communications
materials

MATTERS ARISING

https://doi.org/10.1038/s43246-022-00236-4

Concerns about global phosphorus demand for lithium-iron-phosphate batteries in the light electric vehicle sector

Bryan M. Spears[1,2]✉, Will J. Brownlie[1,2], Dana Cordell[3], Ludwig Hermann[4] & José M. Mogollón[5]

ARISING FROM Xu et al. *Communications Materials* https://doi.org/10.1038/s43246-020-00095-x (2020)

Xu et al.[1] offer an analysis of future demand for key battery materials to meet global production scenarios for light electric vehicles (LEV). They conclude that by 2050, demands for lithium, cobalt and nickel to supply the projected >200 million LEVs per year will increase by a factor of 15–20. However, their analysis for lithium-iron-phosphate batteries (LFP) fails to include phosphorus, listed by the Europen Commission as a “Critical Raw Material” with a high supply risk[2]. We outline below that, whilst timely, their analysis is incomplete in that it does not consider the complexities of the global anthropogenic phosphorus cycle in the context of supply chain resilience and sustainability for the emerging LEV sector.

It is essential that LFP phosphorus forecasts be contextualised within the global phosphorus cycle and market to ensure minimal potential conflict between future energy and food systems. In 2020 alone, about 30 Mt of phosphorus (223 Mt of phosphate rock) was mined from finite phosphate rock reserves estimated at 71,000 Mt[3]. This estimate assumes that 30% of the weight of phosphate rock is P_2O_5 (calculated as a global average). Of this mined phosphorus, about 85% was used in fertilisers, 10% for animal feed supplements, and the remainder for other products[4]. In the Xu et al[1]. SD-LFP scenario, i.e., the sustainable development fleet scenario coupled with the LFP battery scenario, we estimate that projected global LEV demand will require >3 Mt phosphorus per year by 2050, representing around 5% of the current global phosphorus demand. For a 60% market share (128 million vehicles per year) by 2050, we assume, simplistically, that the projected demand for lithium at 0.72 Mt per year (SD high electric vehicle stock scenario[1]) can be converted directly to phosphorus demand by multiplying the lithium demand by the mass ratio of $LiFePO_4$ at 4.46 (i.e. 30.97/6.94). This equates to about 25.5 kg phosphorus per electric battery (i.e., (0.72 Mt lithium per year/126 M batteries per year) × 4.46).

Most countries are reliant on phosphorus imports to meet their food demands. Phosphorus demand is currently met by only a few countries, five of which control 85% of the world’s phosphate rock reserves (70% by Morocco, alone)[3]. Phosphorus producing countries like China and the USA[5] may seek to protect their domestic supplies by restricting exports, as was seen in 2008 with China’s export tariff. Future disruptions to secure access to phosphorus are likely to be geopolitical and economic in nature, long before global reserves are exhausted. That is, reliable supply may be insufficient to meet demand in the short- or long-term due to trade barriers, political insecurity and other supply chain factors. At the time of writing, international concern was being raised on the potential impacts of the Russia-Ukraine conflict on fertiliser market volatility; this region being a key exporter of food and fertilisers.

Stable, long-term access to economically viable resources is critical to support a growing LEV sector. Xu et al.[1] argue that the advantages of LFP batteries over other batteries include “lower production costs due to the abundance of precursor materials”. However, this assumption does not consider historical price fluctuations for phosphorus, for example, including price spikes up to 800% in 2008[6]. It is noteworthy that surging biofuel production has been acknowledged as a driver of fertiliser demand and agriculture commodity prices despite only accounting for about 3.6% of global fertiliser demand[7]. During the COVID-19 pandemic, global phosphate prices more than doubled as a result of energy price rises, supply control, and trade policies[8]. Of course, the direct impacts of such price spikes on the LEV sector only come to bear when the cost of phosphorus (in this case) relative to other minerals in LFP batteries is high. Archived data on commodity prices for phosphate rock are available from the World Bank (https://www.worldbank.org/en/research/commodity-markets#3).

Xu et al.[1] only model batteries in LEV. However, the real demand across the energy-sector, for example, including LFP batteries within heavy-duty vehicles and local network energy storage infrastructure, will be much greater. Any analysis of resilience of future materials supply (including phosphorus) for the LEV sector must include comprehensive economic scenarios in the context of these wider market stressors[9] and related interventions designed to secure long-term phosphorus availability for national food systems[6]. Further, phosphorus supply to the LEV sector may become squeezed by the demand from agriculture. Phosphorus demand in the agricultural sector could almost double by 2050[10] and the fertiliser industry is reporting investments to increase production capacity to meet growing food demands in excess of $100 billion[7].

---

[1] UK Centre for Ecology & Hydrology, Bush Estate, Penicuik, Midlothian EH260QB, United Kingdom. [2] School of GeoSciences, The University of Edinburgh, The King’s Buildings, Alexander Crum Brown Road, Edinburgh EH9 3FF, United Kingdom. [3] Institute for Sustainable Futures, University of Technology Sydney, 15 Broadway, Ultimo, NSW 2007, Australia. [4] Proman Management GmbH, Weingartenstraße 92, 2214 Auersthal, Austria. [5] Institute of Environmental Sciences, University of Leiden, Einstein 2, 2333 CC Leiden, The Netherlands. ✉email: spear@ceh.ac.uk

Opportunities for cross-sector circularity are potentially missed by Xu et al.[1] in considering only mined materials as the primary supply to LEVs. To provide clarity on phosphorus, we encourage Xu et al[1]. to extend their analysis to include detailed and comparable future projections, including closed-loop recycling capacity within the LEV sector.

Technological advances in phosphorus recovery and recycling can build resilience within food systems[11], and a similar approach could be considered for LFP batteries. While technological and economic barriers may currently prohibit closed-loop recycling of phosphorus within the LEV sector, phosphorus recycling and recovery from other sectors may provide an opportunity to reduce reliance on mined sources. For example, it is estimated that sewerage connections will increase by 4 billion globally by 2050, and that connections with urine diversion could lead to a doubling of phosphorus being recycled to agriculture to 1.3 Mt per year[12]. The remaining 3 Mt per year from conventional sewage connections (e.g., in the form of vivianite, which is less well suited for agriculture reuse due to its high iron content) may hold promise for reuse in LFP batteries, although the technical[13] and economic feasibility requires development. However, environmental sustainability is currently the dominant driver for greater recycling of phosphorus, and not economics.

Finally, Xu et al.[1] do not present the wider sustainability benefits associated with LFPs. For phosphorus, any reduction in the current anthropogenic load to fresh waters (circa 6 Mt per year[14]) may result in significant ecological benefits[15]. A central tenet of the global phosphorus sustainability discussion is to relieve environmental stress through increased recycling from cross-sector waste streams[16]. We do not propose, here, that phosphorus emissions from the LEV sector to the environment are significant. Global anthropogenic phosphorus emissions remain dominated by agriculture and waste water discharges[14]. However, the logical extension for a sector born to deliver greater environmental sustainability would be to provide leadership in sustainable resource use and recycling. In the LEV sector this should consider mineral recycling from legacy LFP stock and other waste streams. The economic case for this may not yet be compelling, but equally, the responsibility of industry to accelerate mineral recycling opportunities should not be ignored.

Received: 19 May 2021; Accepted: 22 February 2022;

References

1. Xu, C. et al. Future material demand for automotive lithium-based batteries. *Commun. Mater.* **1**, 99 (2020).
2. European Commission. Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the regions. Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability COM/2020/4 (2020).
3. Jasinski, S. M. Mineral Commodity Summaries: Phosphate Rock (U.S Geological Survey, 2021).
4. Gantner, O. Ressourcenstrategische Betrachtung der Kritikalität von Phosphor (Universität Augsburg, 2015).
5. Blackwell, M., Darch, T. & Haslam, R. Phosphorus use efficiency and fertilizers: future opportunities for improvements. *Front. Agr. Sci. Eng.* **6**, 332–340 (2019).
6. Cordell, D., Turner, A. & Chong, J. The hidden cost of phosphate fertilizers: mapping multi-stakeholder supply chain risks and impacts from mine to fork. *Glob. Change Peace Secur.* **27**, 323–343 (2015).
7. IFA. Feeding the earth: food prices and fertiliser markets factors influencing variations in fertiliser market conditions (International Fertilizer Association, 2011).
8. Baffes, J. & Koh, W. C. World Bank Group—Soaring fertilizer prices add to inflationary pressures and food security concerns (2021).
9. World Bank Group—Energy and Extractives. Battery Energy Storage Systems, Clean Energy Global Solutions Group (2020).
10. Mogollón, J. et al. More efficient phosphorus use can avoid cropland expansion. *Nat. Food* **2**, 509–518 (2021).
11. Kabbe, C. & Rinck-Pfeiffer, S. Global Compendium on Phosphorus Recovery from Sewage/Sludge/Ash. Global Water Research Coalition 71 (2019).
12. van Puijenbroek, P. J. T. M., Beusen, A. H. W. & Bouwman, A. F. Global nitrogen and phosphorus in urban waste water based on the shared socio-economic pathways. *J. Environ. Manage.* **231**, 446–456 (2019).
13. Wilfert, P., Kumar, P. S., Korving, L., Witkamp, G. J. & Van Loosdrecht, M. C. M. The relevance of phosphorus and iron chemistry to the recovery of phosphorus from wastewater: a review. *Environ. Sci. Technol.* **49**, 9400–9414 (2015).
14. Beusen, A. H. W., Bouwman, A. F., Van Beek, L. P. H., Mogollón, J. M. & Middelburg, J. J. Global riverine N and P transport to ocean increased during the 20th century despite increased retention along the aquatic continuum. *Biogeosciences* **13**, 2441–2451 (2016).
15. Carpenter, S. R. & Bennett, E. M. Reconsideration of the planetary boundary for phosphorus. *Environ. Res. Lett.* **6**, 14009–14021 (2011).
16. Brownlie, W. J. et al. Global actions for a sustainable phosphorus future. *Nat. Food.* **2**, 71–74 (2021).

Author contributions

B.M.S. led discussions with the authors of the original manuscript, the development of the text, and the estimates of phosphorus demand in the electric vehicle sector. W.J.B. led the estimates of global phosphorus demand, and together with D.C., L.H., and J.M.M., contributed to the development of the text and responses to the original authors' responses to earlier drafts.

Competing interests

The authors declare no competing interests.

Additional information

Correspondence and requests for materials should be addressed to Bryan M. Spears.

Peer review information Primary Handling Editor: John Plummer.