Lithium-ion batteries and the transition to electric vehicles: environmental challenges and opportunities from a life cycle perspective

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Acknowledgements

This thesis is about challenges and opportunities related to the use of lithium-ion batteries. Similarly, I met challenges and opportunities during my PhD journey. I cannot describe the whole story of this PhD journey in this short acknowledgment. But in short, the journey was like a long-distance roller coaster ride where I entered a world of unfamiliar surroundings, exciting collaborations with top-ranking institutes, how to publish high-quality papers, *etc.*

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Curriculum Vitae

Chengjian Xu was born on the 22th of April 1993 in Yancheng, China. After completing his study at the second high school in Jianhu county in 2011, he joined the Jiangsu University of Technology for a Bachelor program with a major in science and technology for circular resource use. From 2011 to 2015, he studied a wide range of courses in Mathematics, Physics, and Chemistry, with a focus on environmental engineering. Between 2015 and 2018, he did a MSc. in environmental engineering at Tongji University, Shanghai. There, he studied waste management and recycling of Waste Electrical and Electronic Equipment. He finished a Master's thesis on the application of ultrasound technology to recover valuable materials from mobile phone batteries. He was part of a team that won the 1st Prize in the 3rd University Challenge China during IEexpo 2017 in Shanghai/China, awarded by Tongji University and the German Water, wastewater, and waste disposal association.

After finalizing his Master's degree in 2018, the Chinese Scholarship Council (CSC) awarded him a grant to do his PhD at the Institute of Environmental Sciences (CML), Leiden University. Between September 2018 and September 2022, he analysed the environmental challenges and opportunities of Electric Vehicle Batteries from a life cycle perspective. In this work, he applied dynamic material flow analysis, prospective life cycle assessment, and battery technology modeling to investigate the future battery material demand and environmental impacts of battery production. In 2021, he won the Stans Award for the best PhD paper from 2020 at CML, Leiden University, for his paper in Nature Communications Materials "Future material demand for automotive lithium-based batteries". From September 2022, he has been hired on a short-term contract by the United Nations Institute for Training and Research in Bonn, to contribute to the Future of Raw Materials (FUTURAM) Horizon Europe project.

List of peer-reviewed publications:

1. Xu, C., Dai, Q., Gaines, L., Hu, M., Tukker, A. & Steubing, B. Future material demand for automotive lithium-based batteries. *Communications materials* **1**, 1-10 (2020).
2. Xu, C., Behrens, P., Gasper, P., Smith, K., Hu, M., Tukker, A. & Steubing, B. Electric vehicle batteries alone could satisfy short-term grid storage demand by as early as 2030. (under revision in Nature Communications)
3. Xu, C., Steubing, B., Hu, M., Harpprecht, C., van der Meide, M. & Tukker, A. Future greenhouse gas emissions of automotive lithium-ion battery cell production. *Resources, Conservation & Recycling* **187**, 106606 (2022).
4. Xu, C., Steubing, B., Hu, M. & Tukker, A. Future greenhouse gas emissions of global automotive lithium-ion battery cells and recycling potential till 2050. (Submitted to Renewable and Sustainable Energy Reviews)
5. Xu, C., Dai, Q., Gaines, L., Hu, M., Tukker, A. & Steubing, B. (2020). Reply to: Concerns about global phosphorus demand for lithium-iron-phosphate batteries in the light electric vehicle sector. *Communications materials* **3**, 15 (2022).

Additional publications:

6. Xu, C., Zhang, W., He, W., Li, G. & Huang, J. The situation of waste mobile phone management in developed countries and development status in China. *Waste management* **58**, 341-347 (2016).
7. Xu, C., Zhang, W., He, W., Li, G., Huang, J., & Zhu, H. Generation and management of waste electric vehicle batteries in China. *Environmental Science and Pollution Research* **24**, 20825-20830 (2017).
8. Zhang, W., Xu, C., He, W., Li, G. & Huang, J. A review on management of spent lithium ion batteries and strategy for resource recycling of all components from them. *Waste Management & Research* **36**, 99-112 (2018).
9. Zhang, W., Liu, Z., Xu, C., He, W., Li, G., Huang, J., & Zhu, H. Preparing graphene oxide–copper composite material from spent lithium ion batteries and catalytic performance analysis. *Research on Chemical Intermediates* **44**, 5075-5089 (2018).