Supplementary Information (SI) for EES Batteries.

# Supplementary Information

## Opportunities and Challenges for the Expansion of LFP Battery Supply Chains

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### Supplemental Calculations, Discussion, and Assumptions

*Section 1: Precursor Demand for EV Applications Assuming 100% LFP Synthesis Yield*

The manuscript states that 2.93 MMT of $H_3PO_4$ (anhydrous), 4.54 MMT of $FeSO_4$ (anhydrous), and 1.10 MMT of $Li_2CO_3$ (anhydrous) are needed to synthesize the 4.71 MMT LFP required to support projected demand in 2045. This section describes the assumptions and calculations that lead to these numbers and shows that 4.71 MMT LFP and 2.93 MMT $H_3PO_4$ are conservative estimates to meet projected demand. Because these are conservative estimates, additional calculations are shown here that describe alternative assumptions that suggest higher estimates may be justified. The calculations summarized in this document are also detailed in an Excel file titled “Calculations Section 4 Precursor Requirements for LFP.”

The global energy demand for LFP EV batteries in 2045 is projected to be 2298 GWh assuming 37% of the energy is met by LFP batteries in 2045 [1], [2]. The LFP mass required to meet that energy demand is 4.71 MMT based on data for LFP battery packs in Guan *et al* Table S1, which shows that 2.05 kg of LFP is required per kWh of battery capacity.[3] We assume here that LFP utilization in batteries will be similar in 2045 to the data in Guan *et al* Table S1,[3] such that the energy obtained in LFP batteries today from a given mass of LFP does not improve with time. Battery technology improves gradually over time so it is possible that slightly more energy will be utilized for the same mass of LFP in the future, which would lead to a smaller demand for LFP and LFP precursors than assumed here; however, LFP is a well-developed battery material that is already well optimized and utilized, so it is reasonable to assume that improved energy utilization from a given mass of LFP is negligible. For reference, in 2024 global energy demand for EVs was 864 GWh and 40% of EV batteries sold were LFP,[4] translating to 346 GWh LFP battery capacity and 1.04 MMT LFP if Guan *et al* Table S1[3] data is assumed.

If 4.71 MMT of LFP is required to meet projected demand in 2045, the most conservative estimate for precursor requirements to manufacture that LFP quantity is to assume 100% yield during synthesis, in which moles of each element are conserved from the precursors

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to the LFP product. Yield will undoubtedly depend on the synthesis process but yield for the two-step synthesis used to prepare LFP commercially today is reported to be high (99.5%) in research literature.[5] If 100% synthesis yield is assumed, it follows that 4.71 MMT of LFP requires precursor masses specified in Table S1 below. While the current industrially relevant synthesis utilizes $H_3PO_4$, $Li_2CO_3$, and $FeSO_4$, alternative Fe and Li precursor quantities are also calculated because there is interest in changing these precursors in some proposed synthetic schemes. Table S1 indicates the amounts of alternative Fe and Li precursors required to replace $FeSO_4$ and $Li_2CO_3$ assuming 100% synthesis yield and conservation of reactant to product moles of each element. Note that $H_3PO_4$ is the only $(PO_4)^{3-}$ precursor considered here for P because other $(PO_4)^{3-}$ precursors are generally synthesized from $H_3PO_4$, so $H_3PO_4$ would be involved even if the precursor target changed relative to current industrial processing.[6], [7] In contrast, LiOH and $Li_2CO_3$ are both readily synthesized at high purity for battery applications, so both are worth considering. Furthermore, there is significant interest expressed in alternative precursors to replace $FeSO_4$, so amounts required for some of these alternatives are presented in **Table S1**.

| Precursor | Precursor Mass (MMT) |
|---|---|
| $Li_2CO_3$ (anhydrous) | 1.10 |
| $LiOH{\cdot}H_2O$ | 1.25 |
| $FePO_4$ (anhydrous) | 4.51 |
| $FePO_4{\cdot}2H_2O$ | 5.58 |
| $FeSO_4$ (anhydrous) | 4.54 |
| $Fe_2O_3$ (anhydrous) | 2.39 |
| $Fe_3O_4$ (anhydrous) | 2.31 |
| Fe metal (anhydrous) | 1.67 |
| $H_3PO_4$ (anhydrous) | 2.93 |

**Table S1.** Precursor masses required to synthesize 4.71 MMT LFP to meet projected LFP demand for EVs in 2045 if the synthesis yield is 100% such that moles of Li, Fe, and $PO_4$ are preserved between moles of each element in the precursors and the LFP product. These values were determined by converting 4.71 MMT LFP into the number of moles of each element and then calculating the mass of each precursor required to deliver the corresponding number of moles needed for LFP.

## *Section 2: Precursor Demand for EV Applications Assuming LFP Synthesis Yield According to Factory Data*

**Table S1** provides a conservative estimate for precursor masses required to support 2045 LFP demand because **Table S1** assumes synthesis yield is 100%, which may be too ambitious. Guan *et al* Tables S4-S5[3] summarize material inputs and outputs from factories in China that produce LFP by the common two step method:

$$FeSO_4 + H_3PO_4 \rightarrow FePO_4 \text{ (\textbf{Step 1})}$$

$$FePO_4 + Li_2CO_3 \rightarrow LiFePO_4 \text{ (\textbf{Step 2})}$$

Each step is performed at a separate factory with separate references as sources for the data summarized in Guan *et al* Tables S4-S5.[3] These tables can be used to calculate the actual amount of each precursor required for commercial LFP synthesis. Actual precursor requirements are expected to be higher than the values in **Table S1** because **Table S1** assumes 100% yield. While yield is likely very close to 100%, some reports suggest that a slight excess of $H_3PO_4$ precursor is used in **Step 1** to prepare $FePO_4$ from $H_3PO_4$ and $FeSO_4$.[8], [9] Analysis of these factory data summarized in Guan *et al* Tables S4-S5[3] also suggests a slight excess of $H_3PO_4$ is used in LFP synthesis, but some assumptions must be made to interpret the data.

Analysis of Guan *et al* Table S4,[3] which describes **Step 2** of the LFP synthesis process reveals that yield of the solid-state reaction step to synthesize LFP is nearly 100%. Each kg of LFP produced is reported to require 0.970 kg of anhydrous $FePO_4$ and 0.238 kg of $Li_2CO_3$.[3] Specifically, yield defined as the number of moles of Li in the LFP product relative to moles of Li in the $Li_2CO_3$ reactant is 98.4%. Similarly, yield defined as the number of moles of Fe or $PO_4$ in the LFP product relative to the moles of Fe or $PO_4$ in the $FePO_4$ reactant is 98.6%. The masses of $FePO_4$ and $Li_2CO_3$ precursors required to synthesize 4.71 MMT LFP (projected demand in 2045) are presented in **Table S2** below. $FePO_4$ is denoted as anhydrous in Guan *et al* Table S4.[3] This is reasonable because $FePO_4$ produced from reaction of $H_3PO_4$ and $FeSO_4$ typically yields $FePO_4.2H_2O$, which is then commonly dried to dehydrate it before the solid state synthesis involving $FePO_4$ and $Li_2CO_3$ to make LFP.[10] $Li_2CO_3$ is assumed to be anhydrous because that is how it is commonly sold and it is not commonly hygroscopic.[11] The values presented in **Table S2** for the species involved in the **Step 2** reaction are only slightly higher than **Table S1** because the yield of the solid-state reaction is close to 100%.

| Precursor | Precursor Mass (MMT) |
|---|---|
| $Li_2CO_3$ (anhydrous) | 1.12 |
| $LiOH{\cdot}H_2O$ | 1.27 |
| $FePO_4$ (anhydrous) | 4.57 |
| $FePO_4{\cdot}2H_2O$ | 5.79 |
| $FeSO_4$ (anhydrous) | 4.68 |
| $Fe_2O_3$ (anhydrous) | 2.46 |
| $Fe_3O_4$ (anhydrous) | 2.38 |
| Fe metal (anhydrous) | 1.72 |
| $H_3PO_4$ (anhydrous) | 3.65 |

**Table S2.** Precursor masses required to synthesize 4.71 MMT LFP to meet projected LFP demand for EVs in 2045 if the synthesis precursor inputs and LFP product outputs from Guan *et al* Tables S4-S5$^{REF}$ factory data are used to calculate precursor requirements instead of assuming 100% synthesis yield (contrary to the 100% yield assumed in **Table S1**). Assumptions about hydration levels of each precursor are discussed in the proceeding and following paragraphs.

The hydration states for Guan *et al* Table S5,[3] which summarizes factory inputs and outputs for the solution synthesis step (**Step 1**), are not as clearly depicted as the solid-state synthesis step in Guan *et al* Table S4.[3] This ambiguity leads to difficulty understanding the synthesis yield and motivates our decision to use 100% synthesis yield numbers in the manuscript and **Table S1**, rather than relying on assumptions that must be made to interpret the data in **Table S2** above. In Guan *et al* Table S5,[3] $H_3PO_4$ (>35%) is specified, indicating that the $H_3PO_4$ is diluted to 35% in water, which is clearly defined. $FeSO_4$ in Guan *et al* Table S4[3] is denoted simply "$FeSO_4$." $FeSO_4$ is often sold complexed with varied amounts of water (e.g., dihydrate, hexahydrate, heptahydrate, and nonahydrate). $FeSO_4 \cdot 7H_2O$ is often the form arising in literature describing the process defined by **Steps 1-2.**[8], [9], [10] However, Guan *et al* Table S4[3] listing only $FeSO_4$ without water denoted implies that the mass value does not include the complexed water. Furthermore, $FePO_4$ is denoted simply as "Iron Phosphate", making its water content unclear, but $FePO_4 \cdot 2H_2O$ is commonly the product synthesized directly from $FePO_4$ and $H_3PO_4$.[10] Each kg of "Iron Phosphate" produced is reported to require 1.80 kg of $H_3PO_4$ (<35%) and 0.808 kg of "$FeSO_4$".[3]

If the masses of $FeSO_4$ and $FePO_4$ reported in Guan *et al* Table S5[3] are assumed to be the masses of their anhydrous forms, the molar ratio of Fe in the reactant (anhydrous $FeSO_4$) relative to moles of Fe in the product (anhydrous $FePO_4$) is 0.8, which is physically impossible because more Fe moles are produced than are consumed. If the masses in Guan *et al* Table S5[3] are assumed to represent various possible $FeSO_4$ (*e.g.,* anhydrous, $7H_2O$, etc.) and $FePO_4$ (*i.e.,* anhydrous, $2H_2O$) water complexes, masses given in the tables corresponding to the combination of anhydrous $FeSO_4$ and $FePO_4 \cdot 2H_2O$ is the most physically reasonable; other combinations lead to yields that are higher than 100% based on Fe mole conservation in the reactants and products. These other assumption scenarios are detailed in Excel workbook "Calculations Section 4 Precursor Requirements for LFP."

Even assuming the masses in Guan *et al* Table S5[3] are $FeSO_4$ and $FePO_4.2H_2O$, the reactant/product Fe molar ratio is slightly lower than is physical (0.98); however, the literature also suggests that $FePO_4 \cdot 2H_2O$ synthesized from $H_3PO_4$ and $FeSO_4$ actually contains more water than the $2H_2O$ complexed to each $FePO_4$ due to water adsorbed onto the surface. Thermogravimetric analysis suggests that the mass of $FePO_4.2H_2O$ is actually 2.18% higher than expected due to this surface water effect.[12] Assuming the mass in Guan *et al* Table S5[3] depicts the total mass of the $FePO_4$ in its as-synthesized form, (two complexed water molecules and surface water) the total mass listed in table should equal (mass $FePO_4$ + mass $2H_2O$)*1.0218. The moles of Fe required can then be calculated from the total mass with these known water contributions. With these assumptions, the molar ratio of Fe in the reactant ($FeSO_4$ with mass in table denoting anyhydrous state) relative to Fe in the $FePO_4.2H_2O$(+2.18% surface water) product is 1.02, which is physically reasonable because the number of moles of Fe consumed slightly exceeds that produced. These hydration assumptions are adopted for the analysis presented in **Table S2** because assuming the masses in Guan *et al* Table S5[3] represent anhydrous $FeSO_4$ and $FePO_4 \cdot 2H_2O$+2.18% surface water leads to physically meaningful results. High yield based on moles of Fe is reasonable because $FeSO_4$ is dissolved in solution and a slight excess of $H_3PO_4$ is often used,[8], [9] suggesting $FeSO_4$ is the limiting reagent in this $FePO_4$ synthesis reaction (**Step 1**).

If the assumptions described above that lead to the values in **Table S2** are correct, then LFP synthesis yield is very high but may also require excess $H_3PO_4$, which is consistent with the literature.[8], [9] **Table S1** assumes 100% synthesis yield with no molar excess of any precursor element required. Therefore, **Table S1** likely underestimates the $H_3PO_4$ needed to meet LFP demand projections in 2045 but reasonably estimates the Fe and Li requirements. If **Table S2** $H_3PO_4$ requirements are used instead, LFP demand may require 20% more $H_3PO_4$ precursor than is stated in the main manuscript (3.65 rather than 2.93 MMT $H_3PO_4$).

## *Section 3: Precursor Demand for EVs and BESS Applications*

The LFP demand in 2045 depicted in the associated manuscript and **Tables S1-S2** only account for LFP required to produce EV batteries because those projections are available and EVs are the primary market; **Tables S1-S2** ignore LFP required for other battery applications such as battery energy storage systems (BESS) and portable consumer electronics. Portable consumer electronics accounted for only ~8% of the Li-ion market in 2024 (94 GWh relative to 1170 GWh total Li-ion)[13] and LFP is not as popular for portable electronics as BESS and EV applications,[14] so it is reasonable to ignore the portable consumer electronics application when considering LFP demand. Conversely, LFP is very popular for BESS because of cost and safety advantages over other chemistries, so it is reasonable to consider it even though BESS is a much smaller market than EVs.

To be best of the authors' knowledge, there are no projections specifically for LFP BESS battery demand in 2045 at the time of writing this manuscript. However, 8000 GWh is the total projected Li-ion demand in 2045 for all applications.[15] Assuming that consumer electronics will remain 8% of the market (as it was in 2024[13]), 7360 GWh is the projected demand in 2045 for BESS and EVs. Subtracting the Li-ion EV projected demand (6210 GWh)[1] from the total projected demand (7360 GWh) gives a rough estimate of 1150 GWh expected demand for BESS in 2045. Currently, 80% of BESS Li-ion installations are LFP batteries (2023).[16] If similar percentages are assumed in 2045, 920 GWh of LFP batteries would be required in 2045 for BESS. Adding that to the 2298 GWh needed for LFP EVs (37% of 6210 GWh)[2] gives 3218 GWh total LFP battery capacity required in 2045 for EVs and BESS, corresponding to 6.60 MMT LFP based on Guan *et al* Table S1.[3]

If one assumes 3218 GWh LFP is required in 2045 for BESS and EVs, as discussed in the previous paragraph, **Table S3** summarizes the resulting precursor requirements needed to meet LFP demand for EVs and BESS. The two columns denote different assumptions that lead to differing precursor requirements: either 100% synthesis yield (similar assumptions to **Table S1**) or synthesis yield from Guan *et al* Table S4-S5[3] factory data (similar to assumptions to **Table S2**). It is reasonable to consider both EV and BESS applications for LFP when trying to understand LFP precursor demand and this table supplements the manuscript calculations, which only account for EV demand.

These data further suggest that LFP and synthesis precursor demand in the main manuscript are underestimated.

| Precursor | Precursor Mass (MMT) Assuming 100% Yield Synthesis | Precursor Mass (MMT) Factory Synthesis Yield |
|---|---|---|
| $Li_2CO_3$ (anhydrous) | 1.55 | 1.57 |
| $LiOH{\cdot}H_2O$ | 1.65 | 1.78 |
| $FePO_4$ (anhydrous) | 6.31 | 6.40 |
| $FePO_4{\cdot}2H_2O$ | 7.82 | 8.11 |
| $FeSO_4$ (anhydrous) | 6.36 | 6.55 |
| $Fe_2O_3$ (anhydrous) | 3.34 | 3.44 |
| $Fe_3O_4$ (anhydrous) | 3.23 | 3.33 |
| Fe metal (anhydrous) | 2.34 | 2.41 |
| $H_3PO_4$ (anhydrous) | 4.10 | 5.11 |

**Table S3**. Precursor masses required to synthesize the 6.60 MMT LFP needed to meet projected LFP demand for EVs and BESS in 2045 for scenarios where LFP synthesis yield is 100% or the synthesis precursor inputs and LFP product outputs from Guan *et al* Tables S4-S5[3] factory data are used to calculate precursor requirements (scenarios described in **Table S1-S2** for EVs, with BESS added here). Assumptions about hydration levels of each precursor are discussed in the proceeding paragraphs.

## *Section 4. Precursor Demand for EVs and BESS Applications Including P demand for $LiPF_6$ Electrolyte*

Because P is also used in the $LiPF_6$ salt that dominates battery electrolytes, it is reasonable to consider the amount of P needed for electrolyte demand in 2045. $LiPF_6$ is used in most Li-ion battery chemistries rather than only in LFP batteries, so it is reasonable to consider P needs for both chemistries. Subtracting the demand for LFP batteries (3218 GWh detailed above) from the total battery demand (8000 GWh) in 2045 and assuming that the balance of battery capacity is NMC batteries for simplicity, NMC battery demand is projected to be 4782 GWh. There likely will be other chemistries than simply NMC and LFP, but this calculation is meant to be an approximation where NMC is used as a surrogate for all other chemistries. NMC batteries utilize a smaller amount of electrolyte (and therefore $LiPF_6$ salt) than LFP batteries,[3] likely due to their higher energy density, which leads to lower pore volume filled with electrolyte. Guan *et al* Table S1[3] reports that 0.21 kg $LiPF_6$ is required per kWh LFP batteries and 0.11 kg $LiPF_6$ is required per kWh NMC batteries. **Table S4** shows the moles of elemental P needed to meet the demand for $H_3PO_4$ in LFP batteries when considering three different cases: (1) EVs, (2) EVs+BESS, and (3) EVs+BESS including the P demands for $LiPF_6$ electrolyte. $LiPF_6$ salt demand is calculated to include electrolytes needed for both LFP and NMC chemistries assuming these chemistries were used to meet the 8000 GWh demand in 2045. In the first two cases, demand for $LiPF_6$ is not included. In the third case, including the moles of P needed for $LiPF_6$ salt increases the total molar demand of P by about 15% relative to considering only the moles of P needed for synthesizing LFP for EVs and BESS.

| Calculation Scenario | GigaMoles P Assuming Factory Synthesis Yield | Mass (MMT) $H_3PO_4$ or $H_3PO_4$ Equivalent* Assuming Factory Synthesis Yield |
|---|---|---|
| EVs only | 37.2 | 3.65 |
| EVs + BESS | 52.1 | 5.11 |
| EVs + BESS + $LiPF_6$ electrolyte | 60.2 | 5.90* |

**Table S4**. Summary of projected P requirements in 2045 needed under varied LFP demand scenarios. Calculations denote and moles of P needed and the corresponding mass of anhydrous $H_3PO_4$ needed if considering only EV demand versus EV and BESS demand. These mass data are replicated from **Tables S2-S3** and are depicted assuming synthesis yield informed by Guan *et al* Tables S4-S5[3] factory data. These data are summarized here for convenient comparison to the third scenario that includes P requirements for LFP cathodes in EVs and BESS as well as P requirements for $LiPF_6$ electrolyte used in LFP and NMC batteries in 2045. *To convert to a consistent mass scale for convenient summation of P requirements, the moles of P needed for $LiPF_6$ electrolyte were used to calculate an equivalent $H_3PO_4$ mass that would be needed if the moles of P in $LiPF_6$ were instead converted with P mole conservation to $H_3PO_4$. This equivalent $H_3PO_4$ value includes the $H_3PO_4$ required for LFP cathode synthesis as well as the P mole equivalent of $H_3PO_4$ needed for $LiPF_6$ salt in the electrolytes for NMC and LFP batteries.

The $LiPF_6$ and $H_3PO_4$ masses needed for battery electrolytes and LPF cathode materials, respectively, cannot be compared fairly on a mass basis because these compounds include other elements and P does not represent an equivalent mass percentage in these two compounds. To make these masses easier to compare, the moles of elemental P are converted to the equivalent mass of $H_3PO_4$ that would be required if the moles of elemental P in $LiPF_6$ were converted to $H_3PO_4$ with molar conservation rather than being converted to $LiPF_6$. This equivalent $H_3PO_4$ figure is meant to just act as a convenient construct to make gravimetric comparisons between P needs for $LiPF_6$ and $H_3PO_4$ on a similar mass equivalent. This does not imply that $LiPF_6$ would necessarily be synthesized from $H_3PO_4$ or that such a synthesis would be achieved with perfect yield. Instead, it is just meant to show a minimum equivalent amount of $H_3PO_4$ that would be needed if P in LiPF6 were converted to $H_3PO_4$ to understand whether the P in $LiPF_6$ is significant compared to P requirements for LFP. Though $LiPF_6$ can be made from $H_3PO_4$,[17] it is usually manufactured by the following series of steps: (1) white P ($P_4$) is produced through a thermal process from phosphate ore;[17] (2) $P_4$ is reacted with chlorine gas to make $PCl_5$[18]; (3) $PF_5$ is made by reacting $PCl_5$ with fluorine salts or HF;[19] and (4) $LiPF_6$ is produced from $PF_5$ and LiF.[20]

Even though $LiPF_6$ is not typically made commercially from $H_3PO_4$, **Table S4** presents the mass of equivalent $H_3PO_4$ that the moles of P in $LiPF_6$ would convert to if the P was instead made into $H_3PO_4$ for convenience. Because the P moles were artificially converted to $H_3PO_4$ for **Table S4** with 100% yield, the same 15% increase in $H_3PO_4$ is needed to account for $LiPF_6$ demand in addition to $H_3PO_4$ for LFP cathode demand. However, this artificial construct allows us to compare to the $H_3PO_4$ mass numbers presented in the manuscript; the minimum demand for $H_3PO_4$ discussed in the manuscript

(2.93 MMT) for EVs with 100% yield LFP synthesis could approximately double to 5.90 MMT $H_3PO_4$ equivalent if BESS and P requirements to meet electrolyte demands are included in the analysis (and factory synthesis yields for LFP are used). This implies that a similar increase in P ore would be required to account for these additional demands, although the $LiPF_6$ yields from P ore may be very different than those for $H_3PO_4$ and are outside of the scope of this analysis. Regardless, 15% increased P demand is needed to account for the electrolyte used in batteries above and beyond the P moles needed to synthesize LFP in 2045.

## *Section 5: Fe Ore Demand for EVs and Alternative Precursor Information*

The manuscript states that projected LFP growth would require only 0.11% of current Fe produced globally for steel. This value is derived from the amount of Fe metal needed to synthesize LFP to meet demand in 2045 from **Table S1** (1.67 MMT), assuming 100% synthesis yield in conversion of Fe metal to LFP. The world produced 1,600 MMT of Fe content in usable Fe ore in 2024.[21] The LFP demand for Fe metal in 2045 is therefore ~0.10% of the 2024 world production of Fe content in Fe ore. One could perform the analysis for conversion of Fe ore to Fe battery precursors, similar to that detailed for conversion of P ore to $H_3PO_4$ in the previous sections of this manuscript and Supplementary Information. There are likely significant losses in converting the Fe content in Fe ore to Fe metal or other Fe battery precursors. However, the demand for Fe metal is so low that even an order of magnitude increase in Fe demand stemming from processing inefficiencies and inclusion of BESS applications would not change the conclusion that Fe demand for LFP batteries is expected to be insufficient to compete with or disrupt the steel industry, so those detailed analyses are ignored here.

After pelletization, iron pellets proceed to a blast furnace followed by a basic oxygen furnace (BF-BOF) to produce steel. Alternatively, iron ore is converted via direct reduction (DR) and mixed with scrap steel for processing in an electric arc furnace (EAF). Iron metal exiting the blast furnace or direct reduction could offer a potential iron offtake opportunity for further battery precursor processing. Many alternative iron ore reduction technologies have been proposed, which could be more compatible with high-purity LFP production, such as $H_2$ direct reduced iron ($H_2$DRI), metal oxide electrolysis (MOE), low-energy direct electrochemical reduction (LEDER), and others [22], [23], [24], [25].

## *Section 6: P Ore Demand for EVs*

Using life cycle inventory numbers from the Material Flows through Industry (MFI) tool, projected quantities of $H_3PO_4$ are converted back to demand phosphate rock [26]. This process began with a conversion from anhydrous phosphoric acid calculated in **Table S1** needed for LFP batteries to 75% $H_3PO_4$ found in MFI, this was performed via mass balance. These values were then converted to impure “wet process acid” using an industrial average of dihydrate, hemihydrate, and di-hemihydrate processes and elemental white phosphorus for the thermal process using the life cycle inventories included in MFI. These values were then converted to phosphate rock using respective inventories. To compare phosphate rock consumption for LFP batteries to production and alternate end uses, a conversion from a listed Bone Phosphate of Lime value for the phosphate rock was assumed to be 66% as in[27] and converted to $P_2O_5$ in accordance wit Boutaleb *et al*.[28]

These numbers for phosphate rock demand via thermal and wet processes were then compared to the demand for phosphate rock for fertilizers, calculated using numbers from S&P Global's *Phosphate Rock* report,[29] which indicate that apparent consumption of phosphate rock in 2024 was 66.5 MMT of $P_2O_5$. Of all Phosphate Rock, 74% was used for fertilizers. This comparison yielded ultimate values where 2.93 MMT of $H_3PO_4$ required for LFP production would be equivalent to 10.7 MMT of $P_2O_5$ via the wet process or 2.08 MMT of $P_2O_5$ via the thermal process in phosphate rock. This equates to 4-22% of ore used for fertilizers, respectively.

### *Section 7: Purity of Commercially Available $H_3PO_4$*

| | | VOLTIX BATTERY GRADE | | Phosphoric (Tech) 95% | | Phosphoric (Tech) 75-85% | | | Phosphoric Acid (Food) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Phosphorus Content | as H2PO4 | 75 | 85 | 94 | 96 | 75 | 80 | 85 | 75 | 80 | 85 |
| | as P2O5 | 54.3 | 61.5 | 68.1 | 69.5 | 54.3 | 57.9 | 61.5 | | | |
| | Density | 13.16 | 14.08 | 15.09 | | 13.16 | 13.61 | 14.08 | 13.16 | 13.61 | 14.08 |
| Other Components | Sodium | <50 | <50 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Potassium | <5 | <5 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Nickel | <5 | <5 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Aluminum | <5 | <5 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Copper | <5 | <5 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Cobalt | <5 | <5 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Magnesium | <5 | <5 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Lead | <5 | <5 | N/A | N/A | N/A | N/A | N/A | <3 | <3 | <3 |
| | Chromium | <5 | <5 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Manganese | <5 | <5 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Calcium | <5 | <5 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Sulfer | <50 | <50 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Boron | <50 | <50 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Chloride | <10 | <10 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Iron | <10 | <10 | <50 | <50 | N/A | N/A | N/A | N/A | N/A | N/A |
| | Silicon | <10 | <10 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Sinc | <3 | <3 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Arsenic | <3 | <3 | N/A | N/A | N/A | N/A | N/A | <3 | <3 | <3 |
| | Titanium | <3 | <3 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Fluoride | <5 | <5 | N/A | N/A | N/A | N/A | N/A | <10 | <10 | <10 |
| | Sulfate | <100 | <100 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Cadmium | N/A | N/A | N/A | N/A | N/A | N/A | N/A | <3 | <3 | <3 |

**Table S5**. Comparison of datasheets for available $H_3PO_4$ and listed impurity levels associated with select species of Innophos $H_3PO_4$ products [30], [31], [32], [33].

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