Briefing

Green Transition Denmark

Batteries and minerals in green transport

What is needed and what are the implications?

Lessons from:
The Battery Mineral Loop by the Rocky Mountain Institute

EXECUTIVE SUMMARY

- The electrification of the transport sector brings with it a rapid growth in battery demand, expecting battery capacity to reach 12 TWh by 2050. This projected growth in battery capacity derives a significant demand for critical minerals like lithium, nickel, and cobalt by 97%, 78%, and 80% respectively. However past and expected future developments in battery chemistry, energy density, and recycling can potentially mitigate this growth in raw mineral demand, leading to a peak in virgin mineral extraction by the mid-2030s.

- Measures can be taken to further reduce the need for virgin minerals, while developments in chemistry mix, density, and recycling continue: extending battery lifetimes through reuse, improving vehicle efficiency through better vehicle designs, and improving mobility efficiency through better public transportation infrastructure and urban planning.

- Increasing battery recycling capacity can almost completely remove the need for mining virgin resources, as batteries may require less minerals to deliver the same performance due to continued innovation and developments. In time, recovering minerals from batteries will lead to self-sufficiency for nations, as electrification drastically reduces their oil dependency.

Introduction

Battery-electric propulsion is the most energy efficient way to quickly substitute fossil energy with renewable energy. And even though the battery-electric driveline are much simpler, and requires much less components and materials, the battery in itself requires more of specific raw materials. But just how much is needed and what are the implications?

The production of batteries for electric cars and their raw materials has been part of a defamation campaign from oil industry interests for more than a decade. And the criticism has continued from many sides pursuing other agendas than the green transition of cars. At the same time nobody citizises the same batteries being used for laptops and phones.

Sourcing of materials in a modern world is of little or no public interest – unless it is sourcing for the green transition and combatting climate change. – Then some people really feels it is a problem.

Therefore we are really happy that the Rocky Mountain Institute has looked into the details and made the report The Battery Mineral Loop.

And especially happy that they look into more realistic scenarios and more updated data than have been used in some other scientific analysis.

This briefing tries to summarize the learnings from this report.

Solutions to reduce demand for raw materials

In 2023, total battery sales exceeded 1 TWh and are expected to grow to 5.5-8 TWh by 2030 and 12 TWh by 2050 (Rocky Mountain Institute 2024). This includes 1 TWh for stationary grid storage, a fraction of that for consumer electronics, and the rest for mobility. This past and projected increase in batteries has sparked concern towards the sustainability of mining, as batteries will increase demand for copper, graphite, and rare earth elements, and the demand for critical minerals will increase:

- 97% for lithium
- 78% for nickel
- 80% for cobalt

RMI propose six solutions that can mitigate the need for upscaling mining efforts:

- Deploying new battery chemistries
- Making batteries more energy-dense
- Recycling the mineral content of batteries
- Extending their lifetime
- Improving vehicle efficiency
- Improving mobility efficiency

Developments in battery chemistries, energy density, and recycling have continuously been deployed since 2015 and without them, demand for nickel and cobalt would have been more than twice as high, while lithium demand would be 58% higher. Continuing this trend with increasing battery sales, virgin mineral demand will peak around the mid-2030s.

The chemistry mix: As battery sales scale, innovation continues across new applications and sectors and thus the mix of chemistries will change. Different battery chemistries use varying amounts of minerals and can be modified to alter the demand of different minerals. As forecasted by BNEF, new chemistries are set to grow in the coming decade, leading to a shift in battery mineral demand. Different chemistries are also used in different "cost and use"-cases, e.g. cheaper electric cars favor lithium-iron-phosphate (LFP) batteries. In 2023, LFP technology and cost improvements doubled the projected LFP share of commercial vehicle batteries, which led to a drop in nickel demand by 25-35%.

Energy density: On average, for every doubling of cumulative battery demand, the average energy density of lithium-ion battery cells rose by about 6%. As battery demand continues to grow, energy density can be expected to grow with it, storing more electricity in fewer kilograms. Part of historical density improvements came from chemistry changes, but it is only estimated to make up 2% of the 6% improvement, leading to a net learning rate of 4% per doubling of cumulative battery demand. As battery deployment doubles at least another 4 to 5 times before 2050, density can be expected to rise by over 25%.

Recycling is well underway, according to Circular Energy Storage, as 59% of all lithium-ion batteries were recycled globally in 2019. The CES' more recent assessment suggests a 90% collection rate, while BNEF estimate global collection rates of 60% or more for most sectors. In any case, collection rates are much higher than often cited. Of the batteries that are collected and recycled, 80-95% of minerals can be recovered with current recycling processes.

Energy security concerns have countries around the world boosting battery recycling with ambitious policies. In Europe, the *EU Battery Regulation* and *Critical Raw Materials Act* mandate higher collections rates and more efficient recycling processes, targeting at least 25% recycling of the EU's annual consumption by 2030. The US has introduced the Battery Recycling and Critical Mineral Recovery Act, and China has implemented stringent recycling regulations and has established a robust infrastructure for battery recycling.

Recycling costs differ by region and chemistry. Different labor costs, standards and subsidy schemes contribute, but generally the economics are improving. Today, pyrometallurgical processes are dominant in battery recycling, but newer processes, such as hydrometallurgical, tend to have higher profitability and are thus growing rapidly. Direct recycling methods can further improve competitiveness and have an even lower environmental footprint. As more batteries retire and the utilization of battery recycling facilities increases, the cost of recycling batteries will decrease.

Although mining new minerals may seem more profitable than recycling, this advantage disappears when externalities are considered. Mining does much greater environmental and societal harm, therefore externality pricing policies can turn recycling into the more profitable option.

As of March 2024, total battery recycling capacity exceeds the batteries currently available for recycling – and will continue to outpace retired batteries through 2030, even if battery collection rate increases. The ability to predict end-of-life battery quantities far in advance permits much smoother expansion of recycling capacity, with less financial risk.

Accelerating trends to reach peak mineral demand

Continued developments in the three above-mentioned solutions will lead to **peak mineral demand** around the mid-2030s. These solutions will reduce the 2030 mineral demand by 25% for lithium, 40% for nickel, and 75% for cobalt. All the mineral demand peaks will occur within a single battery's lifetime.

Should the transition unfold faster, the mineral demand peaks will occur earlier. After these peaks, the net mineral demand will start to decline, as recycled materials outpace the growth of gross battery mineral demand. Demand may even reach net-zero in the long term.

Accelerating the trend of new innovations in battery production and recycling, along with renewed attention to efficiency and energy security, can lead to net-zero battery mineral demand by 2050.

Accelerating the trend means:

- Accelerated battery chemistry mix change
  - Novel battery chemistries have made rapid progress toward commercialization, though many are still in a pre-commercial stage.
  - Sodium-ion chemistries are approaching mass market, and would drive down the demand for lithium, nickel, and cobalt.
- Accelerated energy density innovation
  - Energy density improvements are accelerating, where some are making LFP batteries better than ever, others are using improved designs to increase the usable energy per charge.
  - The average energy density could start rising faster as well.
  - The 6% learning rate from the continued trend could be one or two percentage points higher in the accelerated trend.
- Better recycling
  - Given recent developments in recycling policies, there is every reason to believe that a 90% or higher collection rate is within reach compared to today's ≈ 60%.
  - Mineral recovery rates will also improve. China's CATL claims to already recover 99.6% of battery minerals. It is believed that the general market will rise from ≈ 80-95% to 95-99%.
- Longer battery lifetimes
  - Reuse or better maintenance of batteries may contribute to longer lifetimes.
  - Developments between 2021 and 2024 made BNEF increase projected battery lifetimes by an average of two years. "*If progress continues to outpace expectations, we may well see another two-year increase…*".
  - The market for second-life batteries is also projected to grow, becoming a $7 billion market.
- Efficient vehicles

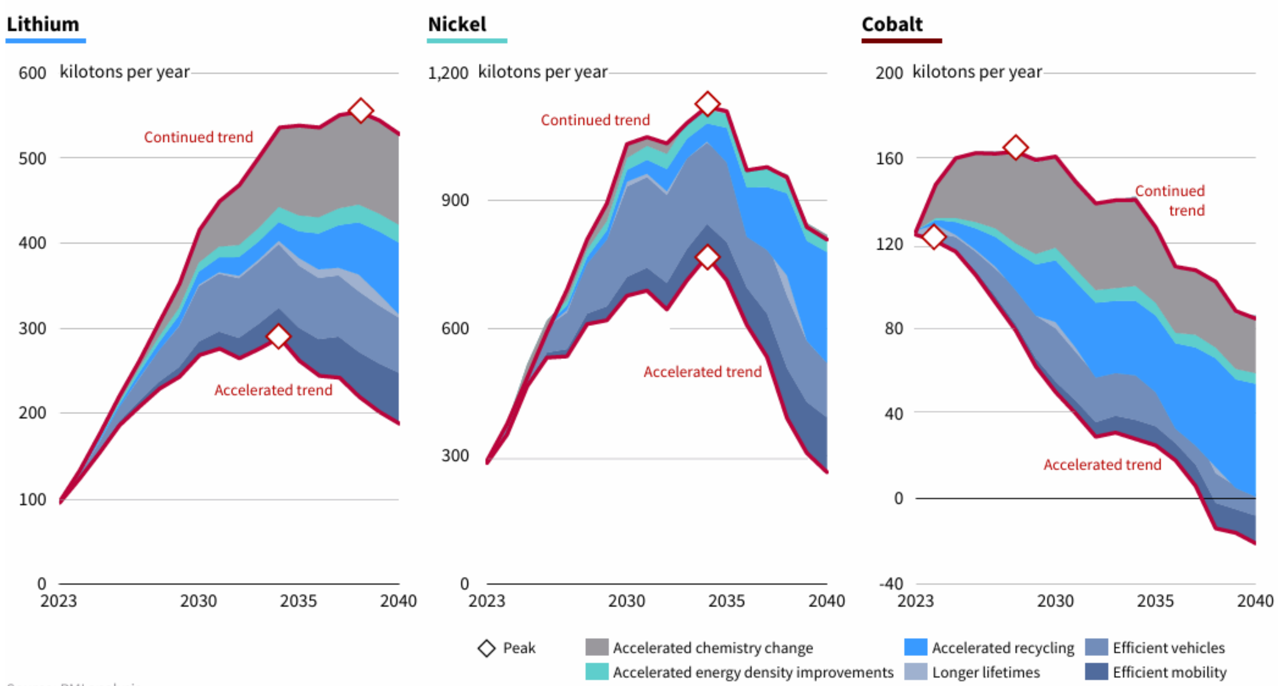
- EVs are already being redesigned from top to bottom to become more affordable. Continued advances in EV efficiency could halve electricity consumption by 2050 according to studies by EPRI and NRDC. In this accelerated scenario, per-vehicle battery demand could drop by 30% by 2030 as outlined in IEA's Global EV Outlook.
- Efficiency improvements could also come from right-sizing vehicles. Popular sedans have grown by 44%, while pick-up trucks have grown 75%. *"US cars gained weight faster than their drivers, but surely the drivers didn't balloon that much"*. Moreover, SUVs' share of EV sales has doubled or tripled across different regions in just five years.

- Efficient mobility
  - Logistics optimization and digitalization can improve utilization, reducing the needed fleet sizes to move the same amount of goods.
  - More cities are accelerating land use reforms to prioritize alternative passenger transport modes. For example, Paris has transformed in recent years and now sees more trips by bike than by car from the inner city to the suburbs. Much more is possible in developing countries, where smart design of infrastructure can provide major benefits. *"… it's easier to build things right than to fix them later".*
  - Successful actions on land-use reform are projected to reduce car and truck demand by 15-20% by 2050 based on analyses by the International Council on Clean Transportation.

Acting on these six accelerated solutions will lead to an even earlier and lower mineral demand peak, under the continued trend.

After peaking, the battery mineral demand will continue to decline, and as the battery demand reaches its maximum, mineral demand can be satisfied with recycling and reuse. If 95% of batteries and collected and recycled, materials can be recovered at 99% efficiency, a net recovery rate of 94% is achieved. This means that over a battery's lifetime, which can be more than a decade, solutions need to curb demand by just 6%

Exhibit 14: Net mineral demand of continued versus accelerated trend, fast battery uptake scenario



Source: RMI analysis

to offset recycling losses. In context: over the past decade, vehicle unit nickel demand has dropped by almost 45%.

An equilibrium between mineral demand and mineral recycling could occur in the mid-2030s, leading to a net mineral demand around zero in the mid-2040s, as shown in exhibit 14.

After reaching mineral circularity, little to no mining would be necessary, assuming the abovementioned initiatives are effective. Only around 125 million tons of minerals need to be extracted before reaching circular self-sufficiency – worth around $1,080 billion at today's prices, equal to $50 billion per year through the mid-2040s. This would enable the phase-out of ICE vehicles in road transport, which consume 17 times more oil (2,150 million tons) annually. This means that the next two decades of mining for battery minerals can become a one-off effort.

Global reserves are already more than sufficient to satisfy future demand, as only half would need to be mined. There is good reason to believe that known reserves will continue to rise, as historically, the more we've looked, the more we've found. Announced mining projects are almost sufficient to reach demand as well, and there is still ample time to scale up mining to meet peak demand in 2035.

From oil dependence to circular independence

Oil dependency poses a constant, imminent risk to 80% of nations, as they rely on constant imports. If oil imports were to stop, these countries would face immediate paralysis. Transitioning to EVs powered by renewables and switching to a completely circular technology system with domestic recycling capabilities, would mean that no nation's economy would be dependent on the geopolitical developments of other countries5. Battery recycling has the potential to become a key geopolitical tool that would improve global security and stability.

China is far in the lead in battery recycling capacity, and their plans dwarf those of the EU and the US in the coming years. The West must increase recycling capacity if they are to derive value from these critical minerals in the future.

Only about 1.5 out of the 9-12 TWh per year in recycling capacity is planned for today, meaning we are less than one fifth into the race. More and better infrastructures for the collection, sorting, recycling, refining and manufacturing of batteries are needed to utilize these critical minerals domestically.

As many vehicles end their life in the Global South, setting up proper recycling, manufacturing and mineral processing facilities here could allow for job creation, economic growth and geopolitical leverage over the battery supply chain. These facilities are already shooting up in parts of the Global South and serve as a logical step to optimize efficiency and support local industries. The EU could play a role through its Global Gateway program and foster bilateral partnerships to advance clean technologies and diffuse the dominance of China in this area.

Rådet for Grøn Omstilling

Green Transition Denmark works on a quick transition towards a zero-emission transport sector.