Material flow analysis model: To avoid a battery crisis, more of us should share small, lightweight EVs

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More of us should share smaller cars with small battery packs, according to NTNU scientists. Credit: Nancy Bazilchuk, NTNU

Most global scenarios and governmental targets for decarbonizing the

transport sector consider battery-powered electric vehicles as a main part of the solution. Enormous amounts of raw materials are needed to build enough batteries and ensure a transition to low-emission vehicles.

Access to lithium is critical, as it is used in all types of EV batteries.

"It seems very likely we'll have a shortage. The key lies in the demand. The demand needs to decrease to avoid long-term supply problems," says Fernando Aguilar Lopez, a Ph.D. candidate at NTNU's Department of Energy and Process Engineering.

There are huge deposits of this super-light, silver-white substance around the world. The problem is that it is not being mined fast enough to keep up with demand for lithium-ion batteries (LIBs) for electric vehicles.

As a result, we may face supply bottlenecks that could last for decades.

Meet MATILDA—A model for supply scenarios

Fernando Aguilar Lopez is an expert in analyzing global material flows. This means he studies raw materials cycles from extraction to production, use, and scrapping. He, postdoc Romain Billy and Professor Daniel B. Müller have developed a material flow analysis model named MATILDA (MATerIaL Demand and Availability). The model was recently introduced in the journal *Resources, Conservation & Recycling*.

The study investigates strategies to manage resource use in EV batteries. MATILDA helps to understand more of the critical factors affecting resource supply. Also, the model calculates how various interventions could mitigate the demand.

"Society urgently needs systemic approaches for addressing supply problems," Müller said.

MATILDA is the most comprehensive model to date for battery raw materials in the global vehicle fleet. Tools such as this can play a crucial role for industry and policy makers to develop strategies to ensure secure and resilient critical raw materials supply chains, Müller said.

The NTNU researchers have explored more than 8,000 scenarios to understand the key drivers of material use.

This assessment showed that profound social and lifestyle changes are the most efficient measures to reduce material supply risks.

To avoid excessive demand for single metals, we need investments in a wider range of new battery technologies, the researchers said.

Nor do we need more, larger, heavier electric cars. On the contrary, more of us should share smaller cars with small battery packs.

"Extending the lifespan of vehicles and batteries by facilitating reuse and replacement will also be crucial in reducing the demand for raw materials," says Aguilar Lopez.

Reducing the demand for certain materials could increase pressure on others. MATILDA shows what happens when this kind of problem shifting happens with cobalt, nickel and lithium. The model also offers alternative solutions.

The researchers says that problem shifting may be critical if the industry collectively shifts towards a new technology at a specific time. One example is the current trend toward lithium iron phosphate batteries (LFP).

In 2021, manufacturers as VW, Volvo and Tesla said they planned to adopt LFP. These batteries are free of problematic, costly substances

such as cobalt and nickel.

The downside is that they require a lot of phosphorus, an essential raw material for the fertilizer industry. Thus, an increase in demand could be susceptible to price shocks, potentially affecting small farmers, and threatening food prices.

Recycling not a solution in the near term

Another finding in the NTNU study is that although necessary, recycling will not significantly reduce the pressure on raw materials in the coming decade. Our EVs are still reasonably new, and not enough of them will be scrapped for recycling until 10 to 15 years from now.

However, MATILDA shows that primary demand can be reduced by improving efficiencies in lithium, aluminum, manganese, and phosphorus recycling. These materials are currently uneconomical to recycle and are not included in the latest EU battery regulations.

Without incentives to recover these materials, they are likely to be lost to the environment, Aguilar Lopez said.

He adds that a key issue is that the proposed EU regulations only target the supply side, but not demand. This means that badly needed changes are not actively encouraged.

Half of new car sales in the U.S. are predicted to be electric by 2030. This is also the target in a recent Executive Order issued by US President Joe Biden. In the EU, all new car sales must be electric by 2035.

Several car manufacturers have said that they will be able to make the transition several years before this deadline.

This means if we don't take measures quickly to increase the production of battery materials, we will be driving at warp speed right into the supply bottleneck.

Bigger cars mean bigger batteries

According to this Climate and Community project report, the average battery pack in the US has increased in capacity by nearly threefold since the first Nissan Leaf hit the road a decade ago.

"We're driving ever larger, heavier cars with massive battery packs. At the same time, we only use these vehicle actively about five percent of the time. The rest of the time, it's parked. Only a few of us drive further than 45 kilometers daily," Aguilar Lopez said.

He sees a lot of indicators that fewer people need to own their own car, and that more of us could be OK with sharing smaller, lighter vehicles. In other words, we need more 30-40 kwh Nissan Leaf-type batteries instead of the 60-100 kwh batteries that are found in most Teslas and SUVs.

"Norwegian politicians have chosen to no longer subsidize the largest and most expensive electric cars. This is one example of a powerful measure that indirectly favors smaller cars," he said.

The researcher believes that moves like this are essential and can inspire both individual countries and the EU.

Analyses show that the world needs more than 300 new lithium mines by 2035 to keep up with demand. Prices have risen by several hundred percent in a few years There is great interest in extraction, but disputes have erupted over new mines in a number of places.

The newest lithium mine in Europe opened around 10 years ago. Some reports say it may take up to 20 years to get a new one up and running. Many initiatives fail and are shut down.

"Ideally, we should have started preparing for this situation 20 years ago," Aguilar Lopez said.

As if that wasn't bad news enough, the new NTNU study only considers resource consumption by private vehicles. But buses, ferries, and other large vessels are also being electrified using batteries.

Machinery is another area where changes are afoot. Müller said the entire mining sector is completely shifting towards electrification and automation.

These additional demands could quickly worsen supply bottlenecks for raw materials.

"Achieving the goals set by the EU and individual countries could thus be problematic. This would also create a significant threat to the climate goals," Aguilar Lopez said.

Although the development of highly efficient solid-state batteries is promising, they do not solve the lithium supply crisis either.

"Actually, solid-state batteries can worsen the situation, requiring more lithium per kilowatt hour—almost twice as much in some cases," Aguilar Lopez said.

Hydrogen fuel cells are becoming a mature technology, but they are expensive. They will be far more effective in ferries and other heavy vessels than in cars.

Lithium-free sodium-ion batteries are another promising alternative. They are in an early R&D stage, so it will take a while before they are road-ready.

"No matter where we turn, we encounter challenges," Aguilar Lopez said.

So what would be the best option to get us out of the lithium supply crunch?

Aguilar Lopez's immediate answer is that cities should be designed for people, not cars.

"Look at Zürich, Vienna, Paris, and Oslo. Major moves are being made in many places to create more pleasant urban areas and entice more people to leave their cars. And quite a lot are doing just that. We need regulations– and of course people must accept them," Aguilar Lopez said.

BATMAN project proposes new measures

Norway was a first mover in terms of electrifying the vehicle fleet. Thus, it is expected to be the first country to have larger amounts of spent batteries once the first EVs reach end-of-life.

Müller, Aguilar Lopez and Guillaume Billy were part of the research team for the BATMAN project, From 2019-2022. The project was designed to investigate opportunities for the Norwegian industry to engage in battery reuse and recycling.

Based on the main findings, the scientists suggested several strong actions:

- Facilitate and finance a broader range of battery research geared towards breakthroughs in chemistries and recycling practices.
- Step up and streamline the development of new lithium mines, also in the EU.
- Increase car sharing and better public transport to reduce overall vehicle ownership.
- More small cars with smaller battery packs.
- Greater numbers of and more efficient charging infrastructure.
- Facilitate the recycling of all materials beyond the ones that are already regulated.
- Extend car and battery life via increased reuse and easier repair and replacement of batteries.

More information: Fernando Aguilar Lopez et al, Evaluating strategies for managing resource use in lithium-ion batteries for electric vehicles using the global MATILDA model, *Resources, Conservation and Recycling* (2023). DOI: 10.1016/j.resconrec.2023.106951

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