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The Economic Challenges of Manufacturing Lithium Ion Batteries in India

Yashvardhan S. Rajan

Bachelor of Science in Civil Engineering & Engineering and Public Policy, Carnegie Mellon University
yvrajan@gmail.com

Abstract— ***India is undergoing a large transformation in its quest for clean energy. With attention on electric vehicles and renewable energy sources, the government is paving the path toward an energy independent and environmentally benign future for India. But are we really going to become energy independent? With Lithium Ion Batteries (LIB) as the drive train for both of these industries, and with minimal manufacturing of lithium ion batteries in India, are we just moving from oil import to lithium battery import? To address these major questions, various stakeholders including the government, vehicle Original Equipment Manufacturers (OEMs), and consumers are exploring the viability of the manufacturing of lithium ion batteries in India. Indian giants such as the Tata group and the Adani group have announced that they will participate in the lithium ion battery industry at large scales, with plans of investing hundreds of crores to set up high-precision and high-throughput factories. However, a major concern yet to be addressed is the actual profitability of manufacturing these batteries. While large investments lead to economies of scale and recent government involvement through FAME II and GST reductions will lead to a reduction in the cost of manufacturing, the lack of an established upstream supply chain, infrastructure, and industry expertise—all of which contribute heavily to reducing costs of manufacturing—casts doubt on the profitability of manufacturing such batteries in India. This article attempts to address these factors and provide relevant insights into the viability of manufacturing lithium ion batteries in India.***

Keywords: Lithium Ion Batteries, Economic Viability, Supply Chain

1. THE MARKET OVERVIEW FOR LITHIUM ION BATTERIES

Lithium Ion Batteries (LIB) have been recognised as the most viable solution in the foreseeable future for electric vehicle battery systems and renewable energy storage. With the E-mobility and Renewable Energy policy set by the Government of India stating 100% Electric Vehicle penetration by 2030 and at least 225 GW of renewable energy capacity, there is a strong demand for lithium ion batteries. In further detail, these goals indicate a major focus on all forms of electric vehicles, including both public and private transport vehicles. A recent study by CSTEP [1], Center for Study of Science, Technology, and Policy , suggests that the number of vehicles would surpass 650 million two wheelers, 130 million four wheelers, and 10 million buses. Given that current EV penetration has been extremely low, 100% EV penetration seems a little out of reach in the given timeframe. However, even if we assume a lower percentage of penetration by 2030, the required amount of battery storage is relatively high. Table 1 below shows the demand of lithium batteries required at a 30% EV penetration by 2030.

TABLE 1: LIB demand in EV and grid sector by 2030, assuming 30% penetration. Credit: CSTEP [1]

EV (considering 30% penetration by 2030)		
Transportation sector	**Energy storage per vehicle**	**Energy storage requirement (GWh)**
2 wheelers: 200 million	1–2.7 kWh	200–540
4 wheelers: 40 million	10–20 kWh	400–800
Buses: 3 million	100–324 kWh	300–970
Energy storage demand for EVs in 2030 (GWh)	900–2300	
Energy storage demand in grid sector by 2030 (GWh)	22	

Table 1 identifies a requirement of at least 922 GWh of energy storage for only 30% EV penetration in the Indian market and a small number for grid-scale application. With complete penetration, the required energy storage would be at least 2700 GWh by 2030. Using this information on demand of lithium ion batteries in India, the value for lithium ion battery industry in India is at least INR 4.5 lakh crore [the calculation can be found in Appendix A] On the supply side, the current global production of lithium ion batteries is 160 GWh [4]), with a concentration of the manufacturers in China, Japan, and South Korea. Companies including Panasonic, LG Chem, and BYD are rapidly expanding so as to capture as much of the market globally. Currently, Indian companies are importing Li-Ion cells from China and making battery packs in India. A report by NITI Aayog [9] identified the minimum requirement of at least 50 GWh cells by 2025, however this number seems to be low compared to the predicted demand. If India wants to move toward energy independence, a major push will be required toward manufacturing lithium ion batteries in India as soon as possible.

2. SUPPLY CHAIN ECONOMICS

Figure 1 below shows the life cycle of manufacturing lithium ion battery packs. First, the raw metals such as Cobalt, Nickel, Manganese, Lithium, Aluminum, etc., are mined in impure forms. Thereafter, further treatment prepares these raw metals to reach high purity and quality to be used in lithium ion cells. Second, the cell components are prepared from the raw materials followed by the cell fabrication/making. Third, the cells are inserted into packs to be used in different applications, such as electric vehicles and stationary storage systems.

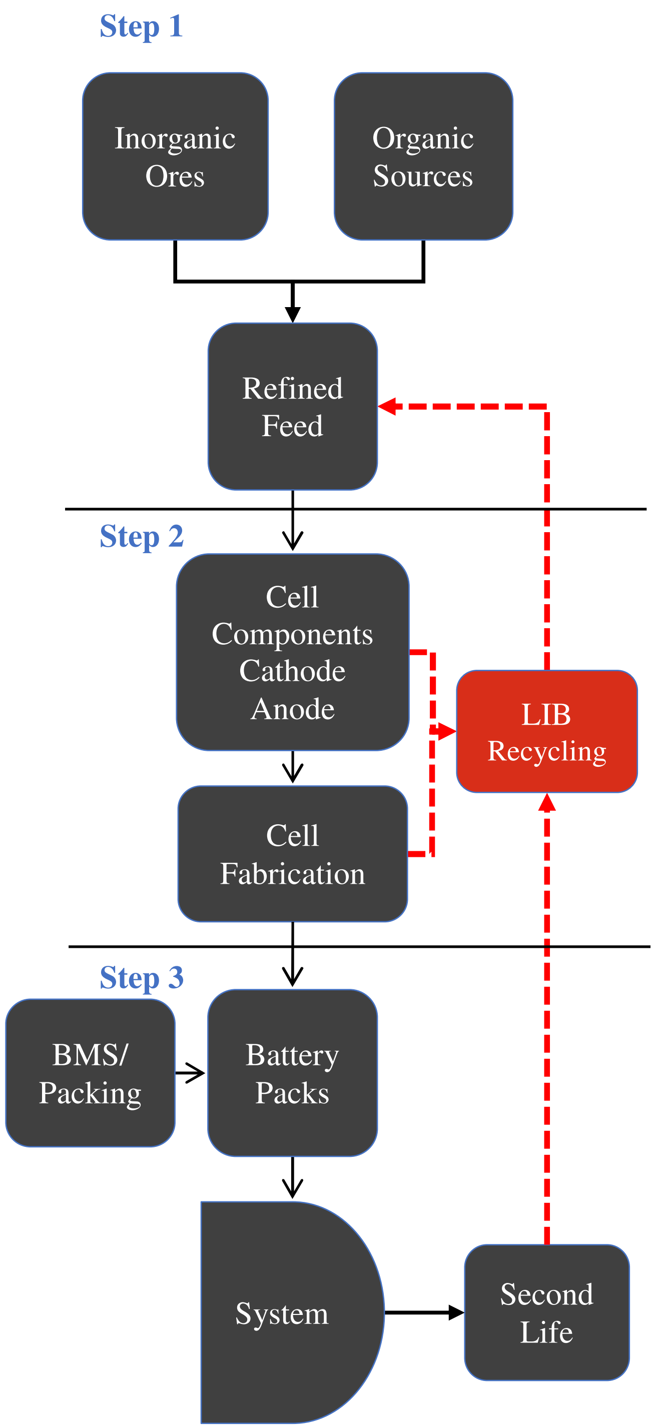

Fig. 1. LIB Life Cycle & Value Chain

While there is disagreement in the cost breakdown in the LIB value chain, a study by the NITI Aayog (NITI Aayog, 2018) [9] suggests the following cost breakdown of Lithium-ion battery manufacturing. The raw material feed (Step 1 in Figure 1), consisting of the mining and refinement of raw materials, has a value of 35 to 40% of the total cost of battery pack. The cell manufacturing (Step 2) has a value add of 25 to 30%, and the pack manufacturing (Step 3), inclusive of the monitoring and management systems, comprise of the remaining 30-40% of the total cost. While cell to pack manufacturing plants have started functioning in India, the others would need to be encouraged.

2.1 Step 1: Raw Material Feed

There are 4 major cost components in lithium ion batteries—cathode, anode, electrolyte, and separator. The cathode consists of an chemically active paste coated on a current collector. The paste is made from a combination of metals (nickel, manganese, iron, phosphate, lithium, cobalt), binder, and conductive carbon, whereas the current collector is usually an aluminum foil. The anode also consists of a chemically active paste coated on a current collector.

The anode paste is made from a combination of graphite, binder(s), and conductive carbon, whereas the current collector is usually a copper foil. The separator used commercially in electric vehicles is likely to be a polyolefin film with ceramic coating, and the electrolyte consists of a mixture of an organic solvent with a lithium-based salt.

Since the ratios and costs of the chemicals vary on use and availability, the effect of the cost of raw material can contribute up to 66% of the cost of manufacturing Lithium ion batteries [1]. A nascent market such as India's must consider which of the raw materials in these 4 components can be manufactured locally and which are to be imported.

For the Indian market, there are two major points to be addressed: Acquisition of material that cannot be mined or refined in India, and the activation of material processing for the material that can be mined or processed in India.

2.1.1 Acquisition of material that cannot be mined in India

There is a lack of abundance of metals such as lithium, nickel, cobalt, and manganese —each of which are extremely important in lithium battery manufacturing—in India. Geographically, these metals are particularly abundant in South America, China, Australia, and Africa. The map (Figure 2) below shows the distribution of countries with Lithium, Cobalt, Manganese and Nickel resources.

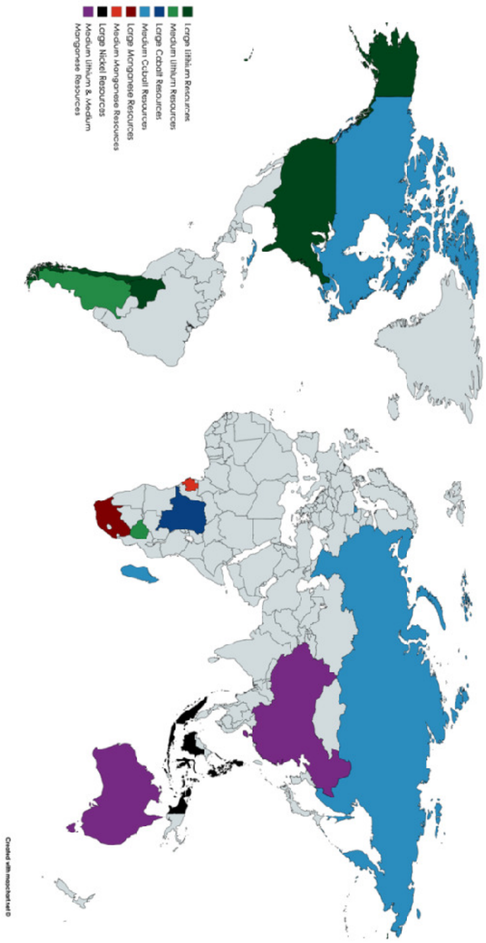

Fig. 2. Global Distribution of Raw Metals for LIB Industry

In the case of lithium sources, lithium is relatively abundant in many parts of the world in the form of brines and hard rock. Certain locations, such as USA, Chile, and Bolivia have large mines and reserves of lithium. RCS Global [4] states that 57% of the world's lithium resources are contained in just three locations, the Salar de Atacama, Chile; the Salar de Uyuni, Bolivia, and the Kings Mountain belt, USA (Salar is Spanish for Salt Lake). The remaining 43% are spread across the world. Cobalt sources, however, are abundant predominantly in the Democratic Republic of Congo. Mckinsey&Company stated that the DRC alone accounted for 70% of globally mined output in 2017, with Russia, Cuba, Australia, and Canada—the next large supply countries—accounted for just 13% of global supply. Nickel resources are concentrated in the Phillipines and Indonesia, whereas Manganese is concentrated in China, South Africa, and Australia. Without these metals sourced at a good price in India, after accounting for import costs, India would have high raw material costs for base metals in manufacturing, heavily impacting lithium battery costs. State owned consortium Khanij Bidesh India Ltd, a joint venture of three central public sector undertakings – National Aluminum Company (NALCO), Hindustan Copper Ltd (HCL) and Mineral Exploration Corporation Ltd (MECL) – has been formed to identify, explore, acquire, develop and process strategic minerals overseas.

A further concern is the refining of these metals for use in lithium battery manufacturing. Lithium ion batteries require high purity metals, with very few to no impurities. Since the mined metals are not ready to be directly used in lithium ion batteries, further chemical refining is required. This process produces various polluting effluents and requires high volumes of water. Since Chinese companies entered the market for mining and refining at an early stage, they conquered the metal refining industry. Furthermore, the mass production and relaxed environmental laws in China have prevented other competitors from other countries to compete at similar prices. For example, between 50-60% of the global refining capacity of Cobalt is concentrated in China. Hence, penetrating the cobalt refining market may be particularly difficult [8].

2.1.2. Activation of material processing for the material that can be mined or processed in India

While India has a dearth of raw metals, India does have abundant sources for other components in the battery.

1. Graphite: India is the second largest producer of graphite, globally, but lacks the processing technology required to make battery-grade graphite suitable for LIB applications. Advancements in processing technology can help the industry to include Indian graphite in the LIB value chain.
2. Binders: Many of the common binders used in lithium ion batteries are used in other industries, some of which are abundant in India. Binders such as SBR (Styrene Butadeine Rubber) are used in car tyres, a large manufacturing industry in India. PVDF, Polyvinylidene fluoride, another binder commonly used in insulation of electric wires, can also be manufactured indigenously.
3. Separator: Typically, LIB cells used in electric vehicles are polyolefin separators, with a coating of ceramic, which provides a safety measure. Polyethylene and polypropylene are already manufactured in India in a large scale, hence moving towards using these materials in the LIB industry should not be incredibly difficult.
4. Current Collectors: Current collectors used in Lithium batteries are made from either carbon coated aluminum, copper, or nickel. These materials are already manufactured in India and with small alterations, could cater to the lithium battery market. For example, India is among the top 5 exporters of Aluminum in the world. Companies such as NALCO and Hindalco could easily adopt aluminum current collector lines for lithium batteries.

The major concern for making any of these materials available for the battery industry is the lack of current industry knowledge in India. However, the opportunity of dominating the lithium battery space with help from the government could be quite incentivising for these companies to move into the industry supply chain. Furthermore, the government or manufacturer could further incentivise foreign market companies that have the aforementioned expertise to invest in the market, or work closely with cell manufacturers in India.

2.2 Step 2: Cell Manufacturing

A thorough financial study of lithium cell manufacturing in India conducted by CSTEP [1] concluded that in order for India to be cost competitive in the cell manufacturing landscape, a factory of 50 GWh is required, and the capital cost for land, equipment, and building would be around 30,000 crore INR. Such a large manufacturing capacity was determined to account for reduced material costs, increased economies of scale, and improved labor economies. The study uses reliable sources of information, performing analyses through case studies as well as research papers previously published. The paper also addresses certain sensitivity studies to show how economies of scale, new technologies, and subsidies would affect the prices of lithium battery cells manufactured in India. However, there are a list of concerns with the realistic outlook of setting up such a large scale plant in India within that budget. The chances that 30,000 crore INR may not be enough to completely support the facility are substantial to cause concern. Some factors to consider are listed below.

2.2.1 Production efficiency

To build and operate a plant in India that not only has theoretical capacity of 50 GWh but also has a realistic capacity of 50 GWh is likely to be extremely challenging. The building of the facility with its strict environmental requirements, the construction and operation of equipment, and logistics are, amongst many other major concerns, difficult to address at such a large facility. As of 2019, there is no singular facility in the world that manufactures cells at 50 GWh/year capacity. The single largest facility globally would be Tesla's (Panasonic) Gigafactory, with a theoretical capacity of 35 GWh but an operational capacity of only 23 GWh. The factory also scraps around half a million cells per day, a very high rate of inefficiency even at 23 GWh. Tesla CEO Elon Musk has further mentioned that the critical reason for the slow production rate is due to these issues. Yet, these inefficiencies have not been corrected, suggesting that the amount of work required by Panasonic to reach the required production efficiency is likely to be tough and may need more funds than already committed.

2.2.2 Scalability

To de-risk such a large investment in manufacturing, a pilot factory or a 'blueprint' would be necessary to demonstrate the operational and practical feasibility of fabricating lithium ion battery cells. One way for doing so would be to create a scalable model in which a single cell assembly line, from incoming raw material until the finished product, is functional and can be replicated. This module would act as a blueprint for understanding the equipment, the movement of material, the level of automation, the expertise required, and most importantly the minutiae of operating the facility. The other concerns with the facility would be the surrounding infrastructure, access to port and rail, ambient conditions, continuous access to electricity, and logistics. A feasibility study must be performed to identify manufacturing companies, brown/green field locations, and appropriate 'blueprint' size of the manufacturing facility.

2.2.3 Reliability of incoming material

The incoming materials such as cathode powder (NMC or equivalent chemistries) and electrolyte (typically Ethyl-Methyl carbonate solvent and Lithium hexafluorophosphate salt) are highly sensitive chemicals. Whilst other materials can be exposed to ambient conditions, these specific materials require delicate handling and no exposure to sun, humidity, or air. Maintaining these conditions is critical to the performance of the battery, and must be addressed individually. A process ensuring the handling of the raw material, and performing quality checks on the raw material would be necessary.

2.3 Step 3: Pack Manufacturing

Pack manufacturing typically includes the assembly of lithium battery cells, BMS (Building Management System), and cooling all packed together in an enclosure to be used in different applications. This step is closely tied to the end user. Since the weight and dimensional requirements are different for each OEM, the pack requirements are mostly determined by the OEM itself. Since the expertise for this part of the value chain already exists with OEMs in India (for example, Tata and Ashok Leyland), they are most likely to be involved in the set-up of pack manufacturing in India. Additionally, government incentives to promote pack manufacturing would be applied here as well. The only concern in this direction would be that in the LIB life cycle, pack manufacturing is around 30% of the entire value chain, hence the value addition to the Indian economy is likely to be limited.

3. THE IMPORTANCE OF GOVERNMENT INVOLVEMENT IN LIB MANUFACTURING

Setting up a large-scale battery manufacturing facility requires a large amount of investment. According to CSTEP [1], a facility of 50 GWh would be the focal point to being cost competitive at 150 $/kWh, and the facility would cost approximately USD 4.6 Billion. To get that large an investment, a consortium of banks and individual corporations would likely be required so as to secure this investment with certain levels of safety for each investor. Furthermore, ancillary industries as well as related infrastructure would be required for the facilitation of the factory. One option to de-risk the investment would be to create several smaller facilities, however the cost advantage may be lost due to loss in factors of production and reduction in raw material costs. Without some form of government aid to incentivise and de-risk the project, many major players in the industry currently may be discouraged to participate in India.

To compete with lack of current battery ecosystems and with international competitive prices of lithium batteries, manufacturers may have to rely on some form of government aid. Gilmar et al. [13] says that 'in an incipient market, subsidies have proven to be critical for the development of new technologies and to foster demand'. Examples such as the government incentives for focused demand on EVs in the United States of America and a similar incentive scheme in Japan provide excellent proof of the same. The best example of the adoption of new technologies would be China's involvement in capturing the entire value chain of electric vehicles, inclusive of lithium batteries, packs, and the vehicles.

In 2010, China barely had any control on the global markets for lithium batteries and electric vehicles, much less on the upstream processes of refining metals. Of the global top ten lithium ion battery facilities, there was only one Chinese company that made the list. The Chinese government recognised the market opportunity to become leaders in the global value chain of electric vehicles. They devised a holistic approach by investing resources, providing subsidies, and giving preferential treatment to companies in China for the creation of a complete ecosystem. Through providing supply side subsidies to suppliers and introducing buyer side incentives, including subsidies, rebates on purchase tax, the issuing of special license plates to allow for better access into congested areas, and free parking, the government was able to help BEVs (Battery Electric Vehicles) and BHEVs (Battery Hybrid Electric Vehicles) to dominate the market, allowing battery manufacturers to produce due to the high demand and volumes. The incentive program was structured such that these industries would receive strong benefits until the adoption in the market is strong, after which the incentives would reduce and eventually disappear as market penetration reached high levels. As of 2019, China now dominates 53% of the global battery manufacturing, with only 6 of the 98 companies in the supply chain being foreign [3].

Based on the lack of availability of premium grade raw material stock, India probably requires a deeply embedded systemic environment that organically permits a resilient growth of the sector with single window support. Under this premise, the government has finally started to push for the indigenisation of manufacturing batteries in India. In March 2019, PM Modi's cabinet approved of a National Mission on Transformative Mobility and Battery Solutions to implement an exhaustive policy framework to support this upcoming market. The mission's objective is to improve focus in the following areas:

1. Manufacturing
2. Specification and standards
3. Fiscal incentives
4. Overall demand creation and projections
5. Regulatory Framework
6. Research and development.

Led by the NITI Aayog, a Phased Manufacturing Plan (PMP) will be released, with initial attention to pack manufacturing followed by cell manufacturing. The union budget released in July indicated lower GST on electric vehicles as well as additional tax deduction of INR 2.5 lakh for loans taken on electric vehicles, indirectly positively impacting lithium battery production. And in late 2019, the government is planning to announce subsidies for manufacturing facilities of 5 GWh size, scaling up to 50 GWh. The potential size of the subsidy plan is around INR 700 crore, with no import and customs duties on materials unavailable in India [6]. Furthermore, the central government is encouraging state governments to provide further incentives, among which Telangana has proactively advocated to support a 5GWh factory, a great step towards bringing MNCs into India.

However, compared to other countries, India may fall short of providing enough support. For example, INR 700 crores (~100 Million USD) in subsidy would be able to support an estimate of 20% of the funds required to set up only one 5 GWh facility, whereas other countries have been known to support up to 40% in direct funding alone of all their battery facilities. Furthermore, providing further incentives may be necessary to help these companies sustain their production. This could include providing lower utility pricing, access to water and port, land, upstream supply chain benefits (access to materials unavailable in India at cheaper costs, long term fixed cost contracts with material suppliers, and no to low import tax and GST). Most importantly, supporting the manufacturing through the customer side would be beneficial. This could include off-take agreements with governmental bodies such as the army, railway ministry, power ministry, department of heavy industry, and others.

CSTEP [1] recommends providing subsidies that were similarly offered in the semiconductor industry. A 25% on capital expenditure and 10% on operating expenditure would help reduce the cost of the battery by approximately 8 $/kWh. Further incentives must be explored in tandem with current global battery manufacturers to identify which incentive schemes would be beneficial and how India can support this industry.

4. CONCLUSION AND RECOMMENDATIONS

The Indian market for lithium batteries is in its final stages of infancy. The attention on the industry is high, while the understanding of the financial economics required for the sustenance of this industry is slowly increasing. All relevant stakeholders—from vehicle OEMs to the government—must recognise the importance of setting up the entire value chain over time so as to unlock the full potential of batteries in India. The establishment of industry clusters will drop the price of manufacturing, increase technical knowledge, build 'in-house' expertise, promote awareness, and most importantly create an ecosystem through which India will become truly independent of foreign energy sources. Finally, India must encourage urban mining to complete the loop. Below are a few recommendations and insights on what may help the Indian market indigenise the largest growing sunrise industry in the world.

4.1 Supply Chain Understanding

A better understanding of value chain is required to see which of the various processes can be made indigenous. Public companies such as NALCO must invest time and resources to master the particularities required for this niche market, and manufacture on a massive scale so as to compete with foreign companies that are already doing the same. Alternatively, Joint Development Programs could also be encouraged, similar to how China built its in-house expertise in the last decade. Furthermore, a deep dive is required for processes further up the value chain, such as metal refinement. These processes tend to reduce the price of incoming raw materials for manufacturers.

4.2 Technology Understanding

India must encourage the transfer and development of knowledge in the lithium ion battery space. The involvement of Indian education systems in the manufacturing process or forming joint development programs between national and international players is crucial for successful transfer of knowledge. A good example of this already occurring is the transfer of information and know-how from ISRO to other companies in the industry.

4.3 Closed Loop Process and Urban Mining Understanding

Unlike Petrol-based products that are unrecoverable once used, products in lithium batteries can be recovered at the batteries' end of life. NITI Aayog identified in its report that in order for India to attain a reliable source of metals that are currently unavailable in India, the recycling of lithium batteries must be exercised. India produces over 2 million tonnes of electronic waste, which is mostly informally recycled in unhealthy environments [12]. Accessing this sector, and combining it with the formal sector, would unravel another multi-billion dollar market.

One way to encourage the current industrial sector to manage the recycling of electronics would be through the enforcement of the currently existing e-waste laws, specifically EPR (Extended Producer Responsibility). A report by Toxic Links [12] shows the current dismal state in which companies operate under the EPR laws, and the required changes that are needed to enforce the same.

4.4 Government Incentivisation Understanding

The government has a good understanding of what incentives work well for manufacturing industries. One approach to incentivise would be through financial incentives, i.e., providing direct and indirect subsidies on both the demand side and supply side. On the demand side, the best way to help the battery manufacturers is to encourage people to buy electric vehicles and batteries for stationary storage (rooftop solar and renewable energy farms). A study by Zhang et al. [2] identified that the greatest incentive for a consumer to switch to electric vehicles was not ethical reasons, but financial and performance based reasons. Hence, the demand side incentives could be in form of providing Electric Vehicle buyers better incentives on loans and taxes, along with subsidising charging infrastructure so that these vehicles can be easily charged anywhere. On the supply side, GST breaks and no import duties on goods that are not available in India are already being implemented. Two important factors must be considered:

1. Further support must be provided on the indigenisation of the supply chain;
2. The governmental body must work closely with current lithium battery manufacturers to identify what incentives would provide them the best benefit.

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