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

Summary for Policymakers

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SUMMARY FOR POLICYMAKERS

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1. 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,

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3. Acknowledgement

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4. Background/Motivation

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 INR14,000 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 INR10,000 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 infrastructural.

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 developing 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).

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 Rs.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 Rs.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 Rs.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

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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

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

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.

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 spill over of the stalling of economic activity and lockdowns resulting from Covid-19 has been the impact on environment. Coronavirus is expected to trigger the largest ever annual decrease in global CO2 emissions (Evans, 2020). The air quality indices of different countries have improved following *"reduction in factory and road traffic emissions of carbon dioxide (CO2), nitrogen oxides (NOx) and related ozone (O3) formation, and particulate matter (PM)"* (Hamwey, 2020). For instance, there was a reduction in Nitrogen dioxide (NO2) 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. NO2 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, 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.

4.1 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***

4.2 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

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

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)

[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.

5. Trade, tariffs, and services restrictions along the EV value-chain

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 USD2.7 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% 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

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

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.

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.

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 to the supply of 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)).

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 sector 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.

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[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.

6. 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 vehicles 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 US$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 US$500 billion on EVs and batteries through 2030 (Lienert and Bellon 2021), which is a significant increase from pre-pandemic levels of US$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 US$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 US$266 billion between 2020 and 2030 (NITI Aayog et al. 2022). Total EV investment announcements in 2021 in India reached US$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 busses 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 US$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 to be precise) 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.

7. Policies and skill gaps

The government, an important stakeholder in the Indian EV ecosystem, has been proactively driving the sector forward via different policies and measures. The first section of the chapter focuses on the role of the government in the Indian EV ecosystem at the centre and the state. The second section of the chapter looks at the specific challenges and skills gap, facing the Indian EV ecosystem and outlines the need for policy intervention to overcome these.

7.1 National and state policies

The national and state policies in the EV sector in India are complementary: The first phase of the FAME India Scheme was implemented through four focus areas namely, demand creation, technology development, experimental trials in selected cities as pilot projects, and improving charging infrastructure. FAME II mainly focuses on supporting electrification of public and shared transportation.

State EV policies have been looked at 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

The inclusion of a PLI schemes for the auto sector, the ACC scheme, along with existing schemes like FAME and state subsidies provide direct fiscal incentives for the brands and an indirect one in the form of investments that these are likely to invite. The objective of all these schemes is to incentivise electric vehicles and alternative fuels, and advanced technologies. This is expected to galvanise localisation and wider adoption and strengthen the EV ecosystem in India.

7.2 The challenge of skill gaps and the need for policy intervention

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 holds 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 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.

8. Financial and technological viability of LIB recycling in India

The LIB market in India is projected to expand rapidly because of increased demand from the automotive and energy storage sector. India has taken several prominent 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 electric vehicles (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 several aspects, especially on recycling to achieve sustainability and strengthen energy security.

This chapter examines the financial and technological viability of LIB recycling in India. Since the information related to technology and costs for LIB recycling in Indian land is not publicly available, 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 capacities, technologies used, and costs related to installation of recycling facilities and their operation was collected from identified stakeholders in one-on-one meetings. Detailed analysis of stakeholder inputs from consultations and review of comments suggests the following.

- LIB recycling is far more expensive than recycling of lead-acid batteries (LAB).[9] The analysis shows that LIB recycling infrastructure is more capital intensive. For a recycling plant with an annual capacity of 1 GWh, it requires more than USD10 million in total capital expenditure (CAPEX).[10] The annual cost involved in the operation of the plant (OPEX) is estimated at around USD5.25 million.[11]
- In terms of technology, hydrometallurgy is found to be a prevalent recycling method since this is more sustainable as compared to pyrometallurgy. With cobalt and lithium recovery being greater than 95 per cent under the process (in some cases, even greater than 99 per cent), recycling firms would prefer the hydrometallurgical method. However, equipment for hydrometallurgy is expensive. For a recycling plant of annual capacity of 1 GWh, the cost involved in installing hydrometallurgical

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

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technology equipment alone is projected to be around USD5 million.

- There is need for greater 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 constantly evolving nature of battery in terms of its chemistry and technology, only standardised technology can make a recycling unit more profitable while continuously increasing recycling coverage and capacity.

- The collection and transportation costs of spent batteries is a major component in recycling cost. In the absence of localisation, a spent battery has to traverse a distance of more than 800 km before it reaches the recycling plant.[13] Setting up recycling plants in a strategically distributed manner will bring down the need for long-range transportation and hence, the cost. Localisation will also generate local economic activity. Quite apart from the need to reduce the cost of collection and transport, the transportation of LIBs is hazardous and hence, highly efficient logistical improvements are needed in collection and transportation of spent LIB packs.

- Low volumes of waste collection hamper the achievement of economies of scale for recycling plants. Improving the coverage of waste collection that could help increase recycling capacity will help realise scale economies.

There have to be greater financial inflows into the LIB recycling industry to increase recycling capacity in the country. A roadmap to ensure financial flows is, thus, necessary. 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 the results available in the public domain. It is suggested that policymakers develop market mechanisms to support financing and technology adoption for LIB recycling while taking steps to improve the efficiency of logistics and transportation systems to achieve higher collection efficiency.

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9. Understanding employment potential of battery recycling in India

Battery recycling presents opportunities not only in terms of making the transition to EVs sustainable but also in terms of generating employment. 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 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 to understand 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.
- The maximum employment in hazardous waste management is in Maharashtra, in the three sample states of Maharashtra, Karnataka, and Haryana.
- Employees in the hazardous waste management sector receive limited social security benefits.

Primary data analysis based on the survey results shows:

- About 53.3 per cent of battery recycling units employ 11-30 workers on the premises.
- A large chunk consists of labourers (76.4 per cent), with management (12 per cent) and technical (2.6 per cent) staff accounting for a much smaller share. In fact, the housekeeping, and others (incl. guards, etc.) (5.4 per cent) category forms a much 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. Further, going ahead the question of quality of jobs over quantity will also take centre stage. 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.

10. Waste to Wealth: Extended Producers Responsibility for Effective Electric Vehicle Battery Waste Management in India

The impacts of climate change and increasing air 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 Lithium-ion waste, the policy approach of Extended Producers Responsibility (EPR) is being increasingly adopted. This working paper 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.
- The 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 less 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.

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