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GHG EMISSIONS PRODUCED DURING THE MANUFACTURING OF LITHIUM-ION BATTERIES USINGGREET MODEL- A COMPARATIVE STUDY

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ABSTRACT

The GHG emissions generated during the production of Lithium-ion batteries has been shown in this theoretical research paper. To find the various types of emissions, GREET Model has been utilized and all the main process in developing the materials for Lithium-ion batteries has been studied. The GREET model has been investigated in which the life cycle analysis of the material i.e. from cradle to grave has been studied. Though the electric vehicles emit less pollutants than I.C. Engine vehicles but the processes that produce electric vehicles emit more GHG emissions. Through the analysis of the model, it has been found out that for each 1 Kg of the material, more than 40.76 Kg of GHG emissions are generated which seems to be a global concern for the environment. Also, in the whole process of Lithium-ion batteries manufacturing, Lithium contributes to higher range of GHG emissions as compared to other materials including anode, cathode, and electrolyte.

Keywords: Emissions, Lithium-ion batteries, GHG-100

1. INTRODUCTION

Global warming has become a major problem for everyone on a micro level, as well as for the future of our children and grandchildren. It has become challenging for countries to control their economic dependency due to the depletion of fossil fuels and their rising prices. Crude oil and electric vehicle prices are skyrocketing, making life tough for low-income families and people. Because of the ongoing Russian invasion of Ukraine and the rise in international crude oil prices, international energy trading has become a source of anxiety. As the price of fossil fuels rises, electric and hybrid vehicles, as well as biofuels, are being used to replace them. Electric vehicles having a range of less than 200 miles on average could attain cost parity with internal combustion engines in 8 years or less [1]. For power transmission, a three-phase brushless DC motor with

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Lithium-ion battery packs and a motor conversion controller has been used. [2]. Some reach cost parity, while others become more cost effective than ICEVs [3]. With specific conditions, hierarchical surpasses conventional approaches by reducing NOx emissions. [4]. Distributed Generation and fuel cell electric vehicles are also emerging as electric systems [5]. Both electric vehicles and internal combustion engine vehicles may significantly reduce GHG emissions [6]. The stock of electric vehicles and carbon dioxide have a substantial impact on the environment, and policy considerations for reducing CO_2 emissions are also highlighted [7]. According to these findings, the production of electric vehicles is unlikely to result in a significant reduction in CO_2 emissions in future scenario [8]. For improving air quality and reducing harmful pollutants all countries governments are emphasizing the switch over to electric vehicles [9]. The disparity between renewable energy and electric vehicle charging causes significant complications that needs to be addressed [10]. When compared to plug-in electric vehicles, battery electric vehicles emit 90% less greenhouse gases and 40% less than fuel cell electric vehicles [11]. India stands on the E-mobility at a glance with groundbreaking revolution in electric mobility with 2656.62 kilotons of carbon dioxide emissions have been reduced and 1800 electric vehicle charging stations have been installed. Companies such as MG ZS, TATA Nexon, TATA Tigor, Mahindra E20 plus, Hyundia Kona, Mahindra Verito are the manufactures of Battery Electric Vehicles [12]. Once the battery is waste what significance it impacts the environment, also the energy density of newly developed battery material will significantly impact [13].

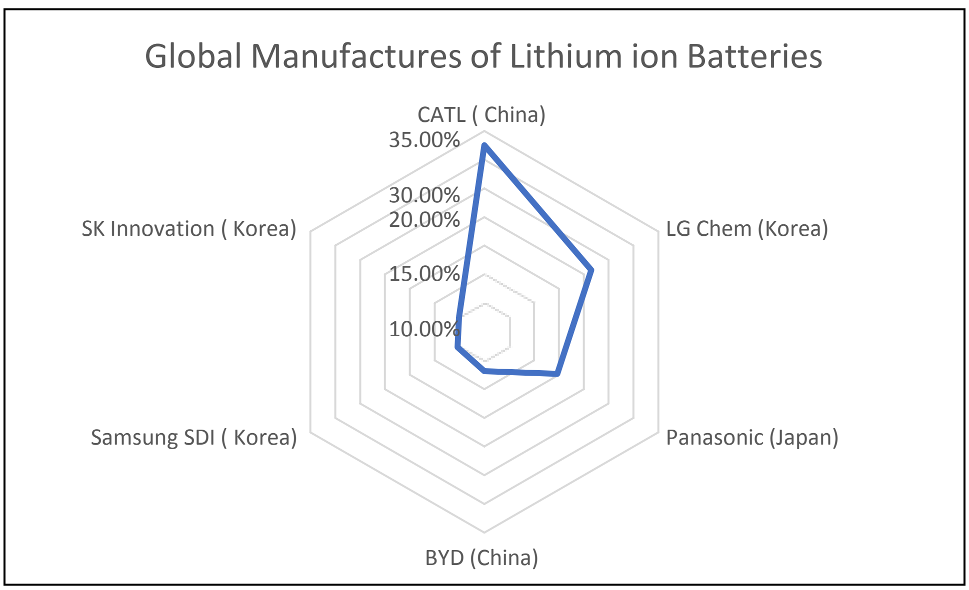

Fig. 1 Global Market share scenario of Lithium ion battery makers (2021) [15]

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Keeping in view the above research articles an attempt has been made to investigate the GHG emissions generated through the application of electric batteries in automobile industry and the contribution of materials in generating these emissions.

1. Material Configurations

Electric vehicles consist of an electric motor, an inverter, a control module, a drive train, and a battery. The power has been stored in the battery stacks that consists of individual cells arranged in series and parallel. Each battery cell contributed individually and its arrangement in the pack plays a very significant role in the power generation and distribution during charging and discharging of the cell. Figure 2 shows the schematic layout of the lithium-ion battery and the flow of electron from the cathode to anode and vice versa, the cathode i.e. positive terminal of the battery consists of Lithium cobalt oxide and anode the negative terminal consists of Graphite on aluminum plates. The figure clearly indicates the material configuration of each lithium-ion cell for study.

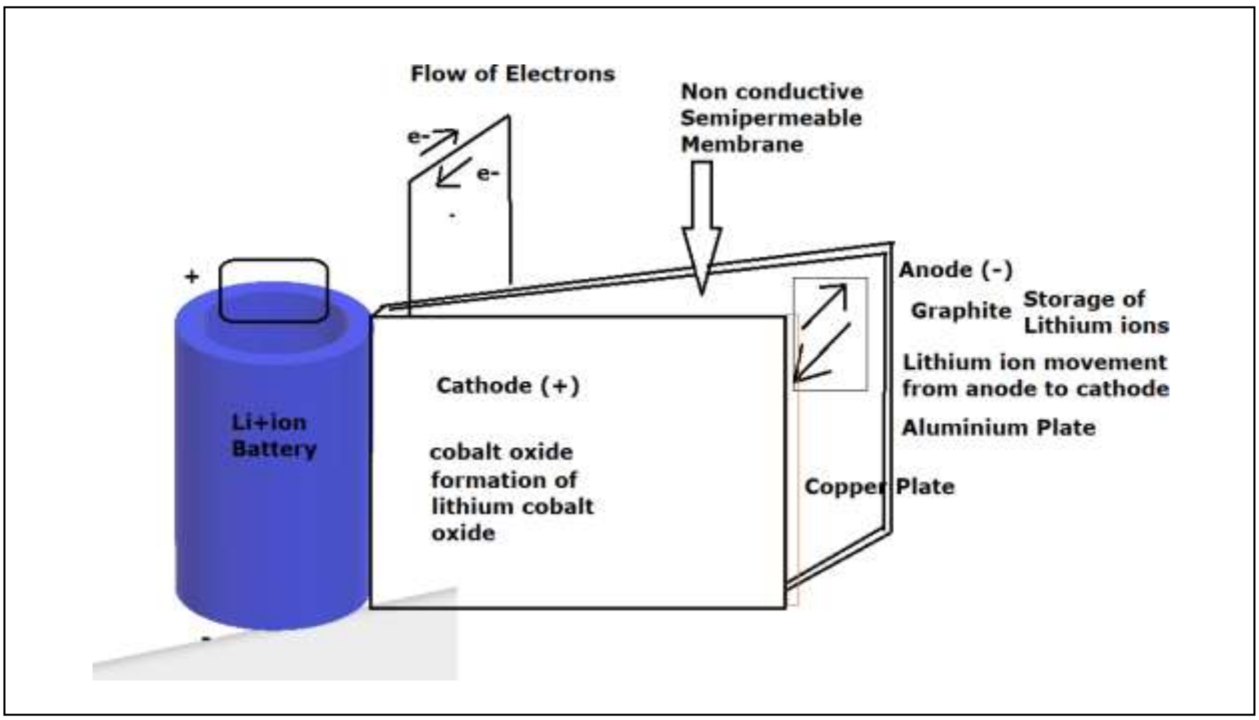

Fig.2. Schematic Layout of the Lithium-ion Battery pack

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2. Cathode Material

2.1 Lithium Metal (Pathway)

Lithium generates dendrites, which cause a short circuit and initiate a runaway reaction on the cathode, causing the battery to catch fire, which is critical to comprehending the material specification. [14]. During the production of Lithium there are three processes (i) Heating and Melting the eutectic for metallic lithium and during this process 6.5000 ton of lithium carbonate along with Potassium carbonate 1.5000 ton with utilizing natural gas 14.1500 mmBTU produces 8 ton of LiCl-KCl eutectic. (ii) Electrolysis for metallic lithium production which is the second process includes 8 ton of LiCl-KCl electrolysis, utilizes 99.06 mmBTU producing 1 ton of Lithium Metal and 5.1080 ton of chlorine. (iii) The third process includes refining of Lithium metal which utilizes 46.6500 mmBTU.

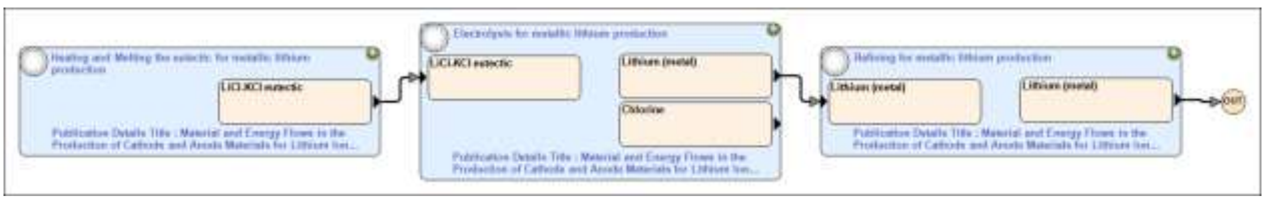

Fig.3. Pathway to produce Lithium Metal

2.2 Lithium Cobalt Oxide (Pathway)

To produce lithium cobalt oxide the main materials are the cobalt oxide and lithium carbonateand also utilizes 19 mm BTU of electricity.

Table 1 Lithium Cobalt Oxide Production

Input	Value	Unit
Cobalt oxide	0.8201	Tons
Lithium Carbonate	0.3775	Tons
Electricity	19	Mm BTU
Output		
Lithium Cobalt Oxide	907.1847	Kg
CO2	203.9620	Kg
GHG-100	21.1819	Kg per Kg of Lithium Cobalt Oxide

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3. Anode Material – Graphite (Pathway)

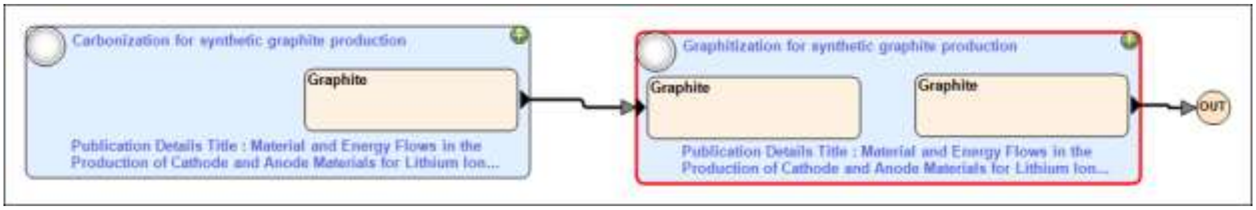

Fig.4. Pathway to produce Graphite

Figure 4 shows the pathway for producing graphite i.e. used for battery manufacturers, through the GREET model it has been seen that the production process takes place in two steps i.e. (i) Carbonization for synthetic graphite production in which the material utilization has been mentioned in the table 1. Also, the Table 3 shows the emission data generated during this process and has been found out that during this process if 1 Kg of the material generated with it the GHG 100 emission value comes out to be 1.3729 Kg.

The graphite material has large graphite grains and can also achieve close to theoretical charge capacity. Think layer of amorphous carbon can significantly protect the vulnerable edges planes from the electrolyte and can also achieve high columns efficiency [14]

Table 2 Carbonization for synthesis graphite production

Process	Value	Unit
Natural Gas	5.1480	mmBTU
Pet coke	0.9500	Ton
Coke	0.2400	Ton

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Table 3 Emission data during the canonization for synthesis graphite production

Emissions	Value	Unit
NOx	9.3000	Kg
PM	4100.5000	gm
PM 2.5	2050.2500	gm
SOx	63.8120	Kg
CO2	437.056	Kg

(ii) the second process is the Graphitization process during which 13.9300 mmBTU of electricity is being utilized and during this process for 1 Kg of the Graphite produces 4.49 Kg of GHG-100.

Table 4 For Graphitization process the material process values

Natural Gas	4	mmBTU
Oxygen	0.8800	Ton
Ethylene	0.7880	Ton
Electricity	2	mmBTU
Emission (CO2)	516.2852	Kg

4. Electrolyte Lithium Hexafluorophosphate (Pathway)

In lithium-ion batteries, lithium hexafluorophosphate has been the most often utilized electrolyte material. The material is soluble in water with a melting point of 200^{o}C and density 2.84 g/cm^{3}.

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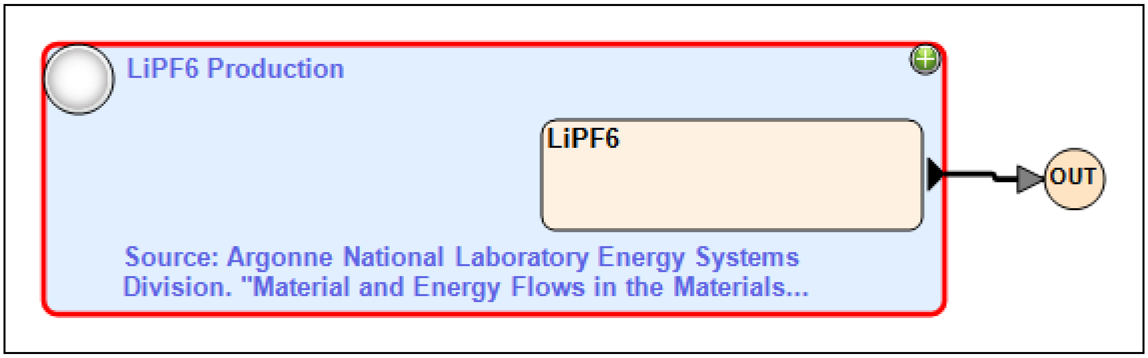

Fig.5. Pathway to produce Lithium hexafluorophosphate

Figure 5 shows the pathway to produce lithium hexafluorophosphate and to manufacture the material requires sulfuric acid 5.8 times for producing approximately 1 Kg and along with residual oil 0.3650 mmBTU (million metric British Thermal Unit) along with electricity consumption 77 mmBTU. For Producing 1 kg of the final material product the GHG 100 emission generated through the process takes 10.6105 Kg emission value.

5. GHG-100 emissions

Figure 6 shows the GHG-100 emissions for materials i.e. Lithium metal, Graphite and Electrolyte LiPF6 and it can be seen that Li Metal produces the maximum GHG emission among the various other materials with a value of 29.03 Kg per Kg of the material manufactured.

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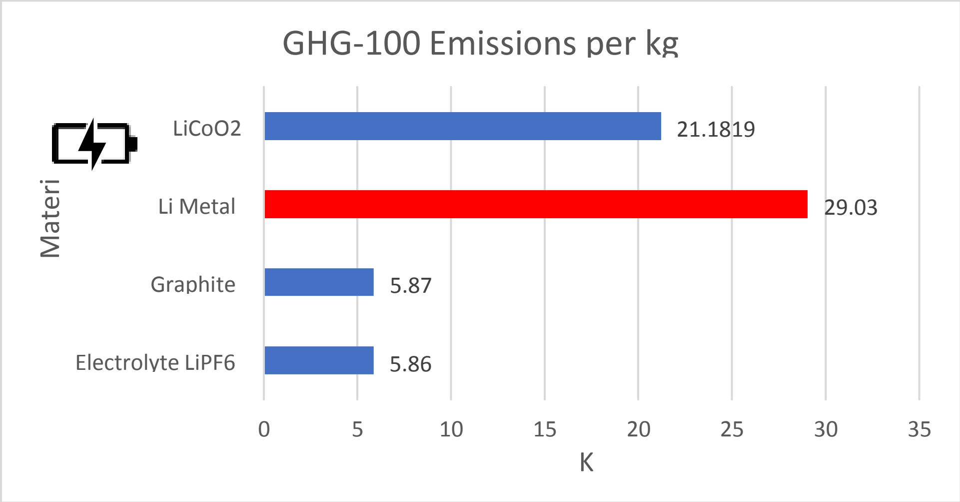

Fig. 6. GHG-100 emissions for various materials

6. Conclusions

While designing Battery cell packs, the expected value of GHG emissions can be estimated. The total contribution of GHG emissions during the procurement of kg of material is 40.76 kg of GHG-

100. The GREET model aids in the prediction of the impact of Lithium-ion Battery-powered vehicles. Liquid electrolyte is an important parameter in electric batteries and the battery life depends on the holding capacity of the electrolyte during the charging and discharging. The inner temperature of the cell pack should be kept below 200^{o}C so that the electrolyte solution does not melt and short circuit does not avail. These data generated through the GREET model shall help the manufacturing industries to find out new materials which are more sustainable and produce less GHG emission and can be a game changer in modern electric vehicles.

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