Introduction

The Government of India (GoI) recently announced plans for transition to all electric transportation by 2030. GoI also introduced the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) policy in 2015, to increase the adoption of Electric Vehicles (EVs) on the road. These are ambitious and positive announcements. An accelerated adoption of EVs will help achieve energy security and reduce local air pollution. In addition, EVs provide opportunities for investments, manufacturing and job creation. However, EV deployment in India has been modest so far. This is because of the high cost of vehicles, lack of EV related infrastructure and awareness among users.

Considering that the battery and related components account for about 40-50% of the EV cost, the overall cost will reduce significantly if there is a reduction in the cost of batteries. There are various commercially available battery technolgies, such as Lead Acid, Nickel Metal Hydride, Nickel-Cadmium and Sodium-Sulphur. However, the Lithium-ion Battery (LIB) is ideal for the requirements of an EV because of its high energy and power density, long cycle life and safer operation. LIB is also an important storage technology for the Renewable Energy (RE) sector and is an important part of the ecosystem for achieving 175 GW targets.

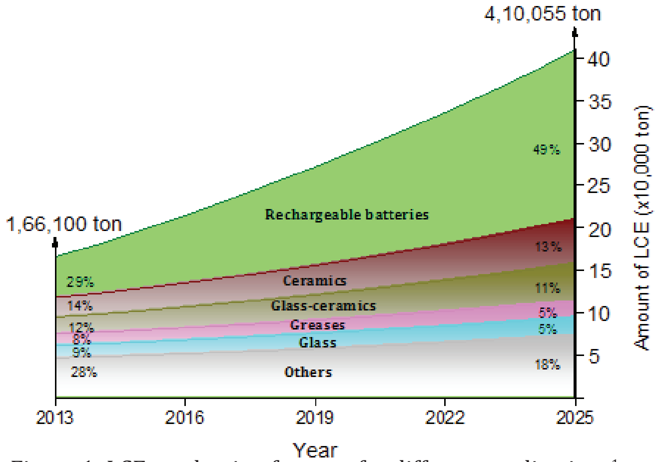

Figure 1: LCE production forecast for different applications[1]

The government's ambitious targets for EVs and RE are expeced to create a huge demand for LIB systems in the coming years. However, at present, India lacks domestic manufacturing capacity at commercial scale and imports LIBs mainly from China and the US.

This Policy Note showcases CSTEP's evaluation of the economics of indigenously manufacturing LIBs. A manufacturing plant of 50 GWh capacity has been considered. The analysis also included a detailed literature survey and industry interactions.

Global LIB Production and Price Trend

Lithium Carbonate Equivalent (LCE) is the generic source of Lithium. It includes Lithium Carbonate, Lithium Hydroxide, etc. The global production of LCE was 166,100 tonne in 2013. The growing demand in the clean energy industry is expected to increase LCE production to about 410,000 tonne by 2025.[1] Figure 1 shows the projected growth in LCE production in various sectors.

Figure 1 highlights that the LIB industry is a major consumer of LCE and its demand will further increase over the coming years. The cost of LIB has also reduced in recent years due to economies of scale in production and increasing demand in portable electronics and EV sectors (Figure 2). The cost reduced from \$ 1000/kWh in 2010 to \$ 227/kWh now.[2] Studies suggest further cost reduction to about \$ 150 /kWh.[2]

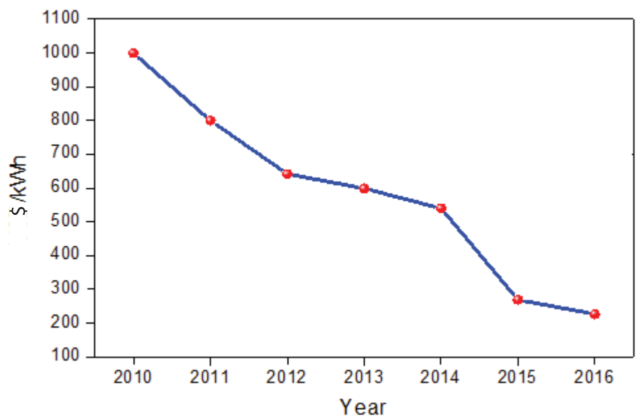

Figure 2: Li-ion Battery price trend in recent years [2]

The global LIB manufacturing capacity was around 76 GWh in 2015. China (51%), Korea (21%) and Japan (16%) are the leading manufacturers.[3] The automotive sector alone accounted for approx. 26 GWh production capacity.[3]

LIB Demand in India: Projections for 2030

At present, the demand for LIB in India's clean energy sector is modest. However, this is expected to increase several folds in the coming years because of the ambitious EV and RE targets. The likely demand for LIBs in EV and grid applications by 2030 (CSTEP estimates) is shown in Table 1. This is based on the following approach and assumptions:

1. In the transportation sector, the number of vehicles on the road by 2030 is expected to be: 200 million two wheelers; 40 million four wheelers (according to LBNL report[4]: 39 million); and 3 million buses. Battery requirement estimation has been done assuming 30% EV penetration[5] (Table 1).

2. In grid-scale applications, the energy storage demand has been determined such that it provides 1 – 3 hours of back-up (morning and evening peak hours). NITI Aayog's IESS 2047 tool[6] has been used, considering a Level 2 scenario.[7] This scenario assumes that Vehicle-to-Grid (V2G) technologies would mature to enable a large fleet of EVs to operate as virtual power plants.

3. It has been assumed that LIBs will be the only electro-chemical storage system.

Based on the above-mentioned assumptions, an estimated storage demand of 900 - 2300 GWh in the EV sector and around 22 GWh in the grid sector will be required (refer to notes in Table 1). Details of the above-mentioned calculations can be provided on request.

Economics of LIB Manufacturing: 50 GWh Plant

A LIB cell consists of electrodes (cathode and anode), a separator and electrolyte. The cathode is fabricated from purified and processed lithium. The anode is mainly made up of graphite. A separator, made of Polyethylene, acts as a barrier between two electrodes and promotes movement of ions from the cathode to anode. Lithium Phospho Fluoride dissolved in organic solvent is the common electrolyte. These components are assembled into a cell and various cells are combined together to make a battery pack.

This analysis considers a 50 GWh LIB manufacturing facility. According to CSTEP's estimates, such a facility would incur a capital cost of around INR 30,000 crore ($ 4.6 billion). It would require about 500 acres of land and generate 6500 jobs. About 3 years will be required to build a plant of this scale. Table 2 provides the other financial assumptions. Detailed assumptions of the cost model can be provided on request.

A financial model was developed to estimate the cost of manufacturing LIB batteries in India. It includes material, labour and energy requirement as well as depreciation, insurance, etc.

Table 1: LIB demand in EV and grid sectors by 2030

EV (considering 30% penetration by 2030)		
Transportation Sector*	**Energy storage per vehicle**	**Energy storage requirement (GWh)**
2W: 200 million	1 - 2.7 kWh	200 - 540
4W: 40 million	10 - 20 kWh	400 - 800
Bus: 3 million	100 - 324 kWh	300 - 970

Energy storage demand for EV in 2030 (GWh)	900 – 2300
Energy storage demand in grid sector by 2030 (GWh)**	22

*Considering exponential fit of 2000 to 2012 data reported in Ministry of Road Transport and Highways, GoI (reference url: http://morth.nic.in/index.asp)
** Considering linear interpolation of 2017 to 2032 data reported in IESS 2047 (reference url http://www.indiaenergy.gov.in/)

Results

Based on the analysis described in the previous sections, an indigenously manufactured LIB battery is expected to cost INR 9614/kWh ($ 148/kWh). The present cost of LIBs is $ 227/kWh.[2] It is important to note that currently a plant of 50 GWh capacity does not exist in the world. The largest capacity plant is 6 GWh.[8] Tesla has plans to build a 50 GWh plant and projects that the cost of LIBs will reduce to $ 150/kWh by 2020.[9] This suggests that if India were to build a plant of 50 GWh, the cost of a battery is expected to be globally competitive.

Figure 3 provides the share of various components involved in indegenously manufacturing LIBs in India.

It is important to note that the raw materials account for the maximum share (66%) of the total battery cost. The separator is a key component of the raw materials and accounts for 24% of total battery cost. Technological innovation, dedicated R&D and economies of scale can help in bringing down the cost of the separator. Graphite and lithium

Table 2: Assumptions for estimating the LIB manufacturing cost in India

Assumptions	
Plant capacity (GWh)	50
Total land area (acre)*	500
Capital cost (INR crore)**	30,000
Employment generation*	6500
Debt : Equity	70:30
Loan repayment period (years)	10
Life of the plant (years)	20
Construction period (months)	36

**source: https://www.tesla.com*
***includes equipment cost from Tesla*

account for 10% and 5% of cost shares, respectively. At present, China dominates the battery grade graphite supplies to the LIB industry. India is the world's second largest producer of graphite. However, a special chemical treatment is required to make it suitable for LIB applications. Hence, advancements in processing technology will help with the inclusion of Indian graphite in the LIB manufaturing value chain. Manganese, Nickel and Cobalt together contribute 7% of the total battery cost. Other materials include Aluminium, Copper and Nickel foil, Polyvinylidene Fluoride (PVDF) and N-Methyl-2-Pyrrolidone (NMP), which comprise 20% of the total battery cost. Most of these components can be manufactured indigeneously.

The Selling, General & Administrative (SG&A) expenses are high, particularly in the initial years of operation. However, over a period of time and with better understanding of technology and market requirements, these are expected to fall and hence, the final manufacturing costs can be further lowered.

The cost assessment doesn't consider any subsidies or policy incentives from the government. Since the capital cost is high ($ 4.6 billion), any support in the form of capital subsidy, similar to what is provided to the semi-conductor industry, will be helpful. With a capital subsidy of 25%, the cost of battery would reduce to $ 145/kWh. The LIB sector is a working capital intensive industry. Therefore, a production subsidy would be helpful in reducing the cost of a battery. The government provides a 10% subsidy on operating expenditure (OPEX) to the semi-conductor solar PV industry. If a similar subsidy is provided to the LIB manufacturing plant (in addition to the 25% capital subsidy), the cost of a battery will further reduce to $ 140/kWh (Figure 4).

Analysis & Recommendations

The analysis described above suggests that if a 50 GWh plant were to be established in India, the cost of battery is expected to be competitive with global costs. The cost can reduce further with policy incentives. Considering India's growing demand for energy storage, there is a case for indigenous LIB manufacturing. Although these plants are capital intensive, they will help secure the supply chain and

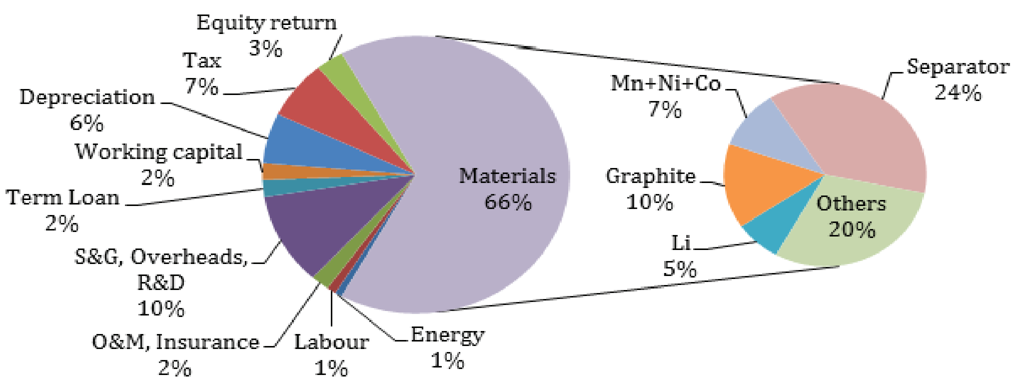

Figure 3: Share of various components in cost of indigenous LIB battery

POLICY NOTE

reduce import dependency. LIB is a strategic component of the clean energy ecosystem and it is opportune to develop a robust indigenous LIB manufacturing industry. India needs to remember the lessons from the semi-conductor solar PV industry, which is entirely dependent on importing solar cells and modules from China. This has made it difficult for manufacturers to enter the upstream supply chain. The LIB industry should not suffer the same fate.

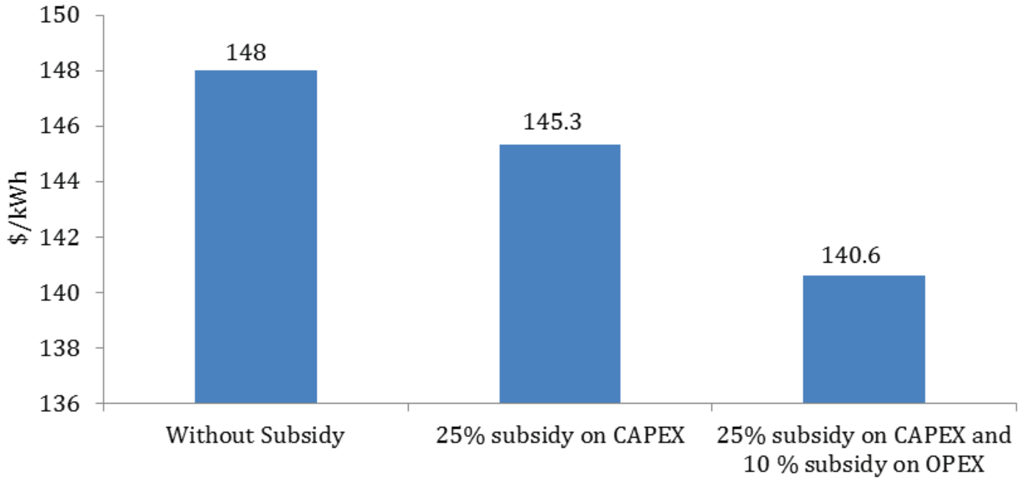

Figure 4: Impact of capital and production subsidy on manufacturing cost of LIBs in India

Policy Interventions

1. As LIB plants are capital intensive, the government could consider providing incentives including subsidies on CAPEX and OPEX. Further, private investors should be encouraged to build consortia to reduce investment risks.

2. Lithium is supplied by only a few countries such as Chile, Argentina, Bolivia and Australia. Therefore, India could consider signing MoUs for assured raw material supply. There should also be trade agreements with Congo and the Philippines for assured supply of components such as Cobalt and Nickel for cathode fabrication.

3. Indian graphite manufacturers should be provided incentives to set-up chemical treatment facilities for synthesis of LIB grade graphite. Considering that India imports LIB grade graphite from China, indigenous manufacturing will help reduce costs.

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