotion of environmentally friendly technologies. Industrial policies typically include R&D grants, government procurement, subsidised loans and loan guarantees, and direct subsidies (Steer, 2013). Industrial policies are "government policies which aim at affecting the structure of an economy" (Eder et al., 2018). There is a distinction made in the literature between horizontal industrial policy (general framework conditions for the economy, e.g., investments in education and basic research) and vertical (or selective) industrial policy (targeted strategies that support specific activities, sectors, or technologies).

Elements of a green industrial policy could include tariffs, subsidies, performance requirements, service sector limitations, government procurement, state owned enterprises, and competition policy (Cosbey, 2017).[22]

Rodrik (2014) examines the green industrial policies of four countries – USA, Germany, China and India and notes that Germany

[22] https://www.un-page.org/files/public/green_industrial_policy_book_aw_web.pdf

and China have the most aggressive policies among the four countries. Green industrial policies should have three key ideas: first, there should be knowledge of technological spill overs, market failures and constraints that impede green investment; second, private investors who are beneficiaries of government support must utilise their advantage and third, the intended beneficiary of the industrial policy should be society.

3. India's Industrial policy framework

3.1. Central level policies

The evolution of industrial policies at the centre through the Industrial Policy Resolution, has been discussed extensively (see Ray and Kar, 2020 for a summary). From the mid-1960s, the private industrial sector was allowed but was to fully conform to the five-year plans through the so-called 'licence raj' system, which controlled all key aspects of business (scale and location of investments, minimum and maximum outputs, and imports). The government's occupation of industrial 'commanding heights' allowed it to directly control investment (Singh, 2008). Industrial licensing played a key role in channelling investment, controlling entry, and expansion of capacity of the industrial sector until 1991. India followed a policy of import substitution until liberalisation in 1991. This meant that imports were substituted with domestic production of goods through high tariffs and quotas. Since 1991, this policy has gradually been withdrawn. Reservation of items for exclusive manufacture by the SME sector was done away with and disinvestment of PSUs was initiated. The liberalisation of the country also meant the removal of quotas and a reduction in the tariffs of most items.

More recently, pro-industrial policy measures like the 2011 National Manufacturing Policy and the 2014 Make in India initiative aimed at attracting MNCs to set up production and design facilities through measures like further sectoral de-licensing, building of industrial corridors, and facilitation of greater government-business co-operation (especially through the Investor Facilitation Centre and the Invest India initiative). Table 12 in the appendix sets out India's recent industrial policy framework. As argued by Ray and Miglani (2020), India has had several horizontal industrial (recent examples include the 'Make in India') and vertical (Automotive Mission Plan 2016-2026 in the automobile sector) policies. The next section discusses some of the policies followed by Indian states.

3.2. State level policies[23]

The role of subnational policies in the internationalisation of firms[24] is not captured much in the literature. In India, the Seventh Schedule of the Constitution defines and specifies the allocation of power and functions between the Union and states. It consists of three lists: Union List, State List and Concurrent List. The State List or List-II is a list of 61 items. According to Sinha (2005), policy interdependence is consequential and systematic in a multilevel system and regional institutions affect investment flows by ensuring complementarity between contradictory organisations such as hierarchical or horizontal forms. In the Indian case (looking

[23]India has quasi-federal structure and the division of powers and functions between the union and states is laid down in the Seventh Schedule to the Constitution of India.

[24] The term internationalisation of firms means movement of firms towards capturing share of the global market.

at the case of Gujarat, Tamil Nadu, and West Bengal), she argues that assessment of subnational strategies for industrialisation show that while all three states pursued state-led development, the proportional role of the public and private sectors differed. The role of the joint sector (public and private) varied considerably in the three states, with the state government adopting the joint sector as a core part of its developmental strategy and encouraging private sector participation in Gujarat. In contrast, in West Bengal all important decisions of the joint sector were subject to the approval of the state government.

In the mid-1960s, every state in India instituted similar organisations to implement central industrial and regulatory policy (Sinha, 2005). In addition, states vied with each other to characterise their districts as "backward" to avail central funds. States used supply side instruments to reduce production costs by subsidising capital and used policies to provide incentives to investment. In addition, demand side policies were used to create new kinds of capital and encourage new businesses; these latter policies 'distinguish an entrepreneurial state from a traditional state' (Eisinger, 1988). Sinha (2005) says that most Indian states followed both supply and demand policies. On the supply side, these included land and power at concessional rates, sales tax refund schemes/sales tax loans, exemptions from octroi, subsidy for feasibility studies, supply of scarce raw material, price preferences, and supply of finance at concessional terms. Some of these policies still continue, as documented in Table 13 in the appendix. On the demand side, policies included development of land (e.g., acquisition of land for industrial estates in Gujarat), development of infrastructure such as roads, sheds, and provision of water, power, etc., thrust/pioneer industry development[25] (e.g., electronics), development of local markets (sales tax exemption for first 5-7 years), and development of local entrepreneurship.

Indian states' policy making has increasingly focused on exports. The contribution of states in national manufacturing export varies widely. IFC-NITI Aayog (n.d.) underline the disparities at the sub-national level in terms of export contribution. On the one hand, Gujarat, Maharashtra, and Tamil Nadu are key exporters accounting for nearly 60 per cent of India's aggregate exports in 2020-21. On the other hand, states situated in the hilly regions find it difficult to become significant contributors to national exports. Pradhan and Das (2015) study the policies of different states and observe that provincial policies play a critical role in the export orientation of local firms. This depends on region-specific factors, which could be market-related or input-related (regional technological capabilities, availability of skilled workers, availability of physical infrastructure, finance, regional distribution of FDI and spatial agglomeration) (Pradhan and Das, 2015). According to Pradhan and Das (2015), states like Karnataka, Gujarat, Maharashtra, and Tamil Nadu have undertaken policies to increase exports and promote FDI. For example, while Karnataka was the first Indian state to unveil a state-level export promotion policy in 2003, Gujarat undertook such policies through the Gujarat Industrial Policy 2009. The Karnataka export promotion policy's aim was to accelerate export growth and achieve double the state's share in all India exports from 7 per cent in 2003

[25] This corresponds closely to the encouragement of a lead firm (or industry. Such industries got special subsidies).

to 15 per cent by 2007. The policy was clearly successful since by 2007-08, Karnataka's share in national exports had increased to 16.3 per cent. The Gujarat Industrial Policy 2009 has been used to promote global sourcing from the state through exports of high-quality products and through process excellence. Through infrastructure enlargement, port development, and clusters, it has promoted the 'Made in Gujarat' as a global brand. The Maharashtra Industrial Policy 2001, aimed to augment exports from industrial units in the state. This was achieved by laying emphasis on investment-friendly industrial policies, improving infrastructure, and setting up special economic zones (SEZs). The focus of the Tamil Nadu Industrial Policy 2003 was on improving the competitiveness of existing industrial units in the domestic and export markets. In order to promote exports, this policy led to the setting up of apparel parks, agri-export zones and special parks, and formulation of an SEZ policy.

Table 14 in the appendix documents the recent state level policies related to industry, entrepreneurship, logistics, SEZs, etc. It also shows the EoDB ranking of each state in 2017, the FDI received between 2000 and 2019, and the GSDP (in current USD terms). As can be seen from Table 13 (though it is not exhaustive), most recent state policies focus on industrial development, MSMEs, or entrepreneurship. Some states also provide subsidies in various forms (Table 13).

Given the crucial role played by the automotive sector in the overall GDP and exports and the movement that is underway from traditional automobiles to EVs, it crucial to take a look at the EV policies in India.

4. EV policies in India – An overview

4.1. Central policies in India to promote electric mobility

The Department of Heavy Industry (DHI), which is the nodal department in Government of India for the automotive sector, has taken a number of initiatives to accelerate the growth and development of the Indian automotive industry. This includes the 10-year vision roadmap for the automotive industry, viz., Automotive Mission Plan (AMP) 2006-16. The AMP 06-16 lays down a roadmap for the automotive industry covering all aspect of its growth, ranging from broad direction on fiscal policies, emissions, safety and globalisation in terms of technical standards, enhancing competitiveness, skill development, testing and homologation, Research & Development, etc.

The AMP 2006-2016 envisages that, by 2016, India will emerge as the destination of choice in the world for the design and manufacture of automobiles and automotive components. The sector's output is targeted to reach USD 145 billion by 2016 with a doubling of the sector's contribution to the GDP from around 5 per cent in 2006 to 10 per cent in 2016. Job opportunities for 25 million people were to be created in the entire value chain. The AMP document captured the expectations and responsibilities of all the stakeholders for a common end objective and is an example of how a government-industry collaborative approach can transform an industry sector. The approach and ethos of AMP has been adopted even more rigorously in the development of the NEMMP 2020 plan.

Given the importance of the initiative, the Government has decided to launch the National Mission for Electric Mobility (NMEM). The adoption of the mission mode approach is intended to provide this initiative the desired level of ownership (both in government and the industry), continued government intervention/support, continued long-term commitment from all stakeholders and a synergised, holistic approach to the complex issues involved in the programme.

NMEM is among the most significant, recent initiatives taken up by the Department on Technology to galvanise the introduction and manufacture of full range of EVs, including hybrids. Based on detailed stakeholder consultations and an in-depth study, the government had approved the taking up of this initiative on a national mission mode. To this end, it has set up high-level apex structures in the form of the National Council for Electric Mobility (NCEM) and the National Board for Electric Mobility (NBEM). NMEM has a two-fold objective – ensuring national energy security and spurring domestic manufacturing capabilities in the full range of EV technologies. The NEMMP 2020 lays down a roadmap for achieving significant penetration of efficient and environmentally friendly EV technologies in India by 2020. The implementation of such an initiative involved rolling out of a comprehensive array of interventions focused on key stakeholders in the EV sector, such as industry, academia, and the government.

As a first step, an enabling mechanism has been set up for speedier decision making. This consists of apex level bodies in the form of the NCEM and the NBEM. The Council comprises ministers from the key central ministries/departments, as well as eminent representatives from academia and the industry, to foster greater collaboration amongst various stakeholders.

The National Council and the National Board will be serviced initially by the NATRiP Implementation Society (NATIS) and later by the National Automotive Board (NAB), once set up. NAB will comprise domain and technical experts and will be the nodal agency for all ongoing and new government initiatives for the automotive sector. This mechanism is intended to provide a centralised platform for all initiatives; enable fast decision making, encourage increased collaboration between various stakeholders, and approve and monitor all allocations that are made from the Government of India for development of EVs.

4.1.1. National Electric Mobility Mission Plan

The National Electric Mobility Mission Plan (NEMMP) 2020, drafted by the Department of Heavy Industry, Ministry of Heavy Industries & Public Enterprises in 2012, targets achieving sales of 6-7 million hybrid and EVs annually from 2020 onwards. The government aims to achieve national fuel security by incentivising buyers to purchase hybrid and EVs by providing fiscal and monetary support[26].

It was estimated that, in 2020, the total new vehicle sales of 6-7 million EVs would result in total liquid fuel savings to the tune of 2.2 to 2.5 MT. The NEMMP 2020 aims to establish benchmarks of EV performance, quality, and safety parameters/standards, pertaining to vehicle and battery performance, durability, and warranties, driving range, charge time, energy efficiency of vehicle, and standardisation of technical characteristics.

[26] https://policy.asiapacificenergy.org/node/2663

The NEMMP 2020 is intended to provide the future roadmap, establish a common set of priorities, and the broad principles and framework to promote the adoption of the full range of electric mobility solutions for India, with the core goals of enhancing national fuel security, providing affordable and environmentally friendly transportation, and mobilising the Indian automotive industry to achieve global manufacturing leadership.

The government is supporting the growth of the hybrid/electric vehicle market by effectively utilising and leveraging demand and supply related interventions, research and development support, infrastructure investments and fuel efficiency measures.[27] The specific targets provided by NEMMP 2020 including the level of demand incentives, their duration, total investment required, etc., are being taken as indicative estimates that can be fine-tuned during the process of formulating specific schemes and interventions under the umbrella scheme.

As part of the NEMMP 2020, the Department of Heavy Industry formulated the FAME India Scheme in 2015 to promote manufacturing of electric and hybrid vehicles. The first phase of this scheme was initially launched for a period of 2 years, commencing from April 1, 2015 up to April 1, 2017,[28] but was subsequently extended up to March 31, 2019 until the notification of FAME Phase II. The main objective of the FAME India Scheme is to encourage the adoption of EVs in India by providing incentives such as subsidies.[29] The first phase of FAME India Scheme was implemented through four focus areas namely, demand creation, technology development, conducting experimental trials in selected cities as pilot projects, and improving charging infrastructure. Market creation through demand incentives was aimed at incentivising all vehicle segments, i.e., 2-wheelers, 3-wheelers auto, passenger 4-wheelers, light commercial vehicles, and buses. The demand incentive was available to buyers of electric vehicles in the form of an upfront reduced purchase price to enable wider adoption. Additionally, grants were also sanctioned for specific projects under pilot projects, and the R&D/ technology development and public charging infrastructure components under the scheme.

4.1.2. Faster Adoption of Manufacturing of (Hybrid &) Electric Vehicles (FAME) I and II

FAME I is under the framework of a demand incentive disbursement mechanism. Incentive amounts have been determined for each category of vehicle like mild hybrid, strong hybrid, plug-in hybrid and pure electric technologies and battery specification. It has been implemented and monitored by National Automotive Board under Department of Heavy Industry. It is one of the Direct Benefit Transfer (DBT) schemes categorised under in-kind mode.

Under FAME Scheme Phase-I, the demand incentive amount was determined for each category (vehicle, technology, and 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.[30]

[30] https://pib.gov.in/PressReleasePage.aspx?PRID=1577880

[27]https://dhi.nic.in/writereaddata/Content/NEMMP2020.pdf

[28]https://heavyindustries.gov.in/writereaddata/UploadFile/notification-fame-india.PDF

[29] https://currentaffairs.anujjindal.in/fame-india-scheme-phase-1/

As per the scheme, depending on the technology they are based on, battery operated scooters and motorcycles are eligible for incentives ranging between INR 1,800 and INR 29,000, and three-wheelers for incentives in the range of INR 3,300 and INR 61,000. For four-wheelers, the incentives range from INR 13,000 to INR 1.38 lakh; for light commercial vehicles, from INR 17,000 to INR 1.87 lakh, and for buses, from INR 34 lakh to INR 66 lakh.[31]

In the first phase of the scheme, about 2.8 lakh EVs were supported with a total disbursement of incentives of INR 359 crore.[32] As of September 2020, 30 original equipment manufacturers (OEMs) and 137 models of all categories of vehicles were registered under this scheme. In addition, 465 buses were sanctioned to various cities/states under this scheme.

Phase I of the FAME India scheme was expected to bring a multitude of advantages, including an estimated 50 million litres of total expected fuel saved due to electrification; 52,700 litres of fuel saving per day; reduction of about 1.3 lakh kg of CO2 emissions per day; and a total CO2 reduction of approximately 129 million Kg during the entire four-year policy period.

The second phase of the FAME India Scheme was implemented from April 1, 2019 for a period of three years. FAME II mainly focuses on supporting electrification of public and shared transportation, and aims to support 10 lakh electric two-wheelers, 5 lakh electric three-wheelers, 55000 four-wheelers and 7000 buses through demand incentives.

With greater emphasis on providing affordable and environment friendly public transportation options, the scheme will be applicable mainly to vehicles used for public transport or those registered for commercial purposes in electric 3 wheelers (e-3Ws), electric 3 wheelers (e-4Ws) and e-bus segments. However, privately owned registered e-2Ws will also be covered under the scheme as a mass segment.[33] To encourage the adoption of advanced technologies, incentives will be extended to only those vehicles that are fitted with advanced batteries like a lithium-Ion battery and other new technology batteries. In addition, the creation of charging infrastructure will be also supported to address anxiety among users of electric vehicles. It is proposed to establish charging stations on major highways connecting major city clusters. On such highways, charging stations will be established on both sides of the road at an interval of about 25 km each.

Phase-II of the FAME India Scheme has been provided with a total budgetary support of INR 10,000 crore. In order to give a further push to clean mobility in public transportation, the Government of India sanctioned 5095 electric buses to 64 cities/State Transport Corporations for intra-city operations, 400 electric buses for intercity operation and 100 electric buses for last mile connectivity to Delhi Metro Rail Corporation (DMRC). This involved an amount of around INR 2,800 crore. These buses will run about 4 billion kilometres and are expected to save cumulatively about 1.2 billion litres of fuel over the contract period, besides reducing CO2 emissions by 2.6 million

[31] https://indiaesa.info/news-menu/28-industry-news-management/1177-government-extends-fame-india-scheme-for-third-time

[32] https://fame2.heavyindustry.gov.in/content/english/15_1_FAMEI.aspx

[33] https://pib.gov.in/Pressreleaseshare.aspx?PRID=1566758

tons.[34] The Department of Heavy Industries has sanctioned 2,636 EV charging stations under the scheme at a cost of approximately INR 500 crore across 24 states/UTs in 62 cities including metros, other million plus cities, smart cities and cities of hilly states across the country so that there will be availability of at least one charging station in a grid of 3 km x 3 km.

Demand incentives on operational expenditure for electric buses will be delivered through state/city transport corporations (STUs) in various parts of the country. There has been a reduction in the goods and services tax (GST) on EVs from a rate of 12 per cent to 5 per cent. The Ministry of Power has also allowed sale of 'electricity as a service' for charging electric vehicles, which will serve as a huge incentive to attract investments in charging infrastructure. The Government has also granted exemption to the battery-operated transport vehicles and transport vehicles running on ethanol and methanol from permit requirements. Moreover, in the 2019-20 budget, the finance minister announced a provision of additional income tax deduction of INR 1.5 lakh on the interest paid on loans taken to purchase electric vehicles.[35]

The Department of Heavy Industry (DHI), being the nodal Department for the automotive sector, has been funding research, design, development, and demonstration projects and spearheading the electric mobility initiative in the country. In the recent past (2010-12), the Ministry of New and Renewable Energy (MNRE) has also incentivised the purchase of electric vehicles through its Alternate Fuels for Surface Transportation Programme (AFSTP), with an outlay of INR 95 crore. The incentive was provided to OEMs that gave at least a one-year warranty and were setting up at least 15 service stations across India.

In addition, the Department of Science and Technology (DST), has a funding scheme for all industries, including the automotive industry. The Council for Scientific and Industrial Research (CSIR) is also active and R&D on lithium-battery technology for EVs[36] is ongoing at the Central Electrochemical Research Institute, Karaikudi. Besides, certain state governments like the Delhi Govt. provide demand side subsidies in addition to VAT and road tax waivers. Owing to these various programmes, there has been a 2- per cent growth in the sales of EV 2-wheelers and Reva[37] recorded a three-fold rise in average monthly sales. However, these initiatives remain largely fragmented, with an inability to yield desired results due to several bottlenecks that hinder the government's initiatives to promote electric mobility. The primary roadblocks include higher cost of EVs, challenges in battery technology, range anxiety, lack of infrastructure and consumer attitude toward electric vehicles. Moreover, past efforts were also characterised by a lack of synergy, continued top level support and ownership both on the part of the government and industry. As such, the fragmented nature of most of the efforts undertaken, the lack of a collaborative approach between the government and industry, and failure to tackle issue holistically led to the initiatives

[34] https://pib.gov.in/Pressreleaseshare.aspx?PRID=1581525

[35] https://pib.gov.in/PressReleasePage.aspx?PRID=1604991

[36] India is also looking towards other battery technologies such as aluminium-air batteries (See https://www.financialexpress.com/auto/electric-vehicles/indian-oil-to-launch-cost-effective-aluminium-air-batteries-for-evs-electric-cars/2093204/)

[37] Reva refers to India's first zero polluting 4-wheeler EV for city mobility.

fizzling out. In order to achieve the potential, a more systematic and collaborative approach is required with a clear long-term roadmap.

4.1.3. Production Linked Incentive (PLI) Schemes

India has been pushing for low carbon-emission alternatives in the auto industry by laying down a framework and introducing policies that are conducive to fostering the EV ecosystem of the country. New EV government incentives such as PLI for advanced chemistry cell (ACC) batteries and the PLI scheme for the auto sector, which predominantly includes green vehicles and advanced technology components, are among the prominent government initiatives to make India a manufacturing hub for electric vehicles in the coming five years.

In 2021, the government announced PLI the scheme for the automobile and auto components sector with an outlay of INR 57,043 crore for a period of five years.

The Cabinet has reduced the scheme for the sector to INR 25,938 crore to shift focus on hydrogen fuel vehicles and electric vehicles.

4.1.3.1 PLI scheme for manufacturing of Advanced Chemistry Cell (ACC) battery storage

On May 12, 2021, the Union Cabinet approved a PLI scheme for the manufacturing of ACC and the development of battery technology in the country to reduce the cost of batteries. The scheme offers an incentive of INR 18,100 crore, which will be provided over a period of five years to boost domestic manufacturing in an effort to make products more competitively priced and reduce the country's dependence on imports. Several meaningful incentives have been offered across the entire value chain in the manufacture of battery powered EVs, as well as supporting infrastructure and export.

The goods and services tax (GST) EVs has also been reduced to 5 per cent from the earlier rate of 12 per cent and GST on chargers or charging stations for electric vehicles has been reduced from 18 per cent to 5 per cent. The PLI scheme aims to boost localisation of electric battery technology development, domestic manufacturing and attract foreign investments.

4.1.3.2 PLI scheme for auto sector to boost electric car production

In September 2021, the centre announced an INR 25,938 crore new PLI scheme for the automobile sector to help boost the production of EVs and hydrogen fuel vehicles in the country. The announcement comes in the backdrop of the scheme announced last year for the entire automobile industry, including vehicle manufacturing and its ancillary units at an estimated cost of INR 57,043 crore for a period of five years.

Now, the Cabinet reduced the scheme for the sector to INR 25,938 crore to shift focus to hydrogen fuel vehicles and electric vehicles to be manufactured in India. The approved PLI scheme for the auto sector is part of the overall production-linked incentives announced for 13 sectors in the Budget 2021-22 with an outlay of INR 1.97 lakh crore. The PLI scheme announced by the government incentivises the production of EVs, hydrogen fuel cell vehicles (FCEVs) and other advanced automotive technology products in the country. As part of the scheme, the government will provide incentives to the automobile industry over five years.

The incentives in this PLI, like most, are purely percentage based, with a maximum of 18 per cent incentives to be offered by the government, based on the incremental turnover of a company. The scheme focuses specifically on EVs and hydrogen fuel cell vehicles and their components and is open to existing automotive companies as well as new investors who have not yet tapped into the auto component manufacturing market. The PLI scheme is further divided into two separate turnover-based components:

a) **Champion OEM Incentive Scheme**: This is a 'sales value linked' scheme, applicable on battery EVs and hydrogen fuel cell vehicles in all segments and offers an incentive ranging from 13-18 per cent.

b) **Component Champion Incentive Scheme**: This is a 'sales value linked' scheme, applicable on advanced automotive technology components of vehicles, completely-knocked-down (CKD) and semi-knocked-down kits, vehicle aggregates of two-wheelers, three-wheelers, passenger vehicles, commercial vehicles, and tractors, offering incentives from 8-13 per cent, with an additional incentive of 5 per cent for component manufacturers of EVs and HFCVs.

The eligibility criteria for the PLI scheme consists of global revenue from an OEM of INR 10,000 crore and for an auto component manufacturer of INR 500 crore. Moreover, they must have a minimum global investment in fixed assets of INR 3,000 crore for OEMs and INR 150 crore for auto-component manufacturers. The quantum of benefit ranges from 34 per cent to 65 per cent of the sale price of EVs.

The government expects the PLI scheme to generate approximately 750,000 jobs in the EV, fuel cell and component industries, and attract investments worth INR 42,500 crore. The PLI schemes focus on streamlining the EV supply and value chain apparatus to build a self-sustaining manufacturing ecosystem for EVs in India. The benefits of PLI can be availed simultaneously along with benefits under FAME II, Advanced Cell Chemistry (ACC) PLI and any other central or state government incentive scheme. The inclusion of a PLI scheme for the auto sector, along with existing schemes like the ACC scheme, FAME and state subsidies provide direct fiscal incentives for brands and for investments in the sector.

4.2. EV policies at the state-level

In addition to the central government's policy initiatives, state governments have been proactively contributing to the EV policy landscape by formulating their own policies. Several states have released their EV policies.

Amongst the states that have launched their EV policies, we have selected three Indian states namely Karnataka, Maharashtra, and Tamil Nadu. These three states have been selected on the basis of the following two factors:

i. Share in aggregate EV registrations: The five states/union territories leading in terms of the share in total EV registrations for 2021 are Uttar Pradesh, Karnataka, Tamil Nadu, Maharashtra, and Delhi as per the VAHAN data. The share in total EV registrations for Uttar Pradesh, Karnataka, Tamil Nadu, Maharashtra, and Delhi stood at 21.42per cent, 10.70 per cent, 9.65 per cent, 9.59 per cent, and 8.29 per cent in 2021.

ii. Presence of automotive clusters and automotive component clusters: In India, four sizeable automotive manufacturing centres/automotive clusters have presence in all four directions. These centres are as follows: (Government of Karnataka, n.d.)

- Delhi-Gurgaon-Faridabad (North)
- Mumba-Pune-Nashik-Aurangabad (West),
- Chennai- Bengaluru-Hosur (South)
- Jamshedpur-Kolkata (East)

The above centres/clusters span across Delhi, Haryana, Maharashtra, Tamil Nadu, Karnataka, Jharkhand, and West Bengal.

Automotive component clusters are present in Manesar, Rae Bareilly, Silchar, Ahmednagar, Pune, Indore, and Chennai (Government of Karnataka, n.d.). These component clusters cover Haryana, Uttar Pradesh, Assam, Maharashtra, Madhya Pradesh, and Tamil Nadu.

Karnataka, Maharashtra, and Tamil Nadu are three of the top five states driving the EV registrations. Further, Maharashtra and Tamil Nadu house both automotive manufacturing centres and automotive component clusters and Karnataka houses automotive manufacturing centre/automotive cluster.

5. An analysis of EV policies of three states

This section analyses the EV policy of three Indian states, namely, Karnataka, Maharashtra, and Tamil Nadu. Each sub-section of this section looks at one specific state's EV policy. An overview of the incentives and measures included under these three respective EV policies is tabulated in Table 15 in the appendix.

Each state EV policy caters to different aspects of the EV sector and contains incentives and measures for different EV sector actors. In Table 2, we classify the provisions contained in the states' EV policies under the following broad categories:

- Supply-side incentives and measures
- Demand-side incentives and measures
- Labour force-related incentives and measures
- Research and development-related incentives and measures
- Charging stations and other network infrastructure-related incentives and measures

Incentives and measures in these broad categories are further classified under different sub-categories.

The categories in the table have been defined as follows:

1. **Supply side incentives and measures:**

    a. **Manufacturing-related**: This sub-category encompasses incentives and measures in the state EV policy pertaining to manufacturing such as provisions for manufacturing/EV parks.

    b. **Exemptions and waivers**: This sub-category encompasses all types of exemptions and waivers provided for in the state EV policy such as tax exemptions, registration charge waivers, stamp duty exemption, and electricity tariff exemption.

c. **Supporting infrastructure-related**: This sub-category encompasses incentives and measures in the state EV policy pertaining to supporting infrastructure such as land-related incentives and measures.

d. **Investment and/or financing-related**: This sub-category encompasses the incentives and measures in the state EV policy pertaining to financing and investment such as investment promotion subsidies.

e. **Other**: This sub-category encompasses any remaining incentives and measures in the state EV policy that have not been included in the aforementioned sub-categories.

2. **Demand side incentives and measures:**

a. **Purchase related**: This sub-category encompasses incentives and measures in the state EV policy that can nudge the consumers to purchase electric vehicles such as purchase subsidy, road tax exemption, parking incentives, and incentives for scrapping.

b. **Post-purchase related**: This sub-category encompasses incentives and measures in the state EV policy that relate to the post-purchase stage such as resale and buyback incentives.

c. **Awareness related**: This sub-category encompasses incentives and measures in the state EV policy pertaining to enhancing consumer awareness with respect to the electric vehicles.

d. **Other**: This sub-category encompasses any remaining incentives and measures in the state EV policy that have not been included in the aforementioned sub-categories.

3. **Labour force-related incentives and measures:**

a. **Employment related**: This sub-category encompasses incentives and measures in the state EV policy pertaining to employment in the sector.

b. **Skilling related**: This sub-category encompasses the incentives and measures in the state EV policy pertaining to skilling in the sector.

4. **Research and development related incentives and measures**: This sub-category encompasses incentives and measures in the state EV policy pertaining to research and development in the sector.

5. **Charging stations and other network infrastructure-related incentives and measures**: This sub-category encompasses incentives and measures in the state EV policy pertaining to various aspects of charging infrastructure in the sector.

Table 2: A snapshot of the three states' EV policies				
Broad category	**Sub-category**	**Maharashtra**	**Karnataka**	**Tamil Nadu**
Supply side incentives and measures	Manufacturing related	Measures taken to complement and/or leverage the Government of India's initiatives, particularly the production-linked incentive scheme in ACC battery manufacturing	Measures taken to establish EV manufacturing zones and provision of flatted factories	Special measures taken for EV battery manufacturing
	Exemptions and waivers		Stamp duty exemption and concessional registration charges[38]	Stamp duty exemption[39]
	Supporting infrastructure related	Speedy EV registration	Complete reimbursement of land conversion fee;[40] dedicated areas for testing EV-related technologies; complete exemption of tax on electricity tariff[41]	Creation of EV parks and vendor ecosystem; promotion of logistic parks and free trade warehousing zones; creation of plug and play manufacturing facilities; complete exemption on electricity tax till December 31, 2025;[42] subsidy on the cost of land[43]

[38] For micro, small, medium, large, mega, ultra-mega, and super mega-firms in EV and EV component manufacturing and EV cell manufacturing, battery pack, and module manufacturing and assembly.

[39] For EV-related and charging infrastructure manufacturing industries in the state that obtain land by sale or lease until December 31, 2022.

[40] For micro, small, medium, large, mega, ultra-mega, and super mega-firms in EV and EV component manufacturing and for enterprises in EV cell manufacturing, battery pack, and module manufacturing and assembly.

[41] For micro, small, medium EV and EV component manufacturing enterprises for the first five years and MSMEs in EV cell manufacturing, battery pack, module manufacturing and assembly.

[42] For EV-related and charging infrastructure manufacturing industries.

[43] EV-related and charging infrastructure manufacturing industries in the state that obtain land from SIPCOT, SIDCO or other government agencies, a 15 per cent subsidy on the cost of land will be provided; the subsidy will be 50 per cent if these are located in Southern districts. This incentive is subject to the condition that the land cost was not claimed as part of capital subsidy. This subsidy will be available on allotments made until December 31, 2022.

Broad category	Sub-category	Maharashtra	Karnataka	Tamil Nadu
	Investment and/ or financing related		Investment promotion subsidies[44] and interest-free loans on net SGST[45]	Complete SGST reimbursement[46]
	Other	Creation of state EV fund	One-time capital subsidy for establishing effluent treatment plants[47]	Capital subsidy on investments[48]
Demand side incentives and measures	Purchase related	Fiscal incentives linked to the vehicle type	Tax exemption on transport as well as non-transport EVs	100 per cent road tax exemption will be provided until December 30, 2022; waiver on registration charges/fees
	Purchase related	Fiscal incentives linked to the vehicle type	Tax exemption on transport as well as non-transport EVs	100 per cent road tax exemption will be provided until December 30, 2022; waiver on registration charges/fees

[44]For micro, small, medium EV and EV component manufacturing enterprises; micro, small, and medium enterprises in EV battery manufacturing and assembling; and large, mega, ultra- mega, super mega EV cell manufacturing and battery pack/module manufacturing enterprises.

[45]For large, mega, ultra-mega, and super mega-firms in EV and EV component manufacturing and EV cell manufacturing, battery pack/module manufacturing and assembly enterprises

[46]Applicable on the sale of EVs manufactured, sold and registered for use in the state. The reimbursement will be given for sales by manufacturers effective until December 31, 2030. The reimbursement will be given up to 100 per cent of the eligible investment.

[47]For micro, small, medium, large, mega, ultra-mega, and super mega EV and EV component manufacturing enterprises and for enterprises in EV cell manufacturing, battery pack, module manufacturing and assembly enterprises.

[48] In the case of intermediate products used in the manufacture of EV and charging infrastructure, where SGST reimbursement is not applicable, a capital subsidy of 15 per cent will be given on eligible investments over 10 years. The capital subsidy will be payable on eligible investments made in the state until December 31, 2025. The cost of land shall not exceed 20 per cent of the total eligible investments reckoned for the purpose of capital subsidy.

Broad category	Sub-category	Maharashtra	Karnataka	Tamil Nadu
	Post-purchase related	Provision of additional incentives (to be transferred to the customers) to OEMs for offering a minimum 5-year warranty for batteries; additional incentives for OEMs offering buyback schemes OEMs offering buyback schemes[49]		
	Awareness-related	Design and enforcement of an awareness programme		
	Other		Building bye-laws amendment[50] and promotion of apartment associations for providing designated plug and/or charging stations	
Labour force related incentives and measures	Employment related			Employment incentive in the form of the reimbursement of employer's contribution to EPF[51]

[49] OEMs who offer buyback schemes for vehicles that are up to 5 years old at a value reduced by not more than 7.5 per cent per year of the age will be eligible for additional incentives. An OEM can avail both the incentives simultaneously; however, the total incentive amount will be limited to INR 12,000. This will be over and above the incentives based on the net value after considering all the above incentives.

[50] For high-rise buildings, new SEZs, technology parks, and apartments.

[51] EV related and charging infrastructure manufacturing units will be provided an employment incentive in the form of the reimbursement of employer's contribution to the EPF for all new jobs created until December 31, 2025. This incentive will be paid for a period of one year and will not exceed INR 48,000 per employee.

Broad category	Sub-category	Maharashtra	Karnataka	Tamil Nadu
	Skilling-related	Amendment of existing courses and/or creation of new courses and development of skill enhancement centres	Establishment of an EV skill development centre, introduction of electric mobility courses, and provision of financial support in the form of stipend for in-plant training to EV manufacturers	Introduction of short-term courses and training
Research and development related incentives and measures		Promotion of EV start-ups	Establishment of 'Karnataka Electric Mobility Research and Innovation Centre', working groups, a venture capital fund for electric mobility research, and a start-up incubation centre	
Charging stations and other network infrastructure-related incentives and measures		Setting up of public charging stations	Different measures catering to different charging and other network infrastructure aspects	Different measures taken up for development of charging and network infrastructure.

(Source: Authors' compilation from different sources)

The table in the appendix (Table 15) captures this classification and presents the details of the policies in the three states. Besides categorising the provisions in these policies in each EV policy, the table also, in a way, allows comparison of these policies.

A glance at the table reveals the differential composition of incentives and measures for each of the three states. While Tamil Nadu and Karnataka's EV policies provides more supply-side incentives, Maharashtra's EV policy is more demand-side incentive oriented. Within the labour-force related incentives and measures, it can be observed that all the three states provide skilling-related incentives. However, only Tamil Nadu provides employment-related incentives. Further, all the three states offer charging stations and other network infrastructure-related incentives and measures in some form or the other.

5.1 Karnataka

5.1.1. Policy overview

The Karnataka state government came out with its five-year EV policy, 'Karnataka Electric

Vehicle and Energy Storage Policy', in 2017. The state government introduced some amendments to the policy in 2021. The state government's aim is to turn Bengaluru into India's EV capital (Commerce and Industries Department, Government of Karnataka, 2017).

The key targets specified in Karnataka's EV policy include (Commerce and Industries Department, Government of Karnataka, 2017) the following:

- Investment target: INR 31,000 crore
- Employment target: 55,000

Besides these key targets, the policy underscores a target of reaching 100 per cent electric mobility in auto rickshaws, cab aggregators, corporate fleets, and school buses/vans by the year 2030 in Bengaluru (Commerce and Industries Department, Government of Karnataka, 2017).

5.1.2. Policy provisions

Table 2 clearly highlights the dominance of supply side incentives and measures, and network-infrastructure-related incentives and measures in Karnataka's EV policy. A notable aspect of the policy is it acknowledges the varied nature of enterprises in the EV industry. The policy has made a distinction in incentive provision according to the size of the enterprises. Under labour force-related incentives and measures, incentives and measures pertain only to skilling.

Under demand-side incentives, the policy offers only tax exemptions under purchase-related measures. The comparative analysis of different states' demand incentives for electric 2Ws and electric cars by Ahmed (2021) shows that Karnataka belongs to the set of states that provide no direct subsidy for either of these categories. Similarly, the incentives for putting in place charging infrastructure is also indirect. Some measures have been introduced to promote EVs in public transportation, such as the launch of 1,000 EV buses, introduction of 'a flexible stage carrier permit policy' and a pilot project (Commerce and Industries Department, Government of Karnataka, 2017). Notwithstanding this, there are no measures in the policy that can directly influence the demand for EVs.

The policy also does not contain any provisions to increase awareness of electric mobility although media reports suggest that the state government initiated an 'e-Mobility Awareness Campaign' in 2018.[52]

The policy document indicates that the state government will facilitate obtaining the required clearances through Karnataka Udyog Mitra to attract investments in the manufacturing of electric vehicles, batteries, and charging equipment (Commerce and Industries Department, Government of Karnataka, 2017). Besides, it will extend incentives to promote the manufacture of better lithium-ion batteries (Commerce and Industries Department, Government of Karnataka, 2017). It will support the use of used EV batteries in solar application and provide battery disposal infrastructure on a public-private partnership basis (Commerce and Industries Department, Government of Karnataka, 2017). Moreover, the state government will support the establishment of a secondary market for EV batteries (Commerce and Industries Department, Government of Karnataka, 2017). However, no specific measures have been spelt out

[52] https://www.thehindu.com/news/national/karnataka/e-mobility-campaign-launched/article22784261.ece

regarding the setting up of a secondary market, promoting the use of used EV battery in solar application and provision of battery disposal infrastructure.

In line with the policy, a technical committee will be tasked with certification of EV components that request for incentives under the policy (Commerce and Industries Department, Government of Karnataka, 2017). However, EV manufacturing units will be an exception to this rule (Commerce and Industries Department, Government of Karnataka, 2017). The policy states that a high-level Inter Departmental Review committee will be established to oversee the policy implementation (Commerce and Industries Department, Government of Karnataka, 2017). Two other tools that will be utilised in this regard are issuance of operational guidelines and creation of a working sub-committee for the purpose of overseeing the policy implementation (Commerce and Industries Department, Government of Karnataka, 2017).

The state government announced two further measures for the EV sector. In the state budget 2021-22, it was indicated that Karnataka may pursue research on solar electric vehicles and its technology (Government of Karnataka, 2021). In the state budget 2020-2021, the state government announced the creation of "Electric Vehicles and Energy Storage Manufacturing Cluster", setting aside INR 10 crore for the purpose (Government of Karnataka, 2020)

5.1.3. Recent Amendments: Karnataka's EV policy

Recently, some changes have been introduced in the EV policy. The state government announced a capital subsidy of 15 per cent on the value of fixed assets with a 50-acre ceiling on the land covered under it. This subsidy is meant for EV sector investors. Another change made is the launch of a production-linked incentive subsidy of 1 per cent on turnover for a period of five years. This PLI is meant for large, mega, ultra, super mega EV assembly and manufacturing units. Further, the state has also offered a stipend with a limit of 50 per cent of the cost of training with a maximum limit of INR 10,000 per month per trainee.[53] The amendments introduced are primarily supply-side incentives.

5.2 Maharashtra

5.2.1. Policy Overview

Maharashtra was one of the first Indian states to formulate and notify an EV policy. Maharashtra's initial EV policy was released in February 2018, providing fiscal and non-fiscal incentives to galvanise the adoption and manufacturing of EVs in the state. The penetration of battery electric vehicles (BEVs) in Maharashtra has remained low despite the incentives offered under the FAME India Scheme and the state EV policy. This is largely due to four critical barriers, namely, high upfront purchase price of EVs, lack of products comparable to ICE vehicles, inadequate public charging infrastructure, and low awareness of EVs or their benefits.

The Maharashtra state EV policy aims to transform Maharashtra into a leading producer of BEVs in India in terms of annual production capacity and for electric vehicles to make up 10 per cent of all new vehicle registrations (around three lakh vehicles a year) in the state by 2025. The state

[53] https://www.hindustantimes.com/cities/others/karnataka-tweaks-ev-policy-to-attract-investment-101622142001614.html

government has committed INR 930 crore to achieve this objective until March 31, 2025. It has also exempted EVs from having to pay road tax and registration charges. This policy applies exclusively to BEVs. Mild hybrid, strong hybrid, and plug-in hybrid EVs are not covered under Maharashtra's EV policy.

The policy aims for EV penetration and charging infrastructure targets are described in Table 3.

Table 3: Policy Targets under Maharashtra's EV Policy 2021

Parameter	Target	Remarks
All vehicles	10%	Share of EVs in new vehicle registrations in the state in 2025
2 wheelers	10%	
3 wheelers	20%	
4 wheelers	5%	
Fleet operators	At least 25% of the urban fleet operated by fleet aggregators/ operators in the state to transition to EVs by 2025.	Applies to e-commerce companies, last-mile delivery/logistics players and mobility aggregators operating in urban areas.
Buses	1. i) In the five targeted Urban Agglomerations (Us), achieve 25% electrification of public transport by 2025 2. ii) Convert fifteen per cent of Maharashtra State Road Transport Corporation's (MSRTC) existing bus fleet to electric vehicles	
Charging infrastructure	Cities: By 2025, city-wise targets of public and semi-public charging stations are as listed below- Greater Mumbai UA – 1500 Pune UA – 500 Nagpur UA – 150 Nashik UA – 100 Aurangabad UA – 75 Amravati – 30 Solapur – 20 Highways: Make following four highways/ expressways fully EV ready by 2025 i. Mumbai Nagpur Expressway ii. Mumbai Pune iii. Mumbai Nashik iv. Nashik Pune	i. Set up at-least one public charging station in a 3 km x 3 km grid or a minimum of 50 charging stations per million population, whichever is higher ii. Set up public charging stations on highways at a distance of 25 km (on both sides of the highways). These stations should cater to the charging requirements of long-haul passenger and freight vehicles like e-buses, electric trucks, etc.
Government vehicle fleet	Starting April 2022, all new government vehicles (owned/leased) operating within major cities to be electric.	

(Source: https://evreporter.com/wp-content/uploads/2021/07/MH-EV-Policy-2021.pdf)

Other important policy targets include targeting at least one gigafactory to manufacture advanced chemistry cell (ACC) batteries in the state.

5.2.2 Policy Provisions

The policy contains demand side initiatives to create demand for the purchase and use of EVs in Maharashtra and to accelerate the transition in the state's transportation ecosystem. Ahmed (2021) points out that Maharashtra is one of the top states providing demand-side incentives both in the form of direct subsidy and road tax exemption for electric 2Ws and electric cars. All EVs sold in the state will be exempted from road tax for as long as the policy is in force. As per the Ministry of Road Transport and Highways' notification of June 18, 2019, all EVs sold in the state will be exempted from the payment of fees for the issue or renewal of registration certificate.

The Maharashtra policy also aims to stimulate manufacturing of EVs in the state through a set of supply side initiatives aimed at attracting investment, facilitating the establishment of manufacturing units, and encouraging the production of EVs, EV components including advanced chemistry cell (ACC) batteries and electric vehicle supply equipment (EVSE). All EVs in the state will be registered with green number plates, irrespective of vehicle type.

Table 4 captures the broad categories under which incentives have been provided to stimulate electric vehicle sector's growth by the Maharashtra government.

Table 4: Demand Incentives for electric vehicles under Maharashtra's EV policy 2021

Vehicle segment	Incentive available	No. of vehicles to be incentivised	Maximum incentive per vehicle (INR)
e-2W (L1 & L2)	INR 5,000/kwh	1,00,000	10,000
e-3W autos (L5M)	INR 5,000/kwh	15,000	30,000
e-3W goods carrier (L5N)	INR 5,000/kwh	10,000	30,000
e-4W cars (M1)	INR 5,000/kwh	10,000	1,50,000
e-4W goods carrier (N1)	INR 5,000/kwh	10,000	1,00,000
e-buses*	10% of vehicle cost	1,000	20,00,000

*Note: *Incentive shall be available for STU buses only.*

(Source: https://evreporter.com/wp-content/uploads/2021/07/MH-EV-Policy-2021.pdf)

Buyers purchasing EVs (except e-buses) before December 31, 2021 are eligible for an early bird discount of INR 5,000/kWh of the vehicle battery capacity. This discount is provided over and above the demand incentives described in Table 4. The maximum early bird discount availed per vehicle has been capped at INR 1,00,000. The early bird scheme also provides for the payment of 50 per cent of the incentives amount to the OEM manufacturers for vehicles sold without battery. The remaining incentive amount (up to 50 per cent) will be provided to the battery swapping energy operator to defray the cost of deposits that may be required from the end user for the use of the battery.

The state also aims to create an ecosystem for environment-friendly **scrapping of vehicles** (including EVs) and plans to prepare a state scrapping policy. The segment-wise, vehicle scrappage incentives are described in Table 5. The Maharashtra government will reimburse the scrappage incentive to the OEM or dealer provided they are able to provide evidence of matching contribution on their part and confirm scrappage of the ICE vehicle in the same vehicle category.

Table 5: Vehicle segment-wise Scrappage Incentives under Maharashtra's EV policy 2021

Vehicle Segment	Scrappage Incentive
e-2W	Up to INR 7,000
e-3W	Up to INR 15,000
e-4W	Up to INR 25,000

(Source: https://evreporter.com/wp-content/uploads/2021/07/MH-EV-Policy-2021.pdf)

The incentives disbursement mechanism (for demand incentives, scrappage incentives, charging infrastructure incentives, supply-side incentives, tax exemptions and reimbursements, etc.) will be made through an online portal to ensure timely transfer to beneficiaries and transparency.

The Maharashtra government hopes to attract investments in setting up manufacturing and R&D facilities for EVs in the state (component manufacturing, vehicle assembly, battery assembly, cell manufacturing, electronics parts manufacturing, recycling of EVs and EV batteries, etc.). All the benefits under 'D+' category of mega projects/other categories will be provided to these industries irrespective of where in the state the manufacturing unit is located.[54] Moreover, EV start-ups will be encouraged on a priority basis under the Maharashtra State Innovation Society.

The Government of Maharashtra also aims to develop at least one gigafactory for the manufacturing of advanced chemistry cells under the Government of India's PLI scheme for advanced chemistry cell (ACC) battery manufacturing, by 2023. The state government will endeavour to offer incentives that significantly enhance/complement the incentives offered under GoI's PLI scheme.

5.2.3 Recent Amendments: Maharashtra's EV policy

The slow uptake of EVs and changes in policy, technology and the market have necessitated that the Maharashtra government take a fresh look at and update its 2018 EV policy to stimulate EV manufacturing and sales in the state. The Government of Maharashtra plans to explore the feasibility of a zero-emission vehicle (ZEV) requirement and credit programme to stimulate EV manufacturing and adoption. It is expected to release the technical details of the plan shortly.

The amended policy also includes the creation of an apex Steering Committee, under the aegis of Government of Maharashtra, which will be responsible for tracking policy progress, addressing major impediments to policy implementation and making necessary amendments to the policy. The Steering

[54] The template for quantum of incentives for Mega Projects and Ultra Mega Projects shall be decided by the High Power Committee under the chairmanship of the Chief Secretary, Government of Maharashtra. However, the Cabinet Sub Committee for mega projects, under the chairmanship of the Chief Minister of Maharashtra will have the powers to sanction customized package of incentives and even offer special / extra incentives for prestigious Mega Projects I Ultra Mega Projects, on a case to case basis with recommendation of High Power Committee.

Committee shall be supported by a dedicated team, or a secretariat called the "Maharashtra State EV Secretariat" responsible for daily functioning of the EV Policy. Moreover, the committee shall also consider providing incentives to new emerging technologies such as fuel cell vehicles as and when these technologies may become more popularly available.

5.3 Tamil Nadu

Tamil Nadu unveiled its EV policy in 2019[55] and is updating it.[56] It has a vibrant automotive sector, with backward linkages with metal industries, capital equipment, trucking, warehousing and logistics.

5.3.1 Policy overview

Tamil Nadu has set out the way in which its EV policy will achieve its objective to create a robust infrastructure for electric vehicles by providing adequate power supply and a network of charging points with favourable power tariff. The objective is to make Tamil Nadu the preferred destination for electric vehicle and component manufacturing units (including battery and charging infrastructure). This will be achieved by supporting and creating the ecosystem and infrastructure to make Tamil Nadu, the EV Hub of India. The state plans to create a pool of skilled workforce for the EV industry through the technical institutions available in the state and create new jobs in the EV industry. It aims to promote innovation in EVs and provide a conducive environment for industry and research institutions to focus on cutting edge research in EV technologies. It plans to recycle and reuse used batteries and dispose of the rejected batteries in an environment friendly manner.

5.3.2 Policy Provisions

The state is a leader in renewable energy, with an installed capacity of 12180 MW.[57] The objectives of the Tamil Nadu EV policy are the following:

- Encourage EV manufacturing and EV marketing

To achieve this objective, the state has offered concessions to promote investment in EV manufacturing, battery manufacturing or assembly, EV charging and equipment manufacturing. The details of the policy are presented in Table 15.

In terms of demand-side incentives, Ahmed (2021) notes the absence of a direct subsidy for either electric 2Ws or electric cars.

5.3.3 Recent Amendments: Tamil Nadu's EV policy

The provisions of the Tamil Nadu EV policy, 2019 have been discussed above. Tamil Nadu is in the process of updating its EV policy.

6. Progress

In this section, we attempt to assess how far the EV policies of the three states have succeeded in achieving their objectives.

The following discussion examines if the presence of an EV policy has influenced the uptake of electric vehicles in the three states under consideration, Karnataka, Maharashtra, and Tamil Nadu. Electric vehicle registrations

[55] https://powermin.gov.in/sites/default/files/uploads/EV/Tamilnadu.pdf

[56] https://www.thehindu.com/news/cities/chennai/government-updating-electric-vehicle-policy/article36641018.ece

[57] https://powermin.gov.in/sites/default/files/uploads/EV/Tamilnadu.pdf

from the VAHAN dashboard are used as a proxy for electric vehicle uptake. Before proceeding further, it is important to note that the data under consideration pertain to battery operated electric vehicles. Further, the period under consideration for the analysis is from 2012 to 2020.

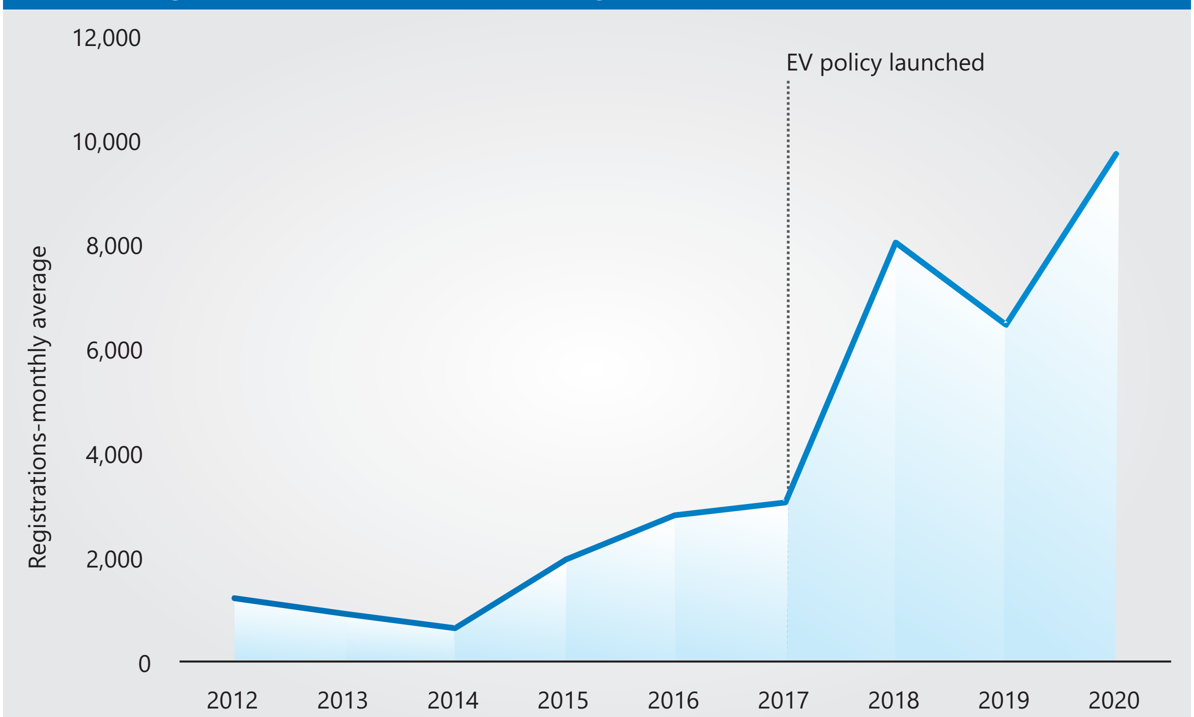
Some concerns with the VAHAN database have been raised;[58] however, since there are no alternative data sources, the VAHAN database has been used here. Therefore, it is necessary to exercise caution while interpreting the results.

6.1. Karnataka

Karnataka's EV policy was framed in 2017 for a five-year period; the policy is due to expire in 2022. The Karnataka approved investments of around INR 22,419 crore in December 2020 for the manufacture of EVs and lithium-ion batteries.[59] Media reports indicate that Mahindra Electric unveiled its plan for investing an additional INR 400 crore over a span of five years in the state in 2018.[60] In 2020, Sun Mobility also revealed its plan to put in place nearly 100 battery swapping stations in Bengaluru by end-2021.[61] Besides, Tesla has expressed interest in the state and indicated its plan to establish an electric car manufacturing unit.[62]

The following figure (Figure 10) illustrates the year-wise electric vehicle registrations in Karnataka from 2012 to 2020.

Figure 10: Annual electric vehicle registrations in Karnataka (2012-2020)



(Source: VAHAN dashboard)

[58] https://www.carandbike.com/news/ola-ellectric-says-vahaan-registration-data-not-updated-real-time-2695545#pfrom=home-ndtv_auto

[59] https://www.livemint.com/news/india/karnataka-approves-ev-manufacturing-projects-of-nearly-rs-23-000-cr-11608565430950.html)

[61] https://yourstory.com/2020/12/sun-mobility-battery-swapping-electric-vehicle-bengaluru-metro/amp

[62] https://www.livemint.com/companies/news/tesla-to-open-manufacturing-unit-in-karnataka-says-cm-yediyurappa-11613233617627.html

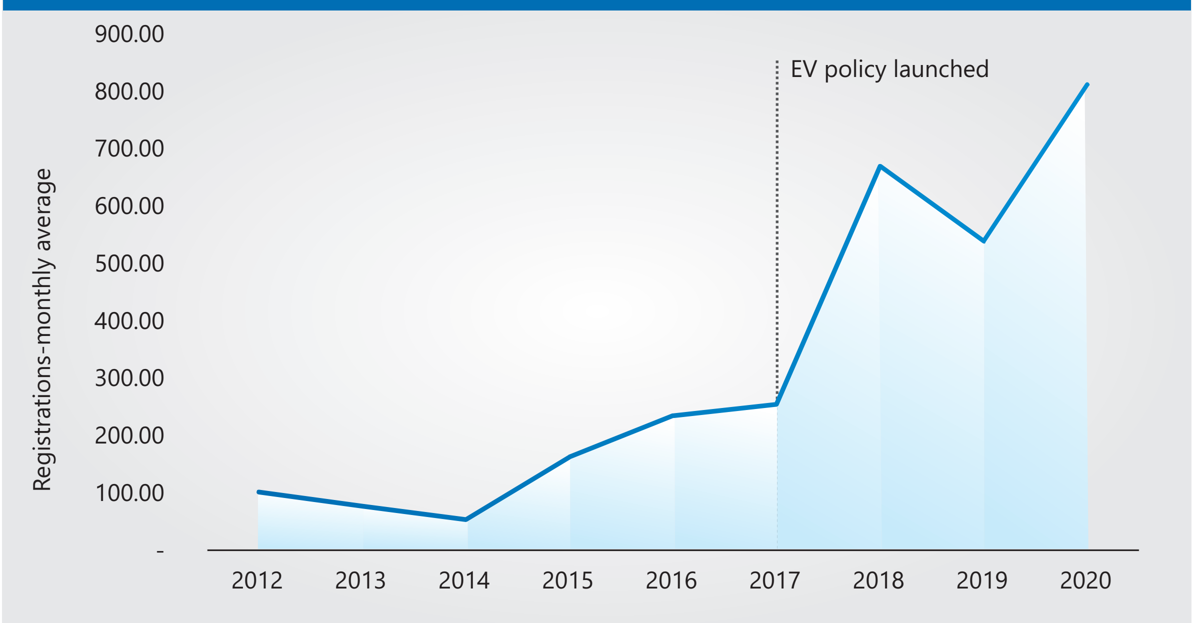
EV registrations in Karnataka stood at 1,216 in 2012. The number of registrations declined for two consecutive years before picking up in 2015. Since 2017, when Karnataka launched its EV policy, EV registrations increased over their pre-policy level. There can be several factors driving registrations upward with the launch of the EV policy can be one of them. The total number of registrations from 2012 to 2020 was around 34,700 (Table 6).

Table 6: Cumulative electric vehicle registrations in Karnataka (2012-2020)

Year	Cumulative electric vehicle registrations
2012	1,216
2013	2,132
2014	2,772
2015	4,716
2016	7,522
2017	10,572
2018	18,597
2019	25,052
2020	34,783

(Source: VAHAN dashboard; Authors' calculations)

Figure 11: Average monthly electric vehicle registrations in Karnataka (2012-2020)



(Source: VAHAN dashboard; Authors' calculations)

On average, there were around 101 EV registrations monthly in 2012. This number increased to around 668 in 2018, the year following the year of the policy launch. The average monthly EV registrations for 2020 stood at around 810. In case of average monthly registrations as well, we observe that the average monthly registrations are higher for the years after the policy was launched as opposed to the pre-policy period.

Table 7: Category year-wise shares in electric vehicle registrations in Karnataka (2012-2020)

Year	2W	3W	4W	H	L	M	Others
2012	64.47	5.59	-	-	29.93	-	-
2013	28.82	41.38	-	-	29.80	-	-
2014	34.38	5.16	-	0.16	60.31	-	-
2015	5.14	66.36	-	0.05	28.40	0.05	-
2016	2.39	80.83	-	0.07	16.71	-	-
2017 EV policy launched	2.03	81.37	-	-	16.60	-	-
2018	17.36	74.59	-	-	8.04	0.01	-
2019	86.32	7.16	-	-	6.52	-	-
2020	89.27	3.12	-	-	7.60	-	-

(Source: VAHAN dashboard; Authors' calculations)

Note: The vehicle categories in the VAHAN dashboard[63] are defined for the present purpose in the following manner. Two-wheeler (2W) includes two-wheeler invalid carriage; two-wheeler NT; and two-wheeler T. Three-wheeler (3W) includes three-wheeler NT and three-wheeler T. Four-wheeler (4W) includes four-wheeler (invalid carriage). Heavy vehicle (H) includes heavy goods vehicle; heavy motor vehicle; and heavy passenger vehicle. Light vehicle (L) includes light goods vehicle; light motor vehicle; and light passenger vehicle. Medium vehicle (M) includes medium goods vehicle; medium motor vehicle; and medium passenger vehicle. Others include other than mentioned above.

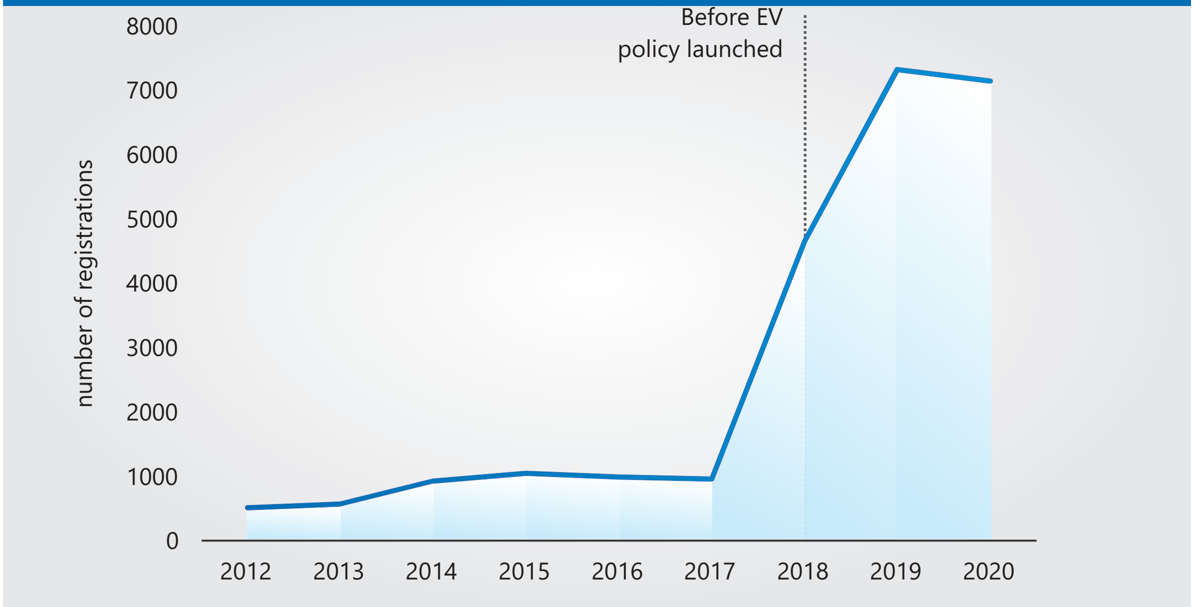
From the table (Table 7), we can observe that 4Ws have zero registrations in the entire period from 2012 to 2020. We notice that in some years, 2Ws contribute substantially to the total registrations whereas in other years 3Ws account for a significant share. While light vehicles accounted for a substantial share from 2012 to 2017, their share has diminished to single-digit levels in the period from 2018 to 2020.

6.2. Maharashtra

The figure below (Figure 12) graphs the year-wise electric vehicle registrations in Maharashtra from 2012 to 2020.

[63] The VAHAN dashboard reports EV registration data for the following categories: two-wheeler invalid carriage; two-wheeler NT; two-wheeler T; three-wheeler NT; three-wheeler T; four-wheeler (invalid carriage); heavy goods vehicle; heavy motor vehicle; heavy passenger vehicle; light goods vehicle; light motor vehicle; light passenger vehicle; light goods vehicle; light motor vehicle; light passenger vehicle; and other than mentioned above

Figure 12: Annual electric vehicle registrations in Maharashtra (2012-2020)



(Source: VAHAN dashboard)

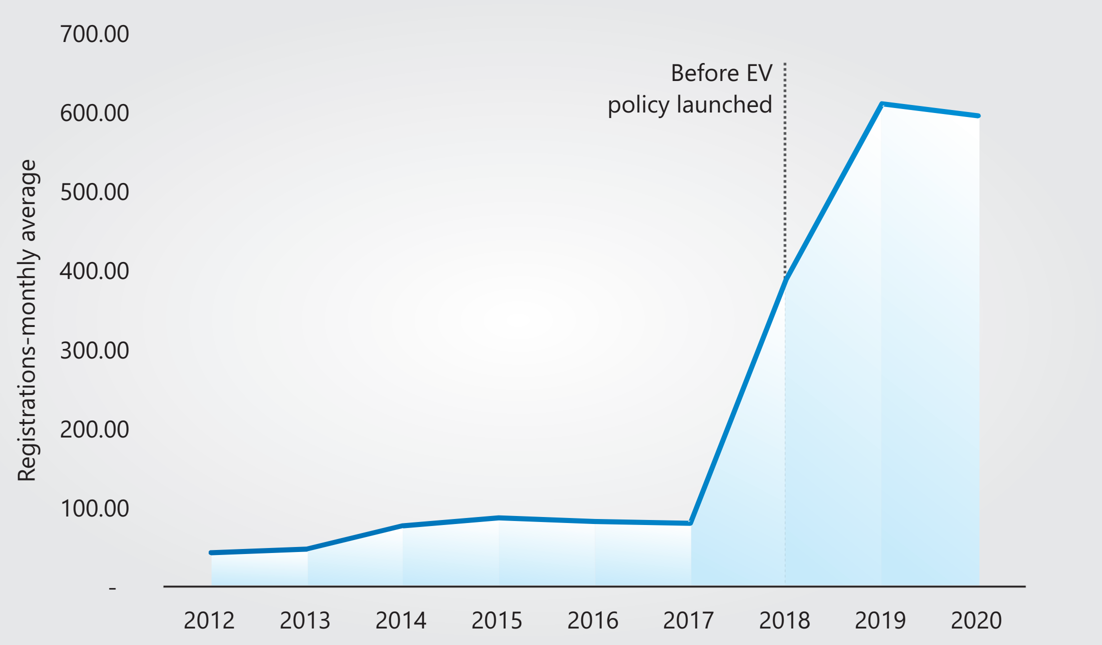
In Maharashtra, EV registrations rose year after year from 2012 to 2015. They recorded a slight decline in the following years, 2016 and 2017. In 2018, the year of launch of the EV policy, EV registrations increased from 957 in 2017 to 4,653 in 2018. Registrations continued on an upward trajectory in 2018 and 2019 and recorded a minor decline in 2020. It can be observed that in the period after the launch of the EV policy, registrations have been higher than the registrations in the pre-policy period. While there can be several factors behind the rising registrations of EV, presence of an EV policy can be one factor propelling the registrations forward. Cumulative registrations (Table 8) from 2012 to 2020 in Maharashtra have touched nearly 24,000.

Table 8: Cumulative electric vehicle registrations in Maharashtra (2012-2021)

Year	Cumulative registrations
2012	512
2013	1079
2014	2001
2015	3044
2016	4033
2017	4990
2018	9643
2019	16964
2020	24107

(Source: VAHAN dashboard; Authors' calculations)

Figure 13: Average monthly electric vehicle registrations in Maharashtra (2012-2020)



(Source: VAHAN dashboard; Authors' calculations)

Figure 13 depicts the average monthly EV registrations[64] for Maharashtra. While the monthly average in all years in the pre-policy period remained below 90, the monthly average in all the years in the post-policy period has stayed above 350. The average monthly registrations in 2019 and 2020 neared 600. This indicates that the launch of the EV policy has had a positive influence in 2018 on average monthly registrations.

Table 9: Vehicle category year-wise shares in electric vehicle registrations in Maharashtra (2012-2020)

Year	2W	3W	4W	H	L	M	Others
2012	96.88	-	-	-	3.13	-	-
2013	92.06	-	-	0.18	7.41	0.18	0.18
2014	94.03	-	-	-	5.86	-	0.11
2015	89.36	0.10	-	0.10	10.35	0.10	-
2016	87.87	0.40	0.10	-	11.53	-	0.10
2017	37.68	41.13	-	0.84	19.83	0.42	0.10
2018 Initial EV policy launched	67.31	27.92	-	0.06	4.71	-	-

[64] Refer footnote 36

Year	2W	3W	4W	H	L	M	Others
2019	78.23	15.49	-	2.31	3.82	0.15	-
2020	70.95	14.80	-	0.57	13.17	0.46	0.04

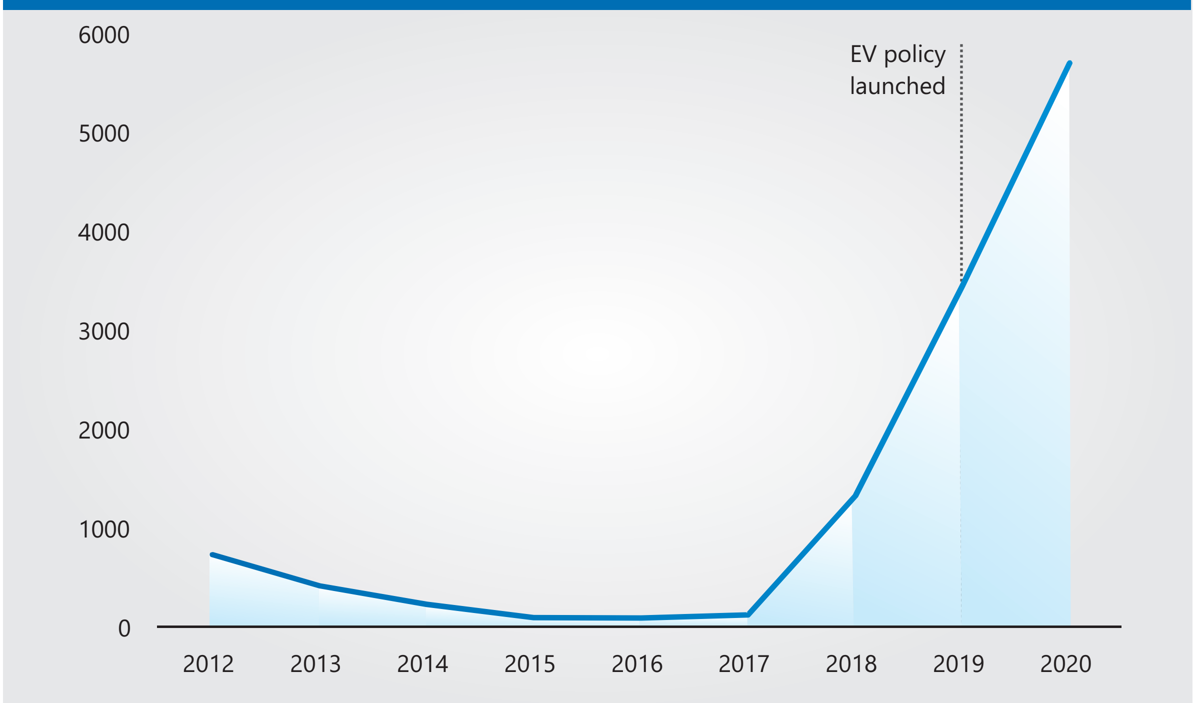
(Source: VAHAN dashboard; Authors' calculations)

Note: The vehicle categories in the VAHAN dashboard[65] are defined for the present purpose in the following manner. Two-wheeler (2W) includes two-wheeler invalid carriage; two-wheeler NT; and two-wheeler T. Three-wheeler (3W) includes three-wheeler NT and three-wheeler T. Four-wheeler (4W) includes four-wheeler (invalid carriage). Heavy vehicle (H) includes heavy goods vehicle; heavy motor vehicle; and heavy passenger vehicle. Light vehicle (L) includes light goods vehicle; light motor vehicle; and light passenger vehicle. Medium vehicle (M) includes medium goods vehicle; medium motor vehicle; and medium passenger vehicle. Others include other than mentioned above.

Amongst, 2Ws, 3Ws, and 4Ws, we see that two-wheelers maintained a dominant share from 2012 to 2020, except in 2017. In 2017, three-wheelers accounted for a 41 per cent share whereas two-wheelers accounted for a 37 per cent share. Since 2017, 3Ws have maintained a double-digit share as compared to a negligible share in earlier years. Four-wheelers accounted for a virtually negligible share throughout the period. Light vehicles also contributed modestly to electric vehicle registrations.

6.3. Tamil Nadu

Figure 14: Annual electric vehicle registrations in Tamil Nadu (2012-2020)



(Source: VAHAN dashboard)

[65] Refer footnote 37

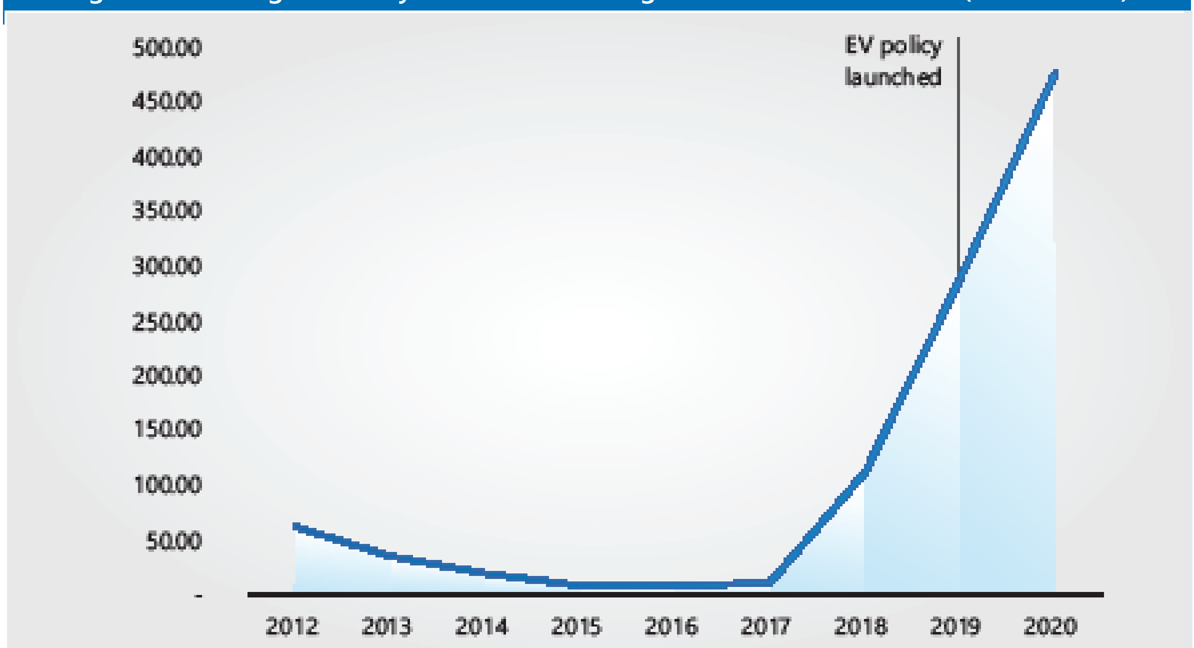
Starting from 729 registrations in 2012, EV registrations in Tamil Nadu steadily declined until 2016. From 2017, the registrations started rising. They increased from 123 registrations in 2017 to 1,325 registrations in 2018. Tamil Nadu released its EV policy in 2019. The registrations for 2019 stood at around 3,400. In the following year, they increased further to around 5,700 registrations. While the registrations were already on an upward trajectory before the policy was launched, the registrations in the post-policy period have remained above 3,000. This can be contrasted with the highest number that the registrations touched in the pre-policy period, which was 1,325 registrations in 2018. The presence of an EV policy in Tamil Nadu can be identified as one of the factors that may have contributed towards pushing the number of electric vehicle registrations forward. The cumulative registrations for Tamil Nadu for the period from 2012 to 2020 were around 12,000.

Table 10: Cumulative electric vehicle registrations in Tamil Nadu (2012-2020)

Year	Cumulative registrations
2012	729
2013	1142
2014	1369
2015	1463
2016	1554
2017	1677
2018	3002
2019	6445
2020	12141

(Source: VAHAN dashboard; Authors' calculations)

Figure 15: Average monthly electric vehicle registrations in Tamil Nadu (2012 – 2020)



(Source: VAHAN dashboard; Authors' calculations)

The average monthly registrations[66] (Figure 15) fell from around 60 registrations in 2012 to around 8 registrations in 2016. They started climbing up in 2017, reaching nearly 10 registrations, and continued their upward movement until 2020, when it touched around 474 registrations. In the pre-policy period, the average monthly registrations reached their highest level in 2018 (nearly 110 registrations) and the average monthly registrations remained below that level in the earlier years. In contrast, the post-policy years have seen average monthly registrations staying above 280 registrations. This underlines the significance of an EV policy in facilitating EV adoption in Tamil Nadu.

Table 11: Vehicle category year-wise shares in electric vehicle registrations in Tamil Nadu (2012-2020)

Year	2W	3W	4W	H		L	M	Others
2012	61.45	0.27	-	1.37		36.08	0.41	0.41
2013	41.50	0.49	-	1.46		56.07	0.24	0.24
2014	22.47	1.32	-	0.44		75.33	-	0.44
2015	14.89	-	-	1.06		82.98	1.06	-
2016	10.99	2.20	-	8.79		75.82	1.10	1.10
2017	25.20	0.81	-	0.81		72.36	-	0.81
2018	95.47	0.30	-	0.08		4.00	0.15	-
2019 EV policy launched	98.43	-	-	0.03		1.54	-	-
2020	95.05	0.04	-	-		4.92	-	-

(Source: VAHAN dashboard; Authors' calculations)

Note: The vehicle categories in the VAHAN dashboard[67] are defined for the present purpose in the following manner. Two-wheeler (2W) includes two-wheeler invalid carriage; two-wheeler NT; and two-wheeler T. Three-wheeler (3W) includes three-wheeler NT and three-wheeler T. Four-wheeler (4W) includes four-wheeler (invalid carriage). Heavy vehicle (H) includes heavy goods vehicle; heavy motor vehicle; and heavy passenger vehicle. Light vehicle (L) includes light goods vehicle; light motor vehicle; and light passenger vehicle. Medium vehicle (M) includes medium goods vehicle; medium motor vehicle; and medium passenger vehicle. Others include other than mentioned above.

In 2012, 2Ws' share stood at around 61 per cent. While its share dwindled till 2016, it increased in 2017 to nearly 25 per cent and then increased further to nearly 95 per cent in 2018. The 2Ws continued to maintain a governing share till 2020 in Tamil Nadu. From 2012 to 2017, light vehicles contributed considerably to the registrations. However, their share cooled to below 5 per cent in the period from 2018 to 2020. 3Ws have marginally contributed to the electric vehicle registrations in the period under consideration. On the other hand, 4Ws' contribution has been zero.

The above analysis highlights that the launch of EV policies in Karnataka, Maharashtra, and Tamil Nadu have positively influenced the electric vehicle registrations in these states. However, it is crucial to note that there may

[66] Refer to footnote 36

[67] Refer to footnote 37

be several factors impacting the electric vehicle registrations and presence of an EV policy can be one of these factors. This data can be seen as a preliminary indicator of the policy. This can also be seen as one of the many indicators that can be employed to gauge policy effectiveness. However, the EV penetration in terms of aggregate annual vehicle registrations for 2020 for Karnataka, Tamil Nadu, and Maharashtra was pegged at 0.81 per cent, 0.38 per cent, and 0.40 per cent respectively as per the VAHAN data implying that the EV penetration in these three states stood at extremely low levels for 2020.

Assessment of the registration data also sheds light on the dominant vehicle segments in the battery-operated electric vehicle space in these three states. While for Karnataka and Maharashtra 2Ws, 3Ws, and light vehicles emerge as important contributors to the overall electric vehicle registrations, 2Ws and light vehicles are significant contributors in case of Tamil Nadu.

Another key observation is a negligible share of 4Ws in all three states. This can be partly attributed to an existing low share of 4Ws in an overall manner and not just for battery-operated EVs. The 4Ws' share in 2020 for Karnataka, Tamil Nadu, and Maharashtra was pegged at 0.02 per cent, 0.01 per cent, and 0.01 per cent respectively as per the VAHAN data.

7. Conclusion and way forward

The EV policy is highly dynamic with active participation of state actors at both the national as well as subnational level. Within the India states, the paper turns towards an in-depth analysis of the EV policies of three states namely Karnataka, Maharashtra, and Tamil Nadu.

As pointed out by Rodrik (2014), India has had several policies for green growth in the past: these include the National Action Plan on Climate Change (2008), including the National Solar Mission Integrated Energy Policy (2006), the National Electricity Policy (2005), the Energy Conservation Act (2001), the Air (Prevention and Control of Pollution) Act (1981) and the Environment (Protection) Act (1986). EV policies are the latest policies pursued by India to address green growth. The state-level policy analyses reveal the distinct nature of each of these policies as they address a different mix of segments. As discussed earlier, Tamil Nadu and Karnataka's EV policies provides more supply-side incentives, while Maharashtra's EV policy is more demand-side incentive oriented. Within the labour-force related incentives and measures, it can be observed that all the three states provide skilling-related incentives however only Tamil Nadu provides employment-related incentives. Further, all the three states offer charging stations and other network infrastructure-related incentives and measures in some form or the other. Further, the degree and extent of incentives offered also differ.

The metric of progress selected in the paper, EV registrations, reflects the positive impact of EV policies in these states. That said, the EV penetration in terms of annual vehicle registrations for 2020 stayed extremely depressed. Further, caution needs to be exercised in dealing with these findings as there may be several factors affecting EV registrations and the presence of an EV policy may be just one of the factors. Nevertheless, data on registration is a metric that could be employed to gauge the effectiveness of an EV policy.

References

Ahmed, A. (2021, December 2). State-Wise EV Subsidies in India: A Handy List of Incentives and Benefits for Electric Vehicles in Each State. Firstpost.

Bhaskar, U. (2021, May 13). PLI scheme for EV batteries gets nod. Retrieved from: https://www.hindustantimes.com/business/pli-scheme-for-ev-batteries-gets-nod-101620856216077.html (Accessed on December 30, 2021)

Cabinet approves ₹26,058 crore PLI scheme for auto, drone sectors. (2021, September 15). The Hindu. Retrieved from: https://www.thehindu.com/news/national/cabinet-approves-26058-crore-pli-scheme-for-auto-drone-sectors/article36470921.ece

Commerce and Industries Department, Government of Karnataka. (2017). Karnataka Electric Vehicle and Energy Storage Policy 2017.

Cosbey, A. (2017). Trade and Investment Law and Green industrial Policy, in Green Industrial Policy: Concepts, Policies, and Country Experiences. Retrieved from: https://www.un-page.org/files/public/green_industrial_policy_book_aw_web.pdf

Department of Heavy Industry, Ministry of Heavy Industries & Public Enterprises, Government of India. (2012, August). National Electric Mobility Mission Plan 2020.

Eder, J., Schneider, E., Kulke, R., and C. D. Konig (2018). From mainstream to progressive industrial policy, Austrian Journal of Development Studies (Journal fur Entwicklungspolitik), 34, 4-14.

Eisinger, P. (1988). The Rise of the Entrepreneurial State: State and Local Economic Development Policy in the US, Maddison: University of Maddison Press.

Environment and Climate Change Department, Government of Maharashtra. (2021, July 23). Maharashtra Electric Vehicle Policy, 2021-Government Resolution No.: MSEVP-2021/CR 25/TC 4. Retrieved from: https://maitri.mahaonline.gov.in/PDF/EV%20Policy%20GR%202021.pdf

Government of Karnataka. (2020). Budget 2020-21.

Government of Karnataka. (2021). Budget 2021-22.

Government of Maharashtra. (n.d.). Maharashtra State Electric Vehicle Policy - 2021 (Draft). Retrieved from: https://evreporter.com/wp-content/uploads/2021/07/MH-EV-Policy-2021.pdf

Grant Thornton (2021). Sector flash: Indian auto industry. April.

IFC and NITI Aayog (n.d.). Export Preparedness Index 2021.

India Energy Storage Alliance. (n.d.). Government extends FAME India scheme for third time. Retrieved from: https://indiaesa.info/news-menu/28-industry-news-management/1177-government-extends-fame-india-scheme-for-third-time

INDIA: National Electric Mobility Mission Plan 2020. (n.d.). Retrieved from: https://policy.asiapacificenergy.org/node/2663

Ministry of Heavy Industries, Government of India. (n.d.). Retrieved from: https://heavyindustries.gov.in/

Popli, S. A. (2021, May 13). Opinion: PLI scheme for ACC – A power boost for Indian EV industry. ET Auto. Retrieved from: https://auto.economictimes.indiatimes.com/news/industry/pli-scheme-for-acc-a-power-boost-for-indian-ev-industry/82594582 (Accessed on December 30, 2021)

Pradhan, J.P. and Das, K. (2015). Manufacturing Exports from Indian States: Determinants and Policy Imperatives. Springer.

Press Information Bureau. (2019, February 28). Cabinet Approves Scheme for FAME India Phase II. Retrieved from: https://pib.gov.in/Pressreleaseshare.aspx?PRID=1566758

Press Information Bureau. (2019, July 9). Ministry of Heavy Industries - FAME India Scheme. Retrieved from: https://pib.gov.in/PressReleasePage.aspx?PRID=1577880

Press Information Bureau. (2019, August 8). Sanction for 5595 Electric Buses under Fame Phase-II. Retrieved from: https://pib.gov.in/Pressreleaseshare.aspx?PRID=1581525

Press Information Bureau. (2020, March 3). Promotion of Electric Vehicles. Retrieved from: https://pib.gov.in/PressReleasePage.aspx?PRID=1604991

Press Information Bureau. (2021, September 24). Government Notifies PLI Scheme for Automobile & Auto components. Retrieved from: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1757651

Ray, S. and S. Kar (2020). 'Kuznets' tension in India: Two Episodes' WIDER Working Paper 2020/24, UNU-WIDER, Helsinki. March 2020.

Ray, S. and S. Miglani (2020). India's GVC integration: An analysis of upgrading efforts and facilitation of lead firms, ICRIER Working Paper No. 386. Retrieved from: http://icrier.org/pdf/Working_Paper_386.pdf

Rodrik, D. (2014) Green Industrial Policy. Oxford Review of Economic Policy, 30(3), pp. 469–491.

Sastry, S. H. M. (2020, June 25). Karnataka Govt to waive registration fee, stamp duty for electric vehicles. Deccan Herald. Retrieved from https://www.deccanherald.com/state/top-karnataka-stories/karnataka-govt-to-waive-registration-fee-stamp-duty-for-electric-vehicles-853729.html

Singh, A. (2008). 'The Past, Present and Future of Industrial Policy in India: Adapting to the Changing Domestic and International investment,' Working paper 376, Centre for Business Research, University of Cambridge.

Sinha, A. (2005). The Regional Roots of Developmental Politics in India: a divided Leviathan, Oxford University Press, New Delhi.

Steer, A. (2013). 'Resource Depletion, Climate Change and Economic Growth', paper prepared for the Global Citizen Foundation Project on 'Towards a Better Global Economy', February. Retrieved from: https://www.gcf.ch/wp-content/uploads/2013/06/GCF_Steer-working-paper-5_6.20.13.pdf

Tamil Nadu Electric Vehicle Policy (2019) Retrieved from: https://powermin.gov.in/sites/default/files/uploads/EV/Tamilnadu.pdf

Appendix

Table 12: Central Level Policies		
Sr No.	**Subsidy Schemes**	**Ministry**
1.	Amended Technology Upgradation Fund Scheme (ATUFS)	Government of India, Ministry of Textiles (MoT)
2.	Scheme for Integrated Textile Parks (SITP)	Government of India, Ministry of Textiles (MoT)
3.	In-situ Upgradation of Plain Power looms	Government of India, Ministry of Textiles (MoT)
4.	Group Work shed Scheme (GWS)	Government of India, Ministry of Textiles (MoT)
5.	Yarn Bank Scheme	Government of India, Ministry of Textiles (MoT)
6.	Common Facility Centre (CFC)	Government of India, Ministry of Textiles (MoT)
7.	Pradhan Mantri Credit scheme for Power loom Weavers	Government of India, Ministry of Textiles (MoT)
8.	Solar Energy Scheme for Powerlooms	Government of India, Ministry of Textiles (MoT)
9.	Grant-in-Aid and Modernisation & Upgradation of Powerloom Service Centres (PSCs)	Government of India, Ministry of Textiles (MoT)
10.	Amended Technology Upgradation Fund Scheme (ATUFS)	Government of India, Ministry of Textiles (MoT)
11.	Modified Comprehensive Powerloom Cluster Development Scheme (MCPCDS)	Government of India, Ministry of Textiles (MoT)
12.	Integrated Processing Development Scheme (IPDS)	Government of India, Ministry of Textiles (MoT)
13.	SAMPADA (Scheme for Agro-Marine Processing and Development of Agro Processing Clusters)	Government of India, Ministry of Food Processing Industries (MoFPI)
14.	Credit Linked Capital Subsidy Scheme for Technology Upgradation (CLCSS)	Government of India, Ministry of Micro, Small & Medium Enterprises (MSME)
15.	Market Development Assistance Scheme for Micro/ Small manufacturing enterprises/ Small & Micro exporters (SSI-MDA)	Government of India, Ministry of Micro, Small & Medium Enterprises (MSME)
16.	Micro & Small Enterprises – Cluster Development Programme (MSE-CDP)	Government of India, Ministry of Micro, Small & Medium Enterprises (MSME)
17.	Prime Minister Employment Generation Programme (PMEGP)	Government of India, Ministry of Micro, Small & Medium Enterprises (MSME)
18.	Marketing Assistance Scheme (MAS)	Government of India, Ministry of Micro, Small & Medium Enterprises (MSME)
19.	Integrated Development of Leather Sector Sub Scheme (IDLSS)	Department of Industrial Policy and Promotion, Government of India, Ministry of Commerce and Industry
20.	"Digital MSME" Scheme for promotion of Information and Communication Technology (ICT) in MSME Sector	Government of India DC(MSME), Ministry of Micro, Small & Medium Enterprises.

Sr No.	Subsidy Schemes	Ministry
21.	Lean Manufacturing Competitiveness Scheme Under National Manufacturing Competitiveness Programme	Development Commissioner (MSME) Ministry of Micro, Small and Medium Enterprises, Government of India
22.	ISO 9000/ISO 14001 Certification Reimbursement	Government of India, Ministry of Micro, Small and Medium Enterprises
23.	Support for Entrepreneurial and Managerial Development of SMEs through Incubators	Government of India, Ministry of Micro, Small and Medium Enterprises
24.	Financial Support to MSMEs in ZED Certification Scheme	Government of India, Ministry of Micro, Small and Medium Enterprises
25.	Design Clinic for Design Expertise to MSMEs	Government of India, Ministry of Micro, Small and Medium Enterprises
26.	Technology and Quality Upgradation Support to MSMEs (TEQUP)	Government of India, Ministry of Micro, Small and Medium Enterprises
27.	Enabling Manufacturing Sector to be Competitive through QMS&QTT	Government of India, Ministry of Micro, Small and Medium Enterprises
28.	Building Awareness on Intellectual Property Rights (IPR)	Government of India, Ministry of Micro, Small and Medium Enterprises
29.	Coir Vikas Yojana (CVY)	Coir Board, Government of India, Ministry of MSMSE
30.	Integrated Skill Development Scheme for the Textiles and Apparel Sector	
31.	Scheme for Capacity Building in Textiles Sector (SCBTS)	

Table 13: State level policies

Sr No.	Subsidy Schemes	Ministry	Applicability
1.	Transport Subsidy Scheme (TSS)	Department of Industrial Policy and Promotion, Ministry of Commerce and Industry	8 States of the North East Himachal Pradesh Uttarakhand Jammu & Kashmir Darjeeling District of West Bengal Andaman & Nicobar Administration Lakshadweep Administration
2.	New Enterprise-cum-Enterprise Development scheme (NEEDS)	Department of Industries & Commerce, Government of Tamil Nadu	Tamil Nadu

Sr No.	Subsidy Schemes	Ministry	Applicability
3.	Unemployed Youth Employment Generation Programme (UYEGP)	Department of Industries & Commerce, Government of Tamil Nadu	Tamil Nadu
4.	Tamil Nadu Rural Roads Improvement Scheme (TNRRIS)		
5.	Tamil Nadu Start-up and Innovation Policy 2018-23		
6..	Assistance of Capital and Interest Subsidy for MSMEs (except service enterprise)	Industries Commissionerate, Government of Gujarat	Gujarat
7.	Assistance for reimbursement of CGTMSE fees for Micro and Small enterprises	Industries Commissionerate, Government of Gujarat	
8.	Assistance in Rent to MSEs	Industries Commissionerate, Government of Gujarat	
9.	Standard Operating Procedure (SOP) for "Scheme for Incentive to Industries"	Industries Commissionerate, Government of Gujarat	
10.	Schemes for Assistance to Labour Intensive Industries	Industries Commissionerate, Government of Gujarat	
11.	Scheme for Financial Assistance to Plastic Industry	Industries Commissionerate, Government of Gujarat	
12.	Gujarat Textile Policy 2012		
13.	Aerospace and Defence Policy		
14.	Scheme for Financial Assistance to plastic Industry		
15.	Scheme for Awards to MSMEs and Export Awards		

Sr No.	Subsidy Schemes	Ministry	Applicability
16.	Scheme for Assistance to Start-ups/innovation		
17.	Scheme for Market Development Assistance		
18.	Gujarat Industrial Policy 2015		
19.	Mukhya Mantri Yuva Udyami Yojana	Department of MSME, Government of Madhya Pradesh	Madhya Pradesh
20.	Mukhya Mantri Swarojgar Yojana	Department of MSME, Government of Madhya Pradesh	
21.	Karnataka Start-up Policy 2015-20		Karnataka
22.	Uttar Pradesh Infrastructure and Industrial Investment Policy – 2012		Uttar Pradesh
23.	Uttar Pradesh Food Processing Industry Policy – 2012		
24.	Uttar Pradesh Information Technology and Start-up Policy 2017-22		
25.	Andhra Pradesh Innovation and Start-up policy 2014		Andhra Pradesh
26.	TUFS – Textile		Maharashtra
	COIR Policy for MSMEs		
	Package Scheme of Incentives for Industries		
	Maharashtra Industrial Policy 2019		
	Maharashtra Start-up Policy 2018		

Table 14: Some recent policy enactments by states				
State	**Ease of doing business ranking (2017)**	**GSDP, Current price ($, billion)**	**FDI inflows (2000-19)**	**Recent policy enacted**
Andhra Pradesh	1	125.6 (2017-18)	18.7 billion (includes Telangana)	1. AP Export Promotion Policy https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-01/Draft%20%20AP%20Export%20Policy.pdf 2. AP Industrial Development Policy 2015-20 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Industrial%20Development%20Policy%20%282015-20%29.pdf 3. AP Industrial Parks Policy 2015-20 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Industrial%20Parks%20Policy%20%282015-20%29.pdf 4. AP Port Policy 2015 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Port%20Policy%202015.pdf 5. AP Single Desk Policy 2015-20 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Single%20Desk%20Policy%20%282015-20%29.pdf
Arunachal Pradesh	34	3.6 (2017-18)		
Assam	17	37.9 (2016-17)		1. Assam Industrial and Investment policy 2019 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-09/final_industrial_and_investment_policy_of_assam_2019.pdf 2. Assam Export and Logistic Policy 2019 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-11/Export%20and%20Logistic%20Policy%20of%20Assam%202019.pdf
Bihar	18	68.3 (2017-18)	113 million (includes Jharkhand)	1. Bihar Industrial Investment Promotion Act, 2016 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-01/AD-01-02-09-2016.pdf 2. Bihar Start-up Policy 2017 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Startup%20Policy%202017.pdf

State	Ease of doing business ranking (2017)	GSDP, Current price ($, billion)	FDI inflows (2000-19)	Recent policy enacted
Chhattisgarh	6	44.6 (2018-19)	1.4 billion (includes Madhya Pradesh)	1. Chhattisgarh Industrial Policy 2014-19 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Industrial%20Policy%20%282014-19%29.pdf 2. Chhattisgarh Innovation Entrepreneurship Development Policy 2015-19 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Innovation%20_%20Entrepreneurship%20Development%20Policy%20%282015-19%29.pdf 3. Chhattisgarh Logistics Park Policy 2018-23 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2018-08/LogisticsParkPolicy2018_12042018.pdf
Delhi		109 (2018-19)	10.14 billion (includes parts of Uttar Pradesh , Haryana) (2018-19)	1. Delhi Industrial Policy 2010-21 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2018-07/Delhi%2BIndustrial%2BPolicy%2B2010-2021.pdf
Goa	19	10.9 (2017-18)	985 million	1. Goa Investment Policy 2014 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Investment%20Policy%202014.pdf 2. Goa Minerals Policy 2013
Gujarat	5	173 (2016-17)	23.2 billion	1. Gujarat Industrial Policy 2015 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Industrial%20Policy%202015.pdf 2. Gujarat Industry Incentive Scheme 2016-21 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Scheme%20for%20Incentive%20to%20Industries%20%282016-21%29.pdf 3. Gujarat Single window Clearance act 2017 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-04/21-09-2017-15-19-23gujarat-single-window-act-2017-21092017.pdf

State	Ease of doing business ranking (2017)	GSDP, Current price ($, billion)	FDI inflows (2000-19)	Recent policy enacted
Haryana	3	93 (2017-18)		1. Haryana Entrepreneur Start-up 2017 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Entrepreneur%20_%20Startup%20Policy%202017.pdf 2. Haryana MSME Policy 2019 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-09/MSME%20policy.pdf 3. Haryana Logistics, Warehousing & Retail Policy 2019 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-04/Notified%20LWR%20policy.pdf
Himachal Pradesh	16	21.7 (20118-19)		1. HP Industrial Policy 2017 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-09/Investment-Promotion-Policy-and-Rules-2019.pdf 2. HP MSME Ordinance 2019
Jammu & Kashmir	22	19.71 (2017-18)		1. Industrial Development Scheme for Jammu and Kashmir 2017 (amended January 2019)
Jharkhand	4	39.6 (2017-18)	113 million (includes Bihar)	1. Jharkhand Industrial and Investment Policy 2016 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Industrial%20_%20Investment%20Promotion%20Policy%202016.pdf 2. Jharkhand Special Economic Zone Policy https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-06/1jharkhandpolicy.pdf
Karnataka	8	216 (2018-19)	40.7 billion	1. Karnataka Industrial Policy 2014-19 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Industrial%20Policy%202014-19.pdf
Kerala	21	106.6 (2017-18)		1. Kerala Industrial and Commercial Policy 2018 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-02/ipeng.pdf

State	Ease of doing business ranking (2017)	GSDP, Current price ($, billion)	FDI inflows (2000-19)	Recent policy enacted
Madhya Pradesh	7	115.7 (2018-19	1.4 billion (includes Chhattisgarh)	1. MP Industrial Promotion Policy 2014 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-02/IPP%20December%202018.pdf 2. Madhya Pradesh Special Economic Zone Policy https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-06/11mp_policy.pdf
Maharashtra	13	387.4 (2017-18)	128.6 billion	1. Maharashtra Industrial Policy 2019 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-04/Maharashtra%20Industrial%20Policy%2002.03.2019.pdf 2. Maharashtra Logistics Park Policy 2018 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-01/MaharashtrasLogisticPolicy.pdf 3. Maharashtra Single Window Policy 2016 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Single%20Window%20Policy%202016.pdf
Manipur	32	3.6 (2017-18)		1. Manipur Industrial and Investment Policy 2017 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Industrial%20%26%20Investment%20Policy%202017.pdf
Meghalaya	34	4.7 (2018-19)		1. Meghalaya Industrial and Investment Promotion Scheme 2016 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Industrial%20Policy%202016_0.pdf
Mizoram	30	2.7 (2017-18)		Mizoram Economic Development Policy 2016 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Economic%20Development%20Policy%202016-17.pdf
Nagaland	28	3.2 (2016-17)		1. Nagaland Industrial Policy 2000 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Industrial%20Policy%202000.pdf

State	Ease of doing business ranking (2017)	GSDP, Current price ($, billion)	FDI inflows (2000-19)	Recent policy enacted
Odisha	14	63.9 (2017-18)	589 million	1. Odisha SEZ Policy 2015 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/SEZ%20Policy%202015.pdf 2. Odisha Industrial Policy 2015 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-04/ODISHA%20Industrial%20policy%20amended.pdf
Punjab	20	74.1 (2018-19)		1. Punjab Industrial and Business Development Policy 2017 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-01/Industrial_and_Business_Development_Policy_2017.pdf
Rajasthan	9	132.2 (2018-19)	1.98 billion	1. Rajasthan Investment Promotion Scheme 2019 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2020-01/RAJASTHAN%20INVESTMENT%20PROMOTION%20SCHEME%20%28RIPS%29%202019.pdf 2. Rajasthan Industrial Development Policy 2019 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2020-01/Rajasthan%20Industrial%20Development%20Policy%202019.pdf 3. Rajasthan MSME Policy 2015 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/MSME%20Policy%202015.pdf
Sikkim	33	3.5 (2017-18)		
Tamil Nadu	15	229.7 (2018-19)	30.7 billion	1. Tamil Nadu Start-up & Innovation Policy 2018-23 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-01/Tamil%20Nadu%20Startup%20%26%20Innovation%20Policy%20%282018-2023%29.pdf 2. TN MSME Policy 2016-17 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/MSME%20Policy%202016-17.pdf

State	Ease of doing business ranking (2017)	GSDP, Current price ($, billion)	FDI inflows (2000-19)	Recent policy enacted
Telangana	2	121.4 (2018-19)		1. Telangana Industrial Policy Framework https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Industrial%20Policy%20Framework.pdf 2. Telangana Innovation Policy 2016 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Innovation%20Policy%202016.pdf
Tripura	25	7.4 (2017-18)		Tripura Industrial Investment Promotion Policy 2017 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-08/TIIPIS-2017_0.pdf
Uttarakhand	11	33.8 (2017-18)		1. Uttarakhand Mega Industrial & Investment Policy 2015 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Mega%20Industrial%20Policy%202015.pdf 2. Uttarakhand MSME Policy 2015 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/MSME%20Policy%202015_0.pdf
Uttar Pradesh	12	215 (2018-19)		1. UP Investment & Employment Promotion Policy 2017 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Industrial%20Investment%20%26%20Employment%20Promotion%20Policy%202017.pdf 2. UP Warehousing and Logistics Policy 2018 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-06/new%20Warehouse%20%26%20Logistic%20Policy.pdf
West Bengal	10	157 (2017-18)	5.6 billion (includes Sikkim, Andaman & Nicobar Islands)	1. WB State Support for Industries Scheme 2013 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/Investment%20and%20Industrial%20Policy%202013.pdf 2. West Bengal Special Economic Zone Policy 2019 https://invest-india-revamp-static-files.s3.ap-south-1.amazonaws.com/s3fs-public/2019-06/9west%20bengal%20policy.pdf

Table 15: Classification of Incentives and Measures in Maharashtra's, Karnataka's, and Tamil Nadu's EV policies

Broad category	Sub-category	States		
		Maharashtra	Karnataka	Tamil Nadu
I. Supply-side incentives and measures	Manufacturing-related	1. The Government of India approved the production-linked incentive (PLI) scheme for advanced chemistry cell (ACC) battery manufacturing on November 11, 2020. The Maharashtra government aims to attract at least one gigafactory for the manufacture of advanced chemistry cells batteries under this Scheme by 2023. It is expected that the Government of India will invite states (through a challenge process) to express interest in setting up of the first 4-5 gigafactories. Government of Maharashtra will endeavour to offer competitive incentives that significantly enhance/ complement the incentives offered under GoI's PLI scheme.	1. The state government will facilitate industrial land for setting up EV manufacturing zones. It will also provide 'Readymade flatted factories' equipped with requisite facilities such as power, water, and testing facilities to establish ancillaries via PPP mode.	1. Special Package for EV battery manufacturing: The government will provide a higher capital subsidy of 20% of eligible investment over 20 years in cases where manufacturing units are engaged in EV battery manufacturing. Such units will also be provided land at 20% subsidy and at 50% subsidy in Southern districts. The special package will be applicable for investments made until December 31, 2025.
	Exemptions, waivers, and concessions		1. The policy provides complete stamp duty exemption to micro, small, medium, large, mega, ultra-mega, and super mega-firms in EV and EV component manufacturing. It also offers registration charges at a concession for these enterprises. 2. Both these provisions also apply to enterprises in EV cell manufacturing, battery pack, and module manufacturing and assembly.[68]	1. EV related and charging infrastructure manufacturing industries in the state that obtain land by sale or lease will be entitled to 100% exemption on stamp duty for transactions till December 31, 2022.

[68] A media report indicates that the state government has completely exempted stamp duty and registration charges for EVs' manufacturing and selling in Karnataka (Sastry, 2020).

Broad category	Sub-category	States		
		Maharashtra	Karnataka	Tamil Nadu
	Supporting infrastructure-related	1. The policy will endeavour to fast-track and ensure time bound registration of EVs, including EV fleets owned by aggregators, last mile delivery providers, logistics players, etc.	1. The policy allows for complete reimbursement of land conversion fee for turning land from agriculture to industrial use for micro, small, medium, large, mega, ultra-mega, and super mega-firms in EV and EV component manufacturing and for enterprises in EV cell manufacturing, battery pack, and module manufacturing and assembly. 2. It will promote the setting up of areas via PPP mode where technologies pertaining to electric vehicles can be tested. 4. It provides complete exemption of tax on electricity tariff for micro, small, medium EV and EV component manufacturing enterprises for the first five years. This provision applies to MSMEs in EV cell manufacturing, battery pack, module manufacturing and assembly.	1. Creation of EV parks and vendor ecosystem: The Government recognises that major investments by EV OEMs can be attracted only if there is dedicated infrastructure and a developed vendor eco system. To create this, the Government will develop exclusive EV parks in major auto manufacturing hubs and in areas that have the potential to attract EV investments. These EV parks will enable the creation of a vendor ecosystem that will serve OEMs. Common facilities will be provided to the vendor industries for prototyping, testing, training, etc., in these EV parks. Incentives under various schemes applicable to the MSME sector and major industries will be extended to these industries, subject to their eligibility. The government will also promote logistic parks and free trade warehousing zones for inventory management. Further, plug and play manufacturing facilities will be created where vendors and OEMs can commence production with minimal capital investment in land and building. 2. EV related and charging infrastructure manufacturing industries in the state will be provided 100% exemption on electricity tax until December 31, 2025.

Broad category	Sub-category	States		
		Maharashtra	Karnataka	Tamil Nadu
				3. EV related and charging infrastructure manufacturing industries in the state that obtain land from SIPCOT, SIDCO or other governmental agencies will be provided a 15% subsidy on the cost of land, and will be provided 50% subsidy if the investment is in Southern districts. This incentive is subject to the condition that the land cost has not already been claimed as part of capital subsidy. This subsidy will be available on allotments made until December 31, 2022.
	Investment and/or financing-related		1.The policy offers investment promotion subsidies for micro, small, medium EV and EV component manufacturing enterprises; micro, small, and medium enterprises in EV battery manufacturing and assembling; and large, mega, ultra- mega, super mega EV cell manufacturing and battery pack/module manufacturing enterprises. 2. It provides for interest-free loans on net SGST for large, mega, ultra-mega, and super mega-firms in EV and EV component manufacturing and EV cell manufacturing, battery pack/module manufacturing and assembly enterprises.	1. 100% of the SGST paid on the sale of EVs manufactured, sold and registered for use in the state will be reimbursed to the manufacturing companies. The reimbursement will be given for sales by manufacturers until December 31, 2030. The reimbursement will be given up to 100% of the eligible investment.

Broad category	Sub-category	States		
		Maharashtra	Karnataka	Tamil Nadu
	Other	1. The Government of Maharashtra aims to create a 'State EV Fund'. The fund will be used to promote EV adoption, including providing incentives for EVs and EV infrastructure. The State EV Fund will aggregate the funds allocated from different instruments like green tax and green cess.	1. The policy provides a one-time capital subsidy for establishing effluent treatment plants to micro, small, medium, large, mega, ultra-mega, and super mega EV and EV component manufacturing enterprises and for enterprises in EV cell manufacturing, battery pack, module manufacturing and assembly enterprises.	1. In the case of intermediate products used in the manufacture of EV and charging infrastructure, where SGST reimbursement is not applicable, a capital subsidy of 15% will be given on eligible investments over 10 years. The capital subsidy will be payable on eligible investments made in the state until December 31, 2025. The cost of land shall not exceed 20% of the total eligible investments reckoned for the purpose of capital subsidy.
II. Demand-side incentives and measures	Purchase-related	1. The Government of Maharashtra will provide fiscal incentives to EV buyers in the state. The incentives are linked to the vehicle type – two-wheelers, three wheelers, four-wheelers and buses – and to the vehicle use case. Vehicle models approved under FAME II Scheme of the Government of India will be eligible for these incentives; state incentives will be provided in addition to FAME II incentives.	1. The policy extends tax exemption for transport and non-transport EVs.	1. 100% road tax exemption will be provided until December 31, 2022. 2. Waiver on registration charges/fees will be done as per Government of India's notification.
Post-purchase-related		-		

Broad category	Sub-category	States		
		Maharashtra	Karnataka	Tamil Nadu
	Awareness-related	1. An awareness programme will be designed and implemented by the state government in partnership with industry players and civil society organisations. The programme will aim to create awareness on EVs, their benefits and the incentive support available under state and central government policies.	-	
	Other	-	1. Apart from introducing amendments to building bye-laws to accommodate charging infrastructure in high-rise buildings, new SEZs, technology parks, and apartments, the state government will encourage apartment associations to make available a designated plug and/or charging station. 2. The policy underlines that charging/battery swapping infrastructure will be set up every 50km on highways. 3. It also states that charging stations for 2Ws will be provided at the parking stations of BMRCL, BMTC, KSRTC, and BBMP and charging infrastructure will be provided for government employees in government buildings.	

Broad category	Sub-category	States		
		Maharashtra	Karnataka	Tamil Nadu
III. Labour force-related incentives and measures	Employment-related			1. EV related and charging infrastructure manufacturing units will be provided an employment incentive in the form of reimbursement of employer's contribution to the EPF for all new jobs created until December 31, 2025. This incentive shall be paid for a period of one year and shall not exceed INR 48,000 per employee.
	Skilling-related	The policy will aim to amend existing courses and/or create new courses on electric vehicle ecosystem to be offered by the state Industrial Training Institutes. The Government of Maharashtra, in partnership with relevant/interested OEMs and service providers, will develop skill enhancement centres to deliver vocational courses on the EV ecosystem. The skill enhancement centres will aim to train ICE mechanics/workforce to repair and service EVs and charging stations.	1. The policy underlines the establishment of an EV skill development centre, introduction of electric mobility courses, and provision of financial support in the form of a stipend for in-plant training to EV manufacturers. Stipend provided as part of the policy will be at a maximum of 50 per cent of the training cost with a ceiling of INR 10,000 per month for each trainee. There is also a ceiling of 50 trainees from a particular company. The financial support will be extended to 1000 individuals annually.	1. Short term (4-6 months) finishing course after the completion of graduate engineering course will be introduced in select engineering colleges and premier technical institutes in collaboration with TNSDC. These courses will be designed in consultation with the EV Industry and will include short internship modules at partnering OEMs. The government will focus on training in light and precision assemblies, electrical powertrains and mechatronics.

Broad category	Sub-category	States		
		Maharashtra	Karnataka	Tamil Nadu
IV. Research and development-related incentives and measures		1. EV start-ups will be encouraged on priority basis under the Maharashtra State Innovation Society.	1. The policy states that 'Karnataka Electric Mobility Research and Innovation Centre', working groups, a venture capital fund for electric mobility research, and a start-up incubation centre will be put in place. Further, it states that battery innovation-centred research programmes in partnership with industry will be launched in educational institutions.	1. EV related and charging infrastructure manufacturing units will be provided an employment incentive in the form of reimbursement of employer's contribution to the EPF for all new jobs created until December 31, 2025. This incentive shall be paid for a period of one year and shall not exceed INR 48,000 per employee.
V. Charging stations and other network infrastructure-related incentives and measures		1. Setup at-least one public charging station in a 3 km x 3 km grid or a minimum of 50 charging stations per million population, whichever is higher. 2. Set up public charging stations on highways at 25 km distance (on both sides of the highways). These stations should cater to the charging requirements of long-haul passenger and freight vehicles like e-buses, electric trucks, etc.	1. Standards-related: As per the policy, the state government will devise standards for battery, charging infrastructure, and swapping in collaboration with industry as well as academia. 2. Land-related: The policy allows for identification and provision of government land parcels on a long lease basis for fast charging stations and infrastructure for battery swapping. It provides for complete reimbursement of the land conversion fee for turning land from agricultural to industrial use for EV charging/battery swapping infrastructure equipment/components manufacturing enterprises.	1. Capital subsidy: An additional capital subsidy of 20% will be offered over and above the eligibility limit for capital subsidy under the existing capital subsidy 16 scheme to MSME units that are engaged in e-vehicle component or charging infrastructure manufacture. 2. Interest subvention: for such e-vehicle component and charging infrastructure manufacturing firms falling under the medium industries category that avail loans from Tamil Nadu Industrial Investment Corporation, 6% interest subvention will be provided as against 3% under the existing scheme. These incentives will be applicable for units that are set up until December 31, 2025.

Broad category	Sub-category	States		
		Maharashtra	Karnataka	Tamil Nadu
			3. Investment and financing-related: 1. The policy provides an investment subsidy for the first 100 fast charging stations. It extends an investment promotion subsidy for micro, small, medium, large, mega, ultra, and super mega EV charging/ battery swapping infrastructure equipment/components manufacturing enterprises. It also offers interest-free loans on net SGST for large/ mega/ultra-mega and super mega enterprises in EV charging/battery swapping infrastructure equipment/ components manufacturing. 2. It extends capital subsidy for charging stations for E2W, E3W, and e-cars, and e-buses, for EV battery switching/ swapping stations for E2W and E3Ws, for EV battery switching/swapping stations for electric cars, and for EV battery switching/swapping stations for electric buses. The capital subsidy has been provided on the charging equipment/machinery with a cap on the amount and for some number of first stations in the state. 4. Electricity-related: 1. The policy states the state government will help in electricity supply provision. The state government will also look into a special tariff for EV charging stations.	3. Transition Support: To assist existing investors to transition into the EV manufacturing system, the principle of maintaining base volume production for expansion projects will not be applicable for EV manufacturers. Further, existing automobile manufacturing companies will be provided a one-me re-skilling allowance for every existing employee in the production line. 4. Institutional Mechanism: The incentives mentioned above shall constitute the 'EV Special Manufacturing Package'. It will be sanctioned to eligible industries by the government based on the recommendation of the Tamil Nadu Industrial Guidance and Export Promotion Bureau. The existing institutional mechanism for disbursal of investment related incentives to major industries and MSME sector shall be applicable to the Special Incentives for the MSME Sector: An additional capital subsidy of 20% will be offered over and above the eligibility limit for capital subsidy under the existing capital subsidy scheme to MSME e-vehicle component or charging infrastructure manufacturers.

Broad category	Sub-category	States		
		Maharashtra	Karnataka	Tamil Nadu
				Further, for such e-vehicle component and charging infrastructure manufacturing firms falling under the medium industry category that avail loans from Tamil Nadu Industrial Investment Corporation, 6% interest subvention will be provided as against 3% under the existing scheme. These incentives will be applicable for units that are set up until December 31, 2025. 2. An EV Venture Capital Fund will be created by the government to offer financial support to EV start-ups to enable them to scale up their business.

(Source: Authors' compilation from various sources)

Chapter 4

Trade and tariffs along the EV value-chain: literature review and stylized facts

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1.Background and introduction

Existing work suggests that road transport accounts for 23 per cent of total global greenhouse gas (GHG) emissions, leading to air pollution as well as global warming (ICTSD, 2017). This situation is even worse for developing countries that are also large net importers of oil, leading to a double whammy of rising air pollution and import bills. Hence, policies addressing decarbonization of road transport are assuming salience in countries across the world, including in India. In addition to reshaping the broader clean energy narrative, such decarbonization efforts have the potential to restructure the entire supply-chain of mobility services by reducing the number of privately-owned ICEs (NITI Aayog and RMI, 2017). A visible manifestation of these efforts is EVs, including not just electric passenger cars but also public or shared transport vehicles including buses, vehicles to transport goods like lorries and trucks, as well as two- and three-wheelers (including scooters and motorcycles). In terms of classification, EVs can be of three types: all-EVs (AEVs), plug-in EVs (PHEVs), or hybrid EVs (HEVs). AEVs are further divided into battery-powered EVs (BEVs) or Fuel-cell EVs (FCEVs).

However, such electrification of road transport will yield economic and environmental benefits only if it is accompanied by decarbonization of the electric grid by switching to solar or wind power. This can then help improve energy independence and security in developing countries as well as create additional employment (termed "green jobs") along the production chain, along with taking countries one step closer to addressing climate change (ICTSD, 2017; 2018). EV deployment has also been linked to the attainment of various United Nations Sustainable Development Goals (SDGs), viz. "ensuring healthy lives and promotion of wellbeing for all at all ages (Goal 3), promotion of sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all (Goal 8), the building of resilient infrastructure, promotion of sustainable industrialisation and fostering of innovation (Goal 9) and taking urgent action to combat climate change and its impacts (Goal 13)" (ICTSD, 2017). Consistent with these goals, the number of EVs has been growing rapidly – the sale of global electric cars reached 2.1 million globally in 2019 and accounted for 2.6 per cent of global car sales in the year, recording a year-on-year growth rate of 40 per cent (IEA, 2020). Additionally, the sale of electric two-wheelers was led by demand from China and India (fleet of 1.26 million in 2019), as was the demand for electric buses and trucks (IEA, 2020).

At the global level, several countries are already emphasizing the deployment of EVs to phase out sales of fossil fuels over the next few decades. These policies have also been matched by private sector innovation to reduce costs of parts and components required to assemble an electric vehicle (ICTSD, 2017). As such, the key elements of an EV use aluminium to construct the body of the vehicle, and lithium-ion battery electrode materials, cobalt, nickel, and graphite (IEA, 2020). The supply chain of these raw materials as well as finished products is heavily dependent on international trade, especially in the case of India. Hence, there is a need to identify and understand this global supply chain network and create policies to address the tariff and non-tariff barriers to such trade (ICTSD, 2017). Such analysis will also help in recognizing the impact of domestic policies on the EV industry and on the overall aim of achieving a clean energy transition. This provides India a huge opportunity to not only integrate in global value chains (GVCs) in EVs but also spur domestic investment and production in the industry.

Several studies have explored value-chains in the EV industry. For instance, Günther et al. (2015) consider EV supply chains from the perspective of their importance in the sustainability of the automotive industry over the next 20 years, focusing almost exclusively on Europe (Germany) and China. Their research suggests that greater electrification in the future can be achieved by lowering battery costs and undertaking more investments in clean technologies. Jussani et al. (2017) describe the battery value chains in China and Latin American countries and emphasize that technological advancements in battery production and large-scale production are both required to lower down EV costs. Masiero et al. (2017) attempt to understand the challenges associated with establishing GVCs in EVs in Japan and South Korea along with opportunities for Brazil's participation in such value-chains. They emphasize the absence of sufficient production scales as a key contributing factor to the high costs of EVs. Li et al. (2018) focus on battery remanufacturing as an end-of-life strategy to develop more sustainable supply chains and support a larger-scale deployment of EVs. Studies have also been undertaken on patent analysis in the automotive industry (Borgstedt et al. 2017) and in the battery R&D field (Golembiewski et al. 2015).

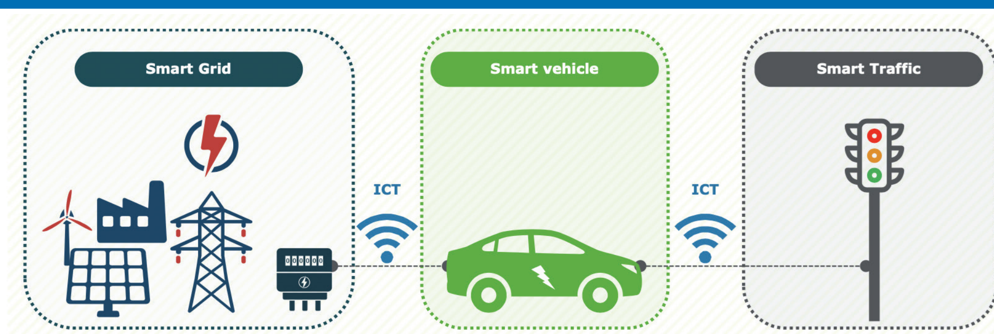
However, not much work has not been done in the Indian context, except for Raman et al. (2019) who provide a value-chain analysis for India in the field of production of EVs, charging infrastructure, services, etc. and with respect to EV policies at the sub-national level. In other work, Gupta and Choudhury (2016) undertake a study of the value chains in India's automotive industry using trade data from a UN database. Although this study does not focus on EV components and parts, it emphasizes the need for India to attract "automobile research centers for companies like Tesla, Google, Uber, nuTonomy, Volvo, and even Apple" and develop the country's electronic expertise for greater GVC participation over the next 15-year period. In a world of regional and global value chains, trade is an important part of a country's economic growth story. Hence, any analysis on trade and tariffs along the EV value-chain is important to (i) understand and appreciate the various components that are used in the EV value chain, from its manufacturing to its functioning and charging infrastructure (end-use) combined with the complementary services used along the value chain; and (ii) determine the scope of India's participation in regional/global value chains in EVs.

However, existing literature suffers from the lack of a consolidated list of goods and services that are traded along the EV value chain, partly due to the lack of appropriate HS codes to account for the technological shift in manufacturing automobiles and partly due to lack of effort. It was only in 2017 that the World Customs Organization (WCO) amended the present HS nomenclature (HS 2017) to include separate HS six-digit codes for the different types of EVs- HEVs, PHEVs and BEVs, in addition to electrically operated motorcycles (ICTSD, 2017). While this revision has eased the identification of trade patterns and barriers associated with EVs, thereby enabling targeted trade policies to increase trade as a cost-cutting measure to promote domestic manufacturing and innovation, there is not much work that has exploited this statistical development either globally or in the Indian context by providing detailed stylized facts.

Illustratively, the importance of trade policies has been stressed in supporting the further diffusion of EVs in global markets through the setting up of an "an efficient and optimal supply chain", along with benefits from the economies of scale in operations (ICTSD, 2017, 2018). This also requires countries to address both tariff and non-tariff barriers to lower EV costs. Additionally, the "issues of access to technologies by firms and countries (including the infrastructure for charging EVs) may also need to be addressed" (ICTSD, 2018). Such policies are expected to facilitate future trade agreements on environmental goods and services to support global diffusion of EVs (ICTSD, 2017). A discussion of tariff and non-tariff barriers as well as challenges in India's automobile industry have been covered in some studies, such as EXIM Bank of India (2017); the challenges include the government's minimum prices imposed on steel imports, low R&D and high taxes and duties, etc. However, existing literature on EVs in India has not studied trade and tariffs along the entire EV value-chain in detail, which is one significant contribution of the present study.

The EV value chain consists of several components. According to Singh et al. (2020), these include: (i) the battery pack (battery cells, modules, thermal management casing, battery management systems, and other mechanical and electronic parts); (ii) electric drive (e-motors, housing, harnesses, and connectors); (iii) power electronics (power distribution modules, DC converters, thermal management, charger systems, and others); and (iv) vehicle interface control module (electronic modules, connectors and harnesses, and software). The software component is covered by ICT services. Meanwhile, a recent report (GIZ and Niti Aayog, 2020) notes that ICT is not only used in EVs but has been used over the years to provide many exciting functions such as anti-lock braking system, electronic stability control, emergency brake assist, etc. However, in EVs, ICT services add another layer of innovation - ICT platforms are used to interconnect different platforms such as smart grid, smart vehicle and smart traffic, allowing them to operate seamlessly (see Figure 16 from GIZ and NITI Aayog, 2020). Other complementary and enabling services used in the manufacture and operation of EVs include engineering services, R&D services, charging services, repair and maintenance services, power and electricity services, recycling services, as well as a whole gamut of other environmental services.

Figure 16: Interconnectivity in EVs via ICT platforms



(Source: GIZ and NITI Aayog (2020))

Meanwhile, international trade in EVs suffers from two main issues. First, production facilities along the EV value chain are concentrated in a few countries such as China, Europe, USA, Japan, and South Korea; this is especially true for battery and electric light-duty vehicles manufacturing. The second issue stems from the application of high tariffs on imports of both EVs and batteries by developing countries. For example, China applies a tariff of 25 per cent on finished EVs, followed by Brazil at 35 per cent, and India at 60 per cent (ICTSD, 2018). These countries also follow the policy of tariff escalation, i.e. duties on finished products are greater than those on import of parts and components. Conversely, Japan and the US follow the most liberal regimes in this regard as the former imposes zero import duties on EVs, while the latter's import policies are liberal for electric motorcycles (ICTSD, 2018).

In contrast, in its Union Budget for 2020-2021, the Indian government recently increased custom duties on EV imports so as to increase the local content in EV manufacturing: rates were increased for imports of Completely Built Units (CBU) of Bus and Trucks from 25 per cent to 40 per cent, Semi Knocked Down (SKD) units of bus, trucks and two wheelers from 15 per cent to 2 per cent, SKD units of passenger vehicles and three wheelers from 15 per cent to 30 per cent, and for Completely Knocked Down (CKD) units of passenger vehicles, three wheelers, two wheelers, bus and trucks from 10 per cent to 15 per cent (Ministry of Finance, Government of India, 2020).

At the same time, the Indian government plans to exempt custom duties on lithium-ion cell batteries to reduce production costs for EVs. Since approximately 35 per cent of the total cost of the EV value chain comprises battery-costs[69], it becomes imperative for them to reduce the import duties on battery storage to reduce the EV costs (GIZ and NITI Aayog, 2020). The government already provides subsidies to investors to set up battery manufacturing facilities for LIBs to cater to the EV industry in India. However, the success of such incentive programmes lies in the efficient procurement of raw material required to produce these batteries (GIZ and NITI Aayog, 2020). Due to the paucity of domestic reserves of core raw materials used to produce batteries, India continues to rely on imports of lithium, cobalt, aluminium, copper, manganese, nickel, and graphite (Singh et al. 2020; Siddiqui 2020). It is dependent on countries such as China, Europe, USA, Japan, and South Korea to meet its demand.

Studies suggest that batteries are a one-time investment and the move to EVs, both by producers and consumers, will substantially reduce the dependence on imported oil used to operate petrol and diesel automobiles. "Every battery purchased will reduce oil imports for many years to come, improving future years' trade balance and reducing India's exposure to oil price shocks. Even though India's electric mobility policies are likely to necessitate significant imports of batteries, battery components, and/or raw materials as India scales up its domestic battery manufacturing capacity in the years ahead, the reduction in oil import costs is likely to more than offset the costs of these imports." (GIZ and NITI Aayog, 2020). Soman et al. 2020 also note that, "compared to

[69] GIZ and NITI Aayog (2020) note that batteries make up 30-35% of total costs, followed by chassis and body (10-15%), battery management and thermal management systems (10-12%), motor (10-12%), power electronics (8-10%) and others (HVAC, control units, etc.).

business-as-usual, in a 30 per cent EV sales (EV30) scenario, up to 12 per cent of reduction of oil consumption from passenger transport can be achieved." This strategy corroborates India's targeted goal of reducing oil imports to improve both trade balance and energy security.

Moreover, the use of additional policy measures - such as those targeting long-term preferential purchase agreements with main partner countries, enhancing capacity to recycle lithium (Singh et al. 2020) and using the multilateral forum to set rules for trade in environmental goods and auxiliary materials - could supplement existing government efforts and reduce the cost of lithium-ion batteries by 25–30 per cent, leading to an overall decline in the prices of EVs (ACMA 2018) as well spur growth in domestic manufacturing that will complement India's overall aim to become a leading global hub in EV production.

At present, with the small volume of sales and lack of domestic manufacturing, most EV-exclusive components are entirely or partially imported by India (Gupta and Choudhary, 2016). Anecdotal evidence, supported by stylized facts in the following section, shows that China is the largest supplier of battery technology as well as components of EVs for India; and this import dependence is likely to rise in the coming years due to unavailability of a substantial hardware manufacturing base in the country.[70] This lack of a component ecosystem has limited the growth of a domestic EV industry in India. Moreover, out of the five largest battery manufacturers in the world, two are Chinese and the other three produce in Chinese territory or in association with Chinese affiliates; thus, it is improbable that the Indian EV market can flourish without Chinese battery technology.[71,72] In fact, from a climate change perspective, it may be more optimal for India to move from being an oil-dependent economy to being a cell-dependent one (Roychowdhury et al. 2021). Any domestic production of batteries will require access to mineral and chemical supply chains as well as large, concerted investment efforts by the government and the private sector. A similar case can be made for electric motors and motor controllers.[73]

Hence, the government is attempting to spur growth in the industry by promoting demand and consumption of hybrid-fuel cars and electric cars. For instance, the government has started the NEMM Plan that "encourages reliable, affordable and efficient EVs that meet consumer performance and price expectations", with an ambitious target to achieve sales of 6-7 million EVs from the year 2020 onwards (Department of Heavy Industry, 2012). In addition to this, the Indian government has also been active in promoting the EV industry and facilitating its greater diffusion on Indian roads. Illustratively, Phase I of the FAME scheme was launched in 2015 to fast track the goals laid out under NEMMP. The scheme targeted spending INR 14,000 crores as incentives to manufacturers and consumers for R&D on EVs and for their purchases, respectively; and

[70] See: https://electricvehicles.in/india-depends-on-china-imports-for-ev-components/

[71] See: https://auto.economictimes.indiatimes.com/news/auto-components/india-short-on-ev-parts-makers-to-rely-on-chinese-imports/68457597

[72] See: https://www.financialexpress.com/auto/electric-vehicles/boycotting-chinese-automotive-imports-is-like-destroying-your-house-to-kill-the-rat-magenta-power/1988160/

[73] See: https://www.financialexpress.com/auto/electric-vehicles/boycotting-chinese-automotive-imports-is-like-destroying-your-house-to-kill-the-rat-magenta-power/1988160/

as investment on developing the necessary charging infrastructure (Innovation Norway, 2018). FAME II was launched in April 2019 and entails budgetary support of INR 10,000 Crores to promote the sale and manufacture of EVs. This new phase targets "electrification of public and shared transportation and aims to support through demand incentives approx. 7000 e-Buses, 5 lakh e-3 Wheelers, 55000 e-4 Wheeler Passenger Cars and 10 lakh e-2 Wheelers." (PIB, Government of India, 2020) besides seeking to support the charging infrastructural set up. It also provides subsidies to incentivize manufacturing of EVs; however, companies need to increase local sourcing of components to avail these benefits (Brar et al. 2021).

The government has also approved the implementation of a production-linked incentive (PLI) scheme to promote production of advanced chemistry cell-battery storage that can be used in EVs, in a bid to reduce battery import dependence, increase local value addition (PIB, Government of India, 2021) and help achieve scale in cell manufacturing (Roychowdhury et al. 2021). In an attempt to support development of charging infrastructure to support EVs, a recent notification by the Ministry of Power (Ministry of Power, 2018) now considers charging as a service and not distribution of electricity, thus delicensing its provision. It has also laid down specific guidelines and standards for charging infrastructure for EVs under the Central Nodal Agency of the Bureau of Energy Efficiency (BEE). This has the potential to invite public as well as private participation in developing charging infrastructure. The government has also introduced various financial incentives to reduce the burden of an initial large investment (GIZ and NITI Aayog, 2020).

Nevertheless, any move to reduce dependence on imports of parts and components required for domestic manufacturing of EVs by raising the associated tariffs is likely to be counterproductive. Although the reduction of imports might spur domestic production, it will drive up total costs and adversely impact local demand for EVs due to a fall in its affordability. Evidence suggests that 4-wheel passengers EVs already comprise less than 1 per cent of total EVs deployed in the Indian market; thus government-mandated local requirement needs will further depress consumer demand (Brar et al. 2021). While high import tariffs could attract tariff jumping FDI in the sector in theory, in practice India remains a difficult place to do business (BEBA, U.S. Department of State, 2020). In an optimistic scenario, any medium-term demand growth in the 4-wheel segment will be led by intra-city taxi and ride-sharing service providers due to high upfront costs, low range and an underdeveloped charging infrastructure that will deter private consumption of e-4 wheelers (Brar et al. 2021). Thus, the low penetration of EVs in the Indian market, coupled with cost-escalating policies to protect an infant EV industry is likely to thwart efforts to reduce dependence on ICE vehicles and control pollution levels in tier-1 Indian cities. In contrast, the case for e-2-wheelers is different due to their small battery packs that can be charged at home; hence, any immediate efforts towards electrification of Indian road transport will be driven by e-2-wheelers (Roychowdhury et al. 2021).

Against this background, we present detailed stylized facts on trade and tariffs of goods that form a part of the entire EV value-chain, using data from UN COMTRADE and UNCTAD TRAINS, respectively. The HS codes for these goods, reported in Table 16, have been compiled from existing literature (OECD, 2015; ICTSD, 2017; WCO, 2019; Ministry of Finance, 2019; Scott and Ireland, 2020), additional sources[74] and based on the authors' own assessment of the parts and components likely involved in different segments of the EV value-chain. This results in a far more comprehensive analysis of trade and tariff patterns relative to extant work. In another significant departure from existing literature, we also examine regulatory barriers to trade in those services that perform complementary and enabling functions in the EV value-chain, using data from the OECD's Services Trade Restrictiveness Index (STRI). The services include ICT, road transport, professional (engineering and R&D), insurance, financial, maintenance and repair, utilities (power and electricity), recycling and other environmental services.

Table 16: Full list of HS codes for trade in EV goods

Electric Vehicle Value chain	HS codes	Source
Battery component (raw material)	253090, 283691, 282520, 280519, 282739, 282690, 250410, 271312, 380110, 854519, 260500, 282200, 810520, 260400, 750210, 750220, 750400	Scott, S. and Ireland, R. (2020)
Battery storage	850760, 85068090, 8532, 850710, 850720, 850730, 850750, 850760, 850780, 850790	Scott, S. and Ireland, R. (2020), OECD (2015), Ministry of Finance, Government of India. (2019)
Charging infrastructure	8425, 842511, 842542, 842519, 84254900, 85044030, 85437099, 85049090, 85044029, 85044090, 85042100	Authors' own analysis
Electric components - manufacturing of the automobile	8501, 85011011, 8539, 85392120, 8512, 851220, 851230, 851240, 851290, 8531, 853180	Authors' own analysis
Manufacturing of the automobile/vehicle	8708, 87089900, 87082900, 87084000, 8703, 87039010, 8702, 870220, 870230, 870240, 8703, 870340, 870350, 870360, 870370, 870380, 8704, 87049012, 8709, 870911, 87091100, 871160, 8714, 87141090, 87149990	ICTSD (2017), World Customs Organization (2019), and Authors' own analysis

(Source: Authors' compilation)

2. Stylized facts on EV goods

2.1 Global trade patterns in EV goods

Table 17 reports data on global trade in goods that form a part of the EV value chain identified in Table 16, in 2010 (an early year for the sake of comparison) and 2018-19. Total exports (imports) of these goods increased from USD 1.6 (1.5) trillion in 2010 to USD 2.7 (2.6) trillion on average over 2018-19, registering a 73.8 per cent (80.4 per cent) increase in value over time. As a share of total merchandise trade, the importance of EV goods increased from

[74] www.connect2.india.com, www.eximguru.com, www.hs.e-to-china.com, www.zauba.com, www.seair.co.in, www.exportgenius.in, www.dripcapital.com, www.infodriveindia.com

10.2 per cent, 9.4 per cent in 2010 to 14 per cent, 13.4 per cent in 2018-19 for exports and imports, respectively. Manufacturing of vehicles was by far the largest component of the EV value-chain, accounting for 81.3 per cent of total exports and 79 per cent of total imports of EVGs during 2018-19. However, the fastest growing component of the EV value-chain has been battery storage; it reported a 133.7 per cent rise in exports and a 118.4 per cent increase in imports over 2010-2018/19.

Table 17: Global trade in EV goods over time (value in USD billion)

EV value chain	Exports			Imports		
	2010	2018-19	Growth (%)	2010	2018-19	Growth (%)
Bat_comp	28.0	36.0	28.5	35.3	50.7	43.6
Bat_stor	48.6	113.4	133.7	56.5	123.5	118.4
Chg_infra	84.5	142.7	68.8	91.2	150.4	64.9
Elec_comp	133.4	213.1	59.8	135.8	228.9	68.6
Mfg_veh	1263.0	2202.0	74.3	1139.7	2077.0	82.2
Total EV goods	1557.5	2707.2	73.8	1458.5	2630.4	80.4
Total goods	15304	19282.55	26.0	15438.1	19560.25	26.7
Share of EV (%)	10.2	14.0		9.4	13.4	

(Source: UN Comtrade; own calculations)

Table 18 reports data on the top 21 exporters and importers of EV goods for the same time period. Germany, Japan, USA, and China were the top four exporters of EV goods in 2010 and during 2018-19, accounting for over 40 per cent of global exports in EV goods. Similarly, the distribution of the top global importers of EV goods was also relatively unchanged over time with USA, Germany, China, UK, Canada, and France being amongst the top six importers, with Canada and France swapping positions during 2018-19. The EV goods global trade distribution is also fairly concentrated with the top 10 (20) traders accounting for over 60 per cent (70 per cent) of global trade in EV goods. Most of the top global EV goods traders are OECD countries, with only China, Hong Kong, Thailand, UAE, Russia, and India being outside that group. Brazil was amongst the top 20 importers in 2010 but dropped out of that list during 2018-19.

Notably, India does not figure amongst the top 20 exporters or importers of EV goods in the world, which points to ample scope for improvement along both dimensions, especially in a world integrated in regional and global value chains. India was the 23rd largest exporter of EV goods in 2010 with an export value of USD 10.8 billion; it's relative ranking in exporting EV goods improved marginally to the 21st position during 2018-19 with an average export value of USD 21.3 billion, registering a near 100 per cent increase over time. India seems to be a relatively less important player in the global distribution of EV goods imports. It was ranked 31st in 2010 with an import value of USD 10 billion though this value nearly doubled to USD 19.6 billion on average over 2018-19 and India's ranking improved to the 25th position.

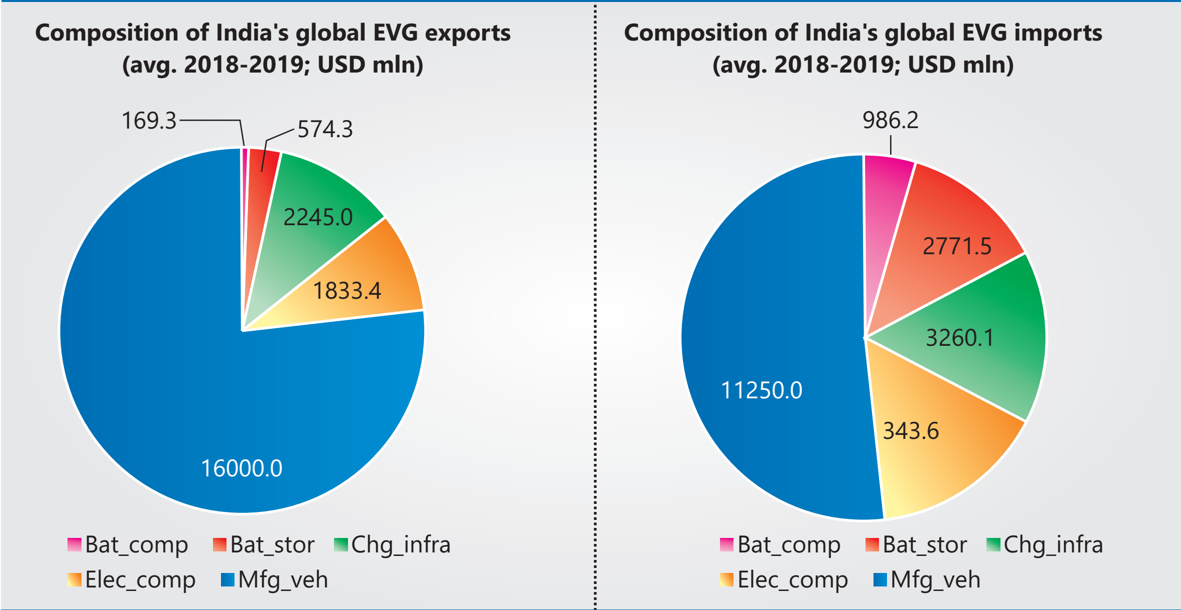
Table 18: Top exporters and importers of EV goods over time (value in USD billion)											
Exports						Imports					
Country	2010	Share (%)	Country	2018-19	Share (%)	Country	2010	Share (%)	Country	2018-19	Share (%)
Germany	238.0	15.3	Germany	463.5	17.1	USA	240.0	16.5	USA	575.0	21.9
Japan	188.0	12.1	Japan	305.5	11.3	Germany	110.0	7.5	Germany	277.0	10.5
USA	116.0	7.4	USA	234.0	8.6	China	95.7	6.6	China	150.0	5.7
China	88.5	5.7	China	169.0	6.2	UK	71.9	4.9	UK	134.5	5.1
South Korea	80.7	5.2	Spain	97.5	3.6	Canada	69.5	4.8	France	91.5	3.5
Mexico	62.6	4.0	South Korea	96.5	3.6	France	67.2	4.6	Canada	90.0	3.4
France	62.2	4.0	UK	88.0	3.3	Italy	50.6	3.5	Spain	90.0	3.4
Canada	56.5	3.6	Canada	69.5	2.6	Belgium	47.1	3.2	Belgium	70.0	2.7
UK	43.5	2.8	France	69.5	2.6	Mexico	40.2	2.8	Italy	60.5	2.3
Italy	43.2	2.8	Belgium	62.0	2.3	Australia	28.5	2.0	Japan	59.5	2.3
Belgium	40.6	2.6	Czech Republic	57.0	2.1	Japan	27.1	1.9	Netherlands	40.1	1.5
Czech Republic	31.7	2.0	Italy	53.5	2.0	Russia	24.8	1.7	Hong Kong	35.9	1.4
Poland	26.7	1.7	Poland	40.1	1.5	Netherlands	24.4	1.7	Poland	32.9	1.2
Thailand	25.5	1.6	Thailand	38.2	1.4	Brazil	24.0	1.6	Australia	32.5	1.2
Netherlands	16.8	1.1	Slovak Republic	36.3	1.3	Hong Kong	23.1	1.6	South Korea	32.1	1.2
Austria	16.7	1.1	Hong Kong	34.9	1.3	South Korea	21.2	1.5	Czech Republic	29.5	1.1
Sweden	16.6	1.1	Turkey	31.2	1.2	Sweden	20.0	1.4	Switzerland	29.3	1.1
Turkey	15.7	1.0	Hungary	28.8	1.1	Poland	18.9	1.3	Russia	29.2	1.1
Slovak Republic	14.9	1.0	Netherlands	28.7	1.1	Turkey	18.9	1.3	Austria	28.7	1.1
Brazil	13.5	0.9	Austria	26.0	1.0	Austria	18.5	1.3	Slovak Republic	26.2	1.0
Hungary	11.8	0.8	India	21.3	0.8	Saudi Arabia	17.2	1.2	UAE	24.3	0.9
Top 21	**1209.7**	**77.7**	**Top 21**	**2050.8**	**75.8**	**Top 21**	**1058.8**	**72.6**	**Top 21**	**1938.5**	**73.7**
Total EV	**1557.5**	**100**	**Total EV**	**2707.2**	**100**	**Total EV**	**1458.5**	**100**	**Total EV**	**2630.4**	**100**

(Source: UN Comtrade; own calculations)

2.2 India's trade in EV goods

Figure 17 shows the composition of India's EV goods trade during 2018-19. Much like global EV goods trade, India's EV goods trade is also dominated by manufacturing of vehicles, which accounted for 76.8 per cent and 51.8 per cent of India's EV goods exports and imports during 2018-19, respectively. In contrast, charging infrastructure and electronic components (as well as battery storage on the import side) are far more important in India's EV goods trade flows relative to the composition of global EV goods trade. Meanwhile, battery components comprised less than 1 per cent of India's EV goods exports and less than 5 per cent of its EV goods imports during 2018-19.

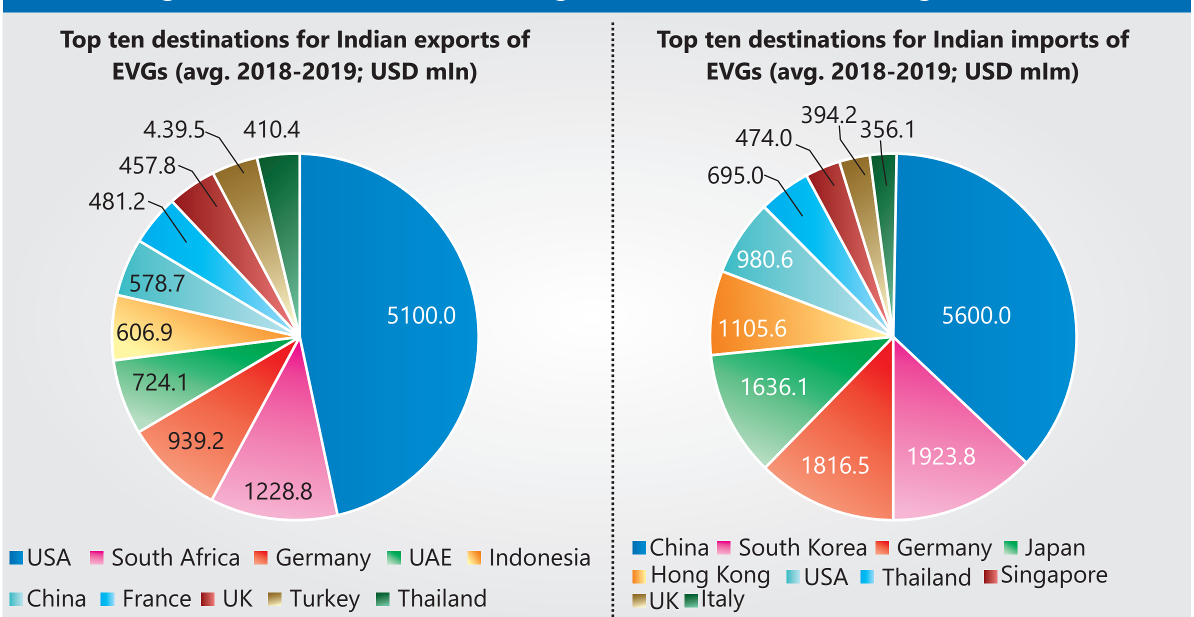
Figure 17: Composition of India's EV goods trade (USD million, avg. 2018-19)



(Source: UN COMTRADE; own calculations)

Figure 18 shows the top ten destinations and sources for India's exports and imports of EV goods, respectively, during 2018-19. The US was by far the largest destination for Indian EV goods exports, accounting for 23.9 per cent of India's total EV goods exports during 2018-19. Meanwhile, China was the largest source by far of India's EV goods imports during 2018-19, accounting for 28.6 per cent of India's total EV goods imports. India's EV goods import distribution was far more concentrated with the top ten source countries accounting for 76.4 per cent of India's total EV goods imports; for exports, the corresponding share was only 51.5 per cent. Notably, India's top ten EV goods trade partners include both OECD and non-OECD countries.

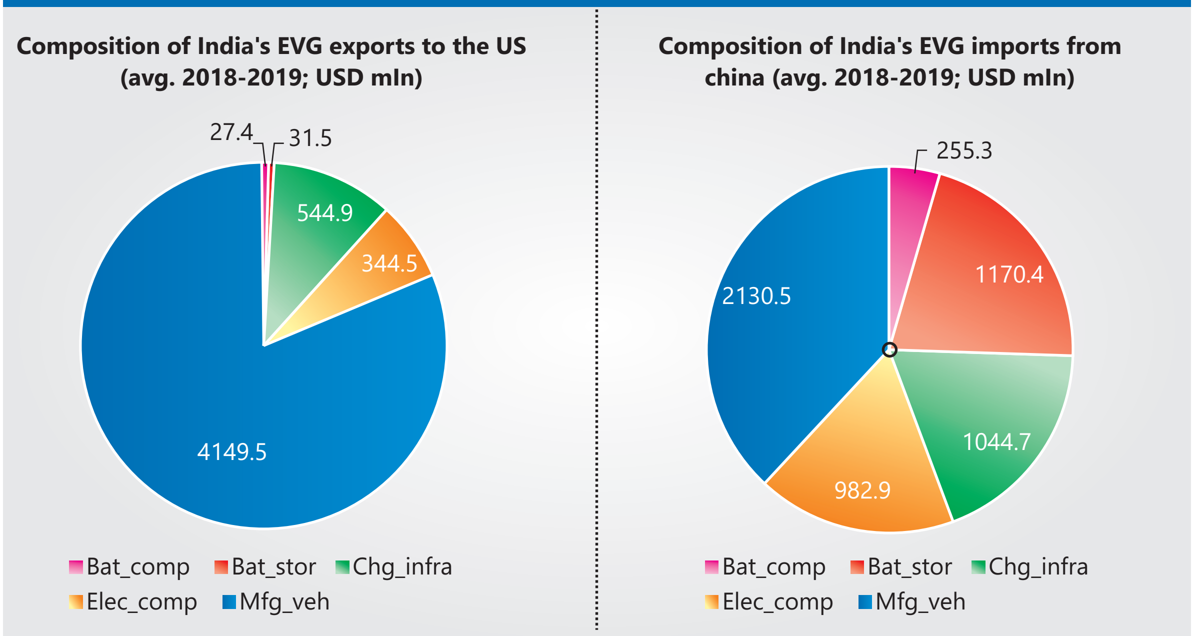
Figure 18: Direction of India's EV goods trade (USD million, avg. 2018-19)



(Source: UN COMTRADE; own calculations)

Figure 19 shows the composition of India's EV goods exports to the US and imports from China[75]. While manufacturing of vehicles also dominates India's EV goods exports to the US, charging infrastructure and electric components are also important with shares of 10.7 per cent and 6.8 per cent, respectively. In contrast, the composition of India's EV goods imports from China is more diversified with manufacturing of vehicles contributing nearly two-fifths and all but battery components accounting for roughly a fifth each of India's total EV goods imports from China.

Figure 19: Composition of India's EV goods trade with its most important partner



(Source: UN COMTRADE; own calculations)

India's exports and imports of EV goods are not just important from supply and demand perspectives. In fact, there are several EV goods[76] where India exhibited a potential for value-chain integration during 2018-19 as observed from the relatively high values of the Grubel-Lloyd index (GLI) of intra-industry trade (IIT)[77], indicating that India was intensive in both exporting and importing disaggregated products within the same HS code. This was particularly true of HS codes 870350 (motor vehicles for transport of less than 10 people with both diesel engine and electric motor), 850710 (electric accumulators) and 282739 (refined lithium), where the value of the GLI exceeds 0.95.

Table 19: HS codes exhibiting potential for value-chain integration (2018-19)

HS code	Exp_value (USD '000s)	Imp_value (USD '000s)	GLI
870350	197.0	187.5	0.975
850710	101472.2	107228.3	0.972
282739	48468.7	53563.7	0.950

[76] The GLI on all HS codes classified as EV goods is reported in Annex table 22.

[77] The GLI is calculated as 1 – (abs(Xi-Mi)/(Xi+Mi)) where X = country i's exports; M = country i's imports.

HS code	Exp_value (USD '000s)	Imp_value (USD '000s)	GLI
380110	43265.3	54903.5	0.881
8709	26463.1	34201.7	0.872
870390	29102.9	21805.9	0.857
870340	92095.0	62911.9	0.812
850720	163050.7	259990.2	0.771
850730	17432.0	31005.9	0.720
8708	6050000.0	11100000.0	0.706
8704	969038.5	513830.8	0.693
870899	1390783.0	2879946.0	0.651
851230	24515.9	53999.8	0.624
850440	1526097.0	3429840.0	0.616
871499	26455.9	61786.4	0.600
851220	206452.4	489133.2	0.594
850110	237206.8	593037.7	0.571

(Source: UN Comtrade; own calculations)

From a policy perspective, it would thus be prudent to liberalize tariffs and non-tariff barriers (NTBs) in India on the HS codes listed in Table 19, in particular. Cost reductions emanating from the liberalization of imported EV goods intermediates would be especially beneficial to the domestic EV goods industry as well as EV goods-exporting firms. This also assumes salience given that India does not seem to be very competitive in exporting EVGs. India exhibited a revealed comparative advantage (RCA) in exporting EV goods in only 9 of the 65 constituent HS codes; in contrast, the US and Germany showed a revealed comparative advantage in over 50 HS codes (see Table 20 which shows values of the computed standardized RCA or SRCA index[78]). Moreover, even in products where India displayed a comparative advantage in exporting, the value of the SRCA was higher in the other countries, suggesting that they may still be more competitive than India. Interestingly, China seemed to be competitive in exporting only 5 of the 62 EV goods HS codes that it exported during 2018-19 even though it is the fourth largest exporter of EV goods. Meanwhile, India had the largest comparative advantage in exporting HS code 850421 (testing charges for machine semi-finished 75 mva, generator transformer along with accessories).

[78] SRCA = (RCA-1)/(RCA+1). The value of the SRCA ranges from -1 to +1. Positive values indicate a revealed comparative advantage in exporting. RCA = (Xik/Xik)/ (Xwk/Xwk) where X = exports, i = country i, k = product and w = world. Thus, the RCA calculates the share of a product in a country's total exports relative to the share of that product in global exports. An RCA value exceeding one denotes comparative advantage in exporting. The SRCA simply normalizes the values of the RCA between -1 and +1, rendering cross-product and cross-country comparisons easier and more meaningful compared to the RCA.

Table 20: SRCA indices for India and the top four global EV goods exporters (2018-19)					
HS code	**India**	**Germany**	**Japan**	**USA**	**China**
8425	-0.32	0.20	-0.05	0.77	-0.90
8501	-0.24	0.40	-0.21	0.66	-0.85
8512	-0.43	0.66	-0.31	0.66	-0.82
8531	-0.64	0.65	-0.28	0.78	-0.93
8532	-0.46	0.48	-0.46	0.56	0.10
8539	-0.51	0.45	0.07	0.69	-0.91
8702	-0.61	0.62	-0.90	0.94	-0.99
8703	-0.50	0.59	-0.46	0.85	-0.88
8704	-0.49	0.40	-0.76	0.96	-0.99
8708	-0.14	0.35	-0.41	0.76	-0.83
8709	-0.05	-0.39	0.11	0.86	-0.97
8714	-0.14	0.36	-0.42	0.46	-0.87
250410	-0.78	0.80	0.61	-0.34	-0.52
253090	-0.56	0.34	0.29	0.00	0.54
260400	-1.00	0.88	0.97	-1.00	1.00
260500	-1.00	-0.16	-1.00		0.99
271312	-0.33	0.15	-0.43	0.40	-0.05
280519	-0.87	0.97	-0.61	0.17	-0.89
282200	-0.95	0.91	0.38	0.09	-0.68
282520	-0.94	-1.00		-0.92	-0.76
282690	-0.75	-0.01	0.97	-0.27	-0.85
282739	0.52	-0.44	0.24	0.09	-0.78
283691	-0.98	0.92	0.92	-0.51	-0.21
380110	0.01	-0.16	0.54	0.27	-0.75
750210	-0.99	0.99	0.22	0.33	-0.36
750220	-0.86	0.91	-0.44	0.50	-0.85
750400	-0.94	0.91	0.67	-0.10	-0.19
810520	-1.00	0.99	0.76	-0.09	0.14
850110	-0.16	0.28	-0.02	0.51	-0.76
850421	0.61	-0.73	-0.21	0.87	-1.00
850440	0.05	-0.04	0.01	0.62	-0.77
850490	0.29	-0.26	-0.22	0.66	-0.73
850680	-0.92	0.87	-0.47	0.74	-0.98
850710	-0.33	0.29	-0.04	0.67	-0.96

HS code	India	Germany	Japan	USA	China
850720	0.03	0.03	-0.46	0.81	-0.94
850730	0.01	-0.13	-0.15	0.73	-0.83
850750	-0.93	0.94	-0.28	0.69	-0.82
850760	-0.97	0.99	-0.22	0.45	-0.69
850780	-0.68	0.41	-0.46	0.84	-0.98
850790	-0.80	0.80	-0.38	0.88	-0.87
851220	-0.37	0.67	-0.41	0.68	-0.82
851230	-0.09	0.22	0.09	0.41	-0.71
851240	-0.56	0.57	-0.15	0.64	-0.81
851290	-0.64	0.70	-0.06	0.66	-0.84
853180	-0.56	0.53	0.00	0.73	-0.95
853921	0.02	0.06	-0.34	0.74	-0.84
854370	-0.78	0.74	0.42	0.47	-0.80
854519	-0.66	0.40	-0.37	0.70	-0.85
870220	-0.94	-0.92	-0.47	1.00	
870230	-0.86	-0.36	-0.95	0.99	
870240	-1.00	1.00	-0.73	0.73	-0.99
870340	-0.78	0.68	-0.67	0.96	-0.86
870350	-0.99	1.00	-1.00	0.79	-0.71
870360	-0.99	1.00	-0.75	0.85	-0.88
870370	-1.00	1.00	-1.00	0.99	
870380	-1.00	1.00	-0.58	0.56	-0.50
870390	0.09	-0.96	0.25	0.96	-1.00
870490	-0.98	0.99	-0.58	0.50	-0.98
870829	-0.57	0.75	-0.57	0.82	-0.86
870840	-0.26	0.44	-0.50	0.77	-0.55
870899	-0.11	0.16	-0.48	0.85	-0.91
870911	-0.73	0.70	-0.32	0.85	-0.89
871160	-0.94	0.98	-0.65	0.66	-1.00
871410	0.24	-0.14	-0.04	0.33	-0.95
871499	-0.63	0.78	-0.56	0.37	-0.65
n(SRCA>0)	9	51	17	56	5
Total HS codes	65	65	64	64	62
Share in total (%)	13.8	78.5	26.6	87.5	8.1

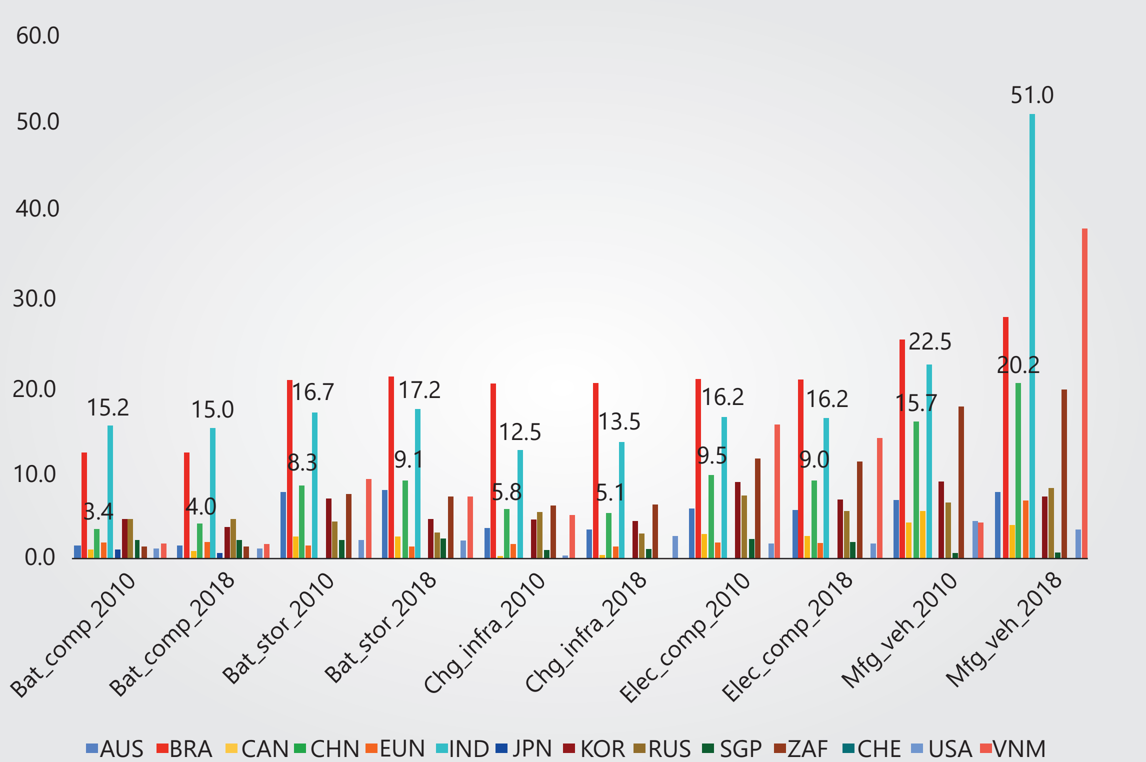
(Source: UN Comtrade; own calculations)

3. Barriers to trade in EV goods

India imposes amongst the highest tariffs on EV goods. Figure 20 shows the simple average applied tariffs on constituent EV goods in 2010 and 2018 for 14 major importers. India imposed the largest tariffs on battery storage and manufacturing of vehicles of all sample countries in 2018 and was only behind Brazil in the remaining EV goods clusters. Moreover, for manufacturing of vehicles, India's simple average tariffs more than doubled from 22.5 per cent in 2010 to 51 per cent in 2018, making it the most restrictive country in the sample by far along this dimension. India also increased tariffs on both battery storage and battery components in 2018 relative to 2010, which again provides evidence of India's import-substitution policies followed in EV goods of late. Notably, India's tariffs are much higher than those in China across EV goods clusters, though China too seems to have become more protectionist over time.

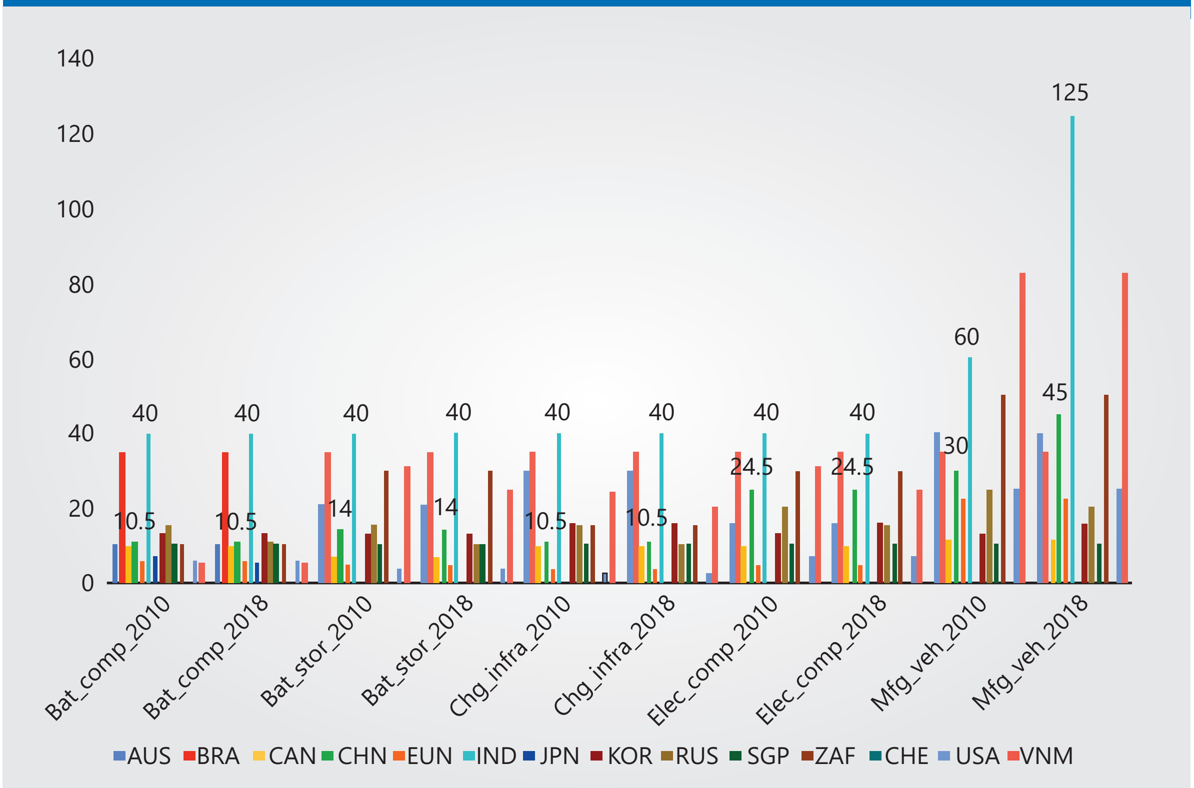
India also has the highest maximum tariff rate on constituent HS codes across EV goods clusters amongst all sample countries (see Figure 21). Moreover, India's maximum tariff rate on manufacturing of vehicles more than doubled from 60 per cent in 2010 to 125 per cent in 2018; Chinese highest applied tariff rates by comparison were 30 per cent and 45 per cent, respectively. In all other EV goods clusters, India's maximum tariff rate was 40 per cent, again far in excess of those imposed by China.

Figure 20: Simple average applied tariffs on EV goods in 2010 and 2018



(Source: UNCTAD TRAINS; own calculations)

Figure 21: Maximum applied tariff rates on EV goods in 2010 and 2018



References

ACMA. 2018. "Study on xEV Market and Opportunities for xEV Component Suppliers." New Delhi: Roland Berger

Borgstedt, P., Neyer, B., & Schewe, G. (2017). Paving the Road to Electric Vehicles – A Patent Analysis of the Automotive Supply Industry. Journal of Cleaner Production, 167(20 November 2017), 75-87.

Brar, L., Burgoyne, B., Eriksson, L., Likhari, R., Skoufa, T., and Williams, L. (2021). The Indian Electric Vehicle Opportunity: Market Entry Toolkit. Catapult Network, United Kingdom

Bureau of Economic and Business Affair, U.S. Department of State. (2020). 2020 Investment Climate Statements: India.

Department of Heavy Industry, Government of India (2012). National Electric Mobility Mission Plan 2020.

EXIM Bank of India. (2017). The Indian Automotive Industry: An International Trade Perspective. Working Paper No. 59. India: Export-Import Bank of India.

GIZ & Niti Aayog (2020). Status quo analysis of various segments of electric mobility and low carbon passenger road transport in India.

Golembiewski, B., Stein, N. V., Sick, N., & Wiemhofer, H. (2015). Identifying trends in battery technologies with regard to electric mobility: evidence from patenting activities along and across the battery value chain. Journal of Cleaner Production, 87(15 January 2015), 800-810.

Günther, H.-O., Kannegiesser, M., & Autenrieb, N. (2015). The role of electric vehicles for supply chain sustainability in the automotive industry. Journal of Cleaner Production, 90(1 March 2015), 220-233.

Gupta, A. and Choudhary, S. (2016). Global Value Chains: Indian Automotive Industry. https://tejas.iimb.ac.in/articles/Global_Value_Chain_Nov2016.pdf

ICTSD. (2017). International Trade Governance and Sustainable Transport: The expansion of electric vehicles. Geneva: International Center for Trade and Sustainable Development (ICTSD) http://www.indiaenvironmentportal.org.in/files/file/climate_and_energy_-_international_trade_governance_and_sustainable_transport.pdf

ICTSD. (2018). The role of trade policy in enabling the global diffusion of electric vehicles. Information Note. Geneva: International Center for Trade and Sustainable Development (ICTSD). https://ictsd.iisd.org/sites/default/files/research/climate_and_energy_-_the_role_of_trade_policy_in_enabling_the_global_diffusion_of_electric_vehicles_final.pdf

IEA. (2020). Global EV Outlook 2020. https://iea.blob.core.windows.net/assets/af46e012-18c2-44d6-becd-bad21fa844fd/Global_EV_Outlook_2020.pdf

Innovation Norway. (2018). India EV Story: Emerging Opportunities. Report. India: Innovation Norway.

Jussani, A. C., Wright, J. T. C., & Ibusuki, U. (2017). Battery global value chain and its technological challenges for electric vehicle mobility. RAI Revista de Administração e Inovação, 14(4), 333-338.

Li, L., Dababneh, F., & Zhao, J. (2018). Cost-effective supply chain for electric vehicle battery remanufacturing. Applied Energy, 226(15 September 2018), 277-286.

Masiero, G., Ogasavarab, M. H., Jussani, A. C., & Risso, M. L. (2017). The global value chain of electric vehicles: A review of the Japanese, South Korean and Brazilian cases. Renewable and Sustainable Energy Reviews, 80(2017), 290–296.

Ministry of Finance, Government of India. (2019). Notification No. 03/2019- Customs.

Ministry of Finance, Government of India. (2020). Budget Speech - Union Budget 2020-2021. Retrieved from https://www.indiabudget.gov.in/doc/Budget_Speech.pdf

Ministry of Power, Government of India. (2018). Notification No. 23/08/2018- R&R.

NITI Aayog and Rocky Mountain Institute. (2017). India Leaps Ahead: Transformative mobility solutions for all. https://www.rmi.org/insights/reports/transformative_mobility_solutions_india

OECD (2015). Domestic Incentive measures for environmental goods with possible trade implications: Electric vehicles and batteries. Joint Working paper on Trade and Environment. COM/TAD/ENV/JWPTE(2013)27/FINAL.

PIB, Government of India. (2020). Promotion of Electric Vehicles. Press Release. Retrieved from https://pib.gov.in/newsite/PrintRelease.aspx?relid=199759

PIB, Government of India. (2021). Cabinet approve Production Linked Incentive scheme “National Programme on Advanced Chemistry Cell Battery Storage”. https://www.pib.gov.in/PressReleasePage.aspx?PRID=1717938

Raman, A., Sahay, R., & Samantray, S. (2019). EV-Ready India Part 1: Value Chain Analysis of State EV Policies. White Paper. Geneva, Switzerland: World Economic Forum.

Roychowdhury, A., Das, S., Mohanty, M. and Srivastava, S. (2021). From Petro to Electro: How prepared is India to ride the energy transition wave? Retrieved from

https://www.downtoearth.org.in/news/energy/from-petro-to-electro-how-prepared-is-india-to-ride-the-energy-transition-wave--76452

Scott, S. and Ireland, R. (2020). Lithium-ion battery materials for electric vehicles and their global value chain. USITC, Office of Industries Working Paper ID-068

Siddiqui, Huma. 2020. “India seeks FTAs with countries that can support ‘Atmanirbhar’ journey in EVs.” Financial Express, August 01.

Singh, Vaibhav, Kanika Chawla, and Saloni Jain. 2020. Financing India’s Transition to Electric Vehicles: A USD 206 Billion Market Opportunity (FY21 - FY30). New Delhi: Council on Energy, Environment and Water.

Soman, A., Kaur, H., Jain, H. and Ganesan, K. (2020). India’s Electric Vehicle Transition: Can electric mobility support India’s sustainable economic recovery post COVID-19? CEEW Report Nov 2020. https://www.ceew.in/sites/default/files/CEEW-India’s-EV-Transition-Post-COVID-19-22Dec20.pdf

World Customs Organization (2019). Classification Decisions – HS Committee 64th Session. http://www.wcoomd.org/-/media/wco/public/global/pdf/topics/nomenclature/instruments-and-tools/classification-rulings/clhs64en.pdf?db=web

Annexure

Table 21: India's EV goods trade with its most important partner by HS code

India's exports to the US		India's imports from China	
Average 2018-2019			
HS code	Value (USD '000s)	HS code	Value (USD '000s)
8425	24807.6	8425	54088.8
8501	203499.3	8501	372251.6
8512	20659.4	8512	131003.5
8531	35059.4	8531	64376.1
8532	24216.7	8532	226401.8
8539	14154.9	8539	165282.5
8703	1559754.5	8702	713.2
8704	641.4	8703	73786.6
8708	1819231.0	8704	8764.3
8709	22060.2	8708	762113.0
8714	9267.4	8709	1486.9
250410	1250.1	8714	492458.2
253090	631.6	250410	16857.8
271312	1134.8	253090	7607.3
280519	6.2	271312	119976.2
282200	41.8	280519	9589.0
282690	293.2	282200	626.1
282739	12048.8	282520	11352.4
283691	54.0	282690	5483.0
380110	10437.5	282739	6101.1
750220	60.3	283691	1164.7
750400	538.8	380110	12168.4
810520	1.9	750210	46737.4
850110	47939.4	750400	34.3
850421	388.2	810520	8047.4
850440	388152.6	850110	84442.4

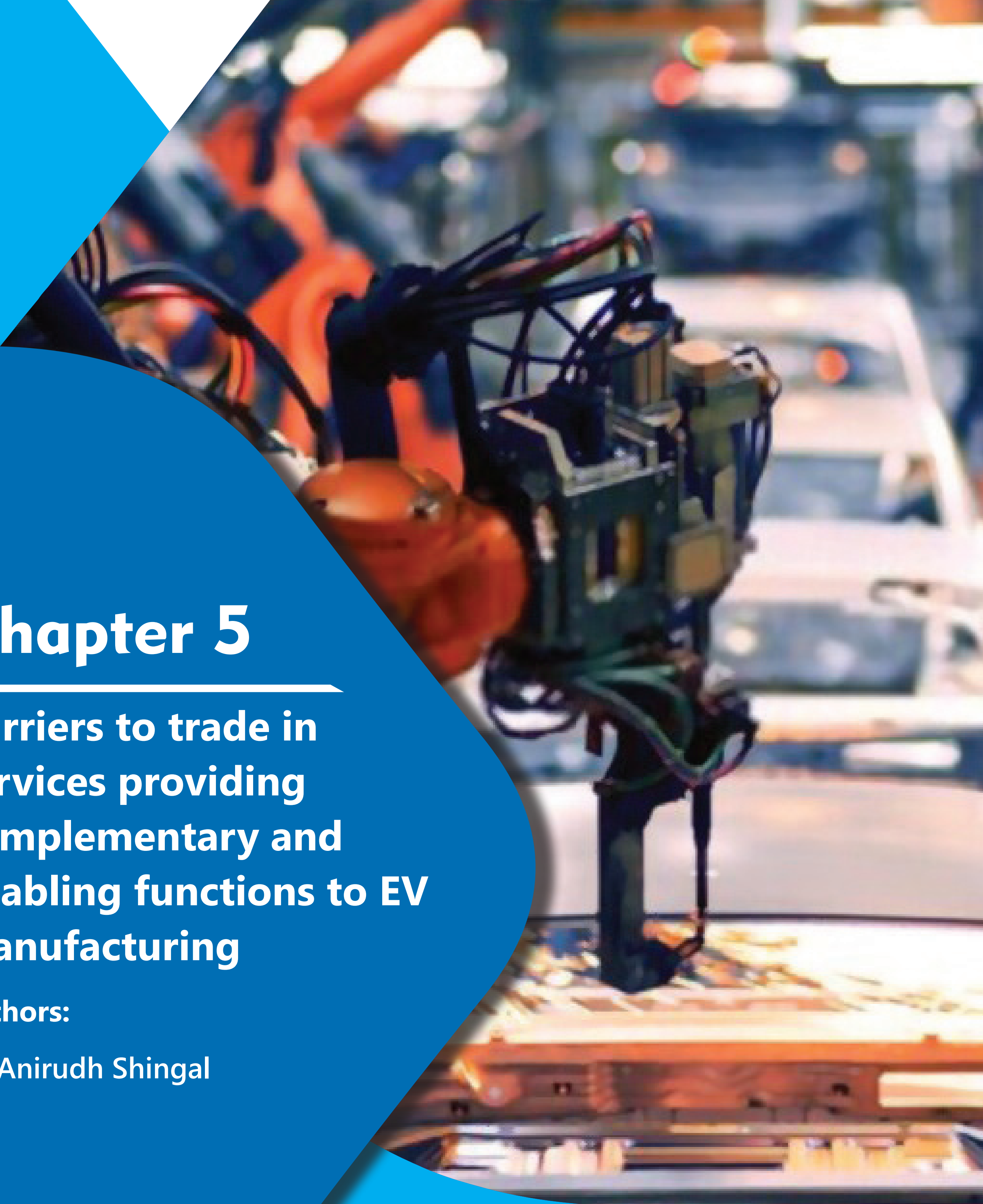
India's exports to the US		India's imports from China	
Average 2018-2019			
HS code	Value (USD '000s)	HS code	Value (USD '000s)
850710	208.0	850490	197292.7
850720	3078.5	850680	38.2
850730	1938.0	850710	3386.5
850750	8.9	850720	70520.9
850760	1236.1	850730	561.4
850780	225.7	850750	2577.0
850790	566.1	850760	848194.5
851220	7315.4	850780	218.0
851230	6888.3	850790	18467.1
851240	2153.8	851220	54464.2
851290	4279.2	851230	17887.9
853180	1876.1	851240	9352.2
853921	660.0	851290	47492.4
854370	17297.9	853180	11149.7
854519	910.1	853921	25178.3
870380	14.9	854370	182333.9
870390	3.2	854519	9566.9
870829	33319.1	870240	500.2
870840	185781.9	870360	23.8
870899	509826.0	870380	20900.9
870911	454.1	870390	10083.9
871160	241.7	870490	683.9
871410	8670.9	870829	100282.5
871499	195.4	870840	65633.9
		870899	89686.0
		870911	1187.3
		871160	40629.8
		871410	439869.2
		871499	21668.4

(Source: UN Comtrade; own calculations)

Table 22: The Grubel-Lloyd index (GLI) for India's EV goods trade (2018-19)			
HS code	**Value (USD '000s)**	**HS code**	**Value (USD '000s)**
HS code	Exports (USD '000s)	Imports (USD '000s)	GLI
8425	74622.2	324665.7	0.374
8501	776128.5	3060445	0.405
8512	278773.6	885214.8	0.479
8531	90918.2	591629.6	0.266
8532	258751.8	1450316	0.303
8539	112032.5	653022.2	0.293
8702	82970.3	7276.541	0.161
8703	5450000.0	1103079	0.337
8704	969038.5	513830.8	0.693
8708	6050000.0	11100000.0	0.706
8709	26463.1	34201.7	0.872
8714	378517.0	1246444	0.466
250410	1707.6	49540.01	0.067
253090	14014.0	58399.65	0.387
260400	128.9	1498.723	0.158
260500	8.4	352.738	0.047
271312	48651.8	375649.4	0.229
280519	509.1	25785.72	0.039
282200	565.7	23540.62	0.047
282520	572.0	36714.52	0.031
282690	1461.8	19690.12	0.138
282739	48468.7	53563.7	0.950
283691	307.3	34610.82	0.018
380110	43265.3	54903.5	0.881
750210	999.1	721739.8	0.003
750220	1758.5	127833.1	0.027
750400	790.4	34496.16	0.045
810520	230.9	95253.61	0.005
850110	237206.8	593037.7	0.571
850421	122259.9	7345.436	0.113
850440	1526097.0	3429840.0	0.616
850490	431237.5	1403509	0.470

HS code	Value (USD '000s)	HS code	Value (USD '000s)
850680	714.7	27442.03	0.051
850710	101472.2	107228.3	0.972
850720	163050.7	259990.2	0.771
850730	17432.0	31005.9	0.720
850750	1657.2	17217.8	0.176
850760	9994.8	3449528	0.006
850780	6226.6	23102.12	0.425
850790	15016.7	177185.4	0.156
851220	206452.4	489133.2	0.594
851230	24515.9	53999.8	0.624
851240	5888.7	31710.81	0.313
851290	41394.4	305890.2	0.238
853180	21977.7	74041.12	0.458
853921	38161.3	123084.1	0.473
854370	90779.7	1354819	0.126
854519	5812.1	258747.8	0.044
870220	160.0	41.278	0.410
870240	0.4	1000.368	0.001
870340	92095.0	62911.9	0.812
870350	197.0	187.5	0.975
870360	1602.9	10200.22	0.272
870370	7.7	164.354	0.090
870380	628.5	49812.64	0.025
870390	29102.9	21805.9	0.857
870490	157.6	3365.427	0.089
870829	428610.3	1561877	0.431
870840	812012.0	2572296	0.480
870899	1390783.0	2879946.0	0.651
870911	933.1	13995.02	0.125
871160	4900.1	81637.71	0.113
871410	266010.3	1097739	0.390
871499	26455.9	61786.4	0.600

(Source: UN Comtrade; own calculations)



Chapter 5

Barriers to trade in services providing complementary and enabling functions to EV manufacturing

Authors:

Dr. Anirudh Shingal

Amongst other factors, foreign investment in EVs also depends on the ability of firms to invest and operate in the importing country in the presence of tariff and non-tariff barriers and regulatory restrictions on service providers of complementary (services that are closely bound in supply with the EVs, either bundled with them or as inputs to them such as computer, distribution, engineering, logistics, transport) and enabling services (that include financial – banking and insurance – and professional – accounting and legal – services).

According to WTO GATS parlance, services trade can be transacted in four different ways, known as the modes of supply. Mode 1 ("cross-border trade") includes all services that can be traded remotely without the need for physical proximity between the buyer and seller, e.g., call centre services. Mode 2 ("consumption abroad") includes services that require the consumer to travel to the country of the buyer for the service to be transacted, e.g., tourism. Mode 3 ("commercial presence") involves transactions between foreign affiliates of an MNC in the host country, e.g., foreign bank operations in the domestic economy. Mode 4 ("movement of natural persons") includes services that require the supplier to travel to the country of the consumer for the service to be transacted, e.g., onsite software programmers.

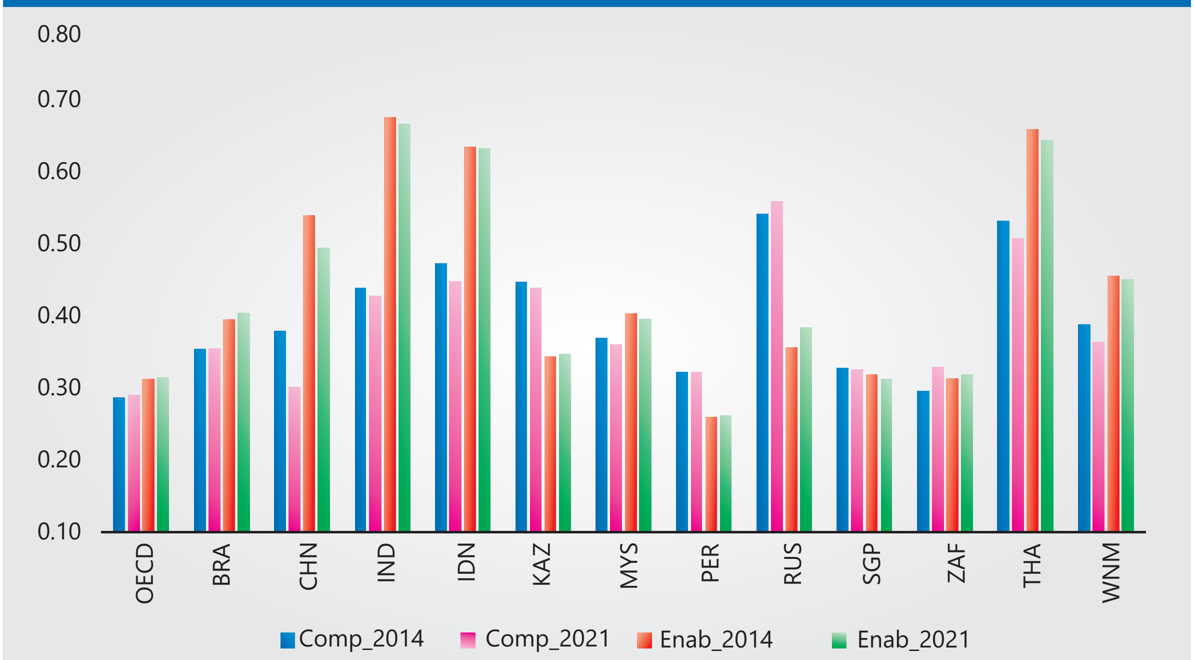
The analysis of barriers to services trade in terms of modes of delivery is based on our understanding of how trade in complementary and enabling services is transacted and the associated regulatory constraints. For instance, barriers specific to Mode 3 trade in these services include restrictions on licence approvals pertaining to fulfilment of technical standards, limited foreign ownership, type of legal entity, scope of activity, local content requirements, nationality or residency requirements to partake in the provision of certain services including public utilities and professional services, government procurement favouring domestic suppliers, public monopolies restricting entry of private service providers, restrictions on acquisition of real estate, security regulations on data transfer and demands to hire domestic staff (Andrew and Thompson, 2000; UNEP, 2018). Similarly, professional qualification requirements, cumbersome visa application procedures, and focus on immigration rules can delay or fully restrict the entry of qualified professionals via Mode 4. In other cases, specialised foreign personnel may be discriminated against due to non-recognition of professional qualifications or the requirement to pass local exams or have domicile to be eligible to practice their trade.

Protection of intellectual property rights is a generic barrier to trade in services that also applies to exports of environmental R&D, technical assistance and analysis services. For example, the possibility of intellectual property right violations and restrictions on repatriation of profits, etc. in importing countries may deter investment in EVs. Mode 3 services in these sectors may also be restricted due to domestic content requirements in production. Moreover, the growing complexity and diversity in product labelling requirements can be used to protect domestic producers and discriminate against foreign firms.

Some of these barriers can be quantified using data on services trade restrictiveness indices (STRI), compiled by the OECD since 2014. In what follows, we provide an analysis of the STRI data for OECD and non-OECD sample countries for both complementary (computer, distribution, engineering, logistics and transport) and enabling (financial and professional) services along different dimensions to draw comparisons with India.

While India has become slightly less restrictive in terms of barriers to complementary services between 2014 and 2021, it is way more restrictive than OECD countries and several non-OECD economies including Brazil, China, Peru, and South Africa (see Figure 22). Russia and Thailand are the most restrictive in terms of barriers to trade in complementary services, while China has liberalised considerably relative to its STRI value in 2014. India's high STRI value in complementary services stems largely from the restrictiveness of its transport services (see Figure 23). India is also the most restrictive country in this sample in terms of barriers to enabling services (driven largely by its high STRI values in legal and accounting services; see Figure 24), followed closely by Thailand and Malaysia (see Figure 22).

Figure 22: Average STRI in complementary and enabling services (2014 vs. 2021)



(Source: OECD STRI; own calculations)

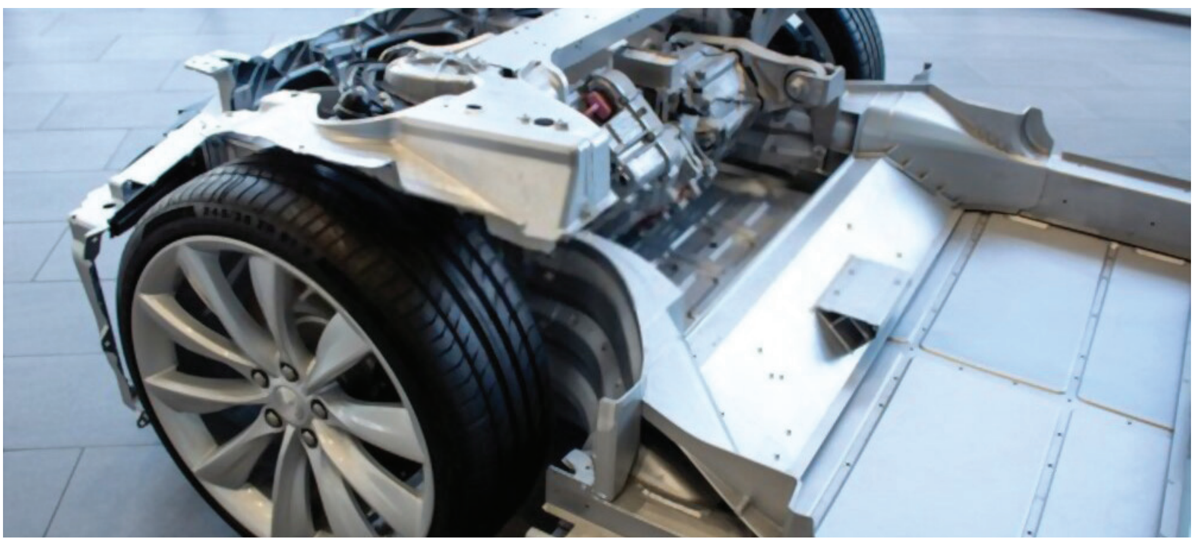
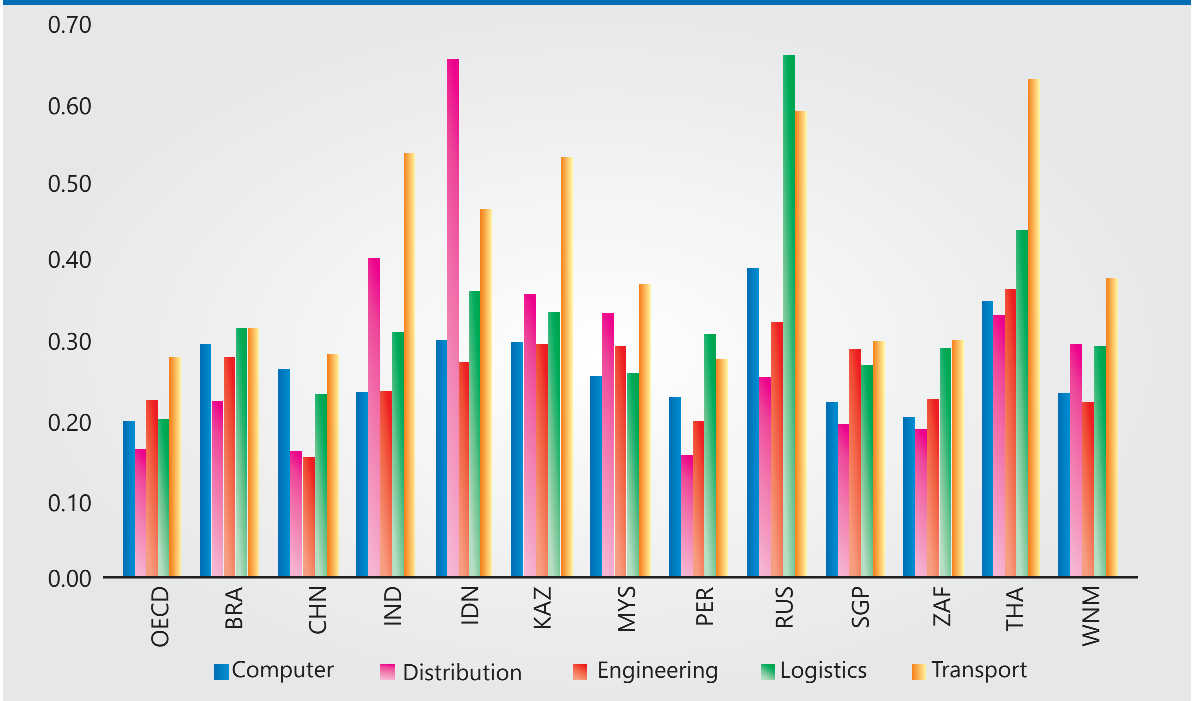
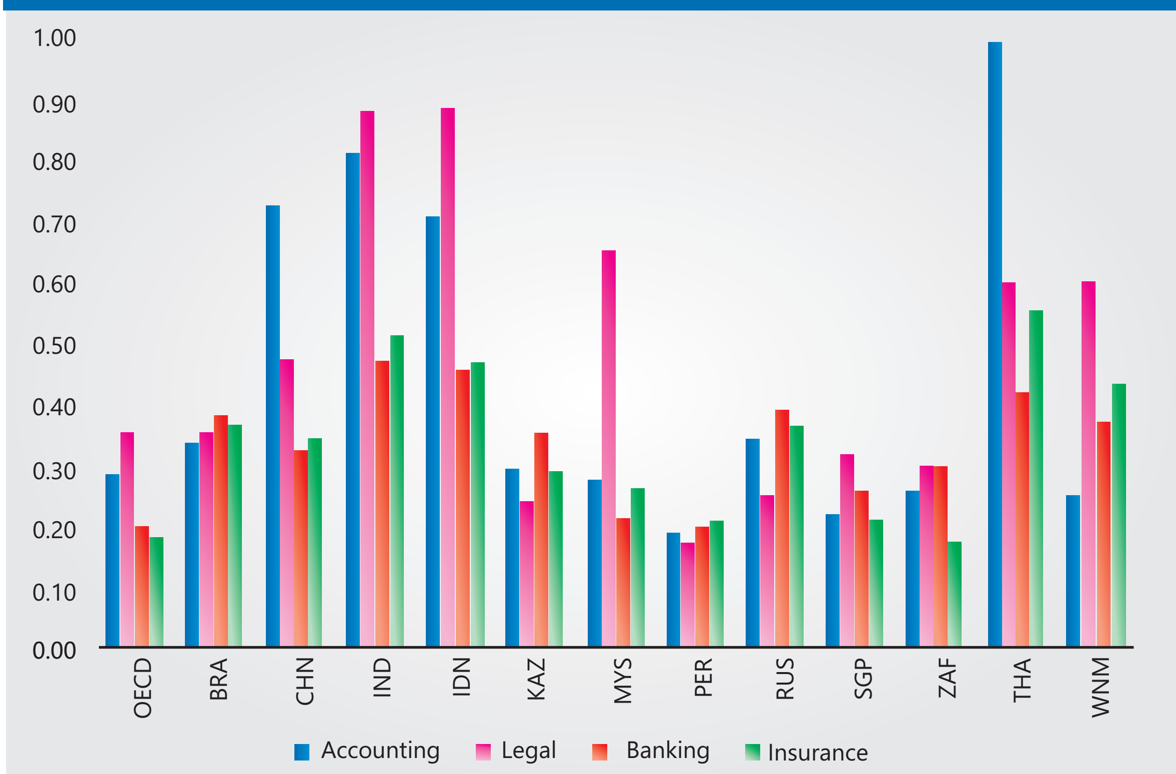


Figure 23: Average STRI in complementary services by sector (2021)



(Source: OECD STRI; own calculations)

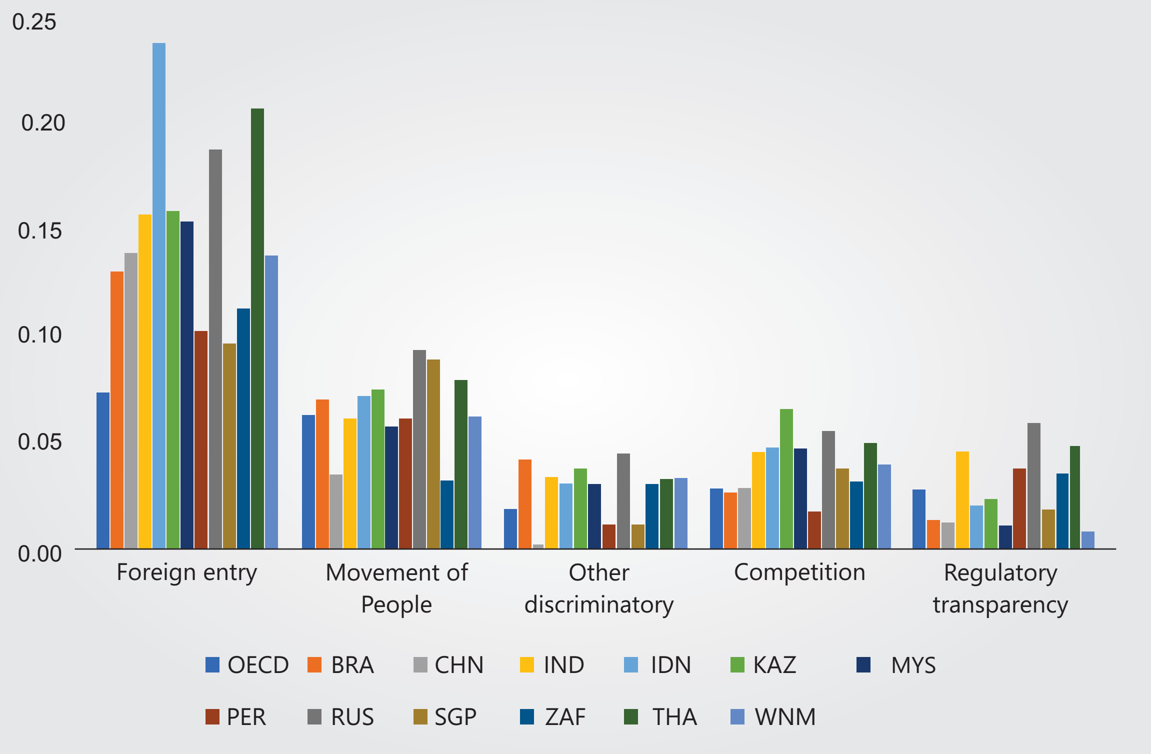
Figure 24: Average STRI in enabling services by sector (2021)



(Source: OECD STRI; own calculations)

The OECD STRI data also provide a classification of barriers by the type of restriction imposed by countries. These restrictions can be broadly divided into five major types (see Figures 25 and 26). Restrictions to foreign entry were the most pronounced amongst all barriers in 2021 for both complementary (see Figure 25) and enabling services (see Figure 26) amongst the sample countries, with India, Indonesia and Thailand being the most restrictive in this regard with respect to enabling services and the latter two countries also for complementary services. In contrast, barriers to competition, regulatory transparency and other discriminatory measures remain low across countries for both sets of services.

Figure 25: Average STRI in complementary services by type of restriction (2021)

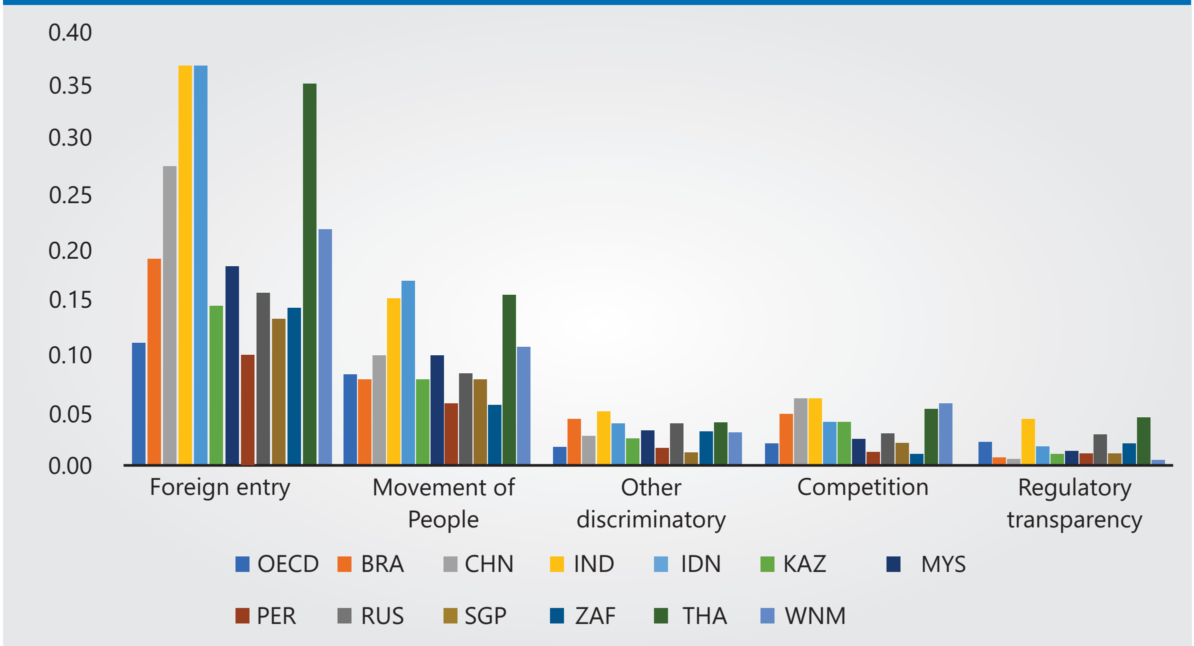


(Source: OECD STRI; own calculations)

More disaggregated analysis for India at the individual sector-level by type of restriction shows considerable heterogeneity. In fact, India is amongst the more restrictive economies, irrespective of the type of restriction, in the case of enabling services, both accounting and legal, driven by barriers to foreign entry and those on Mode 4 (see Figure 27). Restrictions on regulatory transparency and other discriminatory measures are the least constraining across sectors in India, while those on competition are also generally low except in the case of transport and insurance.

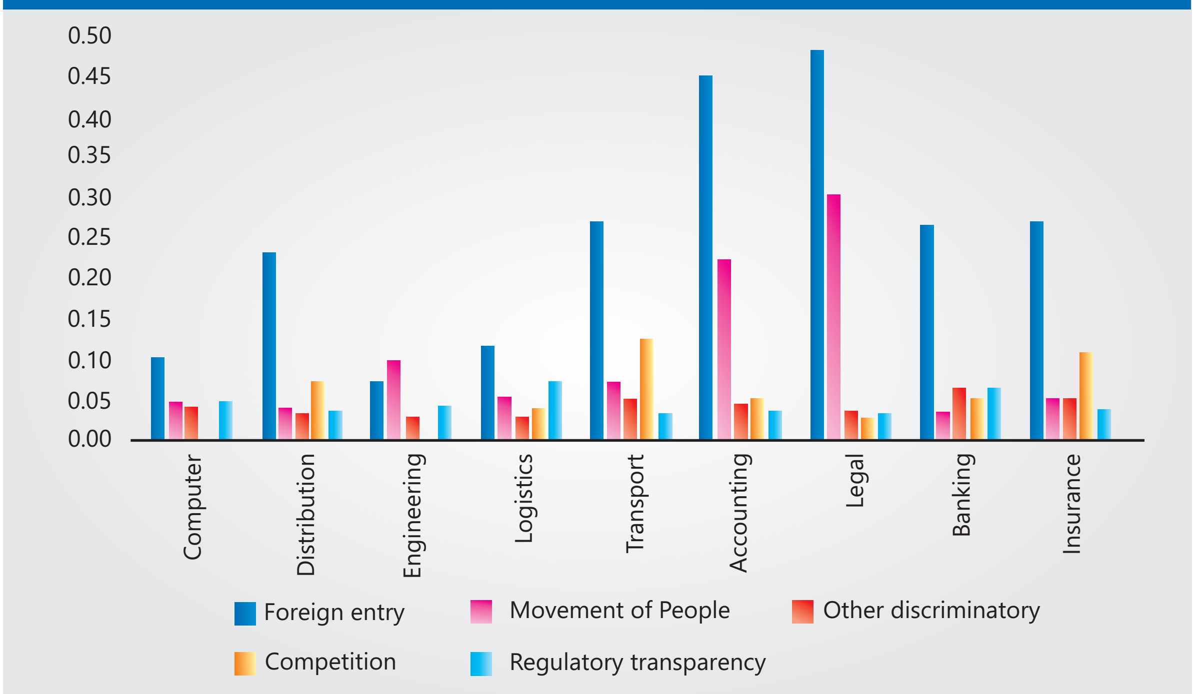
This analysis suggests that both domestic EV manufacturers and potential foreign investors in the EV-space in India are also subject to restrictions on the services side, which need to be liberalised, given the well-recognised complementarities between goods and services and the increasing servicification of economic activity in countries across the world (WTO, 2019).

Figure 26: Average STRI in enabling services by type of restriction (2021)



(Source: OECD STRI; own calculations)

Figure 27: India's average STRI in complementary and enabling services by sector and type of restriction (2021)



(Source: OECD STRI; own calculations)

References

Andrew, D. and R. Thompson (2000). Environmental goods and services: an assessmentoftheenvironmental,economicand development benefits of further global trade liberalization. Available online at: http://www.oecd.org/environment envtrade/1861110.pdf (accessed Feb. 2022)

United Nations Environment Programme (2018). Trade in environmentally soundtechnologies: Implications for Developing Countries. Available online at:https://wedocs.unep.org/bitstream handle/20.500.11822/27595/TradeEnvTech pdf?sequence=1& is Allowed=y (accessed Feb. 2022)

WTO (2019). World Trade Report 2019: The future of services trade.

Chapter 6

Electric Vehicles: Supply, Demand, and Investment Challenges

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The Indian government's push towards widespread adoption of EVs has underlined some of the demand and supply side challenges as well as barriers to investment that are likely to disrupt the commercialisation of EVs (De, 2017). This section first examines factors restricting the supply of EVs in India, followed by an examination of factors influencing the demand for EVs by domestic consumers and finally, discusses barriers to investment faced by domestic and international investors. The answers to these questions cover global issues specific to EVs that also apply to the Indian context; issues faced by EV manufacturers and consumers only in India as well as general investment side issues that will affect EV production in India.

1. Factors affecting manufacturing and supply of EVs in India

The EV value chain in India remains almost entirely dependent on imported inputs for manufacturing electric vehicles, including battery components, especially battery cells (Soman, et al. 2019; Gode, et al., 2021). This reliance adds to the overall production cost of the battery as well as the vehicle that is exacerbated by the lack of a localised supply chain for motors, controllers, power electronics and cell manufacturing in India (Soman, et al., 2019).

While the government has initiated the National Programme on Advanced Chemistry (ACC) Battery Storage, the National Mission on Transformative Mobility and Battery Storage and the Production-linked Incentive Scheme that aim to encourage domestic "giga-scale" production of batteries (Gode, et al. 2021; Rokadiya and Callahan, 2019), producers continue to import raw materials such as cobalt, lithium, nickel and graphite that are integral to the production of EV batteries. Among these mineral imports, lithium is relatively rare, although it is regarded as essential to produce lithium-ion batteries that provide enough power to electric vehicles to match the performance of a vehicle powered by an internal-combustion engine (Upadhyay, et al., 2021). Fortunately for India, the extraction of these raw materials from used batteries (from cell phones, laptops, or vehicles) has been taken up widely; with the right incentives in place, India could be a hub for such battery recycling that can reduce e-waste and reduce dependence on imported raw materials (WRI, 2019). In fact, battery recycling is a crucial step towards the development of an EV ecosystem (Soman, et al., 2019).

The second issue arises from the lack of a skilled workforce or experts to drive innovation, productivity, and sustainability in EV manufacturing in India (Soman, et al., 2019). Individuals

engaged in the traditional automobile sector, therefore, will need to be re-skilled or up skilled through proper training and skill development to be employed in the EV sector (NITI Aayog and GIZ, 2021). For example, the skills required for manufacturing and fixing wear and tear of traditional vehicles (mechanical) are different from those required for electric vehicles (WRI, 2019).

However, the low levels of technology penetration and innovation that could help reduce high manufacturing costs in the sector continue to hinder growth and drive the purchase price of an EV upwards when compared to traditional vehicles in the country (Soman, et al., 2019). Such investments require financial support from public and private banking and non-banking entities that remain reluctant due to lack of confidence in the new technology (Soman, et al., 2019). Hence, there is a need to lower the cost of finance and provide priority-sector lending backed by guarantees to spur production (NITI Aayog and RMI, 2021).

The third issue that has restricted the growth of EV manufacturing in India is the lack of charging infrastructure in the country. This acts as a disincentive for EV producers since demand will remain low until this infrastructural bottleneck is addressed on a national scale. The problem is exacerbated by unreliable power supply that leads to frequent fluctuations and blackouts, adding to overall costs. An increase in the use of EVs is likely to increase the burden on the electric network by pushing up peak loads in distribution grids (NITI Aayog, 2021). The existing grids are not sufficient to handle the added demand due to bottlenecks in distribution capacity at the local level (NITI Aayog, 2021). Hence, upgradation of grid infrastructure is required (EY and BEE, 2019), along with 'smart charging' that can limit the load by controlling charging power levels and maintaining time-based tariffs (NITI Aayog, 2021; Goel, et al., 2021).

Moreover, the lack of public charging points shifts the burden to private parking and charging stations. However, most individuals in Indian cities cannot afford the luxury of private parking, making them dependent on the insufficient public infrastructure to charge their EVs, leading to longer charging and waiting time. This is particularly relevant for smaller cities and towns. A solution to this problem is the installation of removable batteries in EVs that can be "swapped" at dedicated stations, thus reducing the time spent on recharging a vehicle (WRI, 2019). However, producers face yet another dilemma in adopting this solution – swappable batteries would require standardisation of batteries across vehicles, both imported and domestically produced, as well as across different manufacturers catering to various economic and luxury segments (Soman, et al., 2019).

Even if this issue is resolved with sufficient innovation in the sector, unreliable and insufficient power generation in India, the demand for which is likely to increase with future EV penetration, will exert tremendous pressure on the public sector (Rangarajan, 2019; EY and BEE, 2019). Hence, ways to stabilise access to affordable electricity are integral to promoting EVs in India. Another recommendation to expand charging infrastructure and support the move towards electrification of traffic, is to adopt a public-private partnership model to incentivise private entry, while engaging state governments on issues related to land and power (EY and BEE, 2019).

2. Factors restricting demand for electric vehicles

The evolution of the EV market in India as well as across countries faces a number of demand side issues that need to be addressed to increase the use of EVs to replace traditional ICE engines and help meet the twin goals of reducing pollution and reliance on fossil fuels. To begin with, the current models offered in the Indian marketplace are few in number, with limited options or variations (Soman, et al., 2019). These models also come with a range limitation that restricts the use of EVs for long-distance city travel or intercity travel – a major point of discontent for private automobiles buyers in the country (termed "range anxiety"). Coupled with the short range is the issue of long charging times for the vehicle through private or public electric charging points (Soman, et al., 2019). These issues exist for two-wheelers as well as four-wheelers. For two-wheelers in particular, a recent survey conducted by The Energy and Resource Institute (TERI) revealed that most EV owners also simultaneously owned an ICE two-wheeler that could be used for longer work trips due to the range anxiety. Moreover, prospective buyers were concerned about the lack of charging facilities and battery replacement (TERI, 2019).

What is then required is the installation of several recharging points at various locations in cities and on major highways connecting these cities (TERI, 2019). The government's role in this is undeniable – from the installation of charging points to incentivising the entry of private players, collaboration with private providers, granting of permits, and dissemination of information about charger locations (IEDC, 2013). However, as discussed earlier, this is already a supply side issue the government is hoping to solve in the next few years. A solution that has been offered for this is the use of battery-swapping technology in new EVs. Battery-swapping can be carried out at public EV stations. However, a major concern with this is the lack of harmonisation of batteries across manufacturers – local and overseas, as well as across low-, mid- and high-range vehicle models.

For car owners, the high cost of EVs in the market is another deterrent (Soman, et al., 2019; Li, 2019). Cars with similar technical specifications but with IC engines are much cheaper compared to their EV counterparts. The main cost component is the battery itself (WRI, 2019). Added to that is the low re-saleability of the new EV models. demand has failed to pick up in the Indian market. At present, while financial institutions, both public and private, offer loans to consumers to purchase private vehicles (ICE), such loans are not extended for the purchase of EVs. Therefore, the unavailability or high cost of private and public finance (commercial loans) has curtailed the sale of expensive EV models in India (Soman, et al., 2019). However, it is expected that stringent emission regulations could drive up the cost of ICEs and help EVs offer a better deal that is also sustainable (Rangarajan, 2019). Another solution offered by industry experts is that EVs could be sold without the batteries, which make up 70 to 80 per cent of costs, and the batteries could be leased; this will lower costs and increase demand (WRI, 2019). Evidence also shows that although EVs have a higher upfront cost, their lifetime costs are lower due to fuel savings and decreased maintenance costs (IEDC, 2013; WRI, 2019).

The central and state governments in the country have offered financial assistance in the form of incentives to boost sales and entice mainstream buyers. For instance, the Faster Adoption and Manufacturing of Hybrid and EV (FAME) scheme of 2015-16 provided subsidies for electric 2- and 3-wheelers, hybrid and e-cars and buses to incentivise demand and create a marketplace through domestic technological development and increased manufacturing. Its extension, the FAME-II schemes in 2019, provides upfront incentives on the purchase of EVs and for supporting the installation of 2,700 charging stations in metros and major highways (WRI, 2019; PIB, 2019).

There is also evidence that points towards the success of such demand incentives in boosting EV sales in many countries. For example, the Norwegian government imposed a high stamp duty and VAT on ICE vehicles to offset the price difference with EVs. In addition, EV owners were also provided with exemption from road tolls, free recharge sites, free parking, and access to bus lanes to incentivise their sales (Li, 2019). Similarly, in China, EVs are exempt from ownership taxes and registration fees. In Japan, EVs are exempt from tonnage tax and automobile tax while in Germany, EVs are exempt from motor vehicles tax for 10 years (De, 2017).

In addition to centrally sponsored schemes, state governments have also designed their own criteria for EV subsidies (targeting both, eclectic two-wheelers, and four-wheelers) to make them more affordable. Notable examples include the State of Delhi that offers a 100 per cent road tax exemption in addition to a subsidy of INR 5,000 per kWh of battery capacity for two-wheelers and INR10,000 per kWh for electric cars and SUVs. Maharashtra, West Bengal, Assam, and Meghalaya also offer a 100 per cent of road tax exemption along with similar subsidies per kWh. The only difference is in the cap for subsidies – Maharashtra caps the subsidies for two-wheelers at INR 25,000 (compared to INR 30,000 for Delhi, West Bengal, Assam, and Meghalaya at Rs.20,000Assam, while they cap the subsidies for cars at INR 2,50,000 (compared to INR 1,50,000 for Delhi, West Bengal, and Assam and only INR 60,000 for Meghalaya) (Ahmed, 2021).

However, the Society of Indian Automobile Manufacturers (SIAM, 2017) recommends that while cash subsidies are a short-term solution to increase demand for EV, tax rebates, fiscal and non-fiscal incentives can go a long way in sustaining demand and bridging the 'viability gap' to make EVs the preferred choice for consumers. These measures could include, inter alia, a reduction in the GST on EVs, exemption from road tax, priority sector lending for EVs, one-time income tax deduction, attractive power tariffs for charging, and exemption of toll charges and parking fees (SIAM, 2017). These recommendations are in line with the incentives mentioned previously by developed countries and China to increase EV sales.

Despite these efforts, the mentality of the public to maintain the status quo in the market and its buying habits has slowed the adoption of EVs (WRI, 2019). Any change in habits will entail a new learning curve for manufacturers and consumers alike. Additionally, the lack of public awareness of the benefits of EVs adds to the challenges (WRI, 2019). Thus, policies to influence consumer perception and remove misconceptions through a 'dedicated consumer awareness plan' is vital to increasing the uptake of EVs (WRI, 2019; IEDC, 2013).

The recent push to promote shared mobility in the form of pooled rides has replaced the need to purchase private vehicles and has also affected demand for EVs. However, it is anticipated that the next trend would be to integrate EV in the shared mobility space to achieve future sustainability goals (Sharma and Singh, 2021). To this end, a government-led initiative to enable the transition of its fleet completely to EVs could be beneficial to set an example for the public to follow and create demand for EVs (IEDC, 2013; WRI, 2019). They could then devise an incentive mechanism to encourage adoption of EV cabs by public and private companies – a move that will quicken the entry of EVs in the future of shared mobility.

3. Investment barriers faced by domestic and international investors in India

The Indian EV ecosystem is on the verge of a boom, given the large consumer base and untapped market potential. However, domestic, and international investors have shown tepid interest in financing production despite the availability of many government-linked incentive schemes to boost manufacturing of EVs. One of the biggest hurdles to attracting new investment has been the inability to reduce the high upfront cost of EVs in the Indian market that have restricted sales and contributed to sluggish returns (Alluri and Pandey, 2021). The Indian market does not offer very high profit margins for manufacturers due to high interest rates (Hampel, 2021), price competition from ICE vehicles and availability of various low-end models in the market. Hence, it has been extremely challenging for manufacturers to capture market share in India (Alluri and Pandey, 2021). As a result, manufacturers are forced to develop business models that would not be a sustainable option in the long-term (Hampel, 2021). Another factor contributing to low profit margins has been the steep power tariffs in the country that do not leave room for profit on charging facilities that may be offered by manufacturers (Hampel, 2021).

High import tariffs on parts and components essential to produce EVs have also been a discouraging factor for foreign manufacturers. They claim that high tariffs will drive up production costs because they will have to produce these parts locally in India (Alluri and Pandey, 2021). This is a direct consequence of incentives offered by the Indian Government to ramp up local production and create supply chains in the production of EVs; however, these requirements to produce locally will be a deterrent to attracting FDI (Foreign Direct Investment) in the sector.

In fact, foreign investors have been under-confident due to the lack of local supply chains in EV production (Pathak and Patel, 2021), the benefits of which are undeniable for manufacturing sectors. Moreover, the uncertainty in battery technology (Pathak and Patel, 2021), poor infrastructure, especially charging facilities, the high costs of setting up and providing the infrastructure, high land costs (Hampel, 2021), and overall high logistics costs are some other factors that may hinder investment in the sector (Hampel, 2021). For investors and manufacturers that do decide to invest in the Indian EV market, it may be vital to adapt to the specific road and traffic conditions as well as purchasing and driving habits of customers to ensure success (Choudhary, 2021).

As already mentioned, the central and state governments have offered several incentives to spur foreign investment and increase the uptake in domestic manufacturing. However, some reports have pointed towards the lack of clarity on the overlapping incentive mechanism, the distribution of government subsidies across players, and the role of various agencies and departments responsible for EV production and transition in the country (Pathak and Patel, 2021). This has led to confusion and uncertainty for manufacturers and investors. The lack of clarity on charging and emission standards set by the central government has worsened the uncertainty (Morgan Stanley, 2018).

Even globally, the uptake in EV manufacturing has been slow due to the high-risk and large start- up investments required upfront to set up the process (Glandorf, 2020). Moreover, the high prices and undersupply of lithium and cobalt that are central to the production of EV batteries are extreme battery supply bottlenecks that have restricted the global production of EVs. The COVID- 19 pandemic has also hit battery manufacturers in China, forcing them to halt production, and this caused severe distress to many EV manufacturers. Moreover, the pandemic has also slowed down demand in China that offers the largest market for EVs, affecting profits and their future growth plans (Cohen, 2020). Indirectly, this may have impacted the flow of FDI in EV production in India. But the overall investment climate in India has not been conducive to foreign investors. The mandatory requirement to store data locally, the increase in cap on foreign ownership across sectors, and the move to maintain 'Indian' control on management of foreign firms have all been major deterrents to fresh FDI (Brannon, 2021).

References

Ahmed, A. (2021). State-wise EV subsidies in India: A handy list of incentives and benefits for electric vehicles in each state. Firstpost, https://www.firstpost.com/tech/auto-tech/state-wise-ev- subsidies-in-india-a-handy-list-of-incentives-and-benefits-for-electric-vehicles-in-each-state- 9952771.html Accessed on 26 December 2021

Alluri, A. and Pandey, V. (2021). The bumpy road to India's electric car dreams. BBC (British Broadcasting Corporation) News: https://www.bbc.co.uk/news/world-asia-india-58977080 Accessed on 24 December 2021

Brannon, I. (2021). India's hostility to foreign investment threatens long-term growth. Forbes: https://www.forbes.com/sites/ikebrannon/2021/04/12/indias-hostility-to-foreign-investment- threatens-long-term-growth/?sh=2d1aafbb4d1f Accessed on January 02, 2022

Choudhary, S. R. (2021). Billionaire investor Rakesh Jhunjhunwala reveals how he's playing India's electric vehicle market. CNBC: https://www.cnbc.com/2021/02/24/investor-rakesh-jhunjhunwala-on-indias-electric-vehicle-market.html Accessed on 24 December 2021

Cohen, A. (2020). Manufacturers are struggling to supply electric vehicles with batteries. Forbes: https://www.forbes.com/sites/arielcohen/2020/03/25/manufacturers-are-struggling-to-supply- electric-vehicles-with-batteries/?sh=198fbdc41ff3 Accessed on January 02, 2022

De, S. (2017). Electric Vehicles: Roadmap for Upscaling in India. Mohali: Indian School of Business.

Ernst and Young (EY) and Bureau of Energy Efficiency (BEE) (2019). Propelling electric vehicles in India. https://beeindia.gov.in/sites/default/files/2019%20-%20EY%20to%20BEE%20- %20Technical%20study%20on%20EVs%20%26%20Charging%20Infrastructure.pdf Accessed on December 18, 2021

Glandorf, J. (2020). On the move: Unpacking the challenges and opportunities of electric vehicles. Environment and Energy Study Institute: https://www.eesi.org/articles/view/on-the-move- unpacking-the-challenges-and-opportunities-of-electric-vehicles Accessed on December 26, 2021

Gode, P., Bieker, G. and Bandivadekar, A. (2021). Battery capacity needed to power electric vehicles in India from 2020 to 2035. International Council of Clean Transformation Working Paper 2021-07.

Goel, S., Sharma, R. and Rathore, A. K. (2021). A review on barriers and challenges of electric vehicles in India and vehicle to grid optimisation. Transport Engineering. Vol. 6, 100057 Hampel, C. (2021). India plans measures to attract global EV investment. Electrive.com: https://www.electrive.com/2021/03/29/india-plans-measures-to-attract-global-ev-investment/ Accessed on January 02, 2022

IEDC (2013). Creating the clean energy economy: Analysis of the electric vehicle industry. Ireshika, M.A.S.T., Preissinger, M. and Kepplinger, P. (2019). Autonomous Demand Side Management of Electric Vehicles in a Distribution Grid. 7th International Youth Conference on Energy (IYCE), pp. 1-6.

Li, Y. (2019). Demand-side vs. Supply-side EV policies. Global research and Consulting Group, https://www.grcglobalgroup.com/post/demand-side-vs-supply-side-ev-policies Accessed on December 28, 2021

Morgan Stanley (2018). Why India dreams of electric cars. https://www.morganstanley.com/ideas/india-mobility-transformation Accessed on December 28, 2021

NITI Aayog (2021). Handbook of electric vehicle charging infrastructure implementation: Version-1. New Delhi. https://www.niti.gov.in/sites/default/files/2021- 08/Handbook for EV Charging Infrastructure Implementation 081221.pdf Accessed on January 02, 2022

Pathak, M. and Patel, S. (2021). The speed bumps in India's electric vehicle drive that no one's talking about. The Economic Times: https://economictimes.indiatimes.com/industry/renewables/the-speed-bumps-in-indias-electric-vehicle-ride-that-no-one-is-talking-about/articleshow/88144625.cms?from=mdr Accessed on January 03, 2022

PIB (2019). Cabinet approves scheme for FAME India Phase II. https://pib.gov.in/newsite/PrintRelease.aspx?relid=189081 Accessed on December 18, 2021

Rangarajan, S. (2019). Electric vehicle market in India: Evolution, challenges, and solutions. Financial Express, https://www.financialexpress.com/auto/car-news/electric-vehicle-market-in- india-evolution-challenges-and-solutions/1738148/ Accessed on December 19, 2021

Rokadiya, S. and Callahan, J. (2019). Boosting EV growth in India: Missing pieces in the policy puzzle. ICCT:https://theicct.org/blog/staff/boosting-ev-growth-india-20191028 Accessed on December 19, 2021

Sharma, M. and Singh, A. (2021). The future lies in shared mobility and electric vehicles. Outlook money, https://www.outlookindia.com/outlookmoney/opinions-and-blogs/the-future-lies-in-shared-mobility-and-electric-vehicles-6577 Accessed on December 20, 2021

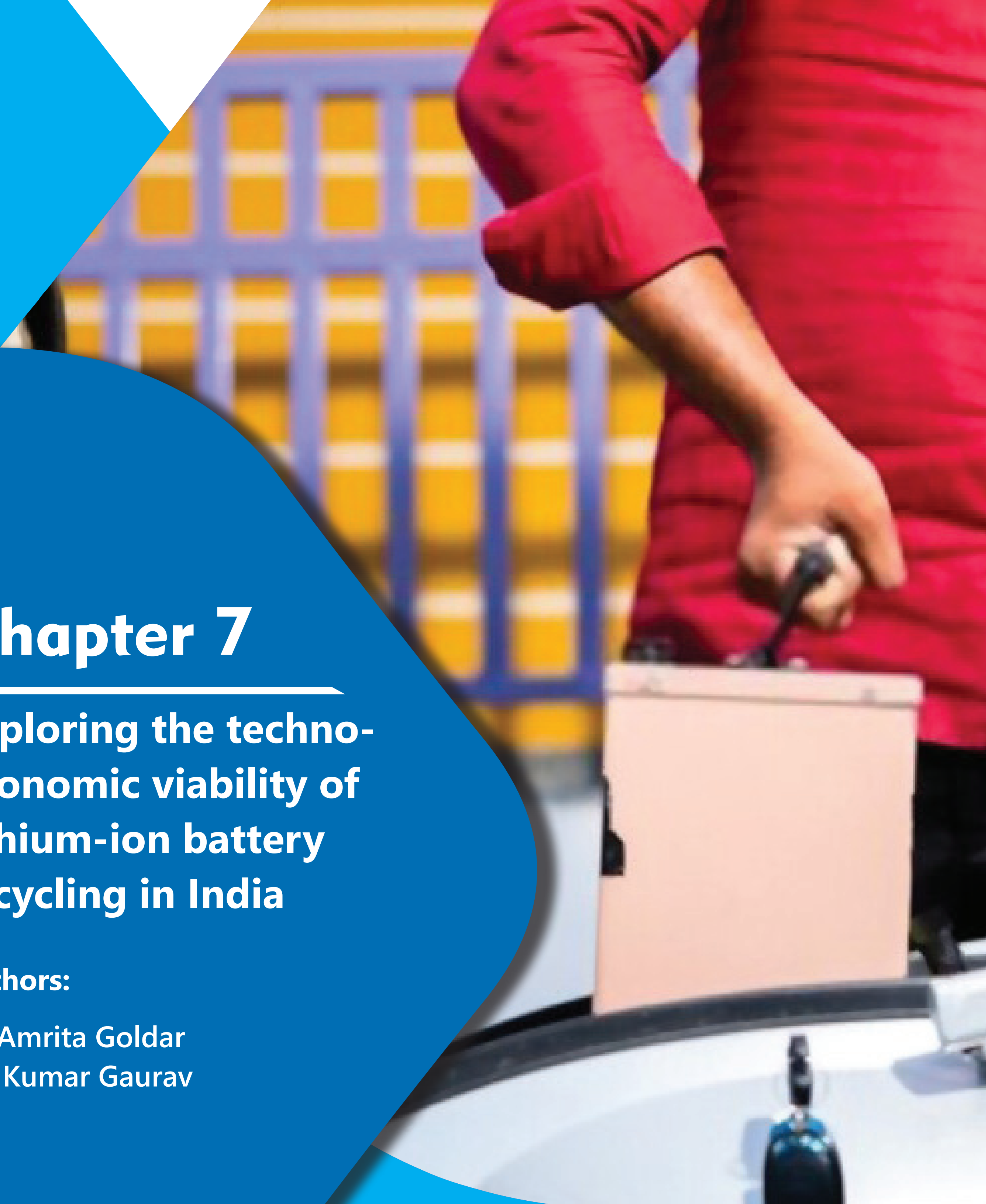
SIAM (2017). Adopting Pure Electric Vehicles: Key Policy Enablers. White Paper on Electric Vehicles.https://www.siam.in/uploadsfilemanager/114SIAMWhitePaperonElectricVehicles.pdf Accessed on December 22, 2021

Soman, A., Ganesan, K. and Kaur, H. (2019). India's electric vehicle transition: Impact on Auto Industry and Building the EV ecosystem. New Delhi: CEEW. https://shaktifoundation.in/wp-content/uploads/2019/10/Indias-Electric-Vehicle-Transition-Report-PDF.pdf Accessedon December 22, 2021

TERI (2019). Faster adoption of electric vehicles in India: Perspective of consumer and industry. https://www.teriin.org/sites/default/files/2019-11/Faster %20 adoption %20 of %20 electric %20 vehicles %20 in %20 India.pdf Accessed on December 24, 2021

Upadhyay, A., Dalal, M., Sanghvi, N., Singh, V., Nair, S., Scurtu, I. C., and Dragan, C. (2021). Electric vehicles over contemporary combustion engines. IOP Conference Series: East and Environmental Science 635 01 2004.

WRI (2019). A guidance document on accelerating electric mobility in India. https://wri-india.org/sites/default/files/Accelerating%20electric%20mobility%20in%20India_WRI%20India_CBEEVIITM.pdf Accessed on December 19, 2021



Chapter 7

Exploring the techno-economic viability of lithium-ion battery recycling in India

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1. Introduction

Urban mining (or recycling) is the reclamation of valuable metals and minerals from any kind of anthropogenic sources such as industrial products, consumer goods, electronic vehicles and batteries, infrastructure, buildings, waste, etc. (Cossu and Williams, 2015). Since the anthropogenic sources such as end-of-life products and electronic waste carry economic value (due to presence of valuable components) even after being used, it makes sense to extract those material values and re-introduce it to form a closed loop supply-chain in the movement towards a circular economy. This reduces the pressure of demand for these metals in the overall value-chain.

According to Cossu and Williams (2015), terms such as 'urban mining', 'waste management' and 'circular economy' are becoming increasingly fashionable nowadays. The reason for this is the emergence of issues such as shortage of primary raw materials, shrinking land area for waste disposal, and the need to protect the environment from contamination. Urban mining eventually reduces virgin mining activities, which in turn reduces environmental damage as virgin mining is associated with several environmental externalities such as water wastage, greenhouse gas (GHG) emissions, and land, air, and water pollution (Recycling / Urban mining, 2021). The benefits associated with urban mining can be summarised as a) preserving economic value by re-using metals that would otherwise be wasted, b) decreasing the pressure of demand for raw materials and c) protecting the environment. Urban mining has been observed to be more economical than virgin mining in a few cases – recycling aluminium in case of end-of-life EVs has been shown to be more cost effective than virgin mining. The cost of extracting a ton of aluminium through urban mining is estimated at USD 1,660, while that for copper is estimated at USD 3,000. The cost of virgin mining are significantly higher (1.5 -1.8 times) (Zeng et al., 2021).

E-waste has economic value; recycling can capture this value and re-introduce it in the supply chain. In India, this process is picking up speed. The industry survey indicated that recycling of e-waste is currently undertaken mainly in the informal sector. There will be a rapid rise in electronic products being used, simply because of rapid population growth, greater industrialisation, modernisation, and digitalisation around the world. These factors will then further increase the demand for housing, automobiles, electronic gadgets, and other consumer goods. Most of these products contain a high proportion of valuable metals and compounds of high purity that can be recovered when these products are discarded (Urban Mining, 2015). This requires a proficient recycling sector. However, while the Indian recycling market is growing, there is still the need to achieve higher recycling efficiency and coverage. As discussed previously, an efficient recycling ecosystem has the potential to create billions of dollars in value. It will also help SDG 8, which is to promote full and productive employment and decent work for all. As the push for greener technologies increases, urban mining can serve as one of the viable solutions to address the challenges posed by SDG 8.4 that focuses on improving resource efficiency in consumption and production.[79]

This chapter aims to present the techno-economics of a LiB recycling plant to inform various stakeholders involved in the EV value chain, especially the recyclers' community in the battery sector, of the economic feasibility of the LiB recycling. Since LiB recycling is still in its infancy in India, only a few studies on the financial and technological viability of lithium-ion recycling are available.

Research questions

This chapter aims to assess the capital expenditure, operating expenditure, collection and transportation, and disassembly costs of recycling and the profitability of LiB recycling in India as well as examine how profitability can be achieved sooner. Further, it highlights the major roadblocks that can hinder India from emerging as a global hub for LiB recycling.

Further, the financial viability of a recycling plant will differ depending on its location since the cost of operation is heavily influenced by location. There are issues related to information gaps and unavailability of data. Nevertheless, there is need for a study on the financial and technological viability of LiB recycling in India, which is what this paper is focused on. This paper is only an initial scoping study and aims to document information, given that no such study has been done till date for India.

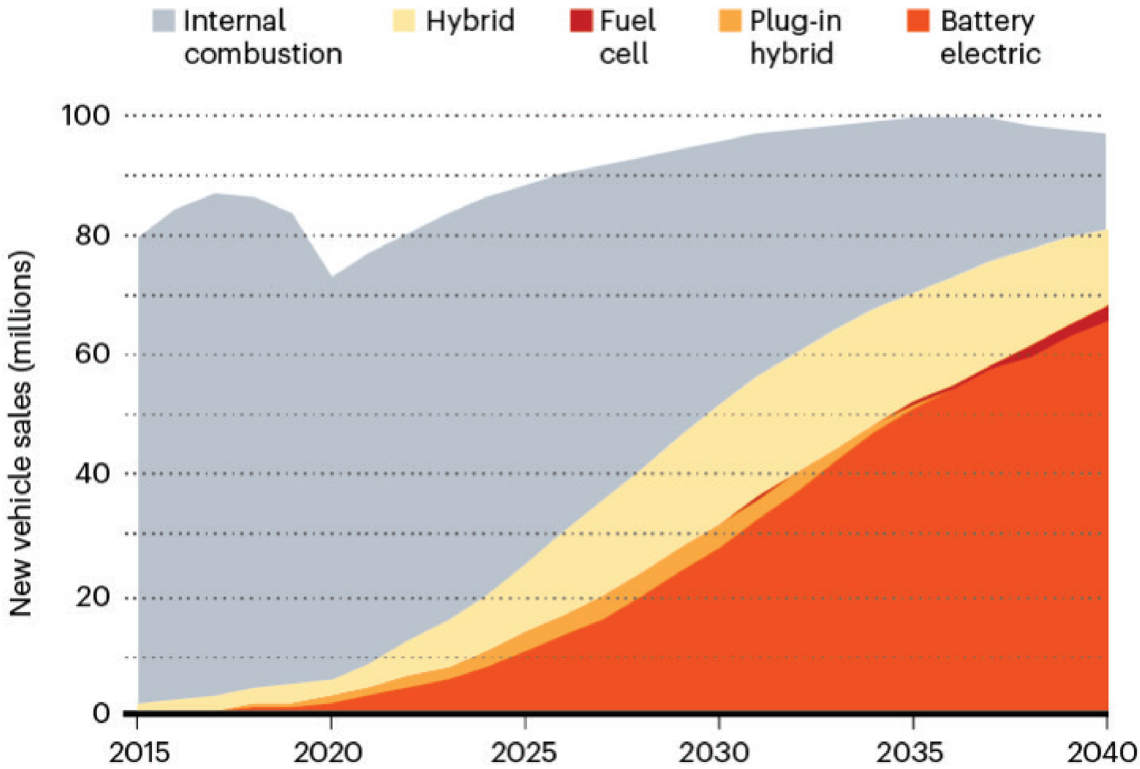
The rest of the chapter is organised as follows. Section 2 provides the assessment of supply-demand dynamics of critical minerals; Section 3 discusses the methodology adopted for estimating recycling cost in the study; Section 4 presents the analysis of the recycling cost for an individual firm, along with the forecast of capital and operating investments needed for the recycling sector in India by 2030, and section 5 concludes the paper.

2. Critical minerals for EVs: Assessing their resource availability and demand

The EV value chain is particularly important in the context of urban mining, as EVs along with their batteries have high amounts of critical metals. The penetration of EV is expected to increase in the future exponentially because of mitigation actions taken by countries to prevent climate change (see Figure 28). New registrations of EVs had increased globally by a whopping 575 per cent from 1,11,320 in 2013 to 7,50,490 in 2017. But overall, the share of EVs in the automobile fleet still remains staggering low at just 0.8 per cent of all vehicle sales in 2017 globally (International Energy Agency (IEA), 2018). The current small share of EVs shows that there is enough opportunity to electrify our vehicles in coming years.

[79] SGD target 8.4 - Improve resource efficiency in consumption and production - Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10 Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead.

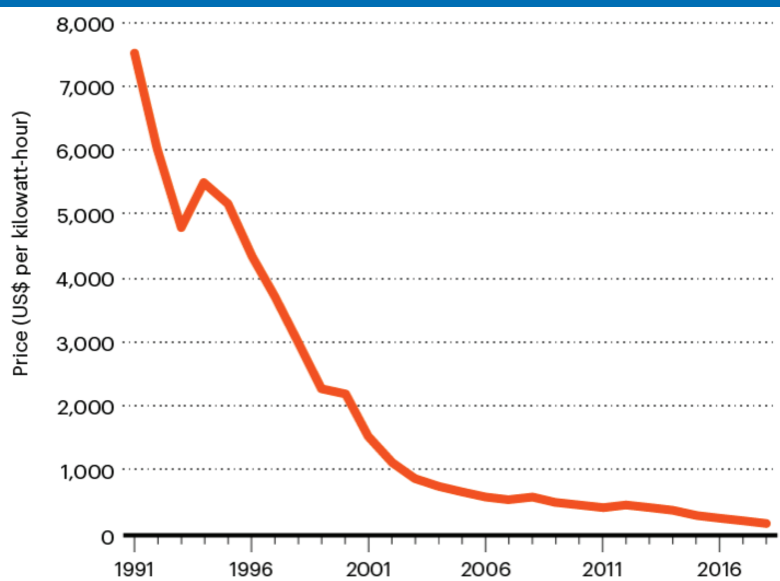
Figure 28: Vehicles sales forecast by 2040



(Source: Castelvecchi (2021))

Additionally, because of scientific and technological breakthroughs, batteries are becoming increasingly affordable as shown in Figure 29, leading to a significant fall in EV prices. The global price of LiBs has decreased by 97 per cent since its introduction in 1991 while properties have significantly increased (Ziegler and Trancik, 2021).

Figure 29: Price of lithium-ion cells



(Source: Castelvecchi (2021))

It is expected that some of the EVs will achieve cost parity with ICE by 2024 or 2025 globally, and all EVs will achieve cost parity with ICE by 2030, provided there is no drastic increase in the prices of materials (Coffin and Horowitz, 2018).

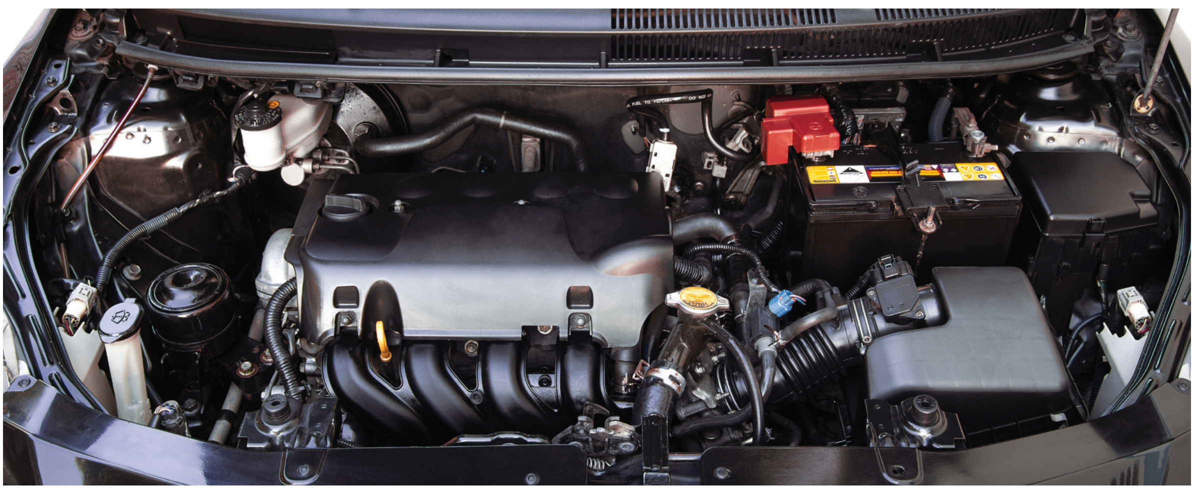
In India, the government is aggressively pursuing the goal of electrification of vehicles through various policies such as National Electric Mobility Mission Plan (NEMMP),[80] FAME I,[81] FAME II[82] and PLI schemes for advanced chemistry cell (ACC) manufacturing.[83] These policies are expected to push the adoption of EVs and, in a base case scenario, the number of EV sales is expected to surpass 100 million units by 2030 as shown in Table 23 below (Singh, Chawla, and Jain, 2020)

Table 23: EV Sales projection across all segments

EV sales FY21 to FY30 (in million)	Base case	High adoption	Low adoption
Two-wheelers	94	103	56
Three-wheelers	3	3	2
Cars (private)	3		
Cars (commercial)	2		
Total	102	112	61

(Source: Singh, Chawala, and Jain (2020))

Since LIBs are at the heart of an EV, the LiB market size will also grow exponentially. According to JMK Research & Analytics, the cumulative capacity in total is expected to reach 250 GWh by 2025 and 800 GWh by 2030, with 80 per cent of this capacity to be captured by EV batteries (Guliya and Jain, 2019), as shown in Figure 30. The remaining percentage will be used in energy storage applications.



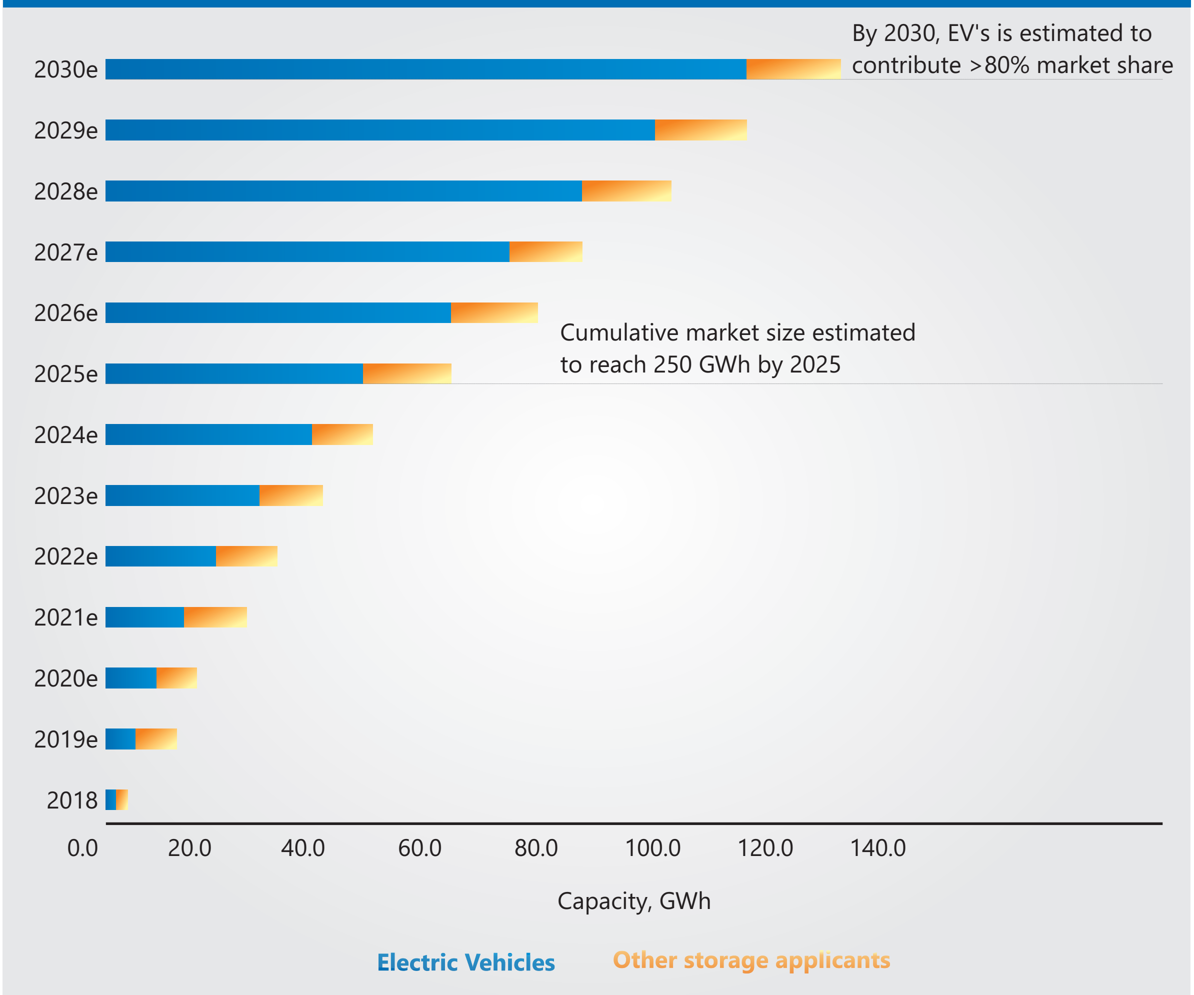
[80] Available at: https://www.iea.org/policies/6201-national-electric-mobility-mission-plan-nemmp Accessed on March 2, 2022

[81] Available at: https://pib.gov.in/newsite/PrintRelease.aspx?relid=191377 Accessed on March 2, 2022

[82] Available at: https://fame2.heavyindustries.gov.in/ Accessed on March 2, 2022

[83] Available at: https://heavyindustries.gov.in/writereaddata/UploadFile/ACC%20Scheme%20Notification%209June21.pdf Accessed on March 2, 2022

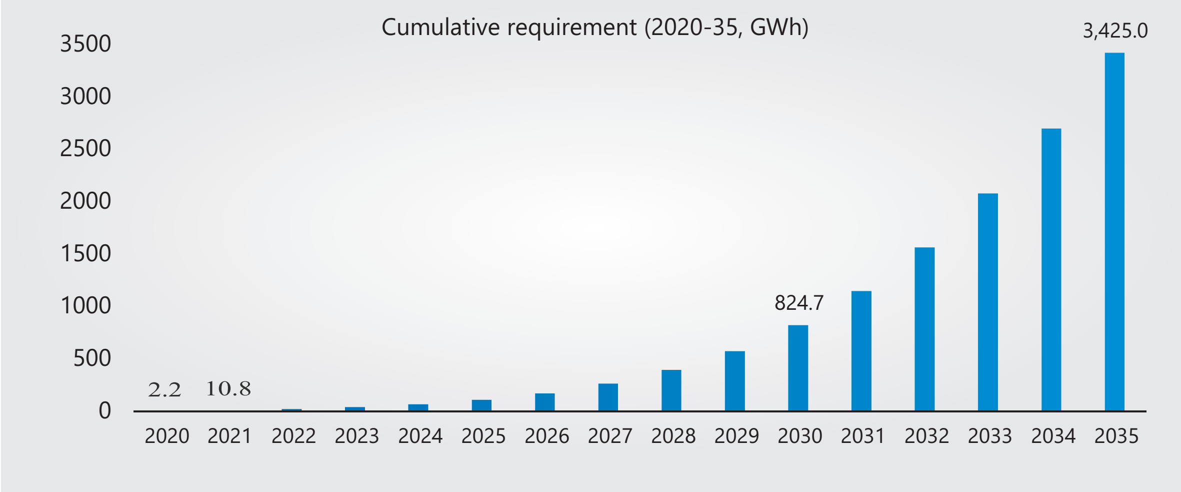
Figure 30: Annual Lithium-ion battery market size in India, GWh



(Source: Guliya and Jain (2019))

Another recent estimate by the International Council on Clean Transportation (ICCT) projects this number at a slightly higher range. In its 30@30 scenario, i.e., 30 per cent of new automotive sales are electric by 2030, it has estimated that cumulative EV battery capacity requirement will reach at 824 GWh by 2030 and 3.4 TWh by year 2035, as shown in Figure 31 (Gode, Bieker, and Bandivadekar, 2021).

Figure 31: Cumulative EV battery capacity requirement (GWh)



(Source: Gode, Bieker, and Bandivadekar (2021))

Metals that are critical for the EV value chain are lithium (Li), cobalt (Co), graphite (C), nickel (Ni), manganese (Mn), though the exact LiB chemistry varies depending on the type of battery. Most of the materials required for LiB will not face any availability problems in the future, but a few critical metals (such as cobalt) present a risk due to its geographical concentration. Further, since governments all around the world are concentrating on a higher offtake of EVs, the availability of lithium could also become a problem under a heavy EV adoption scenario in the near future. The demand for lithium is expected to increase by a factor of 18 to 20 while that for nickel to increase by 18 to 31 times, cobalt by 17 to 19 times and other materials by 15 to 20 times (Xu et al., 2020). According to another estimate, demand of cobalt and lithium metals will increase by 37 and 18 times, respectively by 2030 (Jones, Elliott, and Nguyen-Tien, 2020). Closed loop recycling can play a significant role in reducing this demand pressure.

Countries are racing to massively pump up their metal mining capacity. It is interesting to note that India ranks 9th on the top 25 list of nations which have the capacity to supply battery materials. However, it will have to be dependent on foreign nations to meet it demand of critical minerals as India does not have its own resources. On a comparative note, China has highest access to raw material refining capacity (80 per cent globally) and matching mining capacity. It is also the world's largest producer of graphite. It is expected to remain a dominant player in the supply chain of EV critical metals.

Current trends show that only five countries have deposits of critical metals. The major concentration of minerals (both Lithium and Nickel) is in Australia, whose government has already declared these metals as highly critical metals for their economy. Australia, thus, is likely to become the new Middle East, given the world's dependence on them for these critical metals. Other key suppliers include Brazil, which is among the world's top producers of graphite, nickel, manganese, and lithium. Other countries in the region, i.e. Bolivia, Chile and Argentina collectively account for 58 per cent of global lithium reserves. Congo (Democratic Republic of Congo) provides majority of world's demand of cobalt (around 68 per cent).

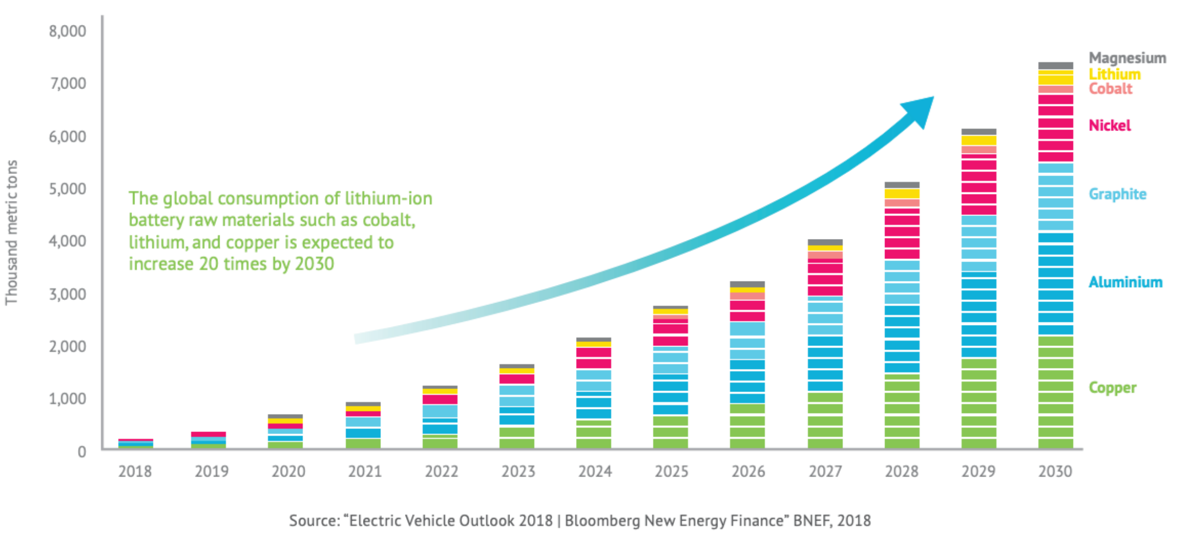
With this situation, the world as a whole will face issues with its massive EV deployment plans in near future as critical metals will become increasingly scarce and geographically concentrated.

India's demand for critical metals

Urban mining will be crucial for India, given its lack of reserves of critical metals and the expected increase in demand of EVs arising from the push towards the adoption of EVs, renewable energy, and energy storage. India is poised to surpass 100 million units of EV sales by 2030 (Singh, Chawala, and Jain, 2020) and it will need to have a supply of critical materials for 158 GWh of LiB production annually by 2030 just for EV transportation. Addition of battery storage for energy will result in even higher battery capacity needs.

According to Singh, Chawala, and Jain (2020), battery demand for EVs will grow from 5 GWh in 2021 to 158 GWh in 2030, whereas JMK Research and Analytics estimates annual LiB market to increase from 2.9 GWh in 2018 to 132 GWh in 2030, with cumulative LIB market demand to increase to 800 GWh by 2030 (Guliya and Jain, 2019). Currently EV batteries represent only 35 per cent of LiB usage, but this will increase to 80 per cent by 2030. This would lead to not just an increase in the demand for critical metals, but the demand for aluminium and copper that represents a major fraction of battery pack material would also increase manifold by 2030 (see Figure 32). If the spent batteries do not get recycled and disposed of in a sustainable manner, it will affect our environment and biodiversity negatively.

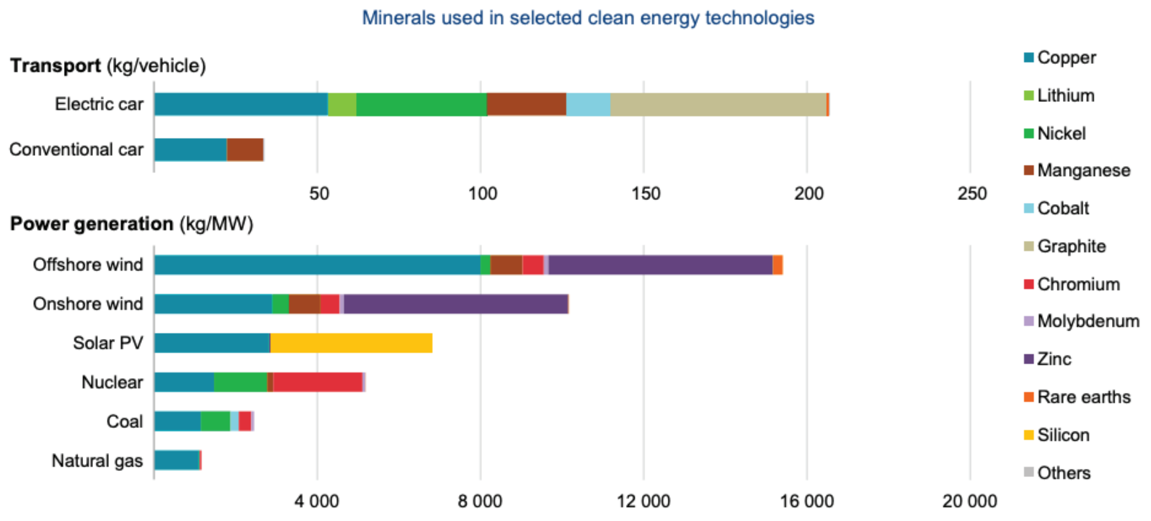
Figure 32: Metals and materials demand from LiB in passenger EVs



(Source: Guliya and Jain (2019))

According to Argonne National Laboratory, the battery pack for one EV car can contain up to 14 kg of cobalt, 8 kg of lithium, 20 kg of manganese and 35 kg of nickel (Castelvecchi, 2021). According to IEA, one EV car can contain up to 200 kg of minerals. Graphite, nickel, and copper are prevalent in clean energy transportation whereas copper, zinc, silicon, and chromium are prevalent in clean power generation technologies (see Figure 33). Recovering these will go a long way in ensuring that it does not pose a risk to the government's efforts towards accelerating a greater adoption of EVs.

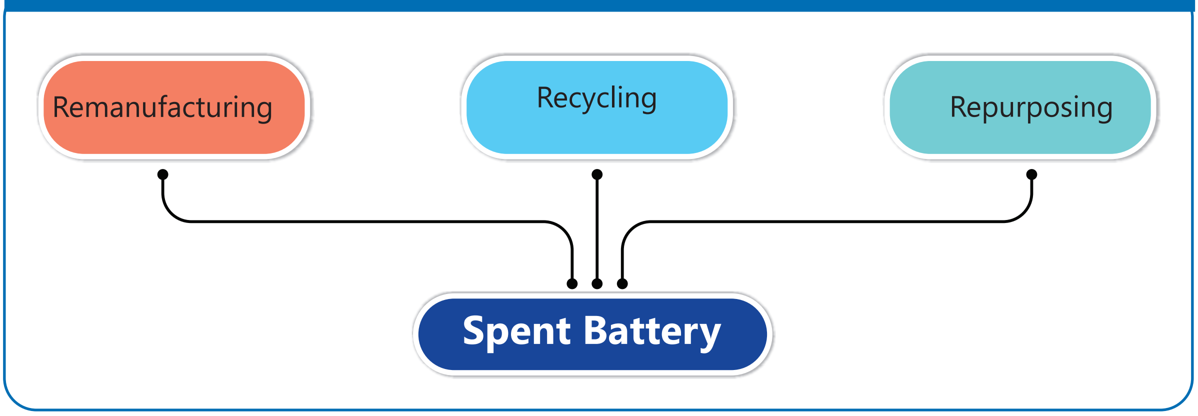
Figure 33: Minerals used in clean energy technologies



(Source: IEA (2021))

Most of the battery capacity will be captured by EV cars and 2-wheelers. Assuming a battery life span of 8 years in EVs and 3-5 years in secondary applications, a battery will reach its end-of-life after a service of 12 years on an average. Hereafter, this will tackle the supply-side obstacles to procuring sufficient stock of spent batteries for an economically viable recycling industry. Currently, India does not have enough supply of spent LiBs for recycling but soon India's EV fleet will begin to discard these batteries, which can be channelled to manufacture new LiBs once a circular value chain is established. Since the number of spent batteries will increase, it is necessary to establish LiB manufacturing based on recycled materials (urban mining) rather than on virgin materials (virgin mining). To tackle the stock of battery waste, there are three viable alternatives: a) remanufacturing, b) repurposing, and c) recycling.

Figure 34: Second life alternatives for spent EV battery



- Remanufacturing: Remanufacturing is basically the dis-assembling of the battery pack and replacing the damaged battery cells in the overall pack to achieve the previous material and energy efficiency (Kampker et al., 2021; Foster et al., 2014). Remanufacturing of EV batteries has been seen to be environmentally beneficial and economically viable (Xiong, Ji, and Ma, 2020; Foster et al., 2014). It is an effective circular economy strategy as EV battery cells retain around 90 per cent of their efficiency even after 10 years, and these can thus be reused and remanufactured for the second life cycle (Standridge and Hasan, 2015; Mahmood and Gutteridge, 2019).

- Repurposing: This is re-using the batteries for non-EV, stationary application. The cells are reconfigured with appropriate control systems (such as a battery management system) to be used for stationary application. Damaged cells are also replaced. This is an alternative to extend the battery life and bring down the overall cost of a battery (Standridge and Corneal, 2014; Kampker et al., 2021; Foster et al., 2014). Repurposing has been seen to be economically feasible but requires unique design, development and manufacturing activities. Lower research and development costs would make repurposing more profitable. (Foster et al., 2014).

- Recycling: Recycling is dis-assembling the entire battery pack and then reclaiming the economically valuable components through various mechanical, physical, and chemical processes. Recycling of LIBs has not been proven economically viable but this will eventually be needed for all spent batteries (Foster et al., 2014). After second life use, the cells will eventually be unable to hold sufficient charge to be used in any application and thus, need to be recycled. Further, literature like Standridge and Corneal (2014) and Foster et al. (2014) has shown that recycling will be profitable when the price of valuable components such as lithium increases by 17 to 20 times. As the price of valuable components increase, recycling will be an economically viable opportunity.

Policy relevance

Given the pursuit of sustainability, this study is relevant for policymakers in the context of circular economy. India has been taking various initiatives to ensure circularity in the economy. The government already notified the Plastic Waste Management Rules, e-Waste Management Rules, Construction and Demolition Waste Management Rules, Metals Recycling Policy, etc. A new draft of the battery waste management rules is also underway. To transform our economy from linear to circular, the government has identified 11 focus areas including scrap metal (ferrous and non-ferrous), electronic waste, lithium ion (li-ion) batteries, solar panels, etc.[84]

The Indian government has also been active in promoting the EV industry and facilitating its adoption. For instance, Phase I of the Faster Adoption and Manufacture of Hybrid and Electric Vehicles (FAME) scheme was launched in 2015 to fast track the goals laid out under NEMMP. The scheme targeted spending INR

[84] https://pib.gov.in/PressReleasePage.aspx?PRID=1705772

14,000 crore as incentives to manufacturers for R&D and for consumers for purchases, and as investment to develop the necessary charging infrastructure. FAME II was launched in April 2019 and entailed a budgetary support of INR 10,000 crore to promote the sale and manufacture of EVs. This new phase targets "electrification of public and shared transportation" and aims to support through demand incentives, approximately 7,000 e-buses, 5 lakh e-3 wheelers, 55,000 e-4 wheeler passenger cars, and 10 lakh e-2 wheelers, besides seeking to support the setting up of charging infrastructure. States/UTs have also taken different varied approaches to scale up EV deployment. For instance, Delhi's policies are driven by the need to tackle air pollution and to create more jobs for battery swapping operators; Karnataka plans to undertake R&D investment and developing itself as a technology hub while Kerala's focus is on using energy-efficiency systems; Tamil Nadu is looking to develop an EV venture capital fund, and on providing tax incentives for manufacturers, and subsidies for land and parking spaces for EVs. There are also several private sector initiatives to increase EV manufacturing and penetration in the country. For instance, National Thermal Power Corporation (NTPC), Indian Oil, and Tata Power plan to set up more charging stations across India; and Amara Raja is looking at enhancing its R&D capabilities to develop battery packs. Mahindra & Mahindra and Tata Motors are the major Indian EV manufacturers. The former has been the pioneer of electric mobility in India and introduced their first e-car in 2001.

Study approach

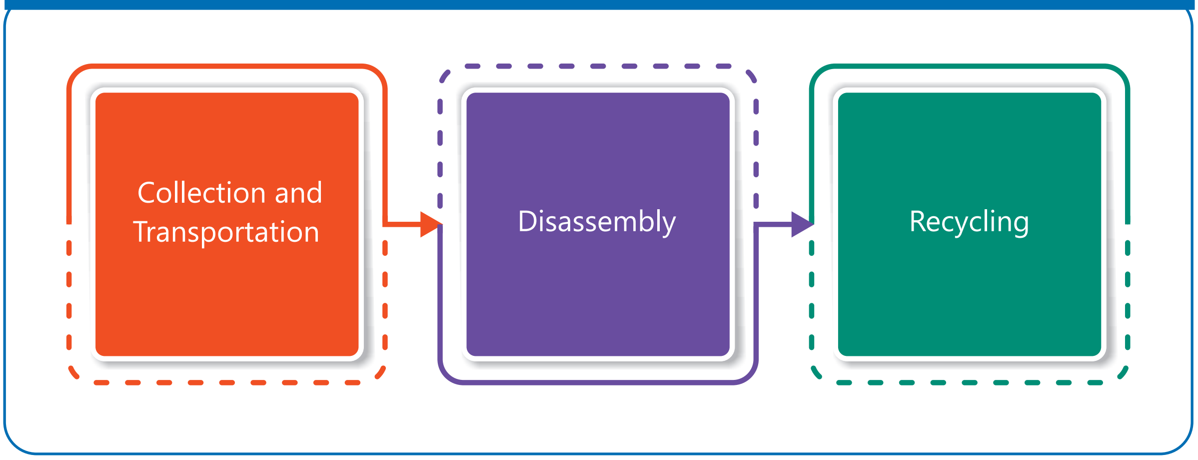
Given the urgent need to integrate circularity in the EV supply chain, this chapter looks at the financial and technological viability of LiB recycling in India. Since information related to technology and costs for LiB recycling in India is not publicly available, a scoping survey was conducted to collect data through a survey. The data was captured as a part of an ICRIER model to understand the techno-economics of LIB recycling. Twenty recyclers, consisting of both lead-acid and LiB recyclers, distributed across three states (Maharashtra, Haryana and Karnataka) were first identified. Primary data on recycling capacities, technologies used, and costs related to the installation of the recycling facility and its operation was collected from identified stakeholders through one-on-one meetings. Some of the inputs with respect to recycling cost have also been obtained from secondary data and literature.

The study provides an in-depth analysis of battery recycling techniques and other end-of-life options. Existing practices related to recycling and reusing of used batteries in India and other neighbouring countries have been analysed. As battery technologies are still emerging, variations in recycling techniques vis-à-vis battery chemistries have also been analysed. Besides, the chapter also explores how best practices followed in other countries could be applied in India. In order to inform policy, the study also provides recommendations on promoting recycling activity in India.

3. Methodology

For economic analysis and for understanding the financial viability of LiB recycling in the Indian context, a model called as 'open-loop battery recycling model' that focuses on estimating the cost related to collection and transportation, and the cost of recycling has been used. A schematic representation of the model is shown in Figure 35 below. The three parts represent the main cost components of the total recycling cost. Recycling cost is further broken down into initial capital expenditure (CAPEX) required to set up the plant and operating expenditure (OPEX) to run operations.

Figure 35: Open loop battery recycling model



3.1 Cost of collection and transportation

The transportation and collection in open loop battery recycling considers (1) transportation of the spent batteries from their last user to the collection site, and (2) transportation of the spent batteries from the collection site to the recycler. Medium-duty and heavy-duty vehicles are assumed to be the mode of transportation since LIBs are current characterised as hazardous materials for transportation.

The transportation cost is then calculated as follows:

$$\text{Transportation Cost}_{ij} = \sum_{i}^{n} \sum_{j} \text{Distance}_{ij} \times \text{Unit cost}_{j}$$

(Equation 1)

where distance (i,j) is the distance transported by mode j for segment i, and unit cost j is the unit transportation cost for mode j.

The contribution of transportation to the total recycling cost is 7 to 13 per cent for China, South Korea, and the US, depending on the recycling method (Lander and Kendrick, 2021).

3.2 Disassembly cost

Disassembly or dismantling is a complex and intricate process in LiB recycling. Due to lack of standardisation of EV batteries, it has been difficult to automate the disassembly process. Thus, manual disassembly with partial automation is prevalent, which is a time-consuming process and contributes significantly towards the total recycling cost. According to an estimate, for a Tesla Model S battery pack, the disassembly cost amounts to around 2 per cent to the total recycling cost in China, 11 per cent in the US, and 17 per cent in the UK. The significant cost variations is due to the differences in the cost of labour in developed and developing countries (Lander and Kendrick, 2021).

3.3 Cost of recycling

The cost of recycling is broken down into two parts: a) capital cost, and b) operating cost for calculating the total cost of recycling. Costs related to discharge and disassembly are not included in this analysis. Recyclers prefer processing through the hydrometallurgical route, therefore, only costs pertaining to hydrometallurgical routes is considered.

Model Inputs

The required inputs to estimate battery recycling cost include the following:

a) The chemistry of the battery to be recycled,

b) The throughput (tonnes of cells per year) of the recycling plant,

c) The cost of equipment used for the process,

d) The unit price of materials recovered from the process

Based on the specified shares of different chemistries in the spent batteries, the material composition of the feedstock to the recycling plant was calculated, assuming that the mass fraction of the material of spent batteries is the same as that of new batteries, as shown in Annexure (Table 31). The assumed lifetime for the plant is 20 years. These inputs were used to determine the investments needed and the revenue generated.

Table 24 summarises the end treatment of battery constituents of different recycling technologies. Only components that are recyclable have been considered to calculate the revenue after recycling. Components having low economic value (such as plastics, steel etc.,) have not been considered.

Table 24: Treatments of battery constituents for different recycling technologies

	Hydrometallurgical
Active cathode materials	Recycle
Graphite	Recycle
Copper	Recycle
Aluminium	Recycle
Steel	Recycle
Plastics	Burn for energy
Electrolyte	Burn for energy
Carbon black	Landfill
PVDF	Landfill

(Source: Dai et al., (2019))

The number of materials recovered from each of the recycling technologies is determined by the amount of each material in the feedstock.

The default recovery efficiency of each material assumed is summarised in Table 25.

Table 25: Material recovery efficiencies for different recycling technologies	
	Hydrometallurgical
Copper	90%
Steel	90%
Aluminium	90%
Graphite	90%
Plastics	50%
Lithium	90%
Cobalt in output	98%
Nickel in output	98%
Manganese in output	98%

(Source: Dai et al., (2019))

The unit price of materials recovered from the process is shown below in Table 30. Steel and plastics are assumed to be recovered and sold as scrap. In this model, recovered Co/Ni/Mn/Li compounds from cathode materials via hydrometallurgical recycling routes are typically considered as "good as new" by cathode powder producers and therefore are assumed to sell at the same prices as their virgin counterparts.

Finally, the total battery recycling cost is calculated as the sum of transportation cost and recycling cost as shown in Equation 2.

Net recycling cost=transportation cost+recycling cost

(Equation 2)

3.4 Cash flow

A financial model has been constructed to estimate the annual revenue that will be generated (Figure 36). The input components in this model are capital cost, operations costs, transportation cost, etc., and the output is calculated in terms of the market price of the processed metals. The operating cost includes materials and consumables, labour, utilities, maintenance, and general and administrative costs.

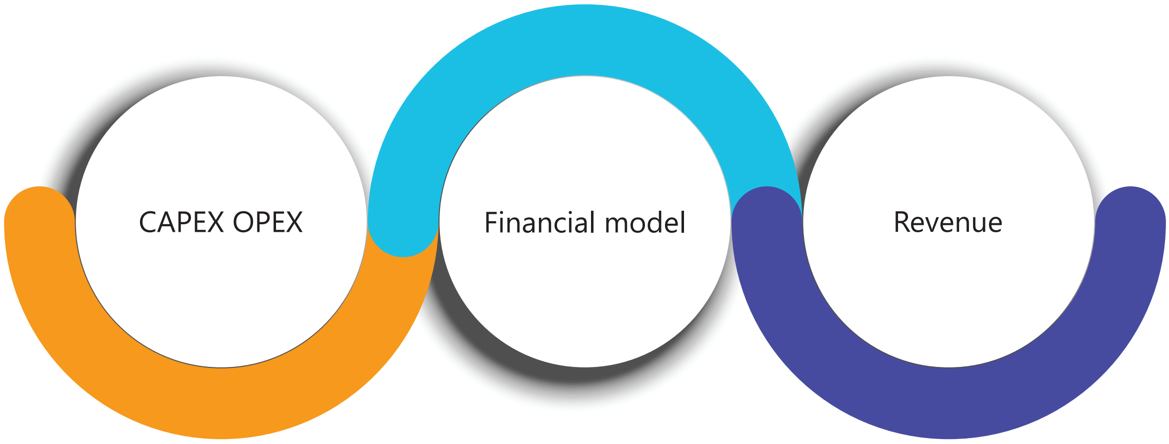
A debt-equity ratio of 70:30 has been considered with the cost of financing assumed to be 7 per cent per annum. A loan payback period of 10 years has been assumed in the cash flow analysis. The capital recovery factor has been calculated based on equation 3 given below and annuity has then been calculated for 10 years.

$$\text{Capital recovery factor } (\text{CRF (i, N)}) = \frac{i(1+i)^N}{(1+i)^N - 1}$$

(Equation 3)

where i = real discount rate and N = number of years

Figure 36: The financial model for a 1 GWh LiB recycling plant



4. Analysis

In this analysis, the case study of a generic LiB recycling unit of capacity 5000 -7000 tons/annum[85] has been considered. The recycling plant has an annual capacity of 1 GWh.[86] To create the income statement forecast for a project life of 20 years,[87] we assumed a constant capacity utilisation of 90 per cent of the total plant capacity.

4.1 Transportation and collection cost

In India, the unit cost for different transportation modes under different transportation scenarios is shown in Table 26; these values for transportation (including collection and handling cost) have been obtained through the survey.

Table 26: Unit cost (INR/ton-km) for different transportation modes

	(INR/ton-km)
Heavy heavy-duty truck	5
Medium heavy-duty truck	5

(Source: ICRIER survey findings)

Assuming that a spent LiB has to be transported over an average distance of 800 km before it reaches the recycling plant[88], a recycling plant of capacity 5000-7000 tons will incur a cost of INR 2 crore **(USD 0.27 million)**[89] per annum for transportation.

[85] ICRIER survey findings

[86] LIB Mass - energy density of 200 Wh/kg has been considered (Yuan et al., 2014)

[87] Generic industrial plant in India

[88] ICRIER survey findings

[89] ICRIER survey findings

4.2 Disassembly cost

The disassembly costs amount to USD 0.25 per kWh (Lander and Kendrick, 2021). Therefore, for 1 GWh of annual capacity, the total disassembly cost amounts to **USD 0.25 million**.

4.3 Recycling cost (CAPEX & OPEX)

The initial capital cost has been obtained from the survey and is shown in the table below. The total capital cost of installing a LiB recycling unit of 5000-7000 tonnes/annum capacity is approximately USD 10.15 million.

Table 27: Capital expenditure (CAPEX)

Capital	USD (million)	Data Source
Capital equipment	5	ICRIER survey findings
• Machinery		
• Mechanical – Shredders		
• Conveyors		
• Reactors		
Installation & construction cost	1	ICRIER survey findings
Technology Acquisition Cost	2	ICRIER survey findings
R&D and testing laboratory set-up cost	0.5	ICRIER survey findings
Land	0.4	Estimated from EverBatt model
Building	1.25	Estimated from EverBatt model
Total	10.15	

(Source: ICRIER survey findings, Dai et al., (2019))

The operating cost has been estimated based on a consumption cost of USD 1,560/tonne of cathode material processed (Neometals, 2021).

Table 28: Operating cost (OPEX)

Heads	USD/ton
Reagents and Consumables	521
Utilities	412
Labour	357
General and Administration	200
Maintenance	70
Total operating cost/tonne	1560
Total annual operating cost (million USD)	7.8
Total annual operating cost including transportation and disassembly (million USD)	8.31

(Source: ICRIER survey findings, Neometals (2021))

4.4 Revenue calculation

Considering a feedstock ratio of NMC111, LFP and NCE of 64:23:13,[90] the maximum amount of metals (in kilograms) that can be recovered with highest possible recycling efficiency and highest recovery efficiency, and annual revenue has been calculated in Table 29. Revenues have been determined by the market selling price of the LiB material powders as shown in Table 30.

The total capital expenditure (CAPEX) for the plant is estimated at USD 8.5 million. Operating expenditure is estimated to be USD 1,560 per tonne (excluding transportation and collection charges).

It has been assumed that the plant operates at a maximum capacity of 90 per cent. Besides, it has been assumed that hydrometallurgical recovery efficiency is the highest possible for lithium, nickel, and cobalt (95 per cent). The recovery efficiency for manganese has been assumed at 78 per cent while a recovery percentage of 90 per cent has been assumed for graphite, based on the survey data and EverBatt model. The total annual revenue has been calculated based on the assumption that 1 GWh of batteries will be processed in one year. The prices of metals recovered has been based on the prices in the EverBatt model as shown in Table 30. The total annual revenue has been calculated based on the prices and mass of metals recovered as shown in Table 29 below. The total annual revenue so estimated amounts to USD 8.46 million.

Table 29: Estimation of mass (in kg) and cost of materials recovered in 1 GWh of feedstock

	Li	Co	Ni	Mn	C	Cu	Al
LCO							
NMC111 - (64%)	88960	252160	250880	234880	768000	480000	256000
LFP - (23%)	34500	0	0	0	184000	172500	92000
NCA - (12%)	13440	17160	91080	0	144000	90000	48000
Total recoverable mass (kg)	136900	269320	341960	234880	1096000	742500	396000
Plant working capacity	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Recovery efficiency	0.95	0.95	0.95	0.78	0.90	0.90	0.90
Mass recovered (tonne)	117	230	292	165	888	601	321
Current prices (USD/tonne)	8440	32000	4868	561	280	1980	1300
Revenue (USD)	987898	7368595	1423285	92501	248573	1190822	416988
Total Revenue (million USD)	11.73						

Notes:

a. *Recovery of steel has not been considered because of its low economic value.*

b. *While calculating the mass of metals from 1 GWh of capacity, an average energy mass density of 200 Wh/kg has been considered (Wentker, Greenwood, and Leker 2019).*

c. *Copper mass fraction of 15% has been considered*

d. *Aluminium mass fraction of 8% has been considered*

e. *Lithium constitutes 3% in the LFP battery - based on molar mass fraction*

Source: Authors' calculations based on Neometals (2021); Olivetti et al., (2017); Dai et al., (2019)

[90] This ratio is based on survey results. NMC: Nickel, Manganese and Cobalt; LFP: Lithium, Iron Phosphate and NCA: Nickel, Cobalt, and Aluminium based battery

Table 30: Price of battery materials	
Commodity	**Price (USD per tonne)**
Cobalt sulphate	32,000
Lithium chloride	8,440
Nickel sulphate	4,868
Copper as sulphate	2,000
Copper as foil	1,980
Manganese sulphate	561
Graphite	280
Aluminium	1,300

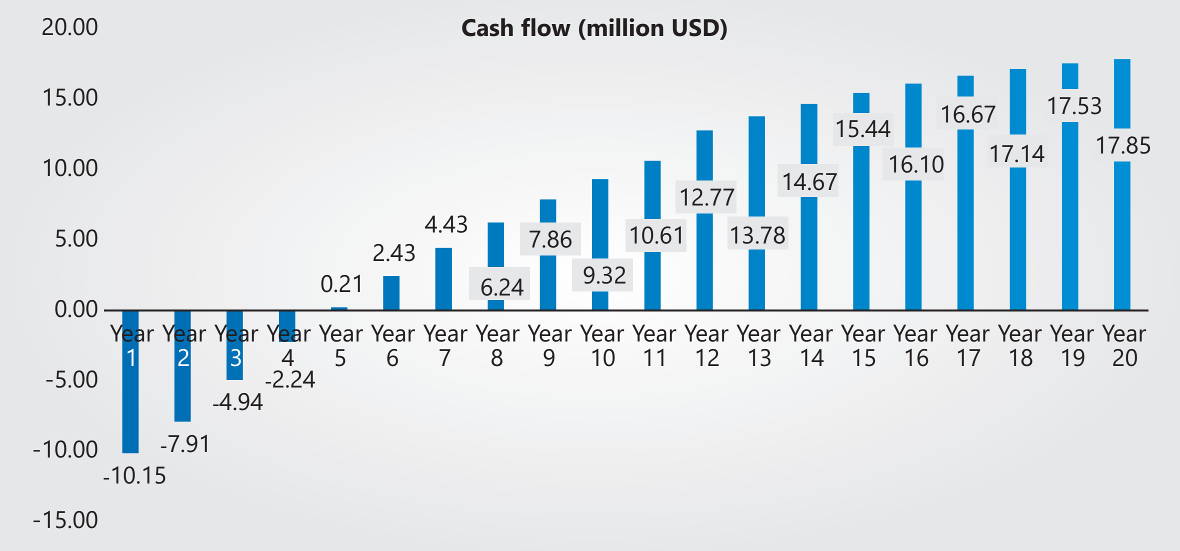
(Source: Dai et al. (2019); Neometals (2021); Guliya and Jain (2019))

4.5 Cash flow

Assuming the plant life to be 20 years, and that it will take one year to set up the plant, a cash flow diagram for the complete plant life cycle has been constructed (see Figure 37). Capital investment at the beginning of year 1 is approximately USD 10.15 million. From the second year onwards, a depreciation of 5 per cent has been assumed in the capital investment, making it USD 0.51 million per year in depreciation. As shown in Table 28, the operating expenditure was calculated at USD 8.31 million and will be applicable from the second year onwards. Total investments (OPEX and depreciation) from the second year onwards, therefore, will be USD 8.82 million while a revenue of USD 11.73 million will start flowing in from the end of second year onwards. The total accumulated cash flow with a discount rate of 5 per cent has been considered to calculate the future inflows of cash to find net present value (NPV). The estimated cash flow shows that the recycling plant will only be profitable after five years as shown in Figure 37. (Refer: Appendices Table 32).

With a debt-equity ratio of 70:30, cost of financing at 7 per cent per annum and a loan payback period of 10 years, the capital recovery factor (CRF) is estimated at around 0.1423 and annuity is calculated as USD 1.011 million for 10 years to be considered in the final cash flow diagram as shown below.

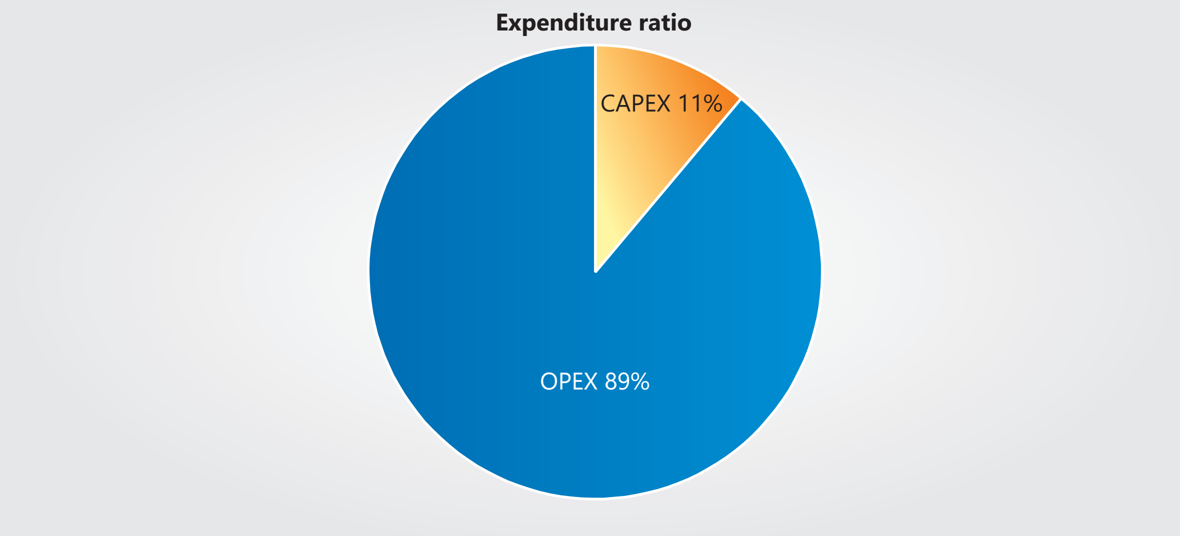
Figure 37: Estimated cash flow (million USD)



(Source: Based on authors' calculations)

When analysing the components of expenditure, CAPEX constitutes only 11 per cent, while OPEX constitutes a larger portion at 89 per cent as shown in Figure 38. Hence R&D to improve recycling technology that reduces the operating cost will improve the profitability of the industry.

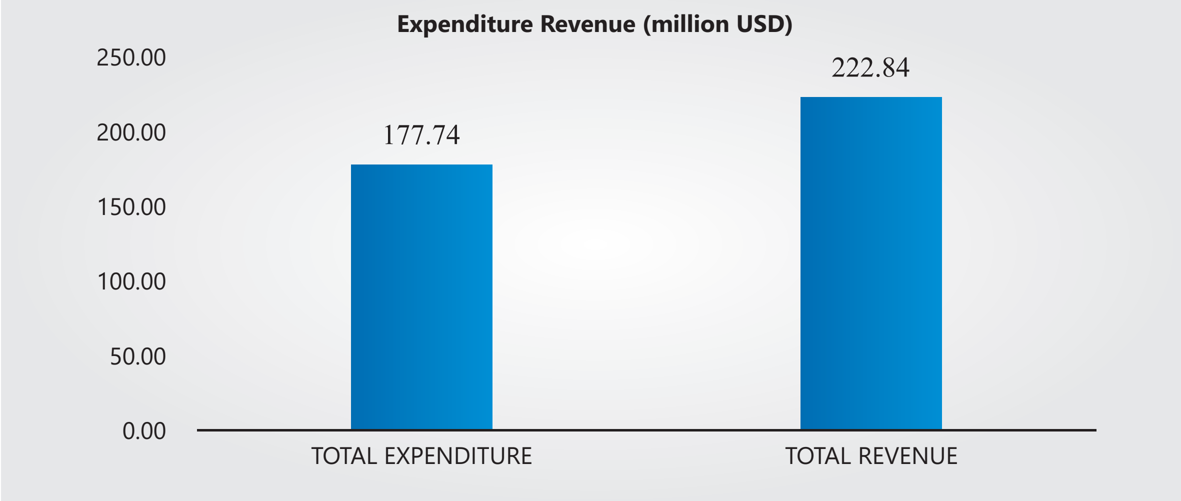
Figure 38: Capital expenditure – operating expenditure ratio



(Source: Authors' calculations)

Over the 20-year lifetime of the plant, the calculations indicate a total expenditure in the range of USD 177 million and total revenue of USD 222 million. The benefit cost ratio comes out to be 1.25. The annualised return on investment is estimated at around 9.33 per cent, which is above current market rates.

Figure 39: Cost benefit analysis (USD million)

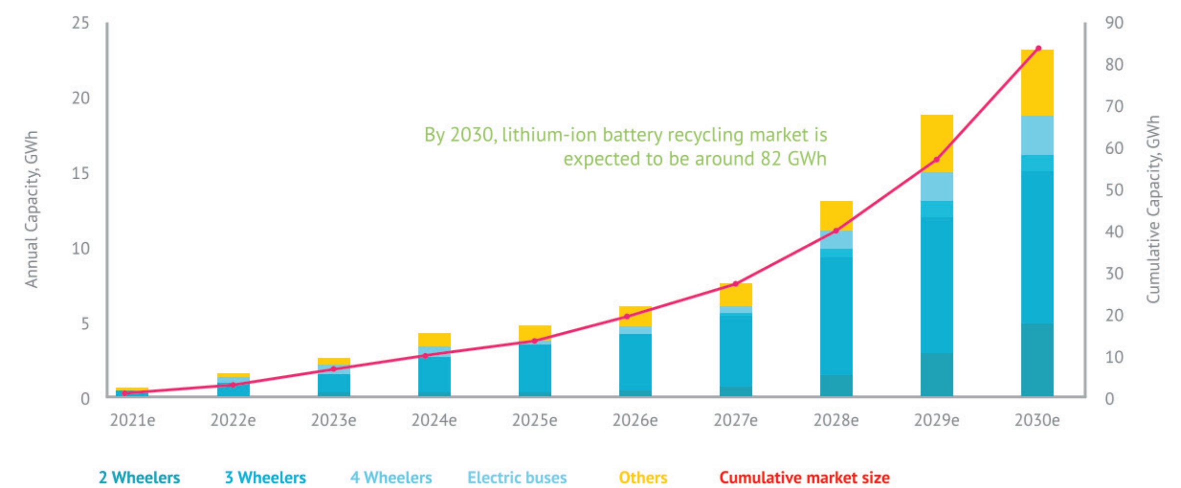


(Source: Authors' calculations)

4.6 Investments needed for recycling capacity

Currently, the demand for recycling in India is quite low, since the low penetration of EVs in the automobile fleet implies that there is not enough supply of spent LiBs to recycle. But Guliya and Jain (2019) estimate that the quantity of spent batteries will amount to a cumulative 80 GWh by year 2030 and an annual recycling capacity of 22-23 GWh will be reached by the year 2030 (see Figure 40), which is significantly larger than the capacity in 2021.

Figure 40: LiB recycling market in India

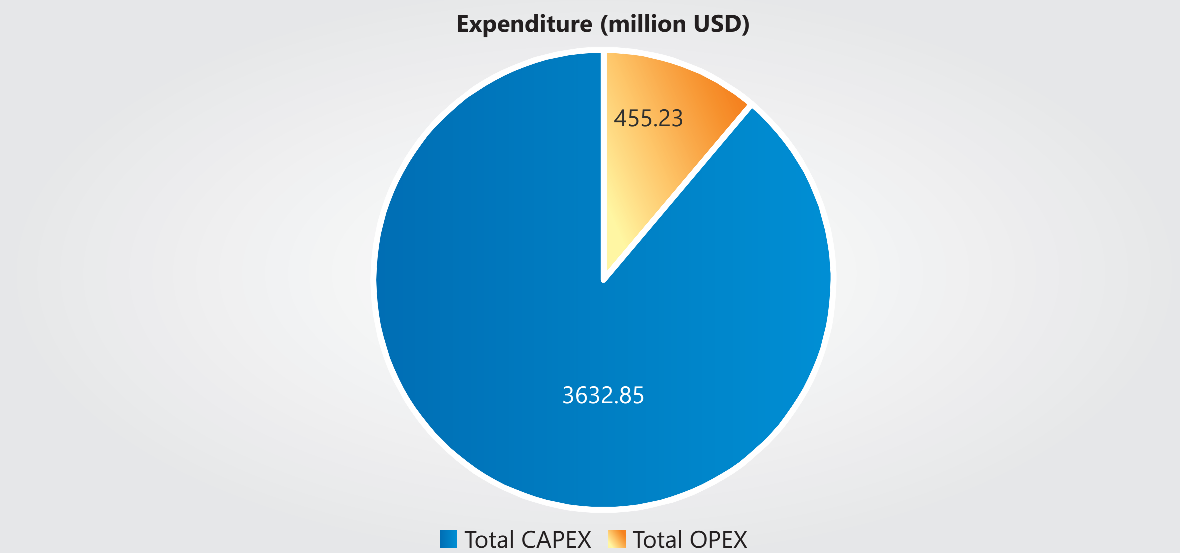


(Source: Guliya and Jain (2019))

Understanding the future projection of spent LiB in India is an important part of the analysis. It provides an estimate of future recycling market potential and has been used to assess the appropriate scale of investment needed to establish full recycling capacity by the year 2030.

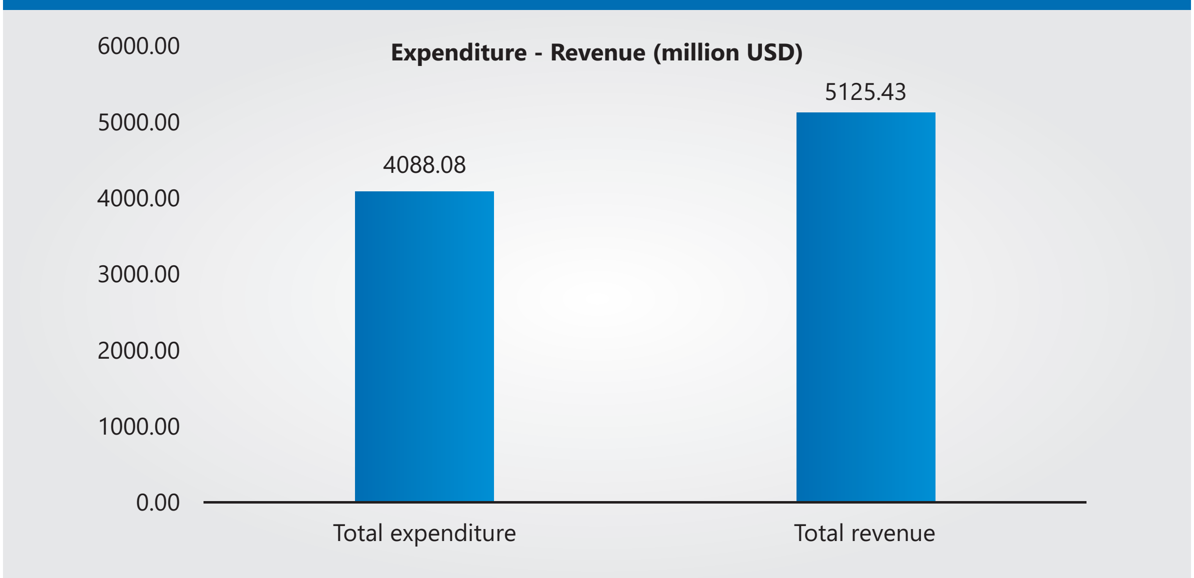
To do so, India will need to invest a total of USD 4.088[91] billion cumulatively to install and operate the infrastructure needed for recycling 23 GWh of spent battery (see Figure 41). The total CAPEX needed is USD 455 million, the total OPEX will amount to USD 3.6 billion, while the total revenue generated will be USD 5.1 billion (see Figure 42).

Figure 41: CAPEX – OPEX needed for India by 2030



(Source: Authors' calculations)

Figure 42: Revenue expenditure (USD million) for India by 2030



(Source: Authors' calculations)

[91] This value is estimated by scaling up proportionally the investment needed for a 1 GWh capacity LIB recycling plant.

5. Conclusion

The analysis shows that LiB recycling infrastructure is highly capital intensive to install, requiring more than USD 10 million for only initial capital expenditure. It also requires complex hydrometallurgical technologies for its operation, while the cost involved in installing hydrometallurgical technologies (equipment including conveyers, shredders, etc.,) alone is projected around USD 5 million. Operating cost is also high, together with the high amount of charges involved just in collection and transportation. Further, there is limited supply of spent LiBs that restrict the growth of LiB recycling. Increasing the recycling capacity may result in the sector achieving economy of scale, and eventually higher profitability.

There is need for a technology agnostic approach to recycling to increase the coverage of ever evolving EV batteries. An individual recycling unit does not recycle more than three types of LiBs. Only standardised technology can make a recycling unit more profitable while continuously increasing its recycling coverage (all type of battery) and recycling capacity. Transportation costs were identified as a major hurdle; aggregation of waste could be explored to improve profitability.

Hydrometallurgy and hydrometallurgy combined with pyrometallurgy is a prevalent recycling method with cobalt and lithium recovery greater than 95 per cent; in one case, it was even more than 99 per cent. Further, recycling firms would prefer only hydrometallurgical method. There is a need of high R&D on sustainable technologies (such as hydrometallurgy) which does not result in higher carbon emission.

It is suggested that the government develops market mechanisms that support financing and technology adoption for LIB recycling. In the absence of proper support, smaller players would be eliminated from the recycling market. Most small players are currently involved in LAB recycling as they do not have the requisite technological and financial capacity to set up LiB recycling plants. To reduce transport and collection costs, there is a need for localisation of recycling activities. For this, it is necessary to develop technology agnostic recycling to cover all kinds of batteries. Setting up recycling plants in a strategically distributed manner will bring down the need for transportation over long distances, bringing down cost. Localisation will also generate local economic activity, given recycling will be a significant industry with a potential valuation of over USD 1 billion in the future.[92] Highly efficient logistical improvements in collection and transportation of spent lithium battery packs, which are hazardous in nature, are needed to make recycling profitable from the 2nd or 3rd year of its operation.

[92] Available at:https://jmkresearch.com/electric-vehicles-published-reports/recycling-of-lithium-ion-batteries-in-india-1000-million-opportunity/ Accessed on February 4, 2022

References

Castelvecchi, By Davide. 2021. "Electric Cars : The Battery Challenge." Nature. https://www.nature.com/articles/d41586-021-02222-1.

Coffin, David, and Jeff Horowitz. 2018. "The Supply Chain for Electric Vehicle Batteries" Journal of International Commerce and Economics, December 2018. https://www.usitc.gov/journals.

Cossu, Raffaello, and Ian D. Williams. 2015. "Urban Mining: Concepts, Terminology, Challenges." Waste Management 45: pp. 1–3. https://doi.org/10.1016/j.wasman.2015.09.040.

CSTEP. 2018. "Indigenisation of Lithium-Ion Battery Manufacturing: A Techno-Economic Feasibility Assessment." Journal of Chemical Information and Modeling 53 (9): 1689–99. https://cstep.in/drupal/sites/default/files/2019-01/CSTEP_RR_LiB_Indigenisation_July2018.pdf.

Dai, Qiang, Jeffrey Spangenberger, Shabbir Ahmed, Linda Gaines, Jarod C. Kelly, and Michael Wang. 2019. "EverBatt: A Closed-Loop Battery Recycling Cost and Environmental Impacts Model." Argonne National Laboratory, 1–88.

Foster, Meaghan, Paul Isely, Charles Robert Standridge, and Md Mehedi Hasan. 2014. "Feasibility Assessment of Remanufacturing, Repurposing, and Recycling of End of Vehicle Application Lithium-Ion Batteries." Journal of Industrial Engineering and Management 7(3): 698–715. https://doi.org/10.3926/jiem.939.

Gode, Pramoda, Georg Bieker, and Anup Bandivadekar. 2021. "Battery Capacity Needed to Power Electric Vehicles in India from 2020 to 2035," . Int. Counc. Clean Transp, February 2021: 1–16.

Guliya, Jyoti, and Shilpi Jain. 2019. "Recycling of Lithium-Ion Batteries in India." JMK Research & Analytics. https://jmkresearch.com/electric-vehicles-published-reports/recycling-of-lithium-ion-batteries-in-india-1000-million-opportunity/.

International Energy Agency. 2018. "Global Outlook 2018" 2012 (2): 17.

International Energy Agency. 2021. "The Role of Critical Minerals in Clean Energy Transitions." IEA Publications.

Jones, Ben, Robert J.R. Elliott, and Viet Nguyen-Tien. 2020. "The EV Revolution: The Road Ahead for Critical Raw Materials Demand." Applied Energy 280 (August 2019): 115072. https://doi.org/10.1016/j.apenergy.2020.115072.

Kampker, Achim, Saskia Wessel, Falko Fiedler, and Francesco Maltoni. 2021. "Battery Pack Remanufacturing Process up to Cell Level with Sorting and Repurposing of Battery Cells." Journal of Remanufacturing 11(1): 1–23. https://doi.org/10.1007/s13243-020-00088-6.

Lander, Laura, and Emma Kendrick. 2021. "Financial Viability of Electric Vehicle Lithium-Ion Battery Recycling Vehicle Lithium-Ion Battery Recycling." ISCIENCE 24 (7): 102787. https://doi.org/10.1016/j.isci.2021.102787.

Mahmood, Khalid, and Fiona Gutteridge. 2019. "EV Batteries Remanufacturing," no. May.

Neometals. (2021). ANNUAL REPORT 2021 : A MINERALS AND ADVANCED MATERIALS PROJECT DEVELOPMENT COMPANY. Neometals.

Olivetti, Elsa A., Gerbrand Ceder, Gabrielle G. Gaustad, and Xinkai Fu. 2017. "Lithium-Ion Battery Supply Chain Considerations: Analysis of Potential Bottlenecks in Critical Metals." Joule 1 (2): 229–43. https://doi.org/10.1016/j.joule.2017.08.019.

Recycling/Urban mining. (2021). Retrieved from SINTEF: https://www.sintef.no/en/expertise/sintef-industry/process-industry/recycling-urban-mining/

Singh, Vaibhav, Kanika Chawla, and Saloni Jain. 2020. Financing India's Transition to Electric Vehicles: A USD 206 Billion Market Opportunity (FY21 - FY30). New Delhi: Council on Energy, Environment and Water. Available on: https://www.ceew.in/cef/solutions-factory/publications/CEEW-CEF-financing-india-transition-to-electric-vehicles.pdf

Standridge, Charles R., and Lindsay Corneal. 2014. "MNTRC Report 12-20 Remanufacturing, Repurposing, and Recycling of Post-Vehicle-Application Lithium-Ion Batteries."

Standridge, Charles Robert, and Md Mehedi Hasan. 2015. "Post-Vehicle-Application Lithium–Ion Battery Remanufacturing, Repurposing and Recycling Capacity: Modeling and Analysis." Journal of Industrial Engineering and Management 8(3): 823–39. https://doi.org/10.3926/jiem.1418.

Statista. 2020. "Lithium-Ion Batteries Worldwide." Statista Dossier on Lithium-Ion Batteries. https://www.statista.com/study/22772/lithium-ion-batteries-statista-dossier/.

Urban Mining. (2015). Retrieved from European Environment Agency: https://www.eea.europa.eu/atlas/eea/copy3_of_folder-story-template

Wentker, Marc, Matthew Greenwood, and Jens Leker. 2019. "A Bottom-up Approach to Lithium-Ion Battery Cost Modeling with a Focus on Cathode Active Materials." Energies 12(3): 1–18. https://doi.org/10.3390/en12030504.

Xiong, Siqin, Junping Ji, and Xiaoming Ma. 2020. "Environmental and Economic Evaluation of Remanufacturing Lithium-Ion Batteries from Electric Vehicles." Waste Management 102: 579–86. https://doi.org/10.1016/j.wasman.2019.11.013.

Xu, Chengjian, Qiang Dai, Linda Gaines, Mingming Hu, Arnold Tukker, and Bernhard Steubing. 2020. "Future Material Demand for Automotive Lithium-Based Batteries." Communications Materials 1(1). https://doi.org/10.1038/s43246-020-00095-x.

Yuan, Ding, Cano Zachary, Aiping Yu, Jun Lu, and Zhongwei Chen. 2014. "Automotive Li-Ion Batteries: Current Status and Future Perspectives,". Electrochemical Energy Reviews, 2(1), pp.1-28.

Zeng, Xianlai, Tongxin Xiao, Guochang Xu, Eva Albalghiti, Guijuan Shan, and Jinhui Li. 2021. "Comparing the Costs and Benefits of Virgin and Urban Mining." Journal of Management Science and Engineering, May. https://doi.org/10.1016/J.JMSE.2021.05.002.

Ziegler, Micah S., and Jessika E. Trancik. 2021. "Re-Examining Rates of Lithium-Ion Battery Technology Improvement and Cost Decline." Energy and Environmental Science 14(4): 1635–51. https://doi.org/10.1039/d0ee02681f.

Appendices

Table 31: LiB cell mass fraction					
	NMC (111)	**LCO**	**NCA**	**LMO**	**LFP**
Cell BOM[93]					
Active cathode material	34.70%	35.30%	30.60%	40.80%	32.70%
Graphite	19.40%	18.50%	22.10%	14.10%	16.80%
Carbon black	2.30%	2.40%	2.10%	2.70%	2.20%
Binder: PVDF	3.00%	3.00%	2.90%	3.00%	2.70%
Copper	15.70%	16.10%	16.70%	15.00%	13.90%
Aluminium	8.20%	8.10%	8.60%	7.80%	7.50%
Electrolyte: LiPF6	2.20%	2.20%	2.30%	2.20%	3.40%
Electrolyte: EC	6.20%	6.00%	6.30%	6.10%	9.40%
Electrolyte: DMC	6.20%	6.00%	6.30%	6.10%	9.40%
Plastic: PP	1.50%	1.80%	1.60%	1.50%	1.30%
Plastic: PE	0.30%	0.30%	0.40%	0.30%	0.30%
Plastic: PET	0.30%	0.30%	0.30%	0.30%	0.30%
Cell mass (kg)	0.856	0.866	0.75	1.045	1.054

(Source: Dai et al., (2019))

Table 32: Cash flow analysis (values in million USD)									
S. no	**CAPEX**	**OPEX**	**Expenditure**	**Revenue**	**Flow**	**Accumulated**	**Acc-(NPV)**	**Debt recovery**	**Total flow**
Year 1	10.15		10.15		10.15	-10.15	-10.15		-10.15
Year 2	0.51	8.31	8.82	11.73	2.91	-7.24	-6.90	1.01	-7.91
Year 3	0.51	8.31	8.82	11.73	2.91	-4.33	-3.93	1.01	-4.94
Year 4	0.51	8.31	8.82	11.73	2.91	-1.43	-1.23	1.01	-2.24
Year 5	0.51	8.31	8.82	11.73	2.91	1.48	1.22	1.01	0.21
Year 6	0.51	8.31	8.82	11.73	2.91	4.39	3.44	1.01	2.43
Year 7	0.51	8.31	8.82	11.73	2.91	7.30	5.45	1.01	4.43
Year 8	0.51	8.31	8.82	11.73	2.91	10.21	7.25	1.01	6.24
Year 9	0.51	8.31	8.82	11.73	2.91	13.11	8.88	1.01	7.86
Year 10	0.51	8.31	8.82	11.73	2.91	16.02	10.33	1.01	9.32

S. no	CAPEX	OPEX	Expenditure	Revenue	Flow	Accumulated	Acc-(NPV)	Debt recovery	Total flow
Year 11	0.51	8.31	8.82	11.73	2.91	18.93	11.62	1.01	10.61
Year 12	0.51	8.31	8.82	11.73	2.91	21.84	12.77		12.77
Year 13	0.51	8.31	8.82	11.73	2.91	24.75	13.78		13.78
Year 14	0.51	8.31	8.82	11.73	2.91	27.65	14.67		14.67
Year 15	0.51	8.31	8.82	11.73	2.91	30.56	15.44		15.44
Year 16	0.51	8.31	8.82	11.73	2.91	33.47	16.10		16.10
Year 17	0.51	8.31	8.82	11.73	2.91	36.38	16.67		16.67
Year 18	0.51	8.31	8.82	11.73	2.91	39.29	17.14		17.14
Year 19	0.51	8.31	8.82	11.73	2.91	42.19	17.53		17.53
Year 20	0.51	8.31	8.82	11.73	2.91	45.10	17.85		17.85
Total	19.79	157.95	177.74	222.84					

(Source: Authors' calculations)

Chapter 8

Understanding employment potential of battery recycling in India

Authors:

Dr. Amrita Goldar
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1. Introduction

The world is moving towards a circular economy with an expanding fleet of electric vehicles (EV). India too, has ambitious plans to achieve EV sales penetration targets of 30 per cent for private cars, 70 per cent for commercial cars, 40 per cent for buses, and 80 per cent for two and three-wheelers by 2030, according to a 2019 NITI Aayog report. If these targets are achieved, there will a corresponding rise in the number of spent LIBs and will necessitate battery waste management, including the setting up of recycling facilities to ensure that these do not up in landfills and pose an environmental and health hazard.

Quite apart from the environmental benefits, there are other social benefits associated with battery recycling. It will provide an opportunity to ensure a complete and successful transition to electric mobility, create business opportunities and provide employment (ORF, 2020). According to a Council on Energy, Environment and Water (CEEW) 2020 report, the achievement of the 2030 EV ambitions will create 1,21,422 jobs across the EV value chain in 2030 itself. These numbers, however, include only those jobs created in battery, powertrain, and charging infrastructure manufacturing and jobs in the electricity sector due to increased electricity consumption by EVs. The CEEW study did not look at the new avenues of job creation that will emerge with the EV transition, namely battery recycling (urban mining), installation, and operation of charging infrastructure, and other services associated with electric mobility, helping offset some of the job losses in the oil and automotive sector likely to result from the phasing out of ICE vehicles. While a loss of jobs in the value-added transition is expected, the transition will need to be just and of promoting equity for all involved stakeholders. The potential of new skilled job creation in the EV sector, particularly in the battery recycling sector has the capability to drive this transition.

Policy Relevance

As India moves ahead on its ambitious EV mobility plans, leading battery manufacturers are setting up battery assembly units, moving into the lithium-ion cell manufacturing business. The higher scale of operations in the battery sector will necessitate recycling and safe disposal of spent batteries. The recycling market in India is expected to pick up pace from 2022 when in-use LIBs will reach their end of life. JMK Research & Analytics (2019) estimates the annual recycling market to translating to an opportunity worth USD 1,000 million in 2030. The combination of a possibly huge and expanding battery market and a growing recycling sector could result in generating employment and economic growth.

To fully utilise this potential, it is necessary to understand the effects of the transition to EVs on employment to enable effective policies. This study contributes to the existing sparse literature on employment in recycling by providing an understanding of the current status and employment generation potential of the battery recycling sector. The analysis will help pinpoint skill gaps as well as the existing advantages. The study uses a combination of a top-down and bottom-up analytical approach.

The structure of the rest of the paper is as follows. Section 2 discusses the research framework with key research focus and the methodology followed; Section 3 analyses secondary data on employment in the hazardous waste sector while Section 4 provides the survey-based results and compares the findings with those derived from the secondary data analysis. Section 5 talks about the dilemma of quality job creation, Section 6 provides policy recommendations, and Section 7 concludes the paper.

2. Research Framework

Key research focus

The study uses a two-step approach to examine employment in battery recycling, examining the broader hazardous waste sector of which batteries are an essential part first, and then examining the battery sector itself. The research focuses on the following issues:

- Hazardous waste sector secondary data analysis: Identification of employment patterns, existing skill prevalence and gaps, as well as issues in this sector
- Identification of the informal component in the existing hazardous sector workforce
- Primary survey data on battery recycling firms: Corroboration of the previously identified factors or identification of distinctive patterns in the employment structure in the battery recycling sector
- Quality of jobs: An assessment of the quality of jobs being created in the sector

This will help identify the pattern of employment, the characteristics of the structure of employment and the skills gaps to draw their implications for required policies and to facilitate a smoother EV transition.

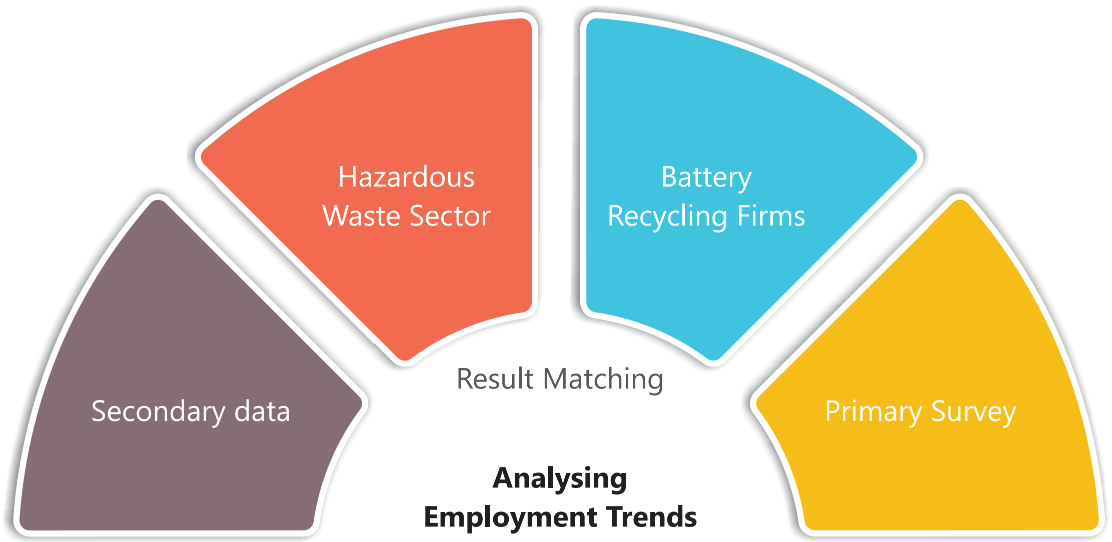
Methodology

The employment analysis in this paper is a combination of a top-down and a bottom-up approach to analysis.

The first step uses a top-down approach, using secondary data for the hazardous waste sector from the latest Periodic Labour Force Survey (PLFS) for 2019-20. PLFS is the new and modified version of the quinquennial employment-unemployment survey (EUS) rounds of the National Sample Survey Organisation (NSSO) aimed at measuring quarterly changes in various labour market statistical indicators in urban areas and generating annual estimates for these indicators both for rural and urban areas. Since there is no specific data on particular hazardous waste, or for e-waste categories, the paper uses data on industries categorised in 'division 38' of the National Industrial Classification (NIC)-2008, which deals with the waste sector. Details on the exact choice of industries are discussed in a later section. The data has been used to examine employment in the hazardous waste industry and outline the probable employment structure in the battery recycling sub-segment.

The second step focuses on a bottom-up approach and uses primary data from the survey of battery recycling firms to first identify possible differences from the findings of the secondary data analysis and second, to outline the current employment structure of battery recycling firms in the three sample states of Maharashtra, Karnataka, and Haryana. These approaches complement each other, facilitating an understanding of employment trends and potential in the battery recycling sector (see Figure 43).

Figure 43: Methodology Structure

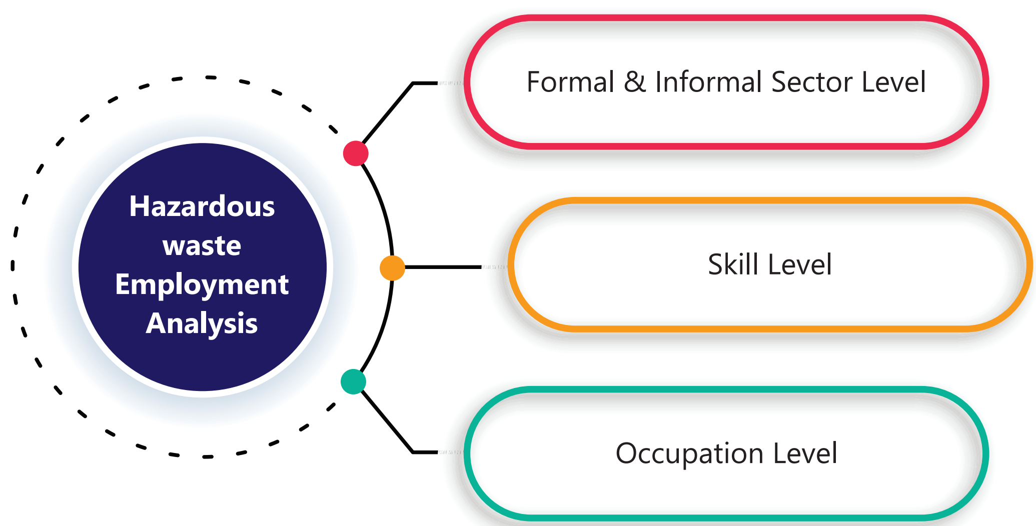


Further, the quality of jobs assessment uses PLFS 2019-20 data on a few vital parameters that define job quality to provide an understanding of the trade-off between volume of employment and the quality of jobs generated in the hazardous waste sector. This will help to identify 'decent work' factor in the sector. Due to the survey data of battery recycling firms being limited in scope, the quality of jobs analysis in the broader hazardous waste sector will help to identify probable patterns that might arise in the battery sub-segment.

3. Secondary Data Analysis: Hazardous Waste Sector

The existing structure of employment in the hazardous waste sector has been looked at in terms of three aspects – division of employment between the informal and formal sectors, skill levels and functional distribution of jobs (see Figure 44) – using data from the PLFS 2019-20.

Figure 44: Hazardous waste employment analysis: Coverage



3.1 Identification of industries

In India, batteries are classified under the Batteries (Management and Handling) Rules, 2001. The government is in the process of updating the rules and a modified version is expected in 2022. These rules govern the overall management for all manufacturers, importers, re-conditioners, assemblers, dealers, recyclers, auctioneers, consumers, and bulk consumers involved in the manufacture, processing, sale, purchase and use of batteries or components thereof. While the rules do discuss the management aspects of battery usage, there is no particular NIC classification of batteries or battery waste in the categorisation. Thus, this paper relies on industries categorised in 'division 38' of NIC-2008 for the analysis which deals with the waste sector. These are not specific but broad categories of waste management. Keeping in mind the hazardous nature of battery waste and the end goal of understanding diverse aspects of end-of life management of batteries, the specific categories of collection of hazardous waste; treatment, and disposal of toxic live or dead animals and other contaminated waste, disposal of used goods, incineration of hazardous waste; materials recovery; and remediation activities and other waste management services have been chosen and are listed in Table 33 below.

Table 33: NIC-2008 sector categories utilised for hazardous waste sector employment analysis

Industry classification	NIC-2008 code
Collection of hazardous waste	38120
Treatment and disposal of toxic live or dead animals and other, contaminated waste, disposal of used goods; incineration of hazardous waste	38221
Materials recovery	38300
Remediation activities and other waste management services	39000

(Source: National Industrial Classification [All Economic Activities) 2008. Central Statistical Organisation. Ministry of Statistics and Programme Implementation, Government of India)

Although other categories in 'division 38' classification also relate to waste, they focus more on municipal solid waste rather than on hazardous waste. Hence, they have not been included in the analysis. However, it needs to be mentioned that due to the lack of a specific categorisation, the obtained employment numbers could tend to lie towards the higher end of the actual sector employment. While we are aware of and acknowledge this fact, we are confident that the obtained numbers will present the hazardous waste sector appropriately and, with the addition of survey results from battery recycling firms, it will be possible to get a fairly representative picture of employment in the waste management sector.

3.2 Introduction of skill component

Skill formation is an important factor in employment generation and economic growth. Cabral and Dhar (2019) discuss the importance of skill development through an extensive literature review, examining various studies. It mentions Pattanaik and Nayak (2013), who talk of how productivity combined with improving skills in the labour force can contribute to increasing employment. Skill development offers multiple benefits. Several macro-level benefits include poverty reduction (Dev, 2013; Agrawal, 2014), tapping the demographic dividend potential in the country (Agrawal, 2012), greater economic and social empowerment of vulnerable groups (Das, 2015; Tara and Kumar, 2016), and generation of employment, greater inclusiveness, and higher sustainable growth (Dev, 2013). Organisation level benefits include faster organisational growth stemming from a more skilled and productive workforce (Saini and Budhwar, 2008; Panda, 2015), opportunities to innovate and develop entrepreneurship capabilities (Bhardwaj, 2014; Hukampal and Bhowmick, 2016), higher job satisfaction (Peters et al., 2010), etc.

Growth in the EV sector will demand a variety of skills, including new skills that require upskilling or reskilling of the workforce. An analysis of the existing skill composition will help identify gaps that need to be filled in to smoothen the transition process, or simply to generate employment.

The skill component in this paper is defined on the basis of education and occupational classes. To classify diverse occupations under different skill levels, a 2016 report of the Ministry of Labour and Employment has been used. It maps the international standard classification of occupational (ISCO)-88 skill categorisation with the national classification of occupation (NCO)- 2004 classification. The report defines skills as *the ability to carry out the tasks and duties of a given job*. This covers two aspects, firstly skill levels that explain the range of tasks and duties involved in a job, and secondly skill specialization that elaborates on the requirement of the field of knowledge, the tools and machinery utilised, the material worked on, and the final products produced. Considering the international level of classification utilised, the report defines four broad skill levels, based mostly on educational categories and levels which appear in the international standard classification of education (ISCED), as described in Table 34.

Table 34: Defining Skill Levels

Skill Level	Skill definition	Educational Requirements
I	Typically involves the performance of simple and routine physical or manual tasks	Primary Education
II	Typically involves the performance of tasks such as operating a machinery and electronic equipment, driving vehicles, maintenance and repair of electrical and mechanical equipment, and manipulation, ordering, and storage information	Secondary Education
III	Typically involves performance of complex technical and practical tasks that require an extensive body of factual, technical, and procedural knowledge in a specialized field	First University Degree
IV	Typically involves the performance of tasks that require complex problem-solving, decision-making, and creativity based on an extensive body of theoretical and factual knowledge in a specialized field	Post-Graduate University

(Source: National classification of Occupations-2015 (code structure) Volume-I, Ministry of Labour and Employment. Available at: https://labour.gov.in/sites/default/files/National%20Classification%20of%20Occupations%20_Vol%20I-%202015.pdf)

The report also stresses the need to modify skill levels under the ISCED to the Indian context given the importance of informal skills in India. It recognises the fact that skills necessary to perform the duties of a given job can be acquired not only through formal education, but also through informal training and experience. Thus, the four skill levels based on educational qualifications as defined for NCO 2004, vis-à-vis the skill levels defined in ISCO – 88, are given below in Table 35.

Table 35: Skill levels as per education levels, defined for NCO 2004 vis-à-vis ISCO – 88

Skill Level	ISCO 88 Educational Requirements	NCO 2004 Educational Requirements
I	Primary Education	Up to 10 years of formal education and/or informal skills
II	Secondary Education	11-13 years of formal education
III	First University Degree	14-15 years of formal education
IV	Post-Graduate University	More than 15 years of formal education

(Source: National classification of Occupations-2015 (code structure) Volume-I, Ministry of Labour and Employment. Available at https://labour.gov.in/sites/default/files/National%20Classification%20of%20Occupations%20_Vol%20I-%202015.pdf)

Occupations were then classified on the basis of the defined four skill levels, as seen in Table 36. The report describes the criteria for attributing skill levels to different occupation categories as the academic and technical qualifications and experience requirement in the job, as well as an understanding of the average job description of the occupation.

Table 36: Skill level division as per NCO-2004 occupation classes

NCO 2004 code at 1 digit	Title	Skill Division
1	Legislators, senior officials, and managers	Not defined
2	Professionals	IV
3	Technicians and associate professionals	III
4	Clerks	II
5	Service workers and shop & market sales workers	II
6	Skilled agricultural and fishery workers	II
7	Craft and related trades workers	II
8	Plant and machine operators and assemblers	II
9	Elementary occupations	I
X	Workers not classified by occupations	-

(Source: National classification of Occupations-2015 (code structure) Volume-I, Ministry of Labour and Employment. Available at https://labour.gov.in/sites/default/files/National%20Classification%20of%20Occupations%20_Vol%20I-%202015.pdf)

Using this occupational distribution of skill levels, the skill variable in this study has been categorised into a broader classification of high, medium, and low-skill level occupations, as indicated below. This is based on the previously discussed educational requirements for the original categorisation of different skill levels.

- **High Skill:** Occupational classes at skill level III or IV
- **Medium Skill:** Occupational classes at skill level II
- **Low Skill:** Occupational classes at skill level I

The ministry report does not apply a skill division to the category of 'legislators, senior officials, and managers' as the skills for duties under this category are highly variable and it is not feasible to link these with any of the four skill levels. However, given the seniority of the designations, we have assigned a 'high' skill level to this occupational classification. It needs to be mentioned that while the report provides the mapping for NCO-2015 codes as well, we have used the NCO-2004 classification, which has been used in the PLFS 2019-20 database. The idea behind introducing occupations is to identify various types of employment for different types of skilled labour in the hazardous waste sector. Further, it is assumed that maximum variability in employment would exist for workers with medium and low level of skills. Medium and low skilled population is assumed to have a higher probability of up-skilling and thus move further up on the employment ladder. They are hence more open to training programs and avenues of skill upgradation in comparison to the high skill set population, which would have relatively limited scope and motivation for additional training.

3.3 Employment results

Before discussing the employment results, it needs to be mentioned that the data for only 'first-visit'[94] rounds, both rural and urban from the PLFS database, has been used. Data was then worked on to arrive at an NIC-2008 industry wise, skill-based classification of employment in the hazardous waste sector. The results are as follows.

3.3.1 Total Employment (formal and informal share)

The PLFS database provides inputs on both the formal and informal sectors of the economy. The coverage classifies proprietary and partnership enterprise types as informal sector enterprises for usual status workers in industry groups/divisions 014, 016, 017, 02-99 of NIC-2008 (NSS, 2021). The NIC-2008 industry codes that are used in the study for the hazardous waste sector fall within these two to three-digit classifications with respect to the informal sector. This sub-section elaborates on the current total employment in the hazardous waste sector as well as the formal and informal breakup of that total.

[94] The Sample definition of PLFS follows a rotational panel sampling design in urban areas. In this rotational panel scheme, each selected household in urban areas is visited four times – one with first visit schedule and other three with revisit schedule. In rural areas there was no revisit.

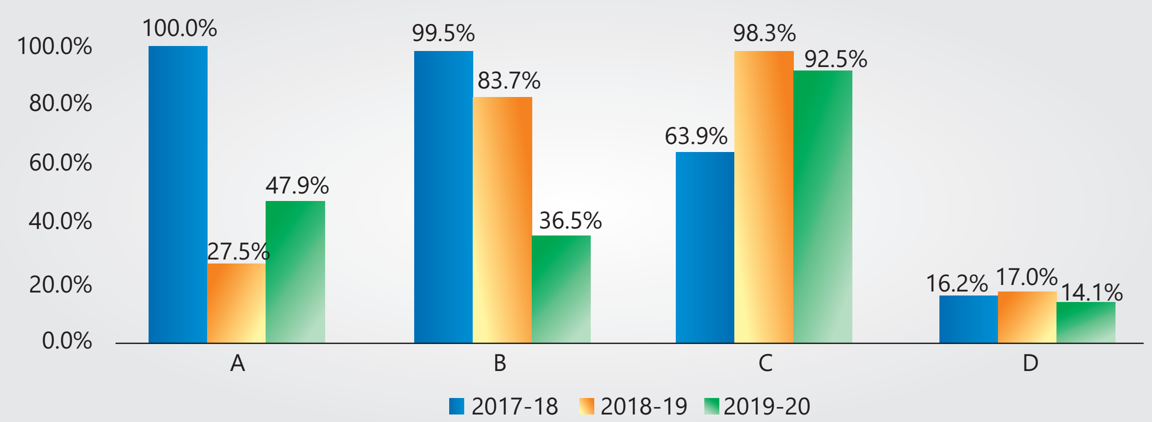
Source: Annual Report Periodic Labour Force Survey July 2019-June 2020.

Table 37: Hazardous waste employment: Total Employment (formal and informal)	
Industry	**Total Employment**
Materials recovery	2,61,58,057
Remediation activities and other waste management services	1,20,84,757
Collection of hazardous waste	1,04,28,882
Treatment and disposal of toxic live or dead animals and other, contaminated waste, disposal of used goods; incineration of hazardous waste	24,95,916

(Source: Authors' calculations on data from PLFS 2019-20)

In terms of total employment, the absolute numbers show the dominance of the *material recovery sector, as depicted in Table 37. It is followed by the remediation activities and other waste management services, collection of hazardous waste, and the treatment and disposa*l sectors, respectively. Using the definition of informal employment in PLFS, Figure 45 shows the share of informal employment over the years from 2017-18 to 2019-20 in the categories under consideration. The figure also indicates the dominance of the informal sector in three of the four categories, i.e., collection of hazardous waste, treatment and disposal and material recovery.

Figure 45: Share of informal employment in hazardous waste sector across PLFS rounds (2017-2020) (%)



where A= Collection of hazardous waste, B= Treatment and disposal, C= Material recovery, and D= Remediation activities and other waste management services

(Source: Authors' calculations on data from PLFS 2017-18, 2018-19, and 2019-20)

As can be observed, the huge employment numbers reported in the hazardous waste sector can be attributed to the dominance of the informal sector. Of the current total employment in the dominant material recovery sector, 92.5 per cent is in the informal route. In fact, of the four categories, only remediation activities has a relatively smaller share of informal employment over the three-year period. While there has been a fall in the share of informal employment in the collection and treatment of hazardous waste in 2019-20, informal employment in material recovery has recorded an increase in 2019-20 as compared to 2017-18. There is a widespread informal network of unauthorised collectors, dismantlers, recyclers, and other intermediaries in waste management in India. The sector dominates waste collection and handling processes with more than a 90 per cent share (Rajya Sabha Secretariat, 2011). The sector consists mainly of small-scale units that are labour intensive, unregulated, and unregistered. These pockets of informal networks often are made up of not only a huge number of workers but also skilled workers. These workers learn on the job and are skilled in recovering precious metals. They are often highly skilled at this extraction process and develop an in depth understanding of the same over the years (ILO, 2019). In spite of the number of workers that includes a fair share of skilled workers, capabilities in the informal sector are not utilised to the full potential. Besides, there is virtually no deployment of safety techniques or technology, making for an extremely dangerous and harmful operational environment.

Material recovery sector accounts for the largest share of employment in hazardous waste management. This classification covers the material recovery of a variety of waste categories and not just hazardous waste or e-waste. It includes the recovery of materials such as paper, plastics, used beverage cans and metals, into distinct categories, from garbage, as well as the processing of metal and non-metal waste and scrap and other articles into secondary raw material. This sector employs a higher share than all the other three included categories. In fact, the sum of employed in all the rest three categories still lays below than the total employment in the material recovery sector alone. However, the employment structure is dominated by the informal segment, as observed previously.

In addition, we find that the surge in employment in the top two categories, viz a viz, material recovery and remediation activities, has been supported by growth in subsidiary employment as well. Along with the sectors garnering primary employment numbers, the share of subsidiary employment in the two sectors has grown over the previous PLFS rounds. In that share of subsidiary employment, remediation activities sector is seen to be taking a lead. Remediation activities perhaps serve as an easier alternative of secondary occupation as compared to material recovery that would involve greater time involvement as well as a pre-requisite skill set.

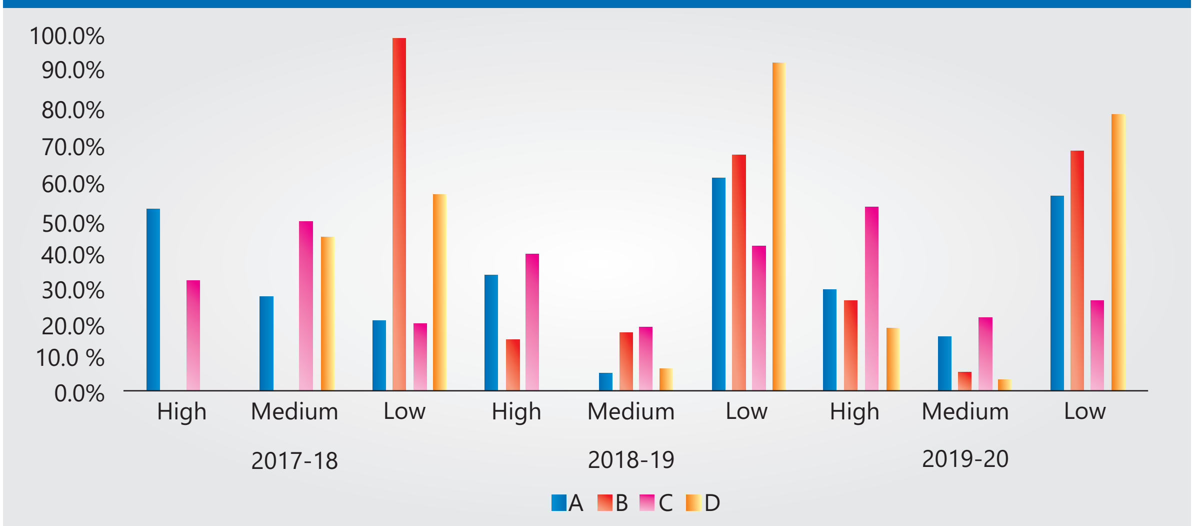
Looking at other sectors, while the treatment of waste does not contribute a considerable share to the employment pie of waste management, the relatively larger employment share of collection of hazardous waste category signifies the still existing inclination towards traditional activities of collection and segregation in the sector. Assumed to be the main magnet of informal employment for many decades, the current employment composition of the collection category shows a fall in informal employment levels to less than half a share.

For comparison purposes, we also estimated the total employment in the traditional collection of non-hazardous waste. Not surprisingly, the number was far higher than that in the collection of hazardous waste and material recovery. Clearly, employment in the waste management sector is highly skewed in favour of the collection of non-hazardous waste. The accelerating adoption of LIBs will make India a significant consumer of LIBs. According to JMK Research & Analytics (2022), the annual LiB market in India is expected to expand from 2.3 GWh in FY 2021 to 116 GWh in financial year (FY) 2030, registering a compound annual growth rate (CAGR) of 52.5 per cent with EVs accounting for about 90 per cent of the overall market. Further, the non-automotive application of LIBs is also expected to increase, from 0.3 GWh to 12 GWh, driven mainly by the telecom sector, grid-scale renewable energy integration and rooftop solar. There could thus be a possible shortage of workers to deal with this rising quantum of hazardous waste such as batteries, etc.

3.3.2 Skill based employment

A skill-based assessment of employment highlights that overall skill structure for categories under consideration signifies a dominance of low skilled employed population, followed by high and medium skill categories, respectively. An analysis of the growth of skilled workers based on data from the PLFS rounds indicates the changing skill profile of workers in the hazardous waste sector (see Figure 46).

Figure 46: Share of skilled employed population in hazardous waste sector across PLFS rounds (2017-2020) (%)



where A= Collection of hazardous waste, B= Treatment and disposal, C= Material recovery, and D= Remediation activities and other waste management services

(Source: Authors' calculations on data from PLFS 2017-18, 2018-19, and 2019-20)

The latest 2019-20 data show that except in the case of the material recovery sub-sector, low skilled workers account for a dominant share of the workforce in the other categories. Given the specification of skill variable, this translates to the fact that the workforce in waste management is majorly based in elementary occupations. This can then be interpreted as more educated and skilled workers shifting to the *material recovery* segment.

The changing share of skilled workforce provides some interesting insights. In the collection of waste category, the sharp rise in the share of low skilled workers as compared to medium and highly skilled labour is likely to lead to a rising share of low-skilled workers in the future. The *material recovery* sector reveals a consistent increase in the employment of high-skilled workers. In the case of both, the *treatment and remediation activities*, the share of low-skilled employment has been consistent although there is a reduction in the share in both sub-categories with the fall being much sharper in the *treatment* sub-category.

The pre-dominance of unskilled workers with low educational levels indicates the scope for skill upgradation in the sector. An analysis of the existing occupational classes will help identify the specific skill gaps that exist. The next section looks at the kind of employment that is on offer in hazardous waste management.

3.3.3 Occupation based employment

The PLFS database provides a distribution of occupations based on three-digit NCO-2004 codes. These codes provide a broad description of occupational designations and can be used to examine occupational distribution in the hazardous waste sector.

The occupation-based employment distribution in the sector, shown in Table 38, indicates that the *Garbage Collectors and Related Labourers* are the largest group of employees, followed by plant operators, domestic and related helpers, etc. The only exception is in the material recovery sector with a significant share of directors and *chief executive* in the sector. However, garbage collectors are the next dominant category in this sub-category as well. It is also noteworthy that the spread of occupations in the hazardous waste sector is generally limited. Again, apart from the material recovery category, all other categories have a limited set of designations.

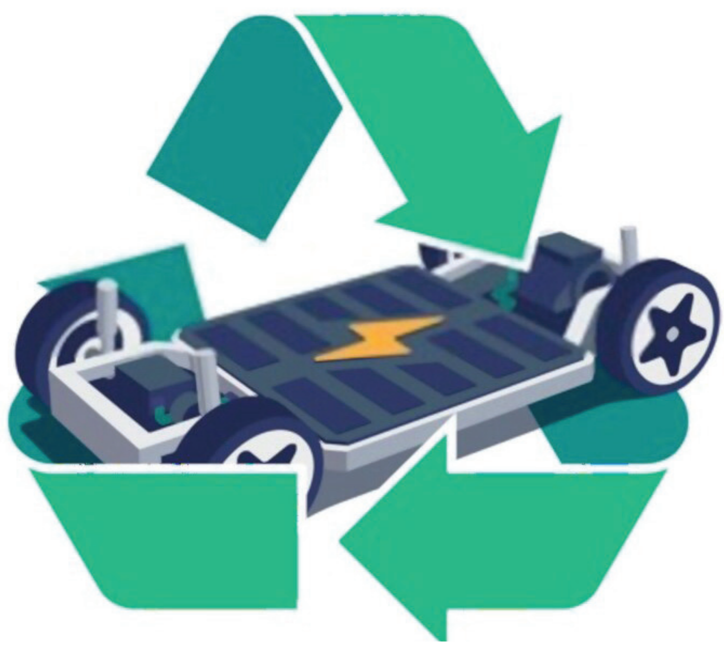


Table 38: Occupation based employment distribution in the hazardous waste sector		
Industry	**Total Employment**	**NCO 2004 Occupation Classification**
Collection of hazardous waste	9,30,941	Directors and Chief Executives
	21,13,536	Social Work Associate Professionals
	9,916	Personal Care Workers
	88,819	Shop Salespersons and Demonstrators
	15,14,292	Market-oriented Animal Producers and Related Workers
	20,937	Metal Moulders, Welders, Sheet Metal Workers, Structural Metal Preparers and Related Trades Workers
	11,43,689	Street Vendors and Related Workers
	45,57,013	Garbage Collectors and Related Labourers
	49,739	Manufacturing Labourers
	1,04,28,882	
Treatment and disposal of toxic live or dead animals and other, contaminated waste, disposal of used goods; incineration of hazardous waste	6,50,964	Directors and Chief Executives
	1,41,925	Machinery Mechanics and Fitters
	13,18,062	Garbage Collectors and Related Labourers
	3,84,965	Mining and Construction Labourers
	24,95,916	
Materials recovery	1,22,10,050	Directors and Chief Executives
	11,31,503	Business Professionals
	3,32,384	Administrative Associate Professionals
	3,55,564	Other Office Clerks
	1,77,638	Shop Salespersons and Demonstrators
	3,18,732	Metal Moulders, Welders, Sheet Metal Workers, Structural Metal Preparers and Related Trades Workers
	4,57,241	Machinery Mechanics and Fitters
	31,58,610	Chemical Processing Plant Operators
	1,20,484	Food and Related Products Machine Operators
	9,52,717	Agricultural and Other Mobile Plant Operators
	4,06,724	Street Vendors and Related Workers
	21,60,411	Domestic and Related Helpers, Cleaners and Launderers
	36,38,593	Garbage Collectors and Related Labourers
	7,37,406	Manufacturing Labourers
	2,61,58,057	

Industry	Total Employment	NCO 2004 Occupation Classification
Remediation activities and other waste management services	8,54,502	General Managers
	11,78,946	Physical and Engineering Science Technicians
	1,60,210	Finance and Sales Associate Professionals
	4,39,646	Other Office Clerks
	10,62,193	Domestic and Related Helpers, Cleaners and Launderers
	83,89,260	Garbage Collectors and Related Labourers
	1,20,84,757	

(Source: Authors' calculations on data from PLFS 2019-20)

The de-composition of employment totals for the hazardous waste categories into different occupational roles highlights the lack of diversity in the sector. A healthy balance of supportive designations seems to be missing in all but one of the categories. The dominance of garbage collectors and related workers flags a major issue – most of these workers are unlikely to be adequately aware of the various and many dangers associated with the activities undertaken in the hazardous waste sector, exposing them to various health problems. Hence, it is necessary to focus on development of adequate skilling platforms to ensure a smoother transition of existing workers to new job avenues during the transition to EV mobility.

While the secondary data analysis dwells on the structure and patterns in the broader overall sector of hazardous waste, it suffers from gaps in terms of a lack of focus on the recycling segment of waste processing. Hence, primary data analysis, based on a survey of three states – Maharashtra, Karnataka, and Haryana – was done to understand occupation-based employment in battery waste management.

4. Primary data analysis: Battery recycling sector

Apart from indicating the employment potential of battery recycling industry in India, the primary analysis also focuses on the technological aspects of battery recycling as has been discussed in our previous work.[95]

The selection of sample states was based on four criteria that are discussed below.

a) Status of hazardous waste generation: For the survey, hazardous waste[96] data provided by the Central Pollution Control Board (CPCB) for the year 2017-18 was used as one of the state selection parameters. The data was used to categorise states based on the amount of annual waste production in the five segments of very low, low, medium, high, and very high based on the annual

[95] For further details, please refer to our working paper titled, Exploring the techno-economic viability of lithium-Ion battery recycling in India

[96] The hazardous waste management rules of 2016 define hazardous waste as any waste which by reason of characteristics such as physical, chemical, biological, reactive, toxic, flammable, explosive, or corrosive, causes danger or is likely to cause danger to health or environment, whether alone or in contact with other wastes or substances. Hazardous waste management rules of 2016; Available at: https://cpcb.nic.in/displaypdf.php?id=aHdtZC9IV01fUnVsZXNfMjAxNi5wZGY=

waste produced by the states. States with medium or high hazardous waste production were considered. The data shows that Karnataka, Maharashtra, and Haryana have high waste production and recycling capacity.

b) Status of authorised/registered recyclers of batteries: The total number of authorised/registered recyclers and their existing recycling capacities was another criterion used to select the states. Data on authorised/registered recyclers was collected through the list of recyclers with state pollution control boards (SPCB) and the CPCB and states were selected on the basis of the concentration and capacity of battery recycling units. The highest number of units was in Maharashtra, followed by Haryana and Karnataka.

c) EV policy status: States with and without EV policies were considered. Both Karnataka and Maharashtra have ambitious EV policies that involve the state governments playing an active role in promoting the adoption of EVs. Haryana currently has a draft EV policy in place.

d) Number of EV and EV component industries: States with higher numbers of EV and EV component units were considered. This involved the compilation of EV and its component industries to understand their geographical distribution within the country. Karnataka, Maharashtra, and Haryana formed the group of states with higher numbers of both EV and EV component units.

It also needs to be mentioned that the bias and uncertainty factor introduced because of the covid-19 pandemic also influenced the sample survey. The next steps involved the identification of recycling units to be surveyed based on the quantity of waste recycled by the unit. A detailed questionnaire was prepared with a focus on employment, technology, and policy implications on the functioning of battery recycling units.

The survey covers 30 surveyed battery recycling firms, spread evenly in groups of ten across the selected three states. The patterns observed in this survey data serve as a crucial indicator of the existing status of battery recycling in the country, highlighting the current capabilities of recycling units and their potential to take on the likely increase in the number of spent batteries as a result of the transition to EVs. As in the case of the secondary data analysis, the primary survey data was examined at three levels. These include employment status of recycling units, educational qualification of workers (skill-based assessment), and type of workers' profile (occupation-based assessment).

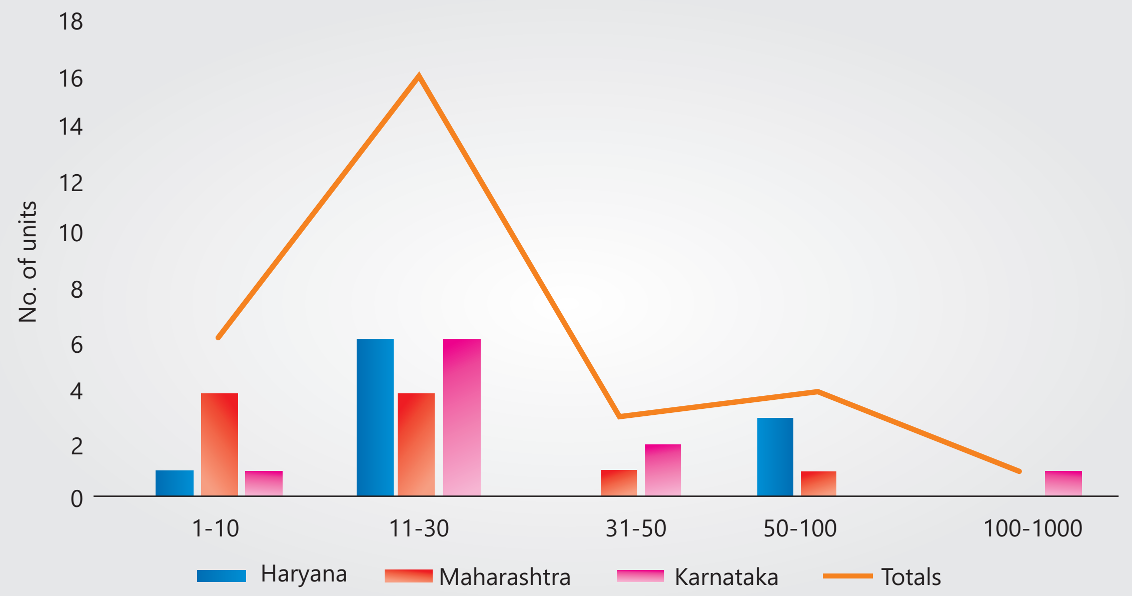
4.1 Data analysis results

The results of the primary data analysis are discussed below.

4.1.1 Employment status of recycling units

All surveyed recycling units were asked for the total number of employees engaged on the premises, that is, the number of employees in the whole firm and not particularly in the main recycling process. As Figure 47 indicates, in the sample size, a majority (53.3 per cent) of battery recycling firms employ between 11 to 30 workers.

Figure 47: Employment status of battery recycling firms



(Source: Primary survey data of battery recycling firms; Authors' calculations)

As Figure 47 shows, a majority of the recycling units operate on a small scale. Along with other barriers of investment, this could prove to be a hindrance to the growth of the industry.

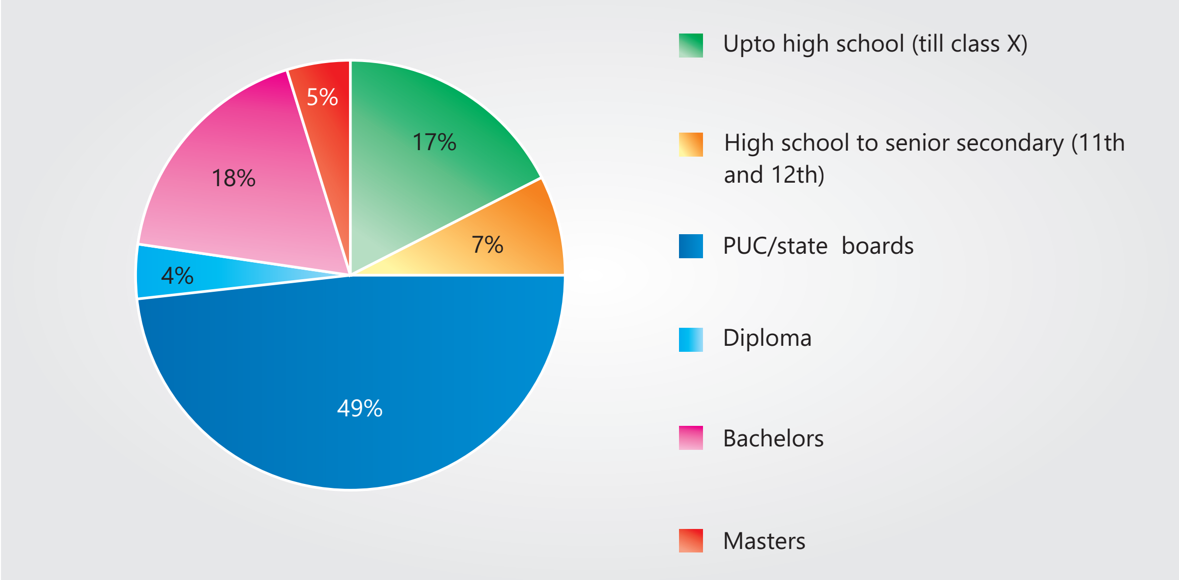
Furthermore, the results yielded by the secondary data analysis revealed the maximum number of employees in the waste management sector to be in Maharashtra. On the other hand, the largest concentration of workers in battery recycling is found in Karnataka. The difference in results is because secondary data analysis was for the hazardous waste sector as a whole. The concentration of workers in Karnataka could be attributed to the concentration of electronic, particularly ICT firms, in Karnataka. Karnataka is known to generate the highest amount of e-waste in the country and is also the hub of many EV start-ups.

4.1.2 Skill based assessment

The second step was to examine the educational qualification of workers involved in the recycling process. Educational attainment was used as a means to identify the level of skills among employees in battery recycling firms. The idea behind specifically focusing on workers engaged in the recycling process was to understand and identify their skill gaps.

As Figure 48 demonstrates, in concordance with the secondary data results, a large proportion of workers (73.3 per cent) have attained only high school level education with low skill levels. The major portion in that is constituted by the category of PUC (11th and 12th) with a share of 48.6 per cent. From the remaining share in the pie, the next relatively far dominant share is formed by the high education class of bachelor's degree (17.8 per cent).

Figure 48: Educational Qualifications of individuals involved in the recycling process: Overall



(Source: Primary survey data of battery recycling firms; Authors' calculations)

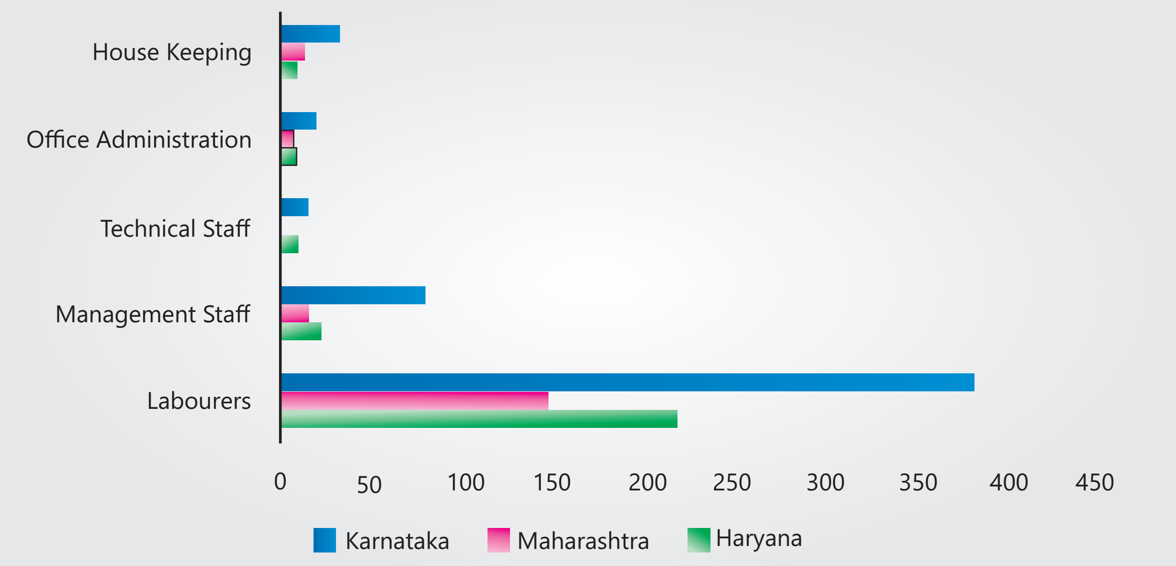
As in the case of secondary data, the analysis of the pattern of skilled employment in the battery recycling sector again highlights the need for skill development. In fact, since these results reflect workers directly engaged in the core recycling process of battery recycling firms, they form a crucial indicator of skill gaps prevalent in the sector. In addition, our policy analysis focusing on producer responsibility organisations (PROs)[97] also found evidence of skill gaps in the sector, indicating a common concern at different stages of waste sector management and operations.

4.1.3 Occupation based assessment

Based on responses as received in the survey, the results show (see Figure 49) that a majority of the employed workforce consist of labourers (76.4 per cent), followed by the management staff (12 per cent). Office administration (3.6 per cent) and technical staff (2.6 per cent) had relatively smaller shares. In fact, the housekeeping and others (including guards, etc.) form a larger share (5.4 per cent) than these medium to high skill categories. Reflecting the trends revealed in the secondary data analysis, the occupation mix in the battery recycling sector seems to also consist overwhelmingly of low to medium skilled workers.

[97] For further details, please refer to our working paper titled, Waste to Wealth: Extended Producers Responsibility for Effective Electric Vehicle Battery Waste Management in India

Figure 49: Occupation categories in battery recycling firms



(Source: Primary survey data of battery recycling firms; Authors' calculations)

Overall, the occupational distribution is similar to that revealed by secondary data analysis with labourers being the dominant occupational category. Albeit information is not available on the exact profile of work performed, it can be assumed that a certain level of skills necessary for different recycling methods and techniques is missing in the sector. Skill gaps are thus prevalent in not just the broader hazardous sector, but in the smaller battery recycling sub-sector as well.

5. Quality vs. Quantity of jobs: A compromise?

An issue that clearly arises from the occupational distribution of workers in the hazardous waste sector as well as the sub-sector of battery recycling is the quality of job generated in the sector. In the quest to raising employment numbers, there is also the need to focus on the quality of jobs created. The critical aspect of quality of employment has found focus in literature as well. Mehrotra and Parida (2019) in their analysis look at different statistics on employment and draw focus on various factors contributing to growth of disheartened labour force in the country. They stress on the poor quality of available non-farm jobs as one the important contributing factors, along with growing unemployment among the educated youth.

The quality of jobs can be assessed based on several criteria. These include the magnitude of contract labour in the sector, provision of social security benefits like pension, provident fund (PF), gratuity, healthcare, maternity benefits to employee, etc., and the availability of direct monetary benefits in the form of welfare expenses, bonus, etc. These quality parameters are important, particularly in terms of determining job security. To assess the quality of jobs in the hazardous waste sector, data from the latest round of PLFS 2019-20 was utilised. PLFS data provide inputs on the availability of a variety of social security benefits like gratuity, PF etc. to the workforce for different NIC code industries. These were estimated for jobs in the hazardous waste sector as identified for the secondary data analysis. The proportion of workers receiving these benefits in the concerned hazardous waste sector segments was estimated.

The results are given in Table 39. PLFS numbers show quality benefits being spread out to a much smaller proportion of the total employed populations across categories. The actual eligible population for receiving any form of social security is vastly restricted. As the second last row of Table 39 shows, a double-digit share of workforce receiving these benefits is only found in the *remediation activities* and the *collection of hazardous waste sectors*. This is astonishing to note that with the dominant share of total employment, the material recovery sector provides essential social security benefits to a mere 3.6 per cent of the workforce in the sector. At the same time, the *treatment of waste* sector does not pay out any such benefits at all. Within this small segment of the workforce across sectors, majority received only PF/pension as social security benefit. Other benefits in the form of gratuity, health care & maternity benefits are not spread out to the workforce, except to a small share in the remediation activities sector.

On the other hand, the share of workforce that is accounted for to be classified as either not eligible for receiving any such benefits, or for which the status is 'not known', forms a majority part of the workforce in the respective sectors, as can be observed from the last row of Table 39. It is interesting to note that data describes 63.5 per cent of the workforce in the treatment of waste sector to be not eligible for receiving any form of social security benefits. The highest share here, is again taken up by the *remediation activities sector*.

Table 39: Availability of Social Security benefits: PLFS 2019-20 data

Social Security Benefits	Collection of hazardous waste	Treatment and disposal of toxic live or dead animals and other, contaminated waste, disposal of used goods; incineration of hazardous waste	Material recovery	Remediation activities and other waste management services
Only PF/ pension (i.e., GPF, CPF, PPF, pension, etc.)	10,56,768		9,36,737	11,78,946
Only health care & maternity benefits				2,52,406
Only PF/ pension and health care & maternity benefits				8,54,502
PF/ pension, gratuity, health care & maternity benefits				9,17,525
Not eligible for any of above social security benefits	55,73,068	15,84,783	95,26,469	63,06,237
Not known				25,75,141
Total	**66,29,836**	**15,84,783**	**1,04,63,206**	**1,20,84,757**

Social Security Benefits	Collection of hazardous waste	Treatment and disposal of toxic live or dead animals and other, contaminated waste, disposal of used goods; incineration of hazardous waste	Material recovery	Remediation activities and other waste management services
Share of the workforce eligible for/receiving some sort of social security in the total employment of the sector	10.1%	0	3.6%	26.5%
Share of the workforce not eligible for/status not known with respect to receiving some sort of social security in the total employment of the sector	53.4%	63.5%	36.4%	73.5%

(Source: Authors' calculations on data from PLFS 2019-20)

The table clearly indicates that the quality of jobs offered in the hazardous waste sector fares behind with respect to the quantity, in terms of the criteria on which the assessment is based. While there could be several reasons for this situation, two probable reasons would include the low skill set of the workers employed in the sector as well as the dominance of unorganised sector firms in the sector. The need is to thus focus policy initiatives not only on skill upgradation for workers but also re-skilling of the existing workforce. Skill development will help to enable a smoother transition of the workforce to the new electric mobility regime and play an essential role in improving the quality of jobs in the sector. Some initiatives have been put in place. The Ministry of Skill Development and Entrepreneurship is running various schemes/programs to impart skilling to the youth through long term and short-term training, including in EV technology modules such as those for 2 and 3-wheeler mechanics (PIB, 2019b). Further, the National Skill Trainers Institute is also framing various modules for imparting training in the EV sector (TOI, 2018).

6. Policy Recommendations

EVs present a crucial opportunity and promise towards a more environment friendly and sustainable economy; however, the corollary is the challenge of responsible recycling of spent batteries. The transition to electric mobility will throw up new employment opportunities that require the development of new skills as well as an upgradation of existing skills to meet the demand for recycling spent batteries appropriately that the transition will entail.

The government can opt for one of two approaches to waste management in the future. One is to continue with the existing structure and functioning of the sector with the focus being on increasing the number of jobs created, keeping the quality check in hindsight. The other way is to transit and move towards an inclusive growth model for the waste sector, which will require fundamental changes, in not just the policy framework but also in the very structure and functioning of the sector. Some critical areas of consideration would be the following:

- Greater collaboration: A collaborative approach at the level of key players in the sector such as battery manufacturers and original equipment manufacturers (OEMs) will help develop second life application solutions as well as effective solutions to issues in the recycling segment. In addition, collaborations between the states and these key stakeholders will help expedite the evolution of the battery use and recycling market and ensure greater focus on the issue of quality job creation in the sector. The government is in the process to come out with new battery waste management rules as well as battery swapping policy. Ensuring a collaborative approach, different stakeholders have been approached to provide their views on the draft to ensure coverage of maximum possible issues and concerns of the sector.

- Adequate skilling: While the present dependence on a low-skilled workers can serve the sector initially, however the future will demand skill upgradation. The battery recycling sector is expected to create jobs along the entire value chain, and thus will demand a variety of skill sets in the future. Technological advances would also lead to skills gaps in the future. As the EV sector scales up, new jobs created in the EV value chain will require imparting training and skilling to create a workforce that can cater to the needs of EV manufacturing. Further, skill upgradation will need to focus on not only imparting adequate skills, but also generate awareness in the existing workforce with respect to the changing and challenging forms of incoming waste like LiB. A combination of education as well as training will help to better prepare the workforce for the EV transition. It may be necessary to outsource the skilling process to the industry by creating mandates, and monitoring and evaluation systems. The government, whilst increasing domestic capabilities of skilling, can also promote innovation through increased collaborations and funding of research organisations (OMI, 2022).

- Partnership between formal and informal sector: Greater cooperation between the formal and informal recycling sectors can help to improve the quality of jobs created as well as the functioning of the sector. It would be necessary to dignify the job market for informal workers in the hazardous waste sector. This will help them to not only enjoy social security benefits but will also aid the waste management sector to tap the immense skill levels that these workers bring to the table with years of informal training.

7. Conclusion

To understand the opportunities that the transition to electric mobility provides in terms of employment generation, this paper used a two-step approach using secondary data and primary data analysis to examine the policy initiatives that could be taken to realise these as well as the goal of ensuring environment friendly, sustainable development. While secondary data focused on the broader hazardous waste sector, primary data provided insights from a survey of battery recycling firms. However, in interpreting the results, it needs to be kept in mind that the secondary data relates to the hazardous waste sector as a whole rather than just the battery recycling segment. Nonetheless, the secondary and primary data analysis combines to provide insights to the sector and aid in the identification of bottlenecks for framing better policies in the future.

Both sets of data show the dominance of low skilled workers in the waste management industry, with far fewer workers in relatively high-skilled technical and managerial roles. The low skill levels in the industry at present could pose a challenge, given the technical skills needed for sub-categories such as material recovery within the hazardous waste industry in general and the battery recycling sector in particular. Hence, future policy initiatives need to focus on reskilling workers in the sector and the adoption of a more collaborative approach towards handling, processing, and recycling hazardous waste between the formal and informal sectors. Such reskilling will not only enable the absorption of workers in the changing global EV automotive manufacturing setup but could also upskill the existing workforce and help them retain their relevance after the transition to electric mobility is complete.

Further, the quality of job analysis revealed that the waste management sector offers limited to no social security benefits to its workforce. The lack of a wider distribution of essential quality benefits in the workforce of hazardous waste sector underlines another significant gap. This situation again reiterates the need of a crucial focus on skill development in waste management. Such initiatives will not only help the overall workforce but will also help improve working condition for the majority of informal workers in the sector, to enable them to be covered under the social security schemes as workers in the organised sectors are entitled to.

References

Agrawal, T. (2012), "Vocational education and training in India: challenges, status and labour market outcomes", Journal of Vocational Education & Training, Vol. 64(4), pp. 453-474, doi: 10.1080/ 13636820.2012.727851.

Agrawal, T. (2014), "Skill development in India: an examination", Journal of Education and Work, Vol. 27(6), pp. 629-650, doi: 10.1080/13639080.2013.787485.

Associated Chambers of Commerce & Industry of India (ASSOCHAM). 2018. Delhi-NCR will generate 1,50,000 MT e-waste by 2020: ASSOCHAM study. New Delhi. Available at: https://www.assocham.org/newsdetail.php?id=6677. Accessed on January 28, 2022

Bhardwaj, B.R. (2014), "Impact of education and training on performance of women entrepreneurs: a study in emerging market context", Journal of Entrepreneurship in Emerging Economies, Vol. 6(1), pp. 38-52, doi: 10.1108/JEEE-05-2013-0014.

Cabral, C. and Dhar, R.L., 2019. Skill development research in India: a systematic literature review and future research agenda. Benchmarking: An International Journal. Available at: https://www.researchgate.net/profile/Clement-Cabral-3/publication/332565015_Skill_Development_Research_in_India_a_Systematic_Literature_Review_and_Future_Research_Agenda/links/60b8487592851c209d5e5d40/Skill-Development-Research-in-India-a-Systematic-Literature-Review-and-Future-Research-Agenda.pdf . Accessed on January 25, 2022

Das, A.K. (2015), "Skills Development for SMEs: mapping of Key Initiatives in India", Institutions and Economics, Vol. 7(2), pp. 120-143.

Dev, S.M. (2013), "Post-2015 development agenda: employment and growth with special reference to India", IDS Bulletin, Vol. 44(5), pp. 63-71

Forti V., Baldé C.P., Kuehr R., Bel G. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA),Bonn/Geneva/Rotterdam. https://ewastemonitor.info/wp-content/uploads/2020/11/GEM_2020_def_july1_low.pdf. Accessed on January 31, 2022.

Hukampal, S.S. and Bhowmick, B. (2016), "Innovation network for entrepreneurship development in rural Indian context: exploratory factor analysis", International Journal of Innovation and Technology Management, Vol. 13(4), pp. 1-20, doi: 10.1142/S0219877016500164.

ILO and Women in Informal Employment Globalizing and Organizing (WIEGO). 2013. Women and Men in the Informal Economy: A Statistical Picture. Second Edition. (Geneva, ILO). https://www.ilo.org/wcmsp5/groups/public/---dgreports/---stat/documents/publication/wcms_234413.pdf

ILO, 2019. From waste to jobs: Decent work challenges and opportunities in the management of e-waste in India, International Labour Office, Sectoral Policies Department (Geneva). https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/publication/wcms_732426.pdf

JMK Research & Analytics, 2019. Recycling of Lithium-ion batteries in India- $1,000 million opportunity. October 2019. https://jmkresearch.com/electric-vehicles-published-reports/recycling-of-lithium-ion-batteries-in-india-1000-million-opportunity/

JMK Research & Analytics. (2022). Lithium-Ion Battery (LiB) Manufacturing Landscape in India Market Trends and Outlook. January 2022. Available at: https://jmkresearch.com/electric-vehicles-published-reports/lithium-ion-battery-lib-manufacturing-landscape-in-india-jan-2022/.

Ministry of Environment, Forest, and Climate Change (2001). Batteries (Management and Handling) rules, 2001. Notification. New Delhi, the 16th May, 2001. Available at: https://hspcb.gov.in/content/laws/battery/Batteries_Rules.pdf

Ministry of Finance (2016). Economic Survey 2015-16, Volume I and II, New Delhi, India: Department of Economic Affairs. Ministry of Finance, Government of India. Retrieved from http://indiabudget.nic.in/es2015-16/epaper-vol1.pdf and http://indiabudget.nic.in/es2015-16/epaper-vol2.pdf , accessed on May 31, 2018

Mehrotra, S. and Parida, J.K., 2019. India's Employment Crisis: Rising Education Levels and Falling Non-agricultural Job Growth. http://publications.azimpremjifoundation.org/2119/1/Mehrotra_Parida_India Employment_Crisis.pdf

Ministry of Electronics and Information Technology, 2021. Policy paper on Circular Economy in Electronics and Electrical Sector. Available at https://www.meity.gov.in/writereaddata/files/Circular_Economy_EEE-MeitY-May2021-ver7.pdf

Ministry of Labour and Employment, 2016. National classification of occupations-2015 (code structure) Volume-I, Ministry of Labour and Employment. Available at https://labour.gov.in/sites/default/files/National%20Classification%20of%20Occupations%20_Vol%20I-%202015.pdf

NITI Aayog and Rocky Mountain Institute (RMI), 2019. India's Electric Mobility Transformation: Progress to date and future opportunities. Available at: https://rmi.org/wp-content/uploads/2019/04/rmi-niti-ev-report.pdf

NSS, 2021. Annual Report Periodic Labour Force Survey (PLFS). July 2019-June 2020. Government of India. Ministry of Statistics and Programme Implementation. National Statistical Office. Available at: https://www.mospi.gov.in/documents/213904/301563/Annual_Report_PLFS_2019_20m1627036454797.pdf/18afb74a-3980-ab83-0431-1e84321f75af

OMI Issue Brief | Skilling Indians for an EV-Ready World. February 2022. Available at: https://olawebcdn.com/ola-institute/skilling-indians.pdf

ORF, 2020. Recycling Li-ion batteries: Opportunities and challenges. Available at: https://www.orfonline.org/expert-speak/recycling-liion-batteries-opportunities-challenges-68409/

Panda, D. (2015), "Growth determinants in small firms: drawing evidence from the Indian agro-industry", International Journal of Commerce and Management, Vol. 25(1), pp. 52-66, doi: 10.1108/IJCoMA-12-2012-0080.

Pattanaik, F. and Nayak, N.C. (2013), "Trends and forecasting of employment intensity of growth in India", Journal of the Asia Pacific Economy, Vol. 18(3), pp. 438-459.

Peters, D.H., Chakraborty, S., Mahapatra, P. and Steinhardt, L. (2010), "Job satisfaction and motivation of health workers in public and private sectors: cross-sectional analysis from two Indian states", Human Resources for Health, Vol. 8(1), pp. 1-11.

Press Information Bureau, Government of India (2019b). 'Targets of Skill India Mission'. December 13, 2019. Available at: https://pib.gov.in/PressReleasePage.aspx?PRID=1596324

Press Trust of India, 2019. E-waste sector will create half million jobs in India by 2025: IFC: The Economic Times. Available at: https://economictimes.indiatimes.com/jobs/e-waste-sector-will-create-half-million-jobs-in-india-by-2025-ifc/articleshow/68708339.cms

Rajya Sabha Secretariat (2011). E-WASTE IN INDIA. Occasional Papers. https://rajyasabha.nic.in/rsnew/publication_electronic/E-Waste_in_india.pdf

Saini, D.S. and Budhwar, P.S. (2008), "Managing the human resource in Indian SMEs: the role of indigenous realities", Journal of World Business, Vol. 43(4), pp. 417-434.

Tara, S.N. and Kumar, N.S.S. (2016), "Skill development in India: in conversation with S. Ramadorai, Chairman, National Skill Development Agency & National Skill Development Corporation; former CEO, MD and Vice Chairman, Tata Consultancy Services", IIMB Management Review, Vol. 28(4), pp. 235-243.

Times of India (TOI). (2018). 'Stone for National Skill Training Institute laid at Barang', July 17, 2018. Available at: https://timesofindia.indiatimes.com/home/education/news/stone-for-national-skill-training-institute-laid-at-ba rang/articleshow/65018352.cms

Chapter 9

Waste to Wealth: Extended Producers Responsibility for Effective Electric Vehicle Battery Waste Management in India

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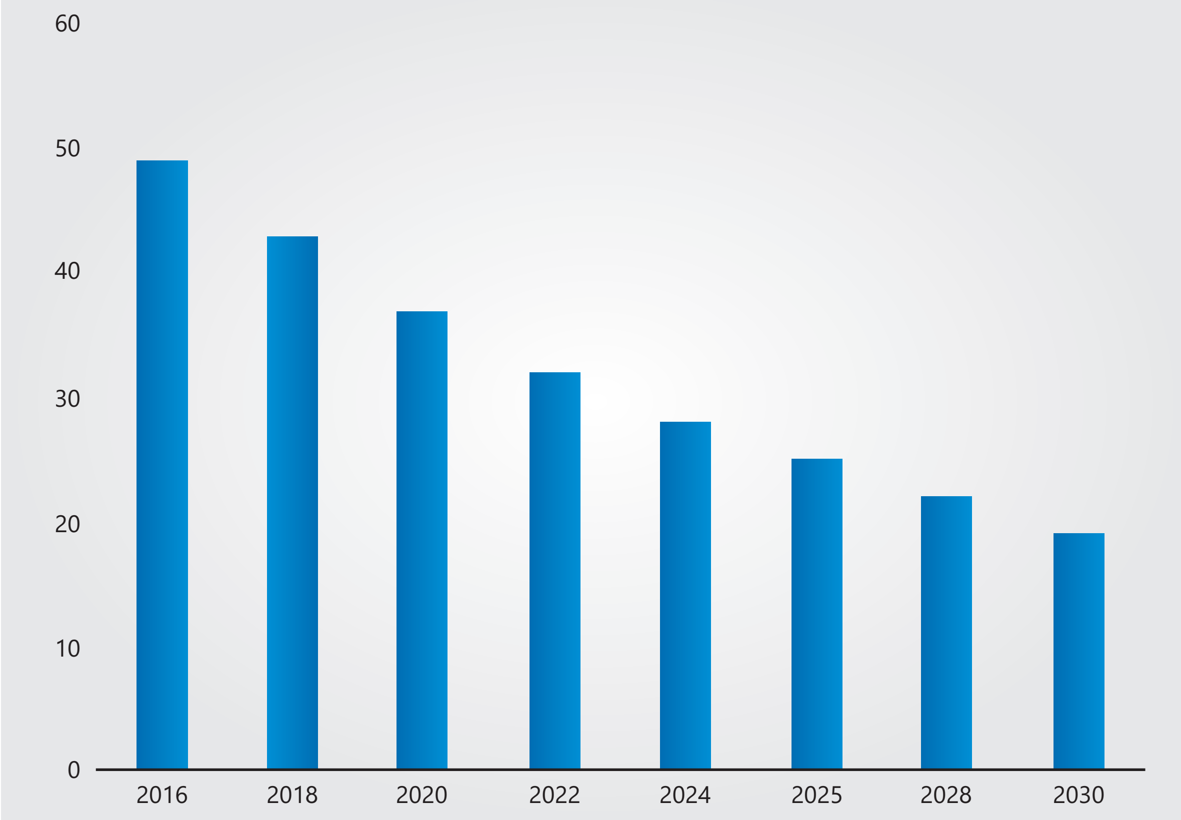
1. Introduction

EVs have emerged as an effective tool in the transition towards a low carbon economy. The Intergovernmental Panel on Climate Change (IPCC) identifies the transportation sector as one of the leading contributors to greenhouse gas emissions globally. Its fourth assessment report highlights that the sector is responsible for 23 per cent of the total energy-related CO2 emissions despite policy interventions and the introduction of more efficient vehicles (IPCC, 2014). Thus, several countries plan to phase out fossil fuel-based vehicles and introduce electric vehicles on a large scale. This policy shift is also reflected in data; the IEA estimates that sales of EVs surpassed the figure of 2.1 million globally in 2019 (IEA, 2020). As ambitious policies continue to roll out, there is likely to be a significant shift in the transportation sector.

Unlike the internal combustion engines powered by fossil fuels, EVs are powered by electric motors that run on electricity stored in a battery. Currently, LiBs are the most common types of batteries used in EVs (Harper et al., 2019). The manufacturing of LiBs is an expensive process and accounts for 37 per cent of the cost of EVs (Figure 50). One of the reasons is that LiBs are made up of noble and critical rare earth metals (Berckmans et al., 2017). The LiB chemistries depend heavily on metals like lithium (Li) and cobalt (Co). The prices of these metals have risen manifold as a result of the increase in the demand for LiBs. Between 2016 and 2018, the cost of Li has tripled, and the cost of Co has quadrupled (Benchhmark Report, 2020; "Lithium Price 2020,".; Pagliaro&Meneguzzo, 2019). Given the projected demand for these metals globally, there is likely to be a shortage of these metals by 2023 even in the most optimistic scenario (Martin et al., 2017). Thus, to supplement an already scarce natural resource, the concept of a circular economy has been widely embraced and several countries including Japan, Korea and China have used the EPR approach to realise circularity. (Li et al., 2020).

India is no exception when it comes to pursuing the principles of a circular economy in battery recycling. The country published a set of draft Battery Waste Management Rules (later mentioned as BWM, 2020) in 2020. The rules target the collection of 90 per cent of battery waste in the initial two years of implementation, scaling up to 100 per cent subsequently. The waste management rule under EPR emphasises the pivotal role of producers in battery waste management. The producer's responsibilities comprise setting up an effective waste battery channelizing system, setting up collection centres, implementing take-back systems, agreements with recyclers and dismantlers either individually or collectively through Producers Responsibility Organisations (BWM, 2020).

Figure 50: Decreasing share of Battery Cost in Electric Vehicles

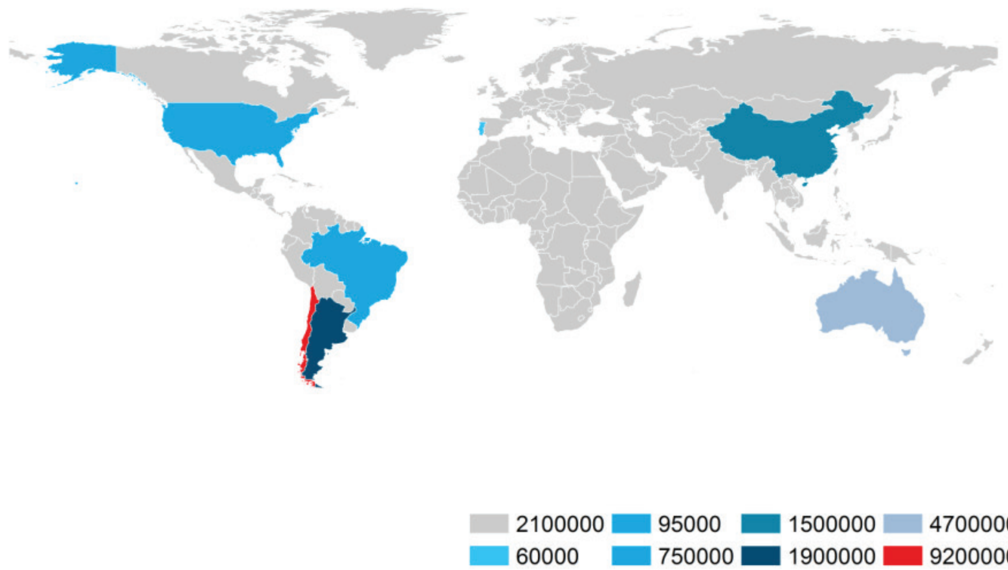


(Source: Statistica (2020))

Developing countries like India are growing steadily, leading to increasing consumption of resources annually. As a result, the waste produced by the country is also increasing. If we continue with the current consumption rate, we will soon face an intertwined crisis of resource scarcity and waste production (Anne Velenturf & Phil Purnell, 2017). The World Bank report "What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050", puts forward a similar argument, pointing out that at the current rate of consumption, global waste generation is expected to jump from 2.01 billion tonnes in 2016 to 3.4 billion tonnes by 2050 (World Bank, 2018). The report estimates that waste generated per person per day averages 0.74 kilograms, and this is expected to increase. With the predicted increase in waste production globally, countries at a macro level and cities at a micro level must start focus on effective waste management.

This pressure on the availability of resources globally might affect the production of the Li-ion batteries globally (Tesfaye et al., 2017). This is why the circular economy and EPR are relevant for EVs. With the recent push towards EVs, the demand for LIBs will also increase globally. while supply is at present sufficient to meet demand, demand is likely to outstrip supplies by 2025 (Latham &Kilbey, 2019). Since lithium is a finite resource and most geological storage is limited to countries like Australia, Canada, and Zimbabwe, after a point in time, the mining of virgin lithium will be more expensive due to limited resource availability, and we would need to recycling industries to fill in the supply gap (Figure 51) (Kavanagh et al., 2018). This resource crunch, however, can be managed efficiently if battery waste can be recycled to recover rare minerals.

Figure 51: Global Reserves of Lithium and their capacities in tons



Note: Map not to scale and without prejudice to International Boundaries

(Source: Jaskula (2021), US Geological Survey (2021))

In 2015, at least 5600 million LiBs cells were sold worldwide, and the market is expected to grow at an annual growth rate of 10.6 per cent from 2016 to 2024; however, only around 5 per cent of total production was recycled in 2015, and the remaining waste went to landfills (Martin et al., 2017; Natarajan & Aravindan, 2018; Velázquez-Martínez et al., 2019).

1.1. Environmental Impact of Li-ion batteries

The battery waste going to landfills has the potential to critically damage the environment (Boxall et al., 2018). A study by (Kjeldsen et al., 2002) pointed out that there is a high probability of heavy metals leaching from landfills to pollute soil and water bodies. Spent Li-ion batteries are loaded with heavy metals like copper, nickel and organic compounds, and inflammable electrolytes like LiMO2, LiM2O4 and LiMPO4 and others (Kabir & Demirocak, 2017). Additionally, since Li-ion batteries contain electrical power even after disposal, they can be a potential health or safety hazard (Zeng et al., 2015). To give an example, long-term exposure to heavy metals like copper could lead to acute and chronic health disease like liver damage and gastrointestinal diseases (Fernández-Luqueño et al., 2010). The pollution of heavy metals also affects soil organisms, the aquatic ecosystem, and plants. Heavy metal pollution in the soil can adversely affect plant and fungal interaction (see Leyval et al., 1997); in water, it can affect aquatic life and biodiversity (see Rai, 2008). With the projected increase of EVs in India, developing an effective waste management strategy for Li-ion waste is critical.

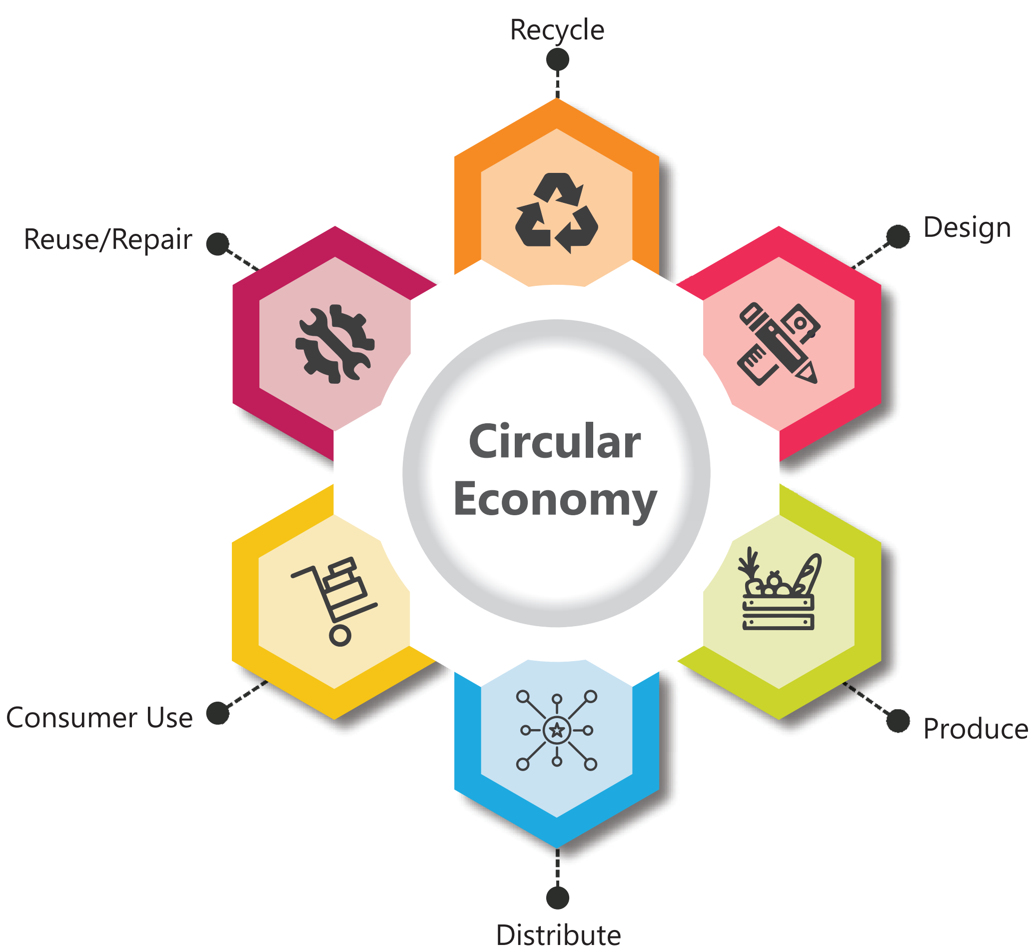
Countries like China have reduced the resource crunch and ceased the stockpiling of battery waste by utilising the circular economy concept. Researchers in China have relied upon integrative technologies to recover rare earth metals from waste streams (B. Wang et al., 2018). The process is a win-win solution as it provides both economic and environmental benefits. This paper aims to analyse whether the EPR policy in India's battery waste recycling industry will be a success story.

2. What is EPR?

The Organisation for Economic Co-operation & Development (OECD) defines EPR as an "environmental policy approach in which a producer's responsibility, physical and/or financial, for a product is extended to the post-consumer stage of a product's lifecycle" (OECD, 2001). The EPR scheme has emerged as an effective tool to manage the product after the attainment of end-of-life. The scheme's usefulness led to its adoption worldwide, and over 400 schemes currently exist worldwide.

Earlier, the management of the waste produced was the sole responsibility of municipalities and the local government. However, with the implementation of EPR, the responsibility has been transferred to producers (Park, Posada and Dugand., 2018). The overall implementation of the EPR mechanism aims to streamline two aspects: the primary aim is effective upstream design management of the product and the secondary, efficient downstream management of the product post-end-of-life (Park, Posada and Dugand, 2018, Dawson, Ahuja and Lee, 2021). The overall implementation of the EPR strategy helps transform the linear economy into a circular economy.

Figure 52: Circular Economy Concept



While the importance of the EPR scheme can be gauged from the fact that over 400 schemes have been implemented around the globe, it suffers from several lacunae that make its implementation challenging.

The collection of waste from households is a major challenge in any waste management effort. This is particularly so in developing countries, where the lack of a good collection strategy results in waste ending in the informal sector (Awasthi & Li, 2017; Wilson et al., 2006; Xue et al., 2019). While recycling in the informal sector does have the advantage of providing a livelihood to people, it is associated with environmental, social and health risks. In India, for instance, most e-waste ends up in garbage bins; this is picked up by local rag pickers and ends up in the informal recycling sector. The techniques for recycling and extracting precious metals used in the informal sector are primitive (Annamalai, 2015) and unsafe. The informal sector also often uses child labour. Additionally, the entire process adds to the environmental footprint of recycling and defeats the purpose of sustainable recovery of rare metals and waste management.

The second challenge relates to the financial burden of collecting, transporting, and recycling e-waste. The implementation of the EPR mechanism pushes producers to make the product more recycling friendly and invest in waste management technology OECD (2001). There are several mechanisms, such as establishing producers' responsibility organisations, which have been suggested to ensure that the financial burden does not fall solely on producers. (Dawson, Ahuja and Lee, 2021). The mechanism plays an effective role in managing different kinds of waste globally, creating awareness and easing the financial burden on municipalities and governments.

2.1 Policy Instruments

To effectively implement an EPR strategy, a number of policy instruments and their variants have been used. In this section of the paper, some of the policy instruments have been discussed. Table 40 provides a snapshot of the various instruments used to implement an EPR policy.

Table 40: Instruments Used to Implement EPR

S. No.	Type of Policy Instrument	Sub-Category	Definition	Examples
1	Administrative Instruments	Mandatory collection and/ or take-back with recovery/ recycling obligations/ rate	The mandatory collection policy makes it compulsory for manufactures or retailers to collect the product post the end-of-life. These mandates are often combined with a collection goal.	The Oregon State Senate Bill 582[98] introduced at the beginning of 2021; later amended in April and June 2021. The bill set a statewide recycling rate for plastic packaging and food service ware: • At least 25 per cent by 2028 and in subsequent year until 2039. • At least 50 per cent by 2040 and in subsequent year until 2049. • At least 70 per cent by 2050 and in subsequent years.

[98] Available at https://epr.sustainablepackaging.org/policies/SB582B Accessed on 20 January 2022

S. No.	Type of Policy Instrument	Sub-Category	Definition	Examples
		Voluntary collection and/ or take-back with recovery/ recycling obligations/ rate	The voluntary collection or take back policy is based on the eagerness of the industry and there is no law or government regulation mandating compliance or penalties for failure to meet goals.	The carpet industry in the US is under a voluntary recycling agreement. The memorandum of understanding for Carpet Stewardship in 2002 is a voluntary effort by carpet manufacturers to take physical and financial responsibility of the produced carpets after end-of-life (T. Choi, 2017).
		Standards	Setting standards is an important product management strategy for end-of-life waste management. Its importance can be gauged from the fact that there are more than 400 eco labels used in the market place applied to food products and other product categories.	For effective handling and treatment of waste post end-of-life, a legally binding obligation is preferred by several countries. For example in South Korea, a national committee is preparing a set to standards for efficient and effective handling of the end-of-life EV battery waste (Y. Choi & Rhee, 2020).
2	Economic Instruments	Subsidies	Subsidies are an important policy instrument to increase recycling.	Subsidies are often argued to be an important support tool for the recycling industry in the early phases of development (Zhang et al., 2021) . China has been one of the earliest countries to start offering subsidies on recycling of electric vehicle batteries. The earliest attempts include 'Interim Measures for the administration of subsidies for scrapping and renewal of old automobiles', implemented in 2014 to improve recycling of older vehicles (Yu et al., 2021).
		Fund Policy	Fund policy is an important policy instrument under which the producer or importer pays a disposal fee, which is later used to subsidise authorised recyclers and dismantlers.	The Chinese e-waste recycling industry provides an example of the fund policy. While the Chinese fund policy had several lacunae, it still managed to scale the formal e-waste recycling industry (Liu et al., 2017).

S. No.	Type of Policy Instrument	Sub-Category	Definition	Examples
		Deposit-Refund System	Deposit-refund system is a traditional strategy that combines product consumption with a rebate when the product or packaging is returned for recycling (Walls, 2011)	The Deposit-refund system has emerged as a practical solution to managing packaging waste. The system has been established on a voluntary basis in Spain[99] (Abejón et al., 2020).
		Advanced Recycling Fee/ Advanced Disposal Fee	Advanced recycling fee, often called an advanced disposal fee, is a tax assessed on the sales price of product and is later used to cover recycling.	Advanced recycling fee has emerged as a practical solution for e-waste management. In California, the Electronic Waste Recycling Act of 2003 requires consumers to pay a small fee for effective management of waste post the end-of-life of the project.[100] A household survey in California found that a majority of the population was willing to support the advanced recycling fee system by paying 1 per cent of the product cost as a recycling fee (Nixon & Saphores, 2007).
3	Informative instruments	Labelling	Labelling aims to improve the environment by raising awareness and influencing manufacturers to design products in a more environment friendly manner (Chang, 1997).	Labelling has emerged as an effective choice for the food industry by inducing consumers to select from environment friendly options. For instance, the health star rating in Australia is a voluntary front-of-pack labelling initiative to promote healthy and nutritional quality (Mantilla Herrera et al., 2018).

All the policy instruments mentioned above influence upstream waste management and make manufacturers either financially or physically responsible for the end-of-life management of waste.

2.2 What are Producer Responsibility Organisations (PROs), and What Role do they play?

As mentioned earlier, one of the challenges faced by producers included the collection of diffused waste. To ease the process of collection, PROs were introduced. PROs are an organisation that acts as a middle man between collection points and producers and charge producers for the service.

Producers have played an important role in collecting waste across the globe. For example, in China, either producers or PROs need to reach a particular collection target, failing to which attracts heavy penalties (Hou et al., 2020).

[99] Available at https://cms.law/en/int/expert-guides/plastics-and-packaging-laws/spain Accessed on January 25, 2022

[100] Available at https://www.calrecycle.ca.gov/electronics/retailer Accessed on January 25, 2022

Currently, there are 68 existing PROs operating in India, and a significant number are involved in the collection of e-waste (CPCB, 2021).

2.3 EPR and Circular Economy Case-Studies

With more than 400 schemes operating globally, there are several EPR success stories in various parts of the globe. This section highlights a few of the successful case studies across the globe.

1. Korea: Korea is one of the largest producers of lithium-ion batteries and is also making swift progress in battery waste management with the development of recycling technologies. Since the 1990s, Korea has increasingly focused on waste management strategies to manage the country's waste effectively. In this regard, the country in the 2000s implemented the EPR. As of 2014, the EPR list consists of 32 products (OECD, 2014) and this list was recently revised to accommodate 17 more products.[101]

Waste management in Korea is legally binding under the 'Act on Resource Recirculation of Electrical and End of Life Vehicles'[102] and 'Act on the Promotion of Saving and Recycling of Resources' under which producers and PROs are required to fulfil their obligation to recycle waste. Producers or PROs are supposed to recycle 95 per cent of the waste produced from the end-of-life vehicles (Yang et al., 2014). The entire process is monitored by the Korea Environment Corporation (KECO)[103] under the Korean Ministry of Environment. The KECO also produces documents providing detailed statistics on the production and management of waste in Korea.

France: France's EPR scheme is one of the oldest globally. EPR laws in France have existed since 1975 and are spelt out in L.541-10 of the environment code[104]. More than 20 EPR chains are working in France, and batteries and accumulators were introduced as part of the scheme in 2001. The PROs or 'Eco-Organismes' are responsible for collecting various categories of waste in France. Waste is collected either directly by PROs, who charge producers for the service or they support local municipalities in the waste collection process without being directly involved in collecting waste. Producers have the liberty to choose any one of these schemes and have the additional liberty to choose one or several PROs based on their convenience.

While the EPR system in France has been a good example, there has been some degree of ambiguity involved in establishing PROs. The ambiguity revolves around the selection of PROs. The PROs are to be established by producers themselves and need renewal by the public authority every six years.

2. New EU Regulatory Framework for Batteries: Owing to the increasing importance of batteries in sectors such as energy and transportation, the European Union set up the European Battery

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[101] Read more at: http://me.go.kr/home/web/board/read.do;jsessionid=cfbfjm3a4vX8o-VGW1osFiIO.mehome1?pagerOffset=20&maxPageItems=10&maxIndexPages=10&searchKey=&searchValue=&menuId=286&orgCd=&boardId=1467190&boardMasterId=1&boardCategoryId=&decorator=

[102] Read more at: https://elaw.klri.re.kr/eng_mobile/viewer.do?hseq=38440&type=new&key=

[103] Learn more at: https://www.keco.or.kr/en/main/index.do

[104] Read more at: https://uk.practicallaw.thomsonreuters.com/w-010-5542?transitionType=Default&contextData=(sc.Default)&firstPage=true

Alliance for scaling the production of batteries in Europe to back its transition towards renewable energy. In 2018, the Union adopted a strategic action plan on batteries to establish efficient supply chains. This proposal formed a pillar for the 2020 EU legislation on improving the sustainability of supply chains. The legislation lays down specific provisions on securing raw materials, on the carbon footprint associated with the use of batteries and end-of-life handling. The proposed regulations included several new innovations that include the following:

a. Minimising the carbon footprint of EV batteries and rechargeable battery industry.

b. Mandatory minimum levels of recyclable content set for 2030 and 2035. The initial levels of cobalt 12 per cent to be scaled up to 20 per cent, 85 per cent of lead, 4 per cent lithium to be scaled up to 10 per cent, 4 per cent of nickel scaled up to 12 per cent.

c. Increase in collection targets to 65 per cent by the end of 2025 and to 70 per cent by the end of 2030 for waste portable batteries, excluding waste batteries from light means of transport.

d. Increasing recycling efficiencies for lead acid batteries to 75 per cent by 2025 to 80 per cent by 2030. The minimum level of material recovery targets is 90 per cent for cobalt, copper, lead and nickel and 35 per cent for lithium by 2025. By 2030, the recovery targets are to be raised to 95 per cent for cobalt, copper, lead and nickel, and 70 per cent for lithium.

e. After 2027, batteries must be labelled for identification. Depending on the type of batteries, a quick response note would be attached with the battery to provide relevant information regarding the battery.

f. After 2026, a battery passport system will be created for each EV battery and industrial battery placed in the market.

An analysis of the three case studies indicates that while the objectives of EPR adoption were to reduce waste production and promote waste recycling, the waste collection mechanism differed. Korea and France rely on the efficiency of PROs for the collection of waste; the role of PROs in the case of the European Union is unclear. Another notable feature of the EU regulatory framework is the gradual increase in collection targets over a period of time, giving the market enough time to prepare to accommodate increased waste volumes.

Despite the success of the EPR approach in developed countries and a few developing countries, its implementation in India is riddled with several challenges, including effective designing, and achieving collection targets. A series of interviews were done to understand the issues and challenges in implementing an EPR-based policy and its relevance in India.

3. Method: Stakeholder Analysis

We built our research design as a multiple case study using interviews with practitioners and industries as our primary data source. Our analysis includes stakeholders from manufacturers, PROs, NGOs, academics, and others.

3.1. Sampling

As a first step to understanding the role of PROs involved in the waste management industry, we interviewed PROs for an insight into their role in waste collection and waste segregation, and the challenges they faced during the waste collection procedure. Second, to thoroughly understand the waste recycling industry, we surveyed representatives from the lead acid and lithium-ion battery recycling industries. We also added a few more organisations based on the information shared by key informants during the interview (snowball sampling) and interviewed members from academia for an unbiased perspective.

Data was also collected from producers and pollution control bodies in the country. Our sampling provided us with an understanding the waste flow, collection, and recycling processes in the country.

3.2. Data Collection

We relied on semi-structured interviews with PROs and experts to collect the qualitative data. The interview discussed the overall challenges and bottlenecks of the existing EPR scheme in India. In addition to these, we asked them about the overall performance of the existing EPR scheme and the profit margin (which all of them were sceptical about discussing). We also asked the respondents what an ideal setup for effective battery waste recycling in India could be.

The next phase of the data collection was the quantitative survey done with the help of structured questionnaires. The list of recyclers provided by the CPCB was analysed with respect to waste production and waste recycling capacities of states and the states of Maharashtra, Haryana, Karnataka were finalised for the quantitative survey.

3.3. Analysis

The authors studied the qualitative interview notes in-depth and identified an initial set of critical issues affect the functioning of EPR. The interviews were analysed for repeated patterns of flowing information among the conducted interviews. This set of issues was matched with data collected during the quantitative survey for triangulation of the collected data.

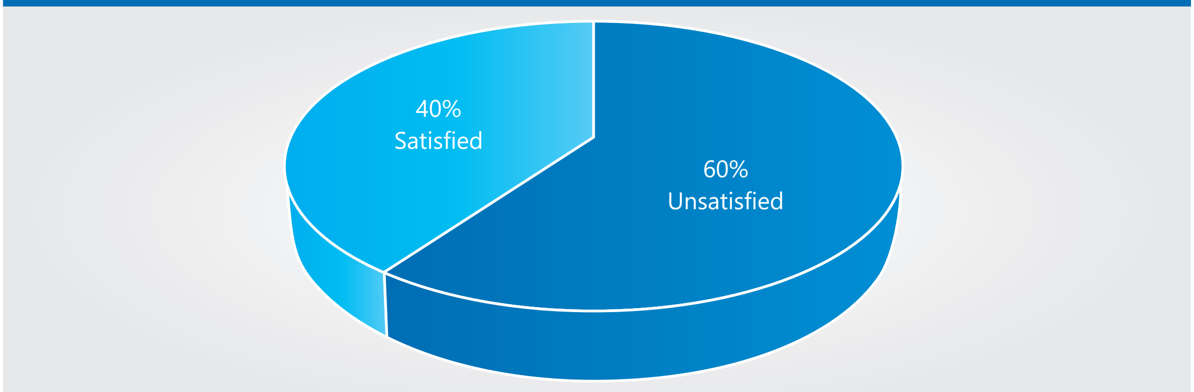
3.4. Discussion and Results

The stakeholder responses reveal several challenges and bottlenecks in the country's existing and draft waste management EPR. The identified bottlenecks and challenges are mentioned in detail in the following subsections.

3.4.1 The conundrum of waste collection and collection targets

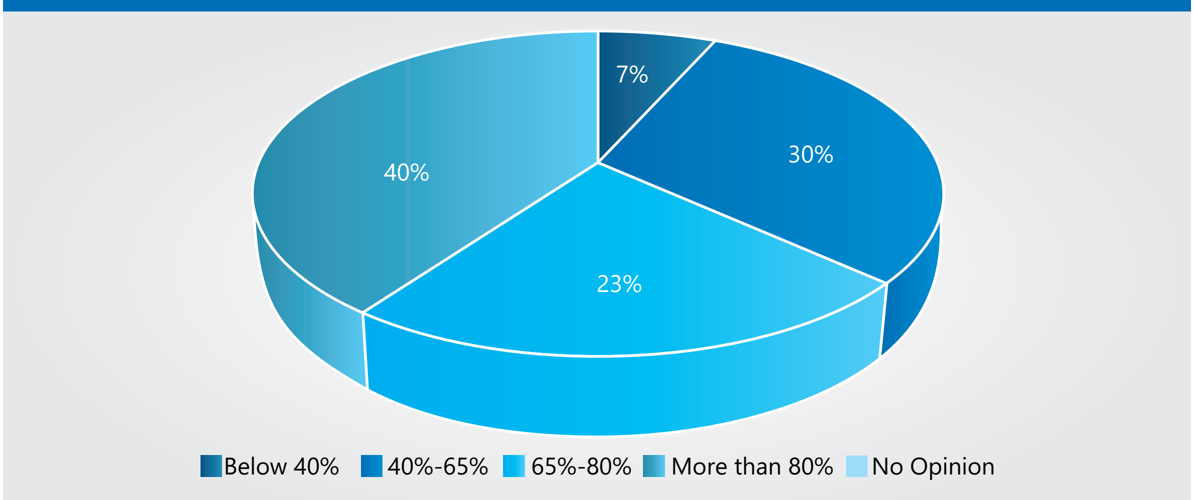
While the publishing of targets in the Battery Waste Management (BWM) 2020 was seen as a welcome move, a majority of stakeholders expressed their concerns over the ambitious collection targets published in the draft rules. The lack of an effective collection system is a significant barrier to effective battery waste recycling. More than 60 per cent of the respondents felt that the currently published targets are ambitious; it was also not clear how they were decided (see Figure 53). Similar problems were reported in countries like China and Japan, where battery waste was not uniformly collected (Terazono et al., 2015; Zeng, Li and Liu, 2015). Additionally, stakeholder felt that even if the collection targets are reached, existing infrastructure would be insufficient to deal with the collected quantum of waste. Hence, the decision on collection targets needs to be backed with significant investment in the recycling industry.

Figure 53: Proportion of Stakeholder Satisfied with Published Targets (% age)



The first step towards designing an effective waste strategy is to develop an understanding of the country's waste generation, recycling capacity, and waste flows. This data would help set more realistic targets. According to the survey, the preferred initial battery collection targets ranged between 60 per cent and 80 per cent and once these are achieved, the stakeholders felt that the targets could be scaled up to 100 per cent (see Figure 54).

Figure 54: Stakeholders Perception about Ideal Waste Collection Targets



> ***I feel that the target is very, very important and crucial, but it has to be realistic.***
> *(A Waste NGO Representative)*

> ***Meeting the waste collection target is not difficult; however, there are multiple players in the market, i.e., formal and informal and thus channelizing the waste to the concerned agencies becomes the problem.***
> *(Waste PRO)*

The sector is dominated by the informal sector. This is not just the case with the battery recycling industry but also with the e-waste industry, where the informal sector collects more the 90 per cent of the waste. Consequently, players in the formal sector are often left with the choice to either collect waste from producers or buy it from the informal sector. Overcoming this barrier remains a challenge for the waste recycling industry in India.

This is not just India's story but also that of other South Asian countries like China, where the informal sector dominates the waste collection nexus. This dominance of the informal sector can be attributed to the reluctance of the formal sector or producer to be actively involved in the waste collection process. Nor were they legally required to do so. While we often see the involvement of the informal sector as a problem, we need to change this perspective and start thinking of ways to leverage the informal sector's networks. When we say leveraging, we do not mean to push for mere documentation in the name of formalisation but actually make them a part of the system. Thus, there is a need to put in place an alternative waste collection mechanism.

> ***The informal sector is extremely comfortable in what they are doing, so there has to be some sort of substantial incentive to convince them to formalise themselves.***
> *(Waste PRO)*

In order to formalise the informal sector, the process of formalisation must be made so lucrative that the sector goes for the formalisation process. A similar exercise was followed in China, where the government initially offered incentives to the recyclers in the informal sector to bring them into the formal sector.

Alternatively, a market-based mechanism could be deployed for effective waste collection. For example, producers can include a deposit fee in the cost of the battery, which is returned to the user once he returns the battery. The lead acid battery industry followed this framework in India, where the customers would receive a refund on purchasing a new battery.

3.4.2 The Shortage of Skilled Labour

The second major issue facing the recycling industry is the lack of skilled labour. The issue was highlighted as a matter of concern by both the recycling industry and PROs, although the skills requirements of the recycling industry and PROs differ.[105] A possible solution to overcome the problem of shortage of skilled labour is the integration of the informal sector with the formal sector. Ezeah et al., (2013) outlined six measures to successfully integrate the formal with the informal sector, i.e., social acceptance, political will, mobilisation of co-operatives, partnerships with private enterprises, management and technical skills, and legal measures. However, the process of formalisation will necessarily be gradual.

> ***"Food and family first – health is secondary for workers involved in the informal sector. Thus, it is crucial to attract and train talent in the informal sector for a successful waste management ecosystem."***
> *(Waste PRO)*

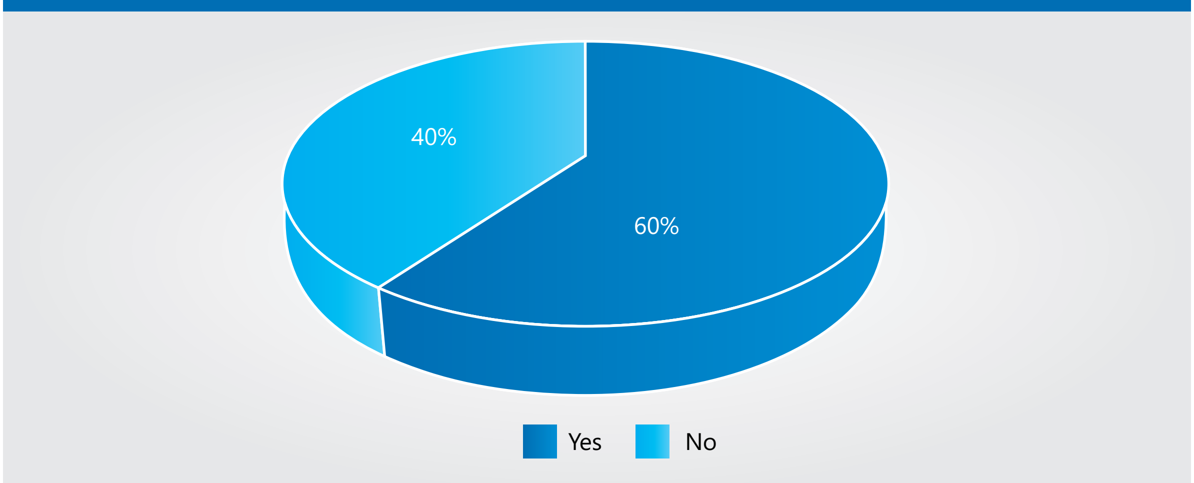
3.4.3 Incentivising the Design for Improved Recycling

The process of EPR was initially designed to incentivise the process of recycling. However, the idea of incentivising recycling was given up and the process has now become more legally binding. Stakeholders stressed the need for incentives to recyclers during the interviews.

> ***"The industry can do with a clear set of subsidies being announced and incentives being created for setting up recycling facilities."***
> *(Waste PRO)*

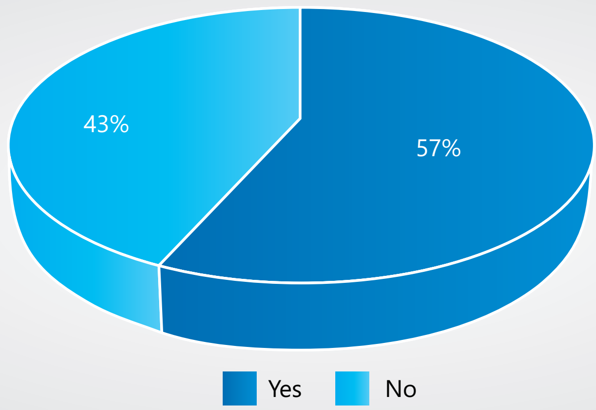
However, while many stakeholders were keen on financial incentives, a significant proportion of stakeholders were in favour of better policy designs to promote recycling.

Figure 54: Stakeholders Perception about Ideal Waste Collection Targets



[105] For in-depth highlights, please see the ICRIER Working Paper titled 'Employment Potential of the Battery Recycling Industry in India and its Economy Wide Linkages.

Figure 56: Proportion of Stakeholders looking for support in the form of policies



A majority of stakeholders were of the opinion that since the industry is in nascent stage of development, a pull in the form of policies or subsidies would help the industry.

4. Policy Implications

This study presents critical issues facing the implementation of the EPR mechanism for the Li-ion battery recycling industry in India. It brings together perspectives from many stakeholders and explores strategy on how the EPR scheme can help India develop into a successful circular economic model.

- There was a clear consensus among stakeholders that existing EPR schemes are pretty ambitious in terms of collection targets. The current infrastructure is inadequate to handle the volume of waste generated. While the country is moving towards the adoption of electric vehicles, lithium ions batteries used in these vehicles will reach end life after 20-25 years of usage. This leaves us with significant time to invest in the recycling infrastructure required for effectively handling the EV battery waste likely to be generated. Another benefit of increasing investment in recycling infrastructure would be the circular economy perspective. Given that India is deficient in some of the critical materials needed to manufacture batteries, establishing a circular economic model would be a good move to secure sustainable resource supply.

  The EPR system is a practical step towards reaching this goal; however, its enforcement must be done with high standards. Additionally, it is also crucial that we collect necessary data on producing waste recycling to understand waste economics better.

- A majority of the stakeholders agreed that there is a shortage of skilled labour in the industry. The pandemic has further exacerbated the existing gap. A more concentrated effort in the form of training is required to fill the skill gap and build capacity.

- Another significant component of recycling is the transportation cost. There is a need to devise a strategy to increase collection efficiency; for this, policymakers will need to come up with business models that will meet with popular acceptance. Additionally, we need to understand the battery waste flow within the country and optimise it with the recycling industries. For instance, if waste from the norther part of the country is being transported to southern part of the country for recycling, it adds up to a significant transportation cost. To avoid that, industries must be established in location where the cost of transportation of waste could be minimised.

Finally, the entire design of EPR must be based on a carrot and stick policy instead of a command-and-control policy. Stakeholders felt that the current policy is not producer friendly. While it punishes producers who fail to fulfil their responsibility; it hardly recognises their efforts for being honest. Thus, there is a need to shift policies towards this directive where we identify players who are performing well and reward them for the long-term sustainability of the policies.

5. Conclusions

As earlier mentioned, the article's main objective was to understand the proposed nuances of the adoption of EPR based policies in India. The research examines the challenges faced by industries in ensuring compliance with EPR policies. Although EPR policies have been implemented for the e-waste industry and the plastics industry, effective waste management is still very much a work in progress. The entire premise of the EPR policy is based upon the' Pollution Prevention Pays' principle and transferring the recycling burden from municipalities to producers. Thus, it is apparent that implementing the EPR policy would lead to an increase in the operational cost of the industry. However, the promotion of recycling needs to be viewed in the context of actions to mitigate climate change and should aim at encouraging innovations that help optimise the use of resources and reduce costs.

Besides, the success of EPR policies also depends on factors like enforcement of policy and capacity building of existing resources for the successful application of the policy.

Author's Note

The views and opinions expressed in this chapter are the authors' and do not necessarily reflect those of ICRIER and IISD. All errors are thus the author's own.

References

AbAbejón, R., Laso, J., Margallo, M., Aldaco, R., Blanca-Alcubilla, G., Bala, A., & Fullana-i-Palmer, P. (2020). Environmental Impact Assessment of the Implementation of a Deposit-Refund System for Packaging Waste in Spain: A Solution or an Additional Problem? Science of the Total Environment, 721, 137744. https://doi.org/10.1016/j.scitotenv.2020.137744

Annamalai, J. (2015). Occupational health hazards related to Informal recycling of E-Waste in India: An Overview. http://www.indiaenvironmentportal.org.in/files/file/informal%20recycling%20of%20E%E2%80%91waste%20in%20India.pdf

Ardi, R., & Leisten, R. (2016). Assessing the role of informal sector in WEEE management systems: A System Dynamics approach. Waste Management, 57, 3–16. https://doi.org/10.1016/j.wasman.2015.11.038

Awasthi, A. K., & Li, J. (2017). Management of electrical and electronic waste: A comparative evaluation of China and India. Renewable and Sustainable Energy Reviews, 76, 434–447. https://doi.org/10.1016/j.rser.2017.02.067

Benchmark report: Cobalt's price rises highlight shift to battery-driven pricing dynamics. (n.d.). Green Car Congress. Retrieved April 28, 2021, from https://www.greencarcongress.com/2020/11/20201130-benchmark.html

Berckmans, G., Messagie, M., Smekens, J., Omar, N., Vanhaverbeke, L., & Van Mierlo, J. (2017). Cost Projection of State of the Art Lithium-Ion Batteries for Electric Vehicles up to 2030. Energies, 10(9), 1314. https://doi.org/10.3390/en10091314

Boxall, N. J., King, S., Cheng, K. Y., Gumulya, Y., Bruckard, W., & Kaksonen, A. H. (2018). Urban mining of lithium-ion batteries in Australia: Current state and future trends. Minerals Engineering, 128, 45–55. https://doi.org/10.1016/j.mineng.2018.08.030

Chang, S. W. (1997). Gatting a Green Trade Barrier – Eco-Labelling and the WTO Agreement on Technical Barriers to Trade. Journal of World Trade, 31(1). https://kluwerlawonline.com/journalarticle/Journal+of+World+Trade/31.1/TRAD1997007

Choi, T. (2017). Environmental impact of voluntary extended producer responsibility: The case of carpet recycling. Resources, Conservation and Recycling, 127, 76–84. https://doi.org/10.1016/j.resconrec.2017.08.020

Choi, Y., & Rhee, S.-W. (2020). Current status and perspectives on recycling of end-of-life battery of electric vehicles in Korea (Republic of). Waste Management, 106, 261–270. https://doi.org/10.1016/j.wasman.2020.03.015

Constant, S., Oosterhoff, P., Oo, K., Lay, E., & Aung, N. (2020). Social Norms and Supply Chains: A Focus on Child Labour and Waste Recycling in Hlaing Tharyar, Yangon, Myanmar. Institute of Development Studies. https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/15422

Ezeah, C., Fazakerley, J. A., & Roberts, C. L. (2013). Emerging trends in informal sector recycling in developing and transition countries. Waste Management, 33(11), 2509–2519. https://doi.org/10.1016/j.wasman.2013.06.020

Fernández-Luqueño, F., López-Valdez, F., Gamero-Melo, P., Luna, S., Aguilera-González, E. N., Martínez, A. I., Hernández-Martínez, G., Herrera-Mendoza, R., Álvarez, M. A., & Pérez-Velázquez, I. R. (2010). Heavy metal pollution in drinking water – A global risk for human health: A review. African Journal of Environmental Science and Technology, 18.

Harper, G., Sommerville, R., Kendrick, E., Driscoll, L., Slater, P., Stolkin, R., Walton, A., Christensen, P., Heidrich, O., Lambert, S., Abbott, A., Ryder, K., Gaines, L., & Anderson, P. (2019). Recycling lithium-ion batteries from electric vehicles. Nature, 575(7781), 75–86. https://doi.org/10.1038/s41586-019-1682-5

Jaskula, B. W. (2021). Lithium (Data in metric tons of lithium content unless otherwise noted). U.S. Geological Survey, Mineral Commodity Summaries. https://pubs.usgs.gov/periodicals/mcs2021/mcs2021-lithium.pdf

Kabir, M. M., & Demirocak, D. E. (2017). Degradation mechanisms in Li-ion batteries: A state-of-the-art review. International Journal of Energy Research, 41(14), 1963–1986. https://doi.org/10.1002/er.3762

Kavanagh, L., Keohane, J., Garcia Cabellos, G., Lloyd, A., & Cleary, J. (2018). Global Lithium Sources – Industrial Use and Future in the Electric Vehicle Industry: A Review. Resources, 7(3), 57. https://doi.org/10.3390/resources7030057

Kjeldsen, P., Barlaz, M. A., Rooker, A. P., Baun, A., Ledin, A., & Christensen, T. H. (2002). Present and Long-Term Composition of MSW Landfill Leachate: A Review. Critical Reviews in Environmental Science and Technology, 32(4), 297–336. https://doi.org/10.1080/10643380290813462

Latham, E., & Kilbey, B. (2019). Lithium supply is set to triple by 2025. Will it be enough? S&P Global. https://www.spglobal.com/en/research-insights/articles/lithium-supply-is-set-to-triple-by-2025-will-it-be-enough

Leyval, C., Turnau, K., & Haselwandter, K. (1997). Effect of heavy metal pollution on mycorrhizal colonization and function: Physiological, ecological and applied aspects. Mycorrhiza, 7(3), 139–153. https://doi.org/10.1007/s005720050174

Li, X., Mu, D., Du, J., Cao, J., & Zhao, F. (2020). Game-based system dynamics simulation of deposit-refund scheme for electric vehicle battery recycling in China. Resources, Conservation and Recycling, 157, 104788. https://doi.org/10.1016/j.resconrec.2020.104788

Lithium Price 2020 [Updated Daily]. (n.d.). Metalary. Retrieved April 28, 2021, from https://www.metalary.com/lithium-price/

Liu, Z., Tang, J., Li, B., & Wang, Z. (2017). Trade-off between remanufacturing and recycling of WEEE and the environmental implication under the Chinese Fund Policy. Journal of Cleaner Production, 167, 97–109. https://doi.org/10.1016/j.jclepro.2017.08.137

Mantilla Herrera, A. M., Crino, M., Erskine, H. E., Sacks, G., Ananthapavan, J., Mhurchu, C. N., & Lee, Y. Y. (2018). Cost-Effectiveness of Product Reformulation in Response to the Health Star Rating Food Labelling System in Australia. Nutrients, 10(5), 614. https://doi.org/10.3390/nu10050614

Martin, G., Rentsch, L., Höck, M., & Bertau, M. (2017). Lithium market research – global supply, future demand and price development. Energy Storage Materials, 6, 171–179. https://doi.org/10.1016/j.ensm.2016.11.004

Natarajan, S., & Aravindan, V. (2018). Recycling Strategies for Spent Li-Ion Battery Mixed Cathodes. ACS Energy Letters, 3(9), 2101–2103. https://doi.org/10.1021/acsenergylett.8b01233

Nixon, H., & Saphores, J.-D. M. (2007). Financing electronic waste recycling: Californian households' willingness to pay advanced recycling fees. Journal of Environmental Management, 84(4), 547–559. https://doi.org/10.1016/j.jenvman.2006.07.003

OECD (2001), Extended Producer Responsibility: A Guidance Manual for Governments, OECD Publishing, Paris, https://doi.org/10.1787/9789264189867-en.

Pagliaro, M., & Meneguzzo, F. (2019). Lithium battery reusing and recycling: A circular economy insight. Heliyon, 5(6), e01866. https://doi.org/10.1016/j.heliyon.2019.e01866

Rai, P. K. (2008). Heavy Metal Pollution in Aquatic Ecosystems and its Phytoremediation using Wetland Plants: An ecosustainable approach. International Journal of Phytoremediation, 10(2), 133–160. https://doi.org/10.1080/15226510801913918

Tesfaye, F., Lindberg, D., Hamuyuni, J., Taskinen, P., & Hupa, L. (2017). Improving urban mining practices for optimal recovery of resources from e-waste. Minerals Engineering, 111, 209–221. https://doi.org/10.1016/j.mineng.2017.06.018

Velázquez-Martínez, Valio, Santasalo-Aarnio, Reuter, & Serna-Guerrero. (2019). A Critical Review of Lithium-Ion Battery Recycling Processes from a Circular Economy Perspective. Batteries, 5(4), 68. https://doi.org/10.3390/batteries5040068

Velis, C. (2017). Waste pickers in Global South: Informal recycling sector in a circular economy era. Waste Management & Research, 35(4), 329–331. https://doi.org/10.1177/0734242X17702024 Walls, M. (2008). Deposit-Refund Systems in Practice and Theory. 15.

Wang, B., Wang, Q., Wei, Y.-M., & Li, Z.-P. (2018). Role of renewable energy in China’s energy security and climate change mitigation: An index decomposition analysis. Renewable and Sustainable Energy Reviews, 90, 187–194. https://doi.org/10.1016/j.rser.2018.03.012

Wang, X., Gaustad, G., Babbitt, C. W., Bailey, C., Ganter, M. J., & Landi, B. J. (2014). Economic and environmental characterization of an evolving Li-ion battery waste stream. Journal of Environmental Management, 135, 126–134. https://doi.org/10.1016/j.jenvman.2014.01.021

Wilson, D. C., Velis, C., & Cheeseman, C. (2006). Role of informal sector recycling in waste management in developing countries. Habitat International, 30(4), 797–808. https://doi.org/10.1016/j.habitatint.2005.09.005

Xue, Y., Wen, Z., Bressers, H., & Ai, N. (2019). Can intelligent collection integrate informal sector for urban resource recycling in China? Journal of Cleaner Production, 208, 307–315. https://doi.org/10.1016/j.jclepro.2018.10.155

Yu, Z., Tianshan, M., & Khan, S. A. R. (2021). Investigating the effect of government subsidies on end-of-life vehicle recycling. Waste Management & Research: The Journal for a Sustainable Circular Economy, 39(6), 860–870. https://doi.org/10.1177/0734242X20953893

Zeng, X., Li, J., & Liu, L. (2015). Solving spent lithium-ion battery problems in China: Opportunities and challenges. Renewable and Sustainable Energy Reviews, 52, 1759–1767. https://doi.org/10.1016/j.rser.2015.08.014

Zhang, F., Wang, H., & Wu, X. (2021). The Impact of Government Subsidies on Single-Channel Recycling Based on Recycling Propaganda. Energies, 14(23), 8189. https://doi.org/10.3390/en14238189

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