Lithium-iron-phosphate batteries lfp togo

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There are a multitude of LIB life-cycle assessment (LCA) studies focusing on CF19,20,21, but they are known to be sensitive to modelling assumptions and system boundary choices19,22,23. Thus, the comparability of LCA studies is still markedly restricted, and interpreting them typically requires domain knowledge. In addition, there are three major knowledge gaps that limit our current ability to comprehend (unintended) consequences and inform the specific design of pioneering policies, such as the EU Battery Regulation, let alone evaluate and benchmark forthcoming decarbonisation initiatives within the battery sector.

The emission curve for lithium carbonate depicted in Fig. 1a reveals two primary plateaus: the first, characterised by low CF levels, is predominantly sourced from South American brine operations, and the second, approximately three times higher in CF, is mainly composed of Australian hard rock (spodumene) deposits. Moreover, our analysis showed that while the CFs for brine sites exhibit a wide range, spanning from the lowest to the highest values, all spodumene sites--identifiable by grey bar segments in Fig. 1a--fall within the higher CF plateau.

A large share of the covered supply chain (x axis in Fig. 1a) comprises only a handful of mines with high output volumes. Because many values in the literature and databases refer to South American brine operations, the median literature and database CF is skewed accordingly towards those mines, as shown by the horizontal lines in Fig. 1b. However, looking at the global production locations in 2022, it becomes evident that the actual median CF at around 350 kt of lithium carbonate is about three times higher.

Nickel"s emission curve, as depicted in Fig. 1d, can be segmented into three plateaus. The leftmost plateau, accounting for approximately 40% of the covered supply chain, was analysed using the same methodology applied to lithium in Fig. 1a. All mines within this plateau were extracting sulfide ore and corresponded to the non-hatched waterfall segments in Fig. 1f. The CFs in this segment exhibited a hockey-stick curve pattern, with Russia holding the largest market share at the lower CF levels. For a detailed examination of this first plateau, focusing solely on sulfide mines, refer to Supplementary Fig. 4.

The existing literature and database values were generally in line with the modelled CF of sulfide nickel mining (cf. Supplementary Fig. 4). However, the academic literature and databases do not sufficiently cover nickel from laterite sources and thus underestimate the average CF of nickel sulfate. This gap is likely due to the recent exponential growth in LIB demand, which has resulted in the sourcing of mined laterite for LIBs--an ore deposit that used to be mined predominantly for the steel industry31,32. By 2022, Indonesia (home to laterite ore deposits) established itself as the largest nickel mining country, followed by Russia, Canada and Chile (all home to sulfide ore deposits).

The emission curve for cobalt shown in Fig. 1g follows a step-like function, where the four largest mines are all located in the Democratic Republic of the Congo (DRC) and comprise 90% of the covered supply chain. Sites in the DRC mine copper in exclusively stratiform sediment-hosted (SSH) deposits and produce cobalt as a sellable by-product33. Cobalt from SSH deposits accounts for the overwhelming majority of the supply chain (Fig. 1i) while by-product cobalt from laterite and sulfide nickel ore deposits plays a minor role.

Similar to nickel laterite, S& P Global data were not available for graphite. Acknowledging Graphite''s relevance34, we used CF ranges from the academic literature and production volumes from USGS28 and DERA30. Panel types a-c are shown for graphite in Supplementary Fig. 3. Graphite''s supply chain is dominated by China, where synthetic graphite production accounts for around two-thirds, with slightly higher CF and higher CF ranges than natural graphite. Similar to all previous cases, median database values were lower than median literature values.

In this section, we present the global representative CF distributions for LIB with NMC and LFP cathodes. Given the opacity of the supply chain, we assumed no regional material preferences among battery producers. For example, we assumed that Chinese and German battery producers were equally likely to source Chilean lithium carbonate. Next, we combined the four emission curves with regionalised announced LIB production capacities until 2030 to obtain CF distributions for LIB cells using Monte Carlo simulations.

For LFP cells, whose cathodes mainly comprised lithium, iron and phosphate, the global CF distribution closely traced the Chinese distribution, as almost all LFP cell production is announced in China (Fig. 3a). The global 90% confidence interval for LFP spanned 54 to 69 kgCO2e kWh-1 (Fig. 3a) and, given the nickel-free cathode, was smaller and more symmetrical than in Fig. 2a. The median CF ranges, at 58-62 kgCO2e kWh-1 for Europe and China, respectively (Supplementary Table 3), were ~16% lower than for NMC cells, including laterite mining. Differences with respect to production locations were even less pronounced compared to cells with NMC cathodes, because less electricity is required for material synthesis and cell production.

Concerning CF distribution, lithium carbonate and graphite were the largest contributors; non-battery-specific materials gained relative shares compared to LIBs with NMC cathodes. The contribution of electricity and, thus, production location noticeably depended on the production method of the active material. Based on expert interviews, we show results for a ratio of 9:1 (solid-state vs. hydrothermal LFP active material synthesis) in Fig. 3 but also provide separate panels a-c for the two isolated synthesis methods in Supplementary Figs. 8 and 9, respectively. Finally, regardless of the synthesis route, lithium carbonate contributed the most, by far, to the observed variance (Fig. 3c).

In this section, we first summarise this work''s contribution and contextualise our findings. We continue with an in-depth discussion of the implications for environmental and industrial policy before concluding with an outlook.

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