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Assessment of PLI Scheme on EV Manufacturing in India

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1. Introduction

The global consensus among economies is the urgent recognition of the need to establish resilient local supply chains, particularly evident in the electric vehicle (EV) battery manufacturing sector. This strategic shift is closely aligned with international climate objectives, underscoring a collective commitment to sustainable practices and a concerted effort to mitigate the carbon footprint associated with the rapidly expanding electric vehicle industry.

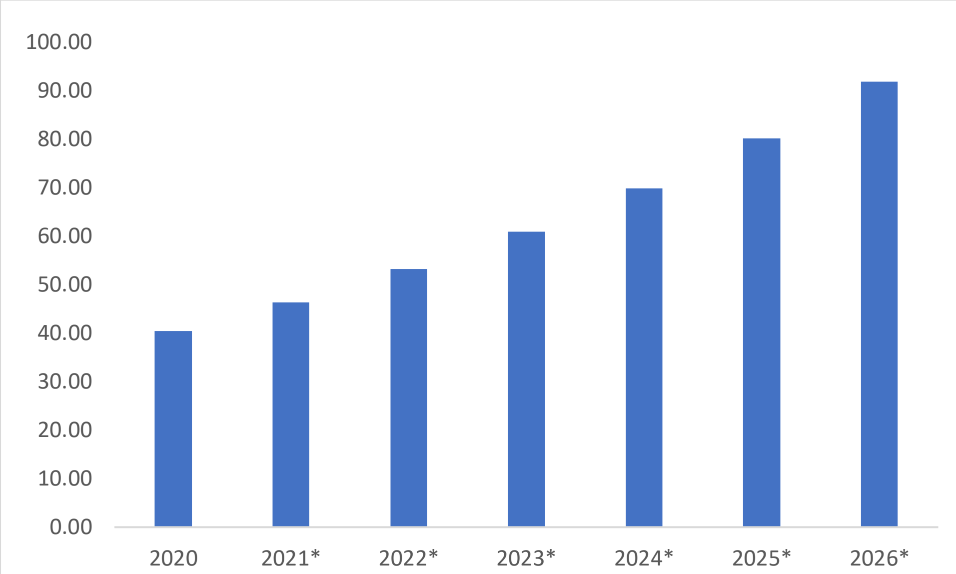
The COVID-19 pandemic acted as a catalyst, revealing vulnerabilities in global supply chains and emphasising the dangers of overreliance on foreign economies for essential components. This prompted a strategic realignment, focusing on reshaping supply networks with an emphasis on localization. As a result, establishing resilient, sustainable, and secure supply chains has become a defining objective for economies across the globe.

In the automotive industry, the imperative to transition towards a low-carbon economy is steering the trajectory towards electric vehicles (EVs). Governments globally are advocating for the establishment of indigenous battery value chains as a fundamental aspect of national industrial policy. This endeavour is fuelled by the twin objectives of reducing supply chain dependencies and taking advantage of the economic prospects offered by the growing EV industry. Countries seek to diminish reliance on unpredictable global markets, strengthen their technological independence, and gain a competitive edge in the worldwide transition to electrification by developing their domestic battery production capacity. In consonance with this global shift, India has implemented supply-side measures and production-based strategies to bolster its EV Battery manufacturing capabilities. This paper attempts to conduct a detailed analysis of India's one such initiative in this domain- the Production Linked Incentives for the Automobile sector.

1.1. Overview of the Global EV Batteries Ecosystem

The EV market has witnessed a remarkable surge, claiming 10% of global passenger vehicle sales, marking a tenfold growth compared to prior years. Norway is at the forefront, with an impressive 80% of its passenger vehicle sales in 2022 being fully electric, outpacing Iceland (41%), Sweden (32%), the Netherlands (24%), China (22%), the entire European Union (12%), and the United States (6%) (IEA, 2023). Batteries, accounting for 30% to 40% of an EV's value, are crucial to this sector. The push towards net-zero emissions further accentuates the strategic importance of securing a reliable supply of essential minerals and metals for battery production. This focus not only drives the quest for resource security but also spurs competition to develop cost-effective and technologically advanced batteries to gain a significant market capitalisation in the growing EV battery industry. (IEA)

Figure 1- Projected size of the global lithium-ion battery market from 2020 to 2026 (in billion U.S. dollars)



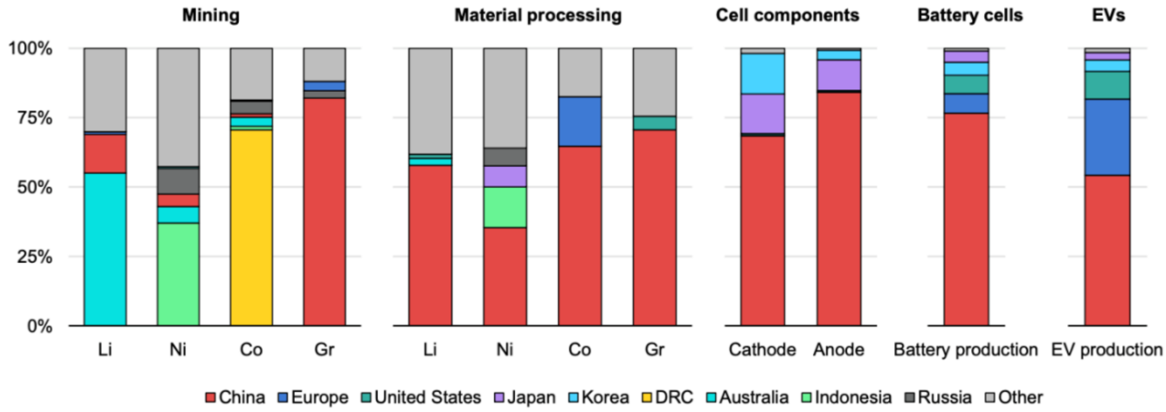
Source- Statista; Research and Markets

In this industry, China is one of the biggest manufacturers and dominates the entire downstream EV Battery Supply Chain. Its strategic planning and efforts spanning over two decades and comprehensive set of battery policies that span production incentives, raw material procurement and processing, research and development, innovation hubs, and stringent battery recycling mandates have paid off. In 2022, electric vehicles accounted for 22% of passenger car sales in China, totalling 4.4 million units. Globally, Chinese companies manufacture 80% of the best-selling electric vehicle models (Jaeger, 2023). China commands a significant portion of the global battery manufacturing sector, with approximately 900 gigawatt-hours of capacity, constituting 77% of the world's total. This nation houses six out of the top ten largest battery producers globally. The key to China's ascendancy in the battery domain lies in its comprehensive control over the electric vehicle (EV) supply chain, right from the processing of raw materials.

To illustrate, China is responsible for processing[7] around 67% of the global supply of lithium, 73% of cobalt, 70% of graphite, and 95% of manganese (Mining Technolgy, 2023). Along with this, China dominates the production capacity of battery cells, holding three-quarters of the global share. This dominance extends to the specialized production of cathode and anode materials, where China is responsible for 70% of the world's cathode material and 85% of anode material production capacity (IEA, 2022).

[7] Battery production required high purity of minerals which can be processed using heavy industrial processes. Unless processed in the specialized way, minerals cannot be used for battery production, increasing the importance China in the supply chain (Source: IEA).

Figure 2- Geographical distribution of the global EV battery supply chain.



Notes: Li = lithium; Ni = nickel; Co = cobalt; Gr = graphite; DRC = Democratic Republic of Congo. Geographical breakdown refers to the country where the production occurs. Mining is based on production data. Material processing is based on refining production capacity data. Cell component production is based on cathode and anode material production capacity data. Battery cell production is based on battery cell production capacity data. EV production is based on EV production data. Although Indonesia produces around 40% of total nickel, little of this is currently used in the EV battery supply chain. The largest Class 1 battery-grade nickel producers are Russia, Canada and Australia.

Source- IEA, 2022

Acknowledging the substantial reliance on China and its dominance within the electric vehicle (EV) ecosystem, nations worldwide are initiating multiple measures to develop strong value chains with an emphasis on localisation. The United States has launched targeted initiatives such as the Battery500 Consortium and the Inflation Reduction Act, alongside various tax incentives to stimulate the battery sector. The European Union has rallied its member states under the European Battery Alliance, supplemented by individual policy measures from its member economies. Japan has introduced the Next-Generation Vehicles strategy and is actively engaging in international partnerships to further its ambitions. In the United Kingdom, programs like the Faraday Battery Challenge are designed to enhance EV battery technology. Meanwhile, India's Production Linked Incentive scheme for the Automobile sector is instrumental in cultivating a robust EV ecosystem. These strategic, battery-centric initiatives are pivotal, augmenting consumer-focused demand incentives across these nations to bolster the adoption of electric vehicles.((Blackridge, 2023), (Council on Foriegn Relations, 2019) (South China Morning Post, 2023) (IEA, 2023) (UK Research and Innovation, 2023) (IEA, 2023))

Table 1- Summary of Major Incentives focused on EV Batteries.

Country	Major Initiatives for EV Batteries
China	**China All-Solid-State Battery Collaborative Innovation Platform (CASIP)** is a consortium which brings together Industry Giants, academic institutions and government resources to accelerate research and development in solid-state battery technology.
	13th Five-Year Plan has incentives focused in battery technology and research
	Made in China 2025 is a strategic plan for enhancing Chinese manufacturing sector with specific support towards EV batteries
	China's National Mineral Resources Plan for 2016-20 aimed at securing supplies of raw materials including the ones required for EV batteries
United States	**Battery500 Consortium** is a multi-institution program working to develop next-generation Li-metal anode cells.
	The U.S. Department of Energy supports projects to enhance battery recycling and manufacturing capacities.
	Inflation Reduction Act (2022) includes a combination of grants, loans, tax provisions and other incentives to accelerate the deployment of clean energy, clean vehicles, clean buildings and clean manufacturing.
United Kingdom	**Faraday Battery Challenge** is investing in research and innovation projects, and facilities, to drive the growth of a strong battery business in the UK.
Japan	**Next-Generation Vehicle Strategy** made to popularise the usage of ZEVs
	Subsidies for Manufacturers of EV batteries
European Union	**European Battery Alliance (EBA)**
	Regulation on batteries as a part of EU Green deal to reduce environmental and social impacts throughout all stages of the Battery cycle

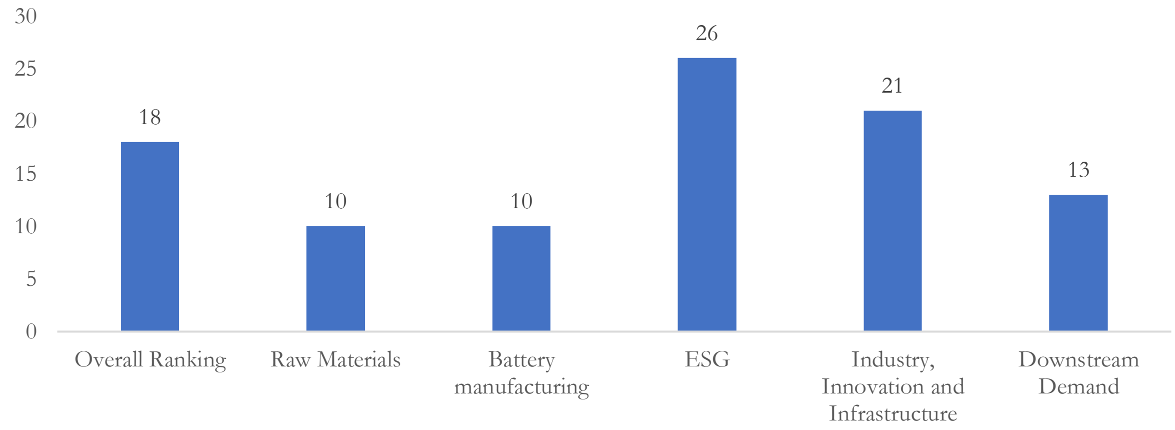
Source - Black Ridge Research, IEA, UKRI, SCMP, CFR, Authors Analysis.

In the analysis of the global lithium-ion battery supply chain by Bloomberg New Energy Finance (BNEF), thirty (30) foremost nations were evaluated on the basis of 45 distinct metrics that span five principal areas: the accessibility and provision of essential raw materials; the production of battery cells and their components; domestic requirements for electric vehicles and energy storage solutions; the supporting framework, innovation, and sectoral growth; as well as

Environmental, Social, and Governance (ESG) factors. In 2022, India stands at the 18th position out of 30 economies in these global lithium-ion battery supply chain rankings. India ranks 10th in access to raw materials, 10th in battery manufacturing, 26th in ESG, 21st in Industry innovation and Infrastructure and 13th in downstream demand (BloombergNEF, 2022)

and Infrastructure and 13th in downstream demand (BloombergNEF, 2022).

Figure- India's Global Lithium-Ion Supply Chain Ranking



Source- BloombergNEF, 2022

Countries globally are working diligently to enhance electric vehicle (EV) battery technologies, a critical move in their strategic pursuit of carbon neutrality and the electrification of transportation fleets. India is currently in the early stages of the EV battery industry and establishing itself within the global ecosystem. There is a noticeable momentum towards progress as the nation is taking deliberate steps towards enhancing its battery ecosystem and its international standing. As India's EV battery sector shows promising growth, it becomes increasingly important to assess the policy instruments that are catalysing this progress.

This research paper provides a critical analysis of the Production Linked Incentive (PLI) scheme in India, with a focus on the PLI for Advanced Chemistry Cells (ACC) within the automobile industry. The paper examines the current policy framework and employs an input-output model to project the potential implications of the PLI ACC policy on the economy.

2. Indian EV Battery Ecosystem

India is actively pursuing its electrification objectives and is committed to various targets including the EV30@30 initiative and decarbonization strategies established at the COP26 summit. Presently, the electric vehicle (EV) market in India is predominantly comprised of two-wheelers (2W), which represent 85%–90% of all EVs sold, succeeded by four-wheelers (4W) at 7%–9%, and three-wheelers (3W) at 5%–7% (Seetharaman, et al., 2023). The market penetration is led by three-wheelers at 8%, followed by electric buses at 7%, electric two-wheelers at 5%, with passenger vehicles at approximately 1%. By 2023, e-rickshaws, which constitute 90% of the three-wheeler segment, reached a penetration rate of 53%, driven by increased accessibility, reduced maintenance costs, advances in technology, and an escalating demand for efficient passenger transit systems (Vahan Dashboard, 2023) (Economic Times, 2023).

Prime Minister Narendra Modi outlined the vision for the future of mobility in India during the 2018 Global Mobility Summit in New Delhi, emphasizing seven key principles: Common, Connected, Convenient, Congestion-free, Charged, Clean, and Cutting-edge (PIB, 2018). Aligning with this vision, Amitabh Kant, G20 Sherpa of India, stressed the importance of transitioning 100% of 2-wheelers and 3-wheelers, and 65%-70% of buses to electric vehicles (EVs) by 2030 to meet the EV30@30 targets. A study by the Council on Energy, Environment and Water (CEEW) posits that reaching a 30% threshold in EV sales could lead to a significant 31% reduction in oil imports, the creation of approximately 121,422 jobs within the EV value chain, a market expansion exceeding INR 2 lakh crore (USD 26 billion) for EV powertrains and batteries, and an investment of about INR 13,372 crore (USD 1.8 billion) in public charging infrastructure by the year 2030 (Soman, Kaur, Jain, & Ganesan, 2020)

The demand for advanced chemistry battery markets in India is forecasted to surge from 20 GWh in 2022 to an estimated 220 GWh by 2030, growing at a compound annual growth rate of about 50%. An increase in battery and electric vehicle manufacturing could result in a reduction in the oil import expenses by an estimated ₹ 2,00,000 crore to ₹ 2,50,000 crore *(CII, 2023)*. However, India's participation in the global EV battery value chain is still in its early stages, mainly involved in battery assembly and depending significantly on imports from China, Taiwan, and European countries.

2.1 India's Initiatives Towards Building the EV Battery Ecosystem

There have been concerted efforts in India that have aimed to provide stimulus to all stakeholders in the ecosystem, catalyzing comprehensive growth in the automotive sector. Initially, the National Auto Policy 2002 sought to modernize the sector and increase value addition. It laid the groundwork for the National Auto Policy 2018, which aimed to upgrade emission standards beyond Bharat Stage VI by 2028, implement Corporate Average Fuel Economy standards, and introduce differential taxation based on vehicle size and CO2 emissions (Ministry of Heavy Industries and Public Enterprises, 2018) (ACMA, Grant Thornton, 2023).

Furthering these efforts, the Government of India's National Electric Mobility Mission Plan (NEMMP) 2020, initiated in 2013, supports the transition to hybrid and electric vehicles to ensure fuel security and environmental sustainability. It sets ambitious sales targets and provides fiscal incentives under the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) schemes. FAME I and II focus on reducing vehicle costs, fostering technological development, funding pilot projects, and building charging infrastructure, aiming to catalyze a transformative shift in the automotive landscape (Ministry of Heavy Industries and Public Enterprises, 2020). In an effort to mitigate the environmental impact of urban transportation, the Green Urban

Transport Scheme (GUTS) was initiated in 2017, targeting a reduction of air pollution in urban areas by transitioning public transport vehicles to eco-friendly alternatives, thus promoting sustainable urban mobility (GOI, n.d.).

The National Automotive Testing and R&D Infrastructure Project (NATRiP), with a total investment of Rs. 3727.30 crore represents a significant commitment by the Government of India to develop world-class automotive testing and R&D facilities. This initiative is designed to elevate India's automotive sector to global standards, integrating it into the worldwide automotive industry while leveraging India's IT prowess to boost the sector's competitive edge (National Automotive Testing and R&D Infrastructure Project, 2019).

To address environmental concerns associated with older vehicles, the Voluntary Vehicle-Fleet Modernization Program (VVMP) was announced. This program aims to organize and regulate the scrappage industry, ensuring it operates transparently and eco-consciously. The VVMP is expected to foster a sustainable ecosystem for the retirement of outdated and polluting vehicles, thereby contributing to the extraction of value from the scrappage process and supporting environmental conservation efforts (Ministry of Road Transport and Highways, 2023).

While the aforementioned policies have been instrumental in the development of the electric vehicle (EV) industry in India, they have focused on consumer incentives and market creation, with scant consideration for the supply-side challenges. Particularly, the critical issue of dependency on imported batteries — the heart of EV technology — remains unaddressed. This research delves deeper into the Production Linked Incentive (PLI) scheme which has been explicitly formulated to bridge the prevailing gap. An exploration of the scheme's framework, the beneficiaries, and the projected implications will be presented. Furthermore, the study will identify existing shortcomings within the PLI scheme and propose policy recommendations to effectively address these deficiencies, thereby enhancing the scheme's impact on India's EV ecosystem.

2.2 Production Linked Incentives

To boost India's involvement in the global value chain, 27 sectors have been identified as key priorities in 'Make In India 2.0'. These sectors were chosen based on the strengths and competitive advantages of Indian industries, the need to reduce imports, the potential for exports, and the creation of jobs. The introduction of the Production Linked Incentive (PLI) schemes, aimed at the manufacturing sector, is a part of this initiative. These schemes are expected to draw in around ₹3 lakh crore in capital expenditure over the next five years. They are anticipated to create employment opportunities for more than 60 lakh people in India and to increase the contribution of the manufacturing sector to the country's total capital formation, which has been between 17-20% from FY12 to FY20. (Ministry of Finance, 2023)

Within the automotive industry, two PLI schemes were announced in 2021: the first, the PLI-Auto initiative, is focused on promoting the production of Advanced Automotive Technology products; the second scheme, is on setting up manufacturing facilities for Advanced Chemistry Cell (ACC). (Ministry of Heavy Industries, n.d.)

2.2.1 PLI for Automobile and Auto Components

This PLI targets the advancement of Zero Emission Vehicles (ZEVs), encompassing both Battery Electric Vehicles (BEVs) and Hydrogen Fuel Cell Vehicles (HFCVs). It is supported by a budgetary allocation of INR 25,938 crore spanning five fiscal years, starting from 2022-23 and extending until 2026-27. Fund disbursement under this scheme is slated to commence in the following financial year, stretching from 2023-24 to 2027-28. (Ministry of Heavy Industries, n.d.).

This scheme is designed to incentivize the indigenous manufacturing of Advanced Automotive Technology (AAT) products, thereby drawing investment into the automotive manufacturing ecosystem. The scheme's core goals are to address cost competitiveness, foster economies of scale, and establish a strong supply chain for AAT products. Moreover, it is anticipated to spur job creation and assist the Automobile Industry in ascending the value chain to produce goods with higher added value (PIB, 2022).

The scheme is divided into two key components: The Champion OEM Incentive, which offers a 'sales value linked' incentive for OEMs manufacturing Advanced Automotive Technology vehicles, covering a diverse array of vehicles and addressing cost disadvantages. Meanwhile, the Component Champion Incentive aims to elevate auto component manufacturers to 'Automotive Champions' status, emphasizing global scaling and market leadership in Advanced Automotive Technology components. (GOI, 2024)

The incentive scheme requires companies to meet all eligibility criteria, including non-automotive firms that can invest in manufacturing Advanced Automotive Technology in India. Eligibility hinges on meeting annual cumulative domestic investment targets and sustained growth from the first year. Investments must come from the applying entity to ensure accountability, with incentives contingent upon annual investment fulfilment. Failure to meet this condition results in a loss of incentives for that year but does not preclude eligibility for future incentives if subsequent investment criteria are met. (GOI, 2024)

To avail of the benefits under the scheme, the Production Linked Incentive scheme outlines specific incentive slabs for Original Equipment Manufacturers (OEMs) and new non-automotive investor companies. For both players, the incentive rates are pegged as a percentage of the sales value, scaling with the sales volume. (GOI, 2024)

This PLI Scheme for the Automobile and Auto Component Industry in India has been successful in attracting a proposed investment of ₹ 74,850 crore against the target estimate of investment ₹ 42,500 crore over a period of five years. The proposed investment of ₹ 45,016 crore is from approved applicants under Champion OEM Incentive Scheme and ₹ 29,834 crore from approved applicants under Component Champion Incentive Scheme (PIB, 2022).

In total, 95 of the applicants[8] have received approval to participate out of the 115 companies that submitted their application in this PLI scheme. Previously, the Ministry of Heavy Industries (MHI) had approved 20 applicants, including their 12 subsidiaries, under the Champion OEM Incentive scheme. Following this, MHI processed further applications for the Component Champion incentive scheme, resulting in 75 applicants and their 56 subsidiaries being accepted. Remarkably, two Auto OEM companies have successfully qualified for both segments of this incentive scheme. (PIB, 2022).

2.2.2 PLI for Advanced Chemistry Cell (ACC)

The scheme was announced with the objective of improving domestic value addition and reducing import dependence. PLI ACC scheme is estimated to reduce imports by ₹ 2,00,000 crore to ₹ 2,50,000 crore on account of oil import bill and increase the share of renewable energy at the national grid level (PIB, 2022). The aim of this scheme is to bolster the infrastructure for Electric Mobility and Battery Storage within India, having a budgetary provision of INR 18,100 crore. It aims to augment the nation's production of Advanced Chemistry Cell (ACC) by establishing Giga-scale ACC and battery manufacturing units that prioritize substantial domestic

[8] Refer Appendix Section I for names of approved applicants.

value addition. The scheme has a two-year gestation period starting from 1st January 2023 to 31st December 2024, followed by a five-year performance period until the end of 2029. Currently, three firms have been awarded a combined capacity of 30 GWh, leaving 20 GWh available for new allocations. (Ministry of Heavy Industries, n.d.)

Eligibility Criteria and Benefits for the PLI ACC scheme:

The PLI ACC scheme is designed to be agnostic with respect to technological preference, granting beneficiary enterprises the autonomy to choose the advanced technology that best aligns with their specific needs. This includes the selection of essential equipment, materials, and goods to establish a cell manufacturing. While there are detailed criteria accessible for the PLI linked to Automobiles and Auto components, there appears to be a lack of precise criteria for the PLI ACC programme. (PIB, 2022).

According to the available information, in this PLI, a minimum of 50% Domestic Value Addition (DVA) will be required to get the incentive. In the PLI ACC scheme, the beneficiary firms are required to achieve a minimum of 25% DVA by the end of 2nd Year and 60% by the end of 5th Year of the scheme. Additionally, these firms are required to invest INR 225 crore per GWh of committed capacity within the initial two years. ((PIB, 2023), (Ministry of Heavy Industries, n.d.)).

Details regarding the distribution of incentives are not exhaustively outlined. However, on the basis of the available information, beneficiaries are required to establish their manufacturing operations within a two-year timeframe. Subsequently, the program will allocate incentives over the following five years, which will be contingent upon the revenue generated from the sales of domestically produced batteries (PIB, 2022). These payments will be determined by factors such as energy efficiency, sales volume, battery lifespan, and the degree of localization. Furthermore, the scheme envisions a collaborative framework involving the state and central governments, alongside the manufacturers. In this tripartite agreement, the state government is expected to facilitate the private sector's efforts by offering land for the construction of the facility and aid in procurement processes. (India Briefing, 2023)

Current Status of the Scheme

For the Advanced Chemistry Cell (ACC) Battery Storage Programme in India, 10 companies placed bids in response to the Request for Proposal issued by the Ministry of Heavy Industries (MHI). The final selection was determined using a Quality & Cost Based Selection (QCBS) process, with bidders ranked according to their technical and financial scores. The ACC capacities have been allocated in order of their rank, till a cumulative capacity of 50 GWh per year. Initially, four companies were selected and five were shortlisted to share the designated 50 GWh capacity. Yet, ultimately, only three of the selected bidders; Reliance New Energy Solar Limited, Ola Electric Mobility Private Limited, formalized their commitment by signing the Program Agreement under the Production Linked Incentive (PLI) Scheme for ACC Battery Storage on July 28, 2022, resulting to undistributed 20 GWh capacity. ((PIB, 2022), (India Briefing, 2022))

The scheme aims for substantial long-term goals, implying a prolonged period before tangible results emerge. Given its recent inception, it is premature to fully assess the scheme's trajectory and its eventual outcomes. Nonetheless, it is imperative to consistently review the scheme's effectiveness and its contribution to the automotive sector and to determine whether the set targets are sufficient in light of the ambitious economic and environmental objectives that have been established. Assessing the broader implications of this policy is critical; it has the potential to catalyse growth not just within the automobile sector but across the entire economy.

The next part of this research is two-fold: initially, it will investigate the existing battery value chain in India, alongside the stakeholders' readiness to embrace a forward looking PLI scheme. Subsequently, the inquiry will extend to assess the PLI schemes' direct, indirect, and ripple effects.

3. Battery Value Chain In India

India's ambition to promote vehicle electrification primarily revolves around two strategic initiatives: the demand incentive scheme known as Faster Adoption and Manufacturing of Electric Vehicles (FAME), which aims to bolster consumer demand and support the development of charging infrastructure, and the Production-Linked Incentive (PLI) schemes, along with a few supportive incentives described in the section above. Despite these efforts, the transition to electric vehicles (EVs) remains slow, uneven, and limited in scope. To date, higher rates of electrification are observed in the smaller vehicle segments such as two and three-wheelers, while the uptake in the four-wheeler segment lags significantly. A discernible over-reliance on demand incentives alone has proven insufficient as a market catalyst to attract investment at the required scale. (Roychowdhury, Chattopadhyaya, & Tripathi, 2023). This gap in the policy framework along with high initial costs and inadequate charging infrastructure is hindering the progress EV in India.

These barriers could be mitigated by enhancing the technical efficiency of electric vehicles, which fundamentally relies on the effectiveness (in terms of both range and cost) of EV batteries. At this critical point, it is essential for policy measures to adapt and advance to facilitate the adoption of EVs and to amplify battery manufacturing capabilities. The transition from consumer-focused incentives, which are most effective in an emerging market, to a comprehensive approach that nurtures the supply chain and fosters an ecosystem conducive to growth is imperative (Ubaid ur Rehman & Aslam, 2022)

Figure 1 Evolution of Policies at varying stages of Market.

Nascent stage of Market

- Purchase Subsidies.
- Tax Rebates.
- Purchase tax exemption.
- Reduction of custom duties and registration.

Maturity Stage of Market

- Fuel regulations.
- Tail- end Emission regulations.
- Carbon emission regulations.

Acceration of Growth

- Focus on Infrastructure growth.
- Improvement in Battery technology.
- Charging Infrastructure
- Advancements in Research and Development.

Source - Ubaid ur Rehman & Aslam, 2022; Authors Analysis.

The International Energy Agency, in its 2023 report on transitioning India's road transport sector, underscores the necessity for electric vehicles to constitute at least 50% of the market within the next decade to align with the 2070 net-zero emissions target. With China's current dominance in the EV market, India's reliance on imports, and its geographical disadvantages in raw material endowments, it becomes critically important to develop a competitive domestic battery industry. For India to emerge as a frontrunner in the global EV ecosystem or to sustain its nascent automobile sector, it must establish battery manufacturing that excels in technology, scale, and cost. Without a steadfast dedication to this sector, India's prospects for gaining a competitive edge or achieving self-reliance in an increasingly vital industry will diminish. Building a robust battery value chain is, therefore, a paramount goal that must be pursued with urgency and strategic focus.

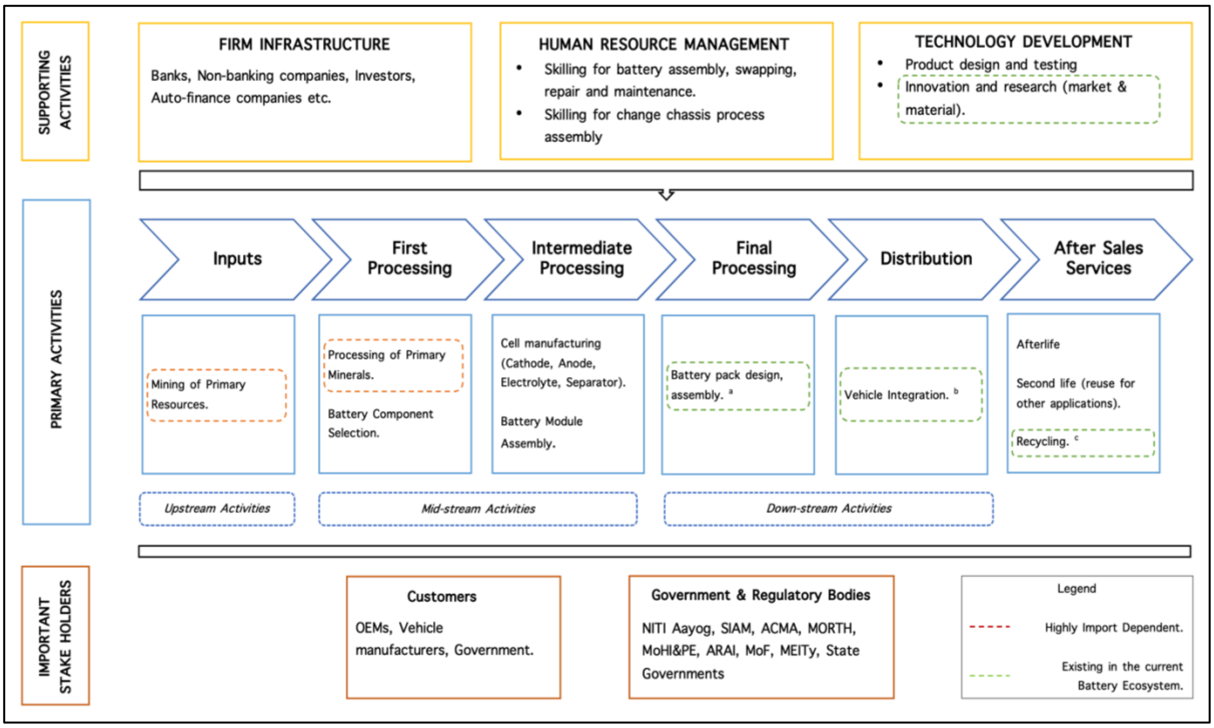
Production-Linked Incentive (PLI) schemes are strategically designed to fortify a competitive electric vehicle (EV) supply and value chain. The efficacy of such policies, however, hinges upon the stakeholders' level of preparedness. A deficit in structural integrity and readiness among the value chain's components could result in a failure to capitalise on the prospective benefits and enhancements that this scheme aims to provide. Therefore, a comprehensive understanding of the value chain's elements and their respective developmental stages is imperative to ensure that the PLI scheme achieve its targeted outcomes.

3.1 Components of Battery Value chain and their presence in India.

India's recent initiation into developing its own value chain for electric vehicle (EV) lithium-ion batteries (LIB) signifies a crucial step towards sustainability. Yet, due to the infancy of this development suggests that not all elements are yet integrated within the local ecosystem. A thorough examination of the existing value chain and the proactive engagement of relevant stakeholders are essential to develop a robust system. The EV Lithium Ion Battery production encompasses six key manufacturing segments: cell cathode, cell anode, cell electrolyte, cell separator, cell assembly, and pack assembly. The creation of these components involves a multifaceted supply chain, including mining firms, refineries, manufacturers of cell components, battery cell manufacturers, and original equipment manufacturers (OEMs), each playing a pivotal role (IISD, 2023)

Figure 4 clearly illustrates the components present in Indian ecosystem, the components that are highly import dependent and the lack of presence of crucial components in the ecosystem. Currently, India's role in this supply chain is primarily limited to assembling batteries, relying heavily on imports predominantly from China, Taiwan, and several European countries. In the fiscal year 2020, India invested close to USD 865 million in importing approximately 450 million units of lithium-ion batteries (EY, 2022).

Figure 2-Current EV Battery Value Chain in India.



[a] Assembly of Cell Packs are undertaken by some firms like Mahindra, Ather, Exide, SunMobility, AmaraRaja. Battery Pack manufacturing is done majorly by ForseePower, Coslight, Pure, Grinntech, Inverted, Trontek, Livgaurd, Okaya, Cyngni, among others. ((Gulia, Gupta, Jadhav, & Garg, 2022) (Shekhar, Sharma, Patel, & Sawant, 2019)

[b] Vehicle Integration is done within the plants by OEMs.

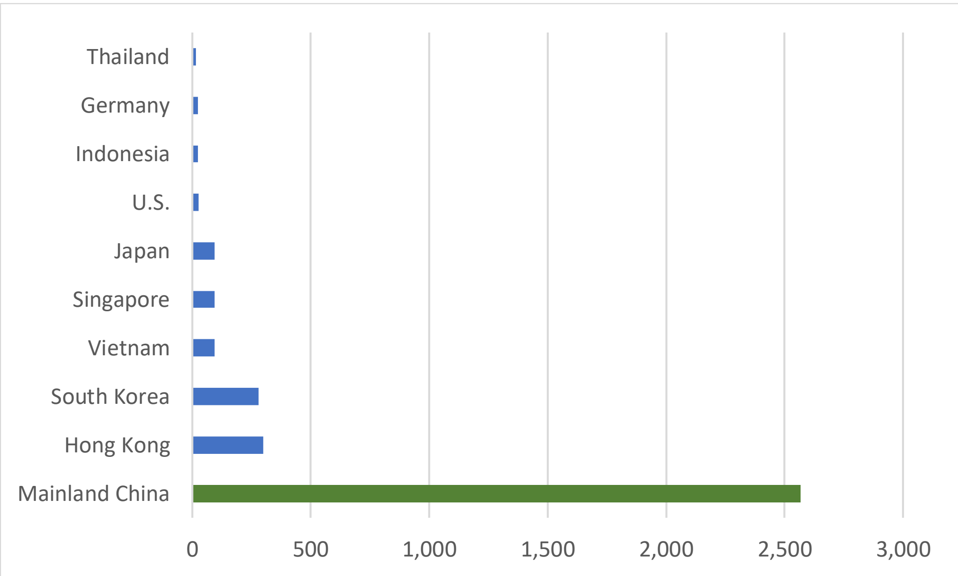
[c] Recycling is integrated with E waste management. Key Battery Recycling Companies in India like TATA Chemicals, Attero Recycling, Lohum Cleantech, Exigo Recycling, SungEel India Recycling, LICO Materials, Eco Tantra, Batx, Ziptrax; take up majority of battery recycling. ((JMK Research and Analytics, 2023) (DTE, 2023)

The value chain illustrates India's lack of key mineral reserves for cell production. This leads to a significant reliance on imports for the required minerals in battery production. India's lack of key mineral reserves for cell production leads to a significant reliance on imports for the required minerals in battery production. In the fiscal year 2023, India's lithium imports reached Rs 23,171 crore from Rs 13,673.15 crore in 2022, underlining the overdependence on foreign resources (Business Today, 2023). Irrespective of the mineral origins, the predominance of processing capabilities in China results to India, along with numerous other global economies, heavily reliant on China for mineral processing. Approximately 67% of global lithium supply, along with 73% of cobalt, 70% of graphite and 95% of manganese is processed by China (Mining Technolgy, 2023). Developing domestic capabilities to process these minerals could propel India to the forefront of the electric vehicle (EV) battery industry.

Recognizing the strategic disadvantage of its mineral import dependence India is turning inward to capitalise on the untapped potential of battery recycling and mineral conservation to achieve energy self-sufficiency. As per Industry research, lithium-ion battery market in India is projected to grow from 2.9 GWh in 2018 to approximately 132 GWh by 2030, representing a compound annual growth rate (CAGR) of 35.5%. This surge in battery usage suggests an expanding pool of 'spent' batteries, which, if not managed, could pose significant environmental and health risks. By 2030, the recycling market could present an opportunity valued at approximately USD 1 billion. Several Indian companies are venturing into this profitable domain by initiating or announcing plans for recycling operations. Noteworthy developments include Tata Chemicals' inauguration of lithium-ion battery recycling in Mumbai, Raasi Solar's plans for a 300 MW plant dedicated to lithium battery recycling, and Mahindra Electric's commitment to battery recycling (JMK Research and Analysis, 2019). Along with the evident economic advantages, recycling batteries makes EVs more environmentally friendly. Government has also tweaked its mining rules in July 2023 allowing entry of private miners after finding its first lithium deposits in Jammu and Kashmir (approximately 5.9 million tonnes). The Atomic Minerals Directorate for Exploration and Research (AMD), an integral part of the Department of Atomic Energy (DAE), is engaged in the exploration for Lithium within promising geological regions in areas of Mandya and Yadgir districts in Karnataka. Initial surface surveys and some subsurface exploratory work conducted by the AMD have revealed the existence of approximately 1,600 tonnes of Lithium resources, in the Marlagalla region of Mandya district, Karnataka (PIB, 2022). These efforts are aimed at making India less reliant on importing materials and to give it an edge in the battery recycling and repurposing business. As there exists scarcity of these important minerals, there's a big opportunity for India to become a leader in the advanced battery service industry.

Along with the absence of abundant natural mineral resources, India's significant importation of battery storage equipment, which amounted to INR 20,000 crore as of 2021, highlights the need for indigenous battery processing and storage technologies. (ETN, 2021). The fiscal year 2023 underscored this dependency with Mainland China emerging as the preeminent supplier of accumulators and batteries to India, totalling imports close to 2.6 billion U.S. dollars (Ministry of Commerce and Industry, 2023). The reliance of India on China for minerals, cells and other components is increasing the import burden. To build a strong EV battery ecosystem capable of accomplishing its economic and environmental goals, India must reduce its dependency on China.

Figure 3- Import value of accumulator and battery to India FY 2023, by leading region (million US Dollars).



Source- Ministry of Commerce and Industry, 2023.

Currently, India is mostly engaged in the downstream processes of battery pack assembly and packaging, which are limited to a few industry players. There is an urgent need to encourage a wider range of players, including large manufacturers and Original Equipment Manufacturers (OEMs), to participate in this sector of the industry. Both the government and the business sector must make significant investments in cell production R&D. The development of low-cost, technologically advanced batteries is critical for India to establish a significant presence in the global battery business.

The predicted economic benefits of lower oil imports may fail to materialise unless import dependence for minerals, cells, and batteries is reduced. This strategy adjustment is required to guarantee that efforts to close the current capacity deficit do not inadvertently reinforce reliance on Chinese imports. Furthermore, the absence of a value-adding component in the industry may limit the establishment of a strong EV ecosystem capable of generating efficient batteries. India's EV market penetration and expansion may suffer as a result of its reliance on imports, as well as the higher costs and limited range of batteries in comparison to other economies.

In this context, the Production-Linked Incentive (PLI) scheme, which are intended to remedy these shortfalls, gain significance. The research will attempt to study the potential multiplier of PLI on Advanced Chemistry Cells on the output , employment and overall economy.

4. Estimating the Impact of the PLI Scheme Using an Input-Output Framework

4.1 Rationale for Choosing Input-Output Model for PLI Analysis

In the examination of the economic multipliers that economic policies have, scholars and analysts have predominantly utilized three approaches: the input-output (I-O) model, the social accounting matrix (SAM) model, and the computable general equilibrium (CGE) model. The I-O model is notably the most prevalent among these due to its straightforwardness and cost-efficiency (Pirmana, Alisjahbana, Yusuf, Hoekstra, & Tukker, 2023). The input-output (IO) model of an intersectoral economy was crafted by Leontief to analyse the structure of the American economy (Leontief, 1936). It was then extended to multiple regions by Isard (1951) in order to include the regional location of economic activities and interregional trade. IO analysis has become a basic tool in national accountancy to depict the intersectoral linkages and the particular contribution of each activity sector to the economy of a nation or a region (Leurent & Windisch, 2015).

The IO model has some inherent shortcomings, in the sense that it is static, and has restrictive assumptions of constant returns to scale and coefficients that are only valid within short-term analyses. Other more sophisticated and dynamic models, like SAM, CGE and econometric computing can overcome these challenges as they also consider price and substitution elasticities, distributions of income across different skill levels and so on. However, the extensive data requirements that are difficult to procure make it hard to apply in many situations ((Masouman, 2013) (Pirmana, Alisjahbana, Yusuf, Hoekstra, & Tukker, 2023)). These limitations make the input-output model the most viable model to study the impacts of exogenous shocks on the economy, study interactions in sectors and direct and indirect repercussions of the same. ((Prakash & Balakrishnan), (Masouman, 2013) (Bezdek, Wendling , & Bezdec, 2005))

There have been several studies using the input-output model to analyse policy, technological, and socioeconomic disruptions. In a 2002 paper (Roy, Das, & Chakraborty, 2002), the I-O model is employed to explore the burgeoning Indian IT industry, assessing the degree of informatization within the Indian economy from 1983 to 1990. In, 2010, Lurweg, Oelgemöller, Westermeier analysed the sectoral employment repercussions of trade. The paper uses the I-O model to identify sectoral dynamics and their broader implications for economic development and specialization. Research focusing on France's transition (Leurent & Windisch, 2015) to electro-mobility and its widespread implications are scrutinized by employing the I-O model to quantify the economic impacts on public finances of adopting electric vehicles (EVs) as opposed to conventional vehicles (CVs). Their study underscores the model's capacity to incorporate fiscal and social transfers, revealing the multifaceted economic consequences of industrial and environmental shifts. In 2022, Chadha & Sivamani constructed a specialized adaptation of the I-O model of a 34-sector hybrid Energy Input-Output Table (EIOT) was constructed based on India's 131-sector Input-Output Table for 2015–16. This endeavour calculates the direct and indirect energy consumption and emissions from intermediate and final-use sectors, demonstrating the model's effectiveness in environmental-economic analysis. Moreover, Pirmana, Alisjahbana, Yusuf, Hoekstra, & Tukker (2023) capitalize on the I-O model's capabilities to assess the potential economic and environmental outcomes of establishing EV production in Indonesia. This study highlights the model's role in evaluating sectoral changes within the context of global economic trends and environmental concerns.

Several studies have integrated various analysis and built on the input output model for a more refined analysis. Masouman (2013) extends the use of I-O modelling by integrating it with econometric methods to form an EC-IO model, applied to the Illawarra region in New South Wales. This hybrid model seeks to enhance the precision of analyses and forecasts pertaining to structural shifts within the regional economy, illustrating the model's flexibility and potential for refinement when combined with other analytical frameworks. In 2021, a study by Adkins, Garbaccio, Ho, Moore, & Morgenstern (2021), investigates the effects of varied carbon pricing strategies across different industrial sectors and time horizons. This approach delineates the short-term utility of the I-O model and the long-term efficacy of the CGE model, emphasizing the temporal scalability of these analytical tools. Finally, the I-O model's relevance in socio-economic analysis is also evident in the study by Prakash & Balakrishnan, which examines the income and employment effects of technological advancements in India. This underscores the model's capacity to trace and quantify the impact of technological progress on the economy's structure and labour market dynamics.

Collectively, these applications of the I-O model, spanning from sector-specific studies to broad economic evaluations, illustrate its enduring value in economic analysis. The model's ability to adapt to diverse analytical needs, be it assessing informatization, environmental impacts, or the nuances of fiscal policy, reinforces its status as an indispensable tool in the arsenal of economic researchers and policymakers.

In this research, the analysis of the direct and indirect impacts of the PLI ACC scheme necessitates the use of a comprehensive model. Considering data availability, the nascency of the EV market and the interaction in the sectors due to the disruption caused by EV batteries, the use of the Input-Output model, as opposed to other dynamic complex models is employed. A comprehensive IO model is constructed to analyse the effect of this new policy on output, imports and employment due to the PLI ACC scheme.

4.2 Input-output model structure and results

The Input-Output Model relies on Input-Output tables constructed using precise data collection and accounting methods. the latest comprehensive I-O table for India was for the fiscal year 2013-14. Given the significant transformations that have occurred in the automobile sector over the past decade, the relevance of the former I-O data has diminished, necessitating consideration of an updated Input-Output Model. Hence, the Input-Output (I-O) table employed in this analysis was procured from the Asian Development Bank (ADB) data repository. This dataset provides a comprehensive series of National Input-Output tables for India, spanning from 2000 to 2022. Our study utilizes the most recent table from 2022, which delineates economic transactions in millions of US Dollars and partitions the Indian economy into 35 discrete sectors.[9]

To estimate the impact of PLI ACC, the battery industry is essential. Given that the current Indian I-O table does not explicitly list a distinct EV or Battery sector among its 35 sectors, we introduced an additional sector to assess the PLI scheme's economy-wide repercussions. The input column has been inculcated from the Japanese Input-output model. The input vectors for this sector are derived from the Japanese I-O model, which has a granular breakdown of 509 industries. Due to the systematized structure of automobile production and the input structure of the automobile industry in these tables, each part is generally considered to be common throughout the world (Suehiro & Purwanto, 2020). The total output and final demand for the sector have been based on the BNEF and CII study estimates.

For the estimation of employment implications, we base our analysis on the sector-specific data from the Periodic Labour Force Survey (PLFS) administered by the National Statistical Office (NSO). PLFS captures both formal and informal aspects of economic activities and offers insights into labour market dynamics. This level of detail enables a more localised understanding of economic activity and labour force dynamics. Furthermore, the PLFS captures data using 5-digit NIC codes, allowing for a higher level of industry-specific analysis for our Input-Output tables. (Kapoor, Ketels, Debroy, & Negi, 2023).

In the absence of a fully-fledged Indian battery sector and its attendant data, we adopt the labor coefficient for "Miscellaneous Electrical Equipment" from the Japanese employment statistics as the closest substitute to the required data. Regarding the battery sector's total output for 2023, the model takes the total output for the battery sector to be 20 GWH, with a value calculated at $139/kWh, culminating in a total output of $2780 million ((BNEF, 2023) (CII, 2023). This aggregate output is then divided into intermediate and final demand, reflecting the dual nature of battery demand—utilization by other sectors and direct end-user consumption. Based on the Japanese I-O table, 35.64% of the demand originates from intermediate sectors, with the remaining 64.36% constituting the final demand. When these proportions are transposed to the Indian context, the final demand translates to $1790.408 million.

The use of NIC codes of Indian sectors, PLFS data, and the Japanese I-O model in congruence, however, introduces a lack of strict demarcations in sectors due to the varying accounting methodologies used in these datasets. The sectors have been meticulously categorized according to the descriptions available within these sources. A detailed theoretical structure of this model is elucidated in Section 2 of the Appendix.

4.3 Results of the model

i) Effects on Output

This section analyses the result of the input-output model created in this research paper to look at the total impact of PLI regarding battery manufacturing. The analysis of the increase in output

[9] The data for the sector "Private households with Employed Persons" and "Public Administration and Defense; Compulsory security" is absent from the provided table, and thus, it is omitted from our analysis.

across various sectors of the economy that was brought about by the expansion of the production of electric batteries offers valuable insights into the interconnectedness of the economy as well as the potential opportunities that exist within it.

The study indicates an observed upsurge in economic output, quantified at $19,389.97 million. The highest increase in output that is observed in the mining and quarrying sector, which amounts to $1536.17 million. This is indicative of the significant demand for raw materials that are essential for the manufacturing of batteries. This surge brings to light the fact that the battery industry is highly dependent on key inputs such as lithium, cobalt, and nickel, all of which are considered to be essential components of contemporary battery technologies. As a consequence of this, the growth of this sector highlights the significance of securing a reliable supply chain for these materials in order to support the further expansion of the battery manufacturing sector.

Furthermore, the significant growth that has been observed in industries that are directly linked to manufacturing, such as chemicals and chemical products ($1039.56 million) and basic metals and fabricated metal ($1334.46 million), highlights the significant role that these industries play in supporting and driving forward activities related to the production of batteries. The electrolytes and cathode materials, as well as the battery casings and connectors, are all components and materials that are essential to the manufacturing of batteries. These industries play a significant role in the provision of important components and materials.

The significant increases that have been observed in industries that are associated with transportation and logistics, such as wholesale trade ($674.55 million) and inland transport ($376.46 million), are a reflection of the ripple effects that increased battery production has had on supply chains that are related to these industries. As the demand for energy storage solutions and electric vehicles continues to rise, there is a corresponding need for efficient transportation networks and distribution channels to facilitate the movement of raw materials, components, and finished products throughout the economy.

It is interesting to note that the modest growth that has been observed in industries such as education ($81.10 million) and health and social work ($21.19 million) suggests that there may be potential indirect benefits that result from increased economic activity and investment. There is a possibility that the expansion of battery production will inspire the creation of new jobs and the growth of income, which will ultimately result in increased levels of discretionary income and increased spending in areas such as education and healthcare.

Table 2- Direct and Indirect effects on Prominent Sectors

Sectors	Increase in Output (in million $)
Direct Effect	
Battery	1,0157.06
Mining and quarrying	1,536.12
Basic metals and fabricated metal	1,334.46
Chemicals and chemical products	1039.56
Rubber and plastics	964.91
Indirect Effect	
Construction	326.76
Financial intermediation	273.67
Retail trade, except of motor vehicles and motorcycles; repair of household goods	201.41
Education	81.11
Health and social work	21.19

Source- Authors Calculations

ii) Effects on Employment

The analysis revealed a significant increase in employment in various key sectors of the economy due to the growth of battery production. **The analysis demonstrates a significant positive impact on overall employment, with a surge amounting to 1.03 million jobs.** The largest increase is in the production of batteries, resulting in the creation of 179,546 additional jobs in the sector.

The Mining and quarrying sector stands out as a top performer, with a notable increase of 34,728 jobs, representing a percentage increase of 1.218%. This increase highlights the sector's important role in supporting the growing battery production industry, as it is heavily involved in obtaining necessary raw materials. Governmental initiatives targeting the exploration of designated mining locales, alongside the advancement of material processing and refining technologies, are anticipated to further bolster employment prospects.

The Rubber and plastics sector experienced significant growth, adding 76,626.659 jobs, which represents a substantial 1.086% increase in employment. This growth reflects potential of the sector's capacity to meet the escalating demand for components and materials that are critical in battery production. Additionally, the chemicals and basic metals sectors have reported employment growth rates of 0.41% and 0.31%, respectively, reinforcing their pivotal role in supplying necessary materials and components for battery manufacturing.

The sector of Other community, social, and personal services has seen growth with an increase of 398,197.336 jobs (0.49%). This sector consists of majority of the service sector components (eg. Professional service, Environmental services, Business and Tech Support services and so on), which has a significant forward linkage with manufacturing of EV Batteries and automobile industry. This sector's role in offering crucial support services to the growing battery production industry leads to increases in employment.

Wholesale trade and commission trade, excluding motor vehicles and motorcycles, experienced a significant increase of 29,330.144 jobs. This sector plays a crucial role in managing the distribution and supply chain of battery-related products, leading to substantial employment growth. It is important to highlight that although some industries show modest growth in employment, their percentage growth rates are still significant. These industries benefit indirectly from the growing demand created by the expanding battery production sector, leading to a positive impact on job creation throughout the economy.

Table 3- Effect on employment of Prominent sectors

Sectors	Increase in Employment (number)	Percentage Increase in Employment
Mining and quarrying	3,4728	1.21
Rubber and plastics	76,626	1.09
Other community, social, and personal services	398,197	0.48
Wholesale trade and commission trade, except of motor vehicles and motorcycles	29,330	0.43
Chemicals and chemical products	14,664	0.41
Basic metals and fabricated metal	31,022	0.31
Electrical and optical equipment	8,047	0.15
Manufacturing, nec; recycling	3,296	0.07
Sale, maintenance, and repair of motor vehicles and motorcycles; retail sale of fuel	6,072	0.07

Source- Authors Calculations

It is evident that the effect of the PLI ACC extends beyond the battery sector and the automobile sector due its massive forward and backward linkages. As illustrated in the value chain, the EV battery value chain relates to the primary activities like mining and extends to the after sales services encompassing professional technical and business services. If the PLI ACC has the intended effect and of manufacturing EV Batteries after setting up 50GWh manufacturing units, the ripple effect is going to have direct and indirect implications in the economy. If this analysis is further extended to incorporate effect of PLI AAT, the implications will be much wider with a greater degree. In essence, PLI ACC has the potential to have in increase in output by $19389.97 million and generate up to 1.03 million jobs, which can be crucial in the Indian economy.

5. Way forward

The structure, pace, and monetary requirements of economic changes differ significantly between economies. Nations that initiated the process of transition early on have achieved a degree of market maturity and have experimented with a variety of techniques to reach their current position. It is critical to reflect on their journey while taking into account their strengths in manufacturing, geographical endowments, and spending capability. In this perspective, it is also critical to recognise the substantial distinctions between these features in other economies and India. Against this backdrop, it is necessary to examine India's own trajectory, analysing its progress, expenses, and strategic goals independently, but with an informed perspective drawn from the experiences of other countries.

This paper attempts a first step to analyse the impact of PLI ACC on output, imports and employment within the Indian economy by employing an Input-Output model. While this analysis is thorough, it is not exhaustive. This research is one of the initial quantitative assessments of the Production-Linked Incentive (PLI) scheme in the Indian economy. It aspires to showcase the preliminary effects of the PLI and to catalyse an informed discourse aimed at refining policy measures in tandem with the dynamic nature of the industry. A comprehensive understanding necessitates an exploration into the secondary PLI scheme focused on Advanced Automotive Technology (AAT) to ascertain a complete view of the impact of production-linked supply-side policies and their efficacy in reinforcing the Electric Vehicle (EV) battery value chain. Further, considering the significance of material endowments, material processing prowess and manufacturing strength of particular economies, an analysis into the trade balance shifts resulting from domestic battery production will solidify these insights.

Future investigations will include the aforementioned assessments, with the intention of finding policy shortcomings and ecosystem components that have been overlooked or undervalued and have the potential to improve India's electric vehicle battery production capacities. In order to decrease India's dependency on imports, it will investigate the potential of the country's battery recycling and repair business, as well as the country's ongoing attempts to create methods for retaining and reusing minerals.

In the battery value chain, India is currently at a vital juncture when it is still in a good position to manufacture components that are inclined towards the future. For this reason, it is vital to conduct an analysis of the existing policies in order to improve them while bringing them into alignment with the economic and environmental goals. A rigorous study of the policies that are currently in place and the modification of those policies to ensure that they correspond with national objectives must be undertaken. India has the capacity to accelerate the adoption of electric vehicles (EVs) by implementing these best practices, which will allow it to better align itself with international trends while also catering to the specific obstacles and opportunities that are present in its own economic environment. A strategic approach of this nature will not only help India achieve its goals, but it will also make a significant contribution to the movement towards environmentally responsible transportation on a worldwide scale.

6. Appendix

6.1 Section I- Applicants approved under the Scheme

Approved Applicants: Ashok Leyland Limited, Eicher Motors Limited, Ford India Private Limited, Hyundai Motor India Limited, Kia India Private Limited, Mahindra & Mahindra Ltd., PCA Automobiles India Private Limited, Pinnacle Mobility Solutions Private Limited, Suzuki Motor Gujarat Private Limited, Tata Motors Limited.

Champion OEM 2W & 3W: Bajaj Auto Limited, Hero MotoCorp Ltd., Piaggio Vehicles Private Limited, TVS Motor Company Limited.

New Non-Automotive Investor (OEM): Axis Clean Mobility Private Limited, Booma Innovative Transport Solutions Private Limited, Elest Private Limited, Hop Electric Manufacturing Private Limited, Ola Electric Technologies Private Limited, Powerhaul Vehicle Private Limited. Existing Automobile and Auto Component Manufacturing Companies Approved under Component Champion Incentive Scheme: Maruti Suzuki India Limited, Pinnacle Mobility Solutions Private Limited, Bharat Forge Limited, Hero MotoCorp Ltd., Advik Hi-Tech Private Limited, Aisin Automotive Haryana Private Ltd., Alicon Castalloy Limited, Aptiv Components India Private Limited, Aptiv Connection Systems India Private Limited, Asahi India Glass Ltd., Asia Investments Private Limited, Automotive Axles Limited, Axletech India Private Limited, BASF Catalysts India Private Limited, Bosch Automotive Electronics India Private Limited, Bosch Chassis Systems India Private Limited, Bosch Limited, Cummins Technologies India Private Limited, Daicel Safety Systems India Private Limited, Dana Anand India Private Limited, Dana TM4 India Private Limited, Danblock Brakes India Private Limited, Delphi-TVS Technologies Limited, Denso Ten Minda India Private Limited, Garrett Motion Technologies India Private Limited, Hella India Automotive Private Limited, Hero Cycles Limited, Imperial Auto Industries Limited, International Tractors Limited, J.K. Fenner (India) Limited, Jay Ace Technologies Limited, Jay Fe Cylinders Limited, KalyaniTechnoforge Limited, Krishna Landi Renzo India Private Limited, Krishna Maruti Ltd., Kyungshin Industrial MothersonPvt Ltd, Linchpin Technologies Private Limited, Lucas-TVS Limited, Lumax Auto Technologies Limited, MahleAnand Thermal Systems Private Limited, Mando Automotive India Private Limited, Minda Corporation Limited, Minda Industries Limited, Mitsubishi Electric Automotive India Private Limited, Motherson Sumi Systems Limited, Motherson Sumi Wiring India Limited, Musashi Auto Parts India Private Limited, Napino Auto and Electronics Limited, Neel Metal Products Limited, Neolite ZKW Lightings Private Limited, Nidec India Private Limited, Padmini VNA Mechatronics Limited, Pricol Limited, Rockman Industries Limited, Sandhar Technologies Limited, Sansera Engineering Limited, Schaeffler India Limited, Sharda Motor Industries Limited, Sona BLW Precision Forgings Limited, Steel Strips Wheels Limited, Sundram Fasteners Limited, Tata Autocomp Systems Limited, Tata Cummins Private Limited, Tata Ficosa Automotive Systems Private Limited, The Hi-Tech Gears Limited, Toyota Industries Engine India Private Limited, Toyota Kirloskar Auto Parts Private Limited, Tube Investments Of India Limited, Valeo India Private Limited, Varroc Engineering Limited, Vitesco Technologies India Private Limited, Wabco India Limited, Yazaki India Private Limited.

New Non-Automotive Investor (Component) Companies: Bharat Heavy Electricals Limited, Ceat Limited.

6.2 Section 2- Structure of Input Output Model

Theoretical understanding of the model employed in the paper is explained as following:

Industry	Industry 1	Industry 2	Industry 3	Industry 4	Final Demand	Total Output
Industry 1	D11	D12	D13	D14	Y1	X1
Industry 2	D21	D22	D23	D24	Y2	X2
Industry 3	D31	D32	D33	D34	Y3	X3
Industry 4	D41	D42	D43	D44	Y4	X4
Value Added	Z1	Z2	Z3	Z4		
Total Output	X1	X2	X3	X4		

Here,

X_i represents the total output for the Industry I

D_{ij} represents the quantity of output from industry i utilized in the production process of industry j

Y_i refers to the final demand of industry I in the economy net of the the output used in other sectors.

Zi refers to the value added to the intermediate inputs by the industry.

Hence the total output of an industry in the above model is given by

$$X_1 = D_{11} + D_{12} + D_{13} + D_{14} + Y_1$$

For a generalized model with n industries, the output for industry i is given by

$$X_i = \text{Sum}(D_{ij}) + Y_i$$

For the input output analysis, we assume that there is a fixed coefficient production. function in the economy i.e the for one unit of production of industry j a fixed input from industry i is required.

The following formula to transform the entries into input coefficients was employed:

A_{ij}= (Contribution of industry I to the output of industry j) / (Total output of industry j)

This assumption leads us to simplifying the output equations for all the industries to the following:

$$X_1 = a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + a_{14}X_4 + Y_1$$

$$X_2 = a_{21}X_1 + a_{22}X_2 + a_{23}X_3 + a_{24}X_4 + Y_2$$
$$X_2 = a_{31}X_1 + a_{32}X_2 + a_{33}X_3 + a_{34}X_4 + Y_3$$
$$X_4 = a_{41}X_1 + a_{42}X_2 + a_{43}X_3 + a_{44}X_4 + Y_4$$

Which can be expressed as

$$Xi = Sum(a_{ij} * X_i) + y_i$$

Here, a_{ij} refers to the input-output coefficient for industry I and industry j, which refers to the amount of output of industry i used for production of 1 unit of output of industry j .

The value of the input-output coefficient of industry i,j is calculated as

$$aij = Dij/Xj$$

The system of equations describing the economy can be expressed in terms of matrices and vectors.

$$\text{As } X = A * X + Y$$

Further simplifying,

$$X – A*X = Y$$
$$X (I- A) = Y$$
$$X = (I-A)^{-1} * Y$$

As the relationship between the variables is linear, the change in total output of an industry by a change in the final demand for the industry can be calculated by a slight modification to the above equation.

The change in output of Industry i, given by del Xi can written as

$$\Delta Xi = (I-A)^{-1} * \Delta Y_i$$

Hence the input-output model can be used to calculate the change in the total output of an industry induced due to change in final demand for the same industry.
For our analysis we assume that the increase in final demand for the battery sector amounts to 9536.64 million USD. The increase in final demand is based upon the fact that it has been predicted that the battery sector would need to grow till 220 GWH in the year 2030. In the year, 2030 it has been predicted that the value of the cost of batteries would come down to $80 / KWH. As per these prices the value of the total output in the year 2030 would be 17600 million dollars. The final demand in the battery sector would be $11,327.60 million. Hence the difference between the final demands gives us the increase in final demand that is needed to achieve the target

The effect of increase in final demand on the employment in various sectors can also be calculated using the input output approach. The increase in total employment in the economy can be calculated by the following equation,

$$\Delta Li = L * (I\text{-}A)^{-1} * \Delta Y_i$$

Here, L refers to the diagonal matrix of the labor input coefficients of each sector. Labor coefficients for each sector is given by Total Employment in the sector/ Total output of the sector in the economy. As the output defined in the model is in million dollars, we calculate the labor coefficients in terms of total employment / total output in million dollars. This gives us the population employed in the economy per million us dollars of output.

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