BRIEFING - FEBRUARY 2026

From mine to recovery: the case for nickel recycling in Europe

The carbon footprint benefits of recycling nickel in Europe

Summary

Scaling battery recycling in Europe will be key to securing a resilient and clean supply of raw materials needed for clean tech in Europe. With significant volumes of scrap and waste batteries becoming available in the coming years, ensuring we have effective capacity in Europe to recover the much needed materials, including nickel, will be vital. How we recycle batteries will be important, ensuring we drive effective, low-carbon processes.

What is the environmental footprint of recycling nickel compared to mining and processing, and how can we scale recycling technologies in Europe? T&E addresses these questions in this briefing, building on [research](#) which showed the potential for battery recycling in Europe.

Overall, the analysis finds that recovering nickel from batteries generally has a lower carbon footprint than mining and refining nickel. For a typical VW ID4 (77 kWh) with an NMC battery, using European recycled nickel can achieve savings of 1200kg CO2e compared to most common primary nickel.

Europe can achieve substantial carbon savings through hydrometallurgical recycling

Carbon footprints of primary and secondary routes

Source: Minviro; BCG • Cradle-to-gate life cycle assessment using an economic allocation approach for the recycling routes

Nevertheless, the recycling route, and other factors such as plant location, can have a huge impact on the overall carbon emissions of the final nickel sulfate produced:

- Hydrometallurgical routes in Europe can reduce the carbon intensity of nickel sulfate by 70% when compared to the dominant primary production routes.
- Emissions stemming from electricity constitute around 15-20% of emissions for hydrometallurgy routes. Therefore, the location of the battery recycler employing this technology can also result in significant reductions in total emissions.
- Compared to China, hydrometallurgical recycling in Europe is estimated to be 21% lower in emissions.

Thanks to Europe's comparatively cleaner grid, Europe can lead the way in low carbon hydrometallurgical recycling. Given the potential in Europe, and the expected feedstock of waste batteries containing nickel to become available, now is the time to ensure Europe has the needed recycling capacity. Nevertheless, the existing recycling capacity across Europe is 10 times below where it needs to be in 2030, with almost half of Europe's battery recycling plans at risk.

In order to scale effective and low-emission recycling in Europe, and develop a truly European Single Recycling market, T&E recommends:

- **Mainstream and prioritise circularity across policy areas and funding streams:** Recycling should be considered as any other clean tech.
- **Ban or significantly limit waste material shipment outside the EU:** to ensure sufficient feedstock for EU recyclers, including nickel, the CEA must prevent material leakage from end-of-life batteries, black mass and related waste products.
- **Simplify intra-EU waste shipment rules** to cut costs and administrative burden by further simplifying the Waste Shipment Regulation.
- **Implement circularity targets in the EU Batteries Regulation** and ensure they benefit EU recyclers, with an amendment to introduce a local preference.

1. Introduction

What is the environmental footprint of recycling nickel compared to mining and processing, and how can we scale recycling technologies in Europe to produce greener batteries? T&E addresses these questions in this briefing, building on research which showed the potential for battery recycling in Europe.

We previously found recycling batteries generally has a lower carbon footprint than mining and refining raw materials due to the high emissions associated with extraction and processing. However, this briefing takes a deeper look at whether this is true across the main nickel recycling routes used today. Having commissioned a life-cycle assessment, we set out recommendations on how to reduce environmental impacts of recycling and scale lower-emission technologies in Europe.

Nickel sulfate is one of the largest contributors to the carbon footprint of battery production, and can contribute on average between 19-32% of a battery's emissions depending on battery chemistry. Producing recycled nickel with a low carbon footprint is key to producing cleaner batteries in Europe.

Recycling end-of-life batteries can strengthen Europe's supply of critical raw materials, needed for clean tech such as electric vehicles. Recycling reduces the need for primary extraction, which alleviates a reliance on imports and minimises environmental impacts associated with mining. Europe has a huge potential to recycle raw materials for reuse in new batteries. As T&E research showed, there will be significant recycling feedstock available in Europe, with around 170 GWh of batteries available for recycling in 2035, rising to 470 GWh by 2040.

Nickel is used in the most common electric vehicle battery chemistries today, notably nickel manganese cobalt (NMC) batteries. While lithium iron phosphate (LFP) and lithium manganese iron phosphate (LMFP) batteries are expected to grow rapidly, nickel-containing chemistries will continue to play a role in Europe's battery mix for decades, with significant volumes of nickel scrap available for recycling by the late 2020s. By developing recycling capacity, Europe can keep valuable and strategically important materials within its borders.

2. Nickel from batteries is primarily recovered through pyrometallurgical and hydrometallurgical processes

With advancements in recycling technologies, up to 95% of nickel can be recovered from batteries at end-of-life. Nickel can be recovered from waste batteries in several ways.

2.1 What are the most common recycling routes for nickel?

Pyrometallurgy is currently the most commercially viable and technically robust method for recovering valuable metals from LIBs (Lithium ion batteries). Pyrometallurgy involves a simple high temperature smelting, burning and subsequent separation to obtain a mixed alloy of Co, Cu, Fe and Ni without the need of sorting.

However, the obtained alloy requires further treatments, such as hydrometallurgy to be separated and purified. Pyrometallurgy results in key materials such as graphite being burned off, which limits the creation of a graphite closed loop in Europe.

Hydrometallurgy is the second most widely used recovery method. This method employs an acid/base or deep eutectic solvent (DES) leaching of spent LIB cathode materials to dissolve metal oxides into an ionic form in aqueous solutions. Metal ions can be recovered as precursors/metal salts of a desired purity via organic solvent extraction, chemical precipitation, separation, and by electrodeposition.

Some recyclers in Europe already combine both methods, for example, Umicore in Belgium.

2.2 Direct recycling

A new approach to battery recycling has been gaining traction in recent years. Instead of dissolving the active material in a battery completely, attempts can be made to refresh or reactivate it to recover any capacity or properties lost during use. This is referred to as direct recycling.

One example is relithiation, which replenishes lithium lost during battery use. By minimising chemical processing, direct recycling is expected to reduce costs and energy use compared with leaching-based methods. However, the approach remains at an earlier stage of commercial development.

2.3 Low emission innovations of hydrometallurgy

Several European companies are developing low-emission variations of hydrometallurgical recycling. These approaches aim to further reduce the carbon footprint of secondary nickel production.

Cylib in Germany has patented a water-based hydrometallurgical process known as OLiC. Arabat in Italy has developed a “green hydrometallurgy” method that uses citric acid derived from citrus fruit waste as a chemical input.

3. Nickel recycling can achieve significant carbon footprint benefits over primary extraction

A life cycle assessment (LCA) by Minviro, commissioned by T&E, examined the carbon intensity of nickel sulfate hexahydrate production from recycled batteries for pyrometallurgic and hydrometallurgic routes. Nickel sulfate hexahydrate is the most widely used nickel input for nickel containing battery chemistries. We have compared this with estimates of carbon intensity from primary production across different methods and geographies.

The LCA of recycled production applied an economic allocation based on a three year historical period from 2021-2024. This allocation method allocates the carbon footprint of the whole recycling process to the different recoverable materials based on their economic value. This means that changes in the future prices of these materials will change the final results. Minviro applied a cradle to grave approach. The cradle is defined as the pre-treatment of spent NMC111 batteries and the end gate was set to the point of battery grade nickel sulfate hexahydrate production.

3.1 Hydrometallurgy emerges as the least carbon intensive production route

The graph below depicts that for our baseline scenarios, hydrometallurgical routes in Europe can reduce the carbon intensity of nickel sulfate hexahydrate by 70% in comparison to the most common primary routes. The majority of primary nickel in batteries is produced from energy intensive processes in Indonesia and other Asian countries using high carbon intensive methods such as HPAL (High-Pressure Acid Leaching) and RKEF (Rotary Kiln Electric Furnace). HPAL in Indonesia currently dominates the global production of final product nickel sulfate. And while primary routes, such as green bioheap leaching of sulfides in Finland, can achieve reduced carbon intensities, these have far lower production volumes, at around 15 kt in 2025.

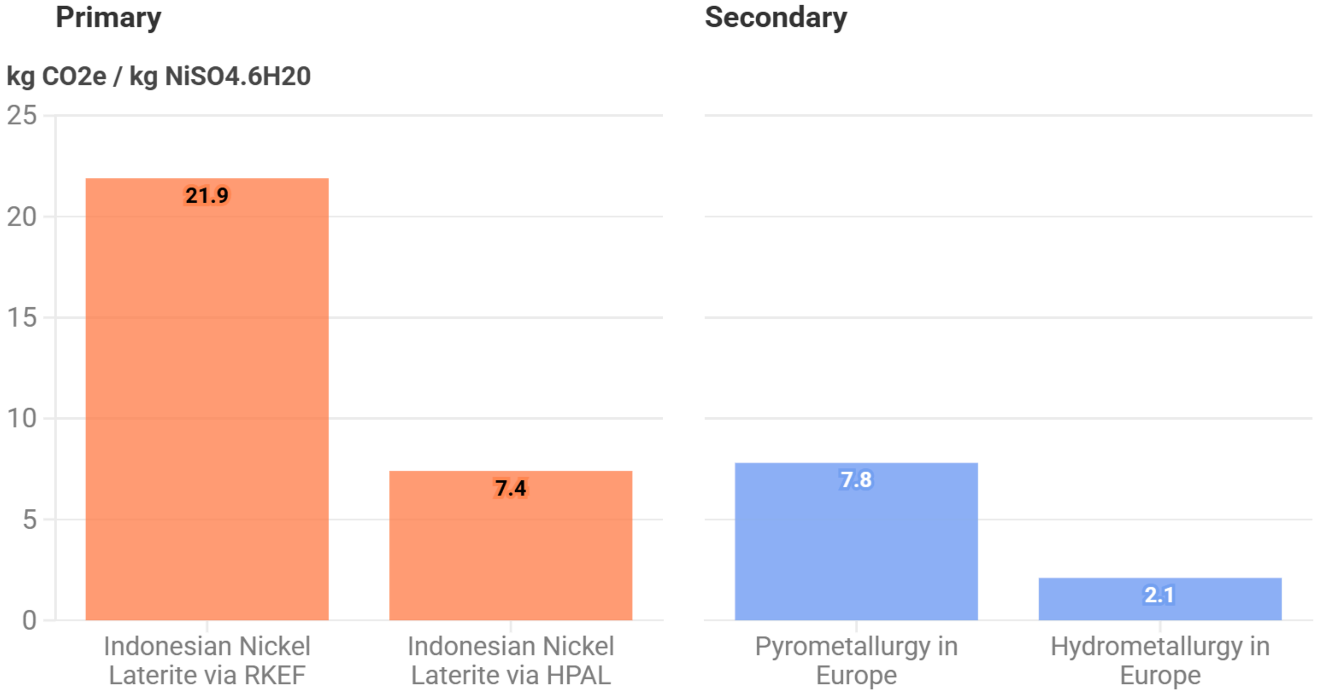
High emissions in RKEF and HPAL stem from electricity usage from coal fired plants.

Pyrometallurgical recycling includes the natural gas consumption in smelting and carbon dioxide direct emissions from the oxidation of the non metallic components such as graphite. Emissions from natural gas contribute to around 40% of the emissions of this route. This leaves scope for emissions reductions in the future through electrification of the smelter processes such as switching to electric boilers and furnaces powered by renewable energy in Europe.

Whilst pyrometallurgical recycling in Europe has a higher carbon footprint than hydrometallurgical routes, and a similar carbon footprint to dominant primary methods such as HPAL, it can still reduce the carbon intensity of nickel sulphate hexahydrate by 65% in comparison to nickel produced in Indonesia via RKEF.

Europe can achieve substantial carbon savings through hydrometallurgical recycling

Carbon footprints of primary and secondary routes



Source: Minviro; BCG • Cradle-to-gate life cycle assessment using an economic allocation approach for the recycling routes

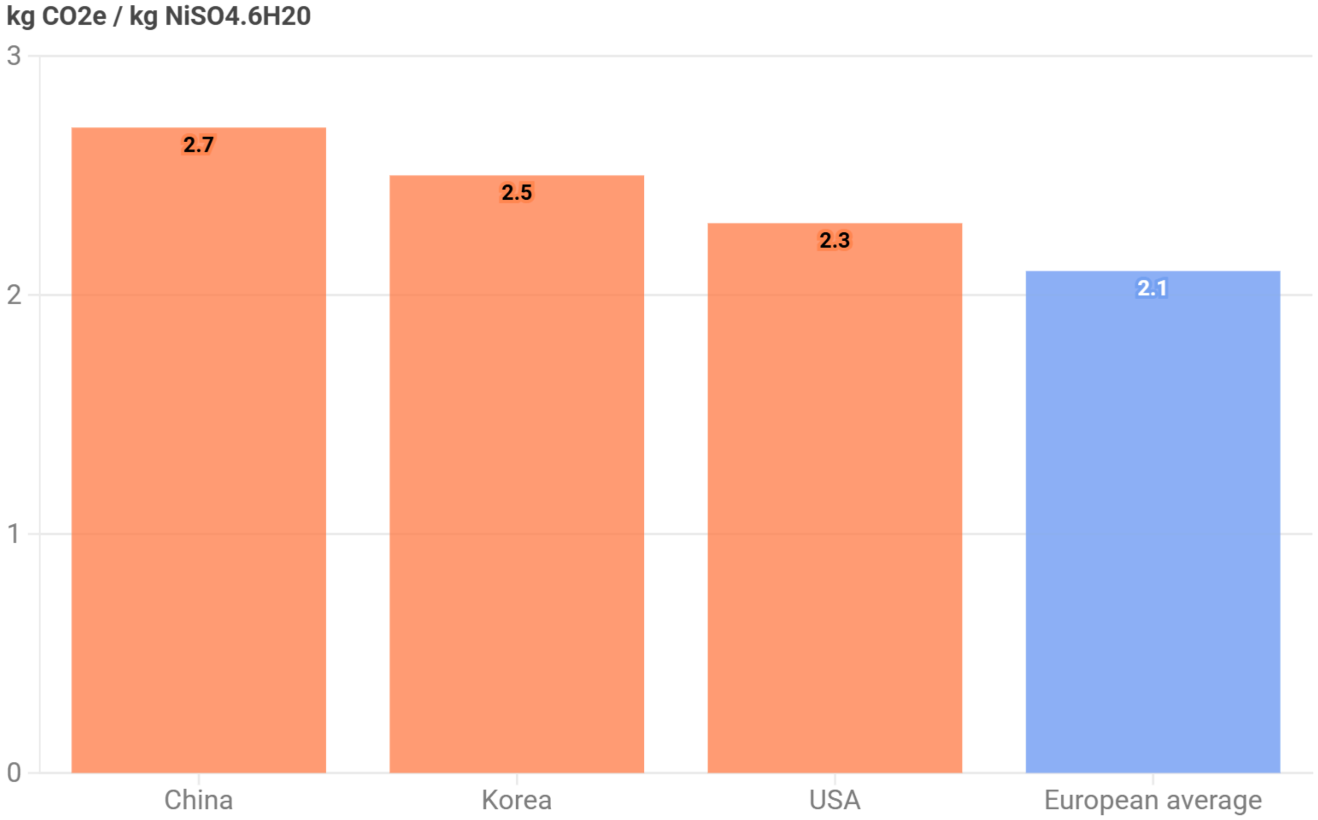
T&E

3.2 Europe can lead the way in low carbon hydrometallurgic recycling

How would our results change if the hydrometallurgic battery recycling took place in other regions? The graph below shows how hydrometallurgy in Europe compares to other countries. It shows that Europe could reduce the carbon footprint of nickel sulfate hexahydrate by 21% compared to China. This is largely driven by lower electricity emissions due to a cleaner grid in Europe.

Europe can achieve significant emissions savings compared to other regions

Electricity emissions are a significant contributor to hydrometallurgy recycling

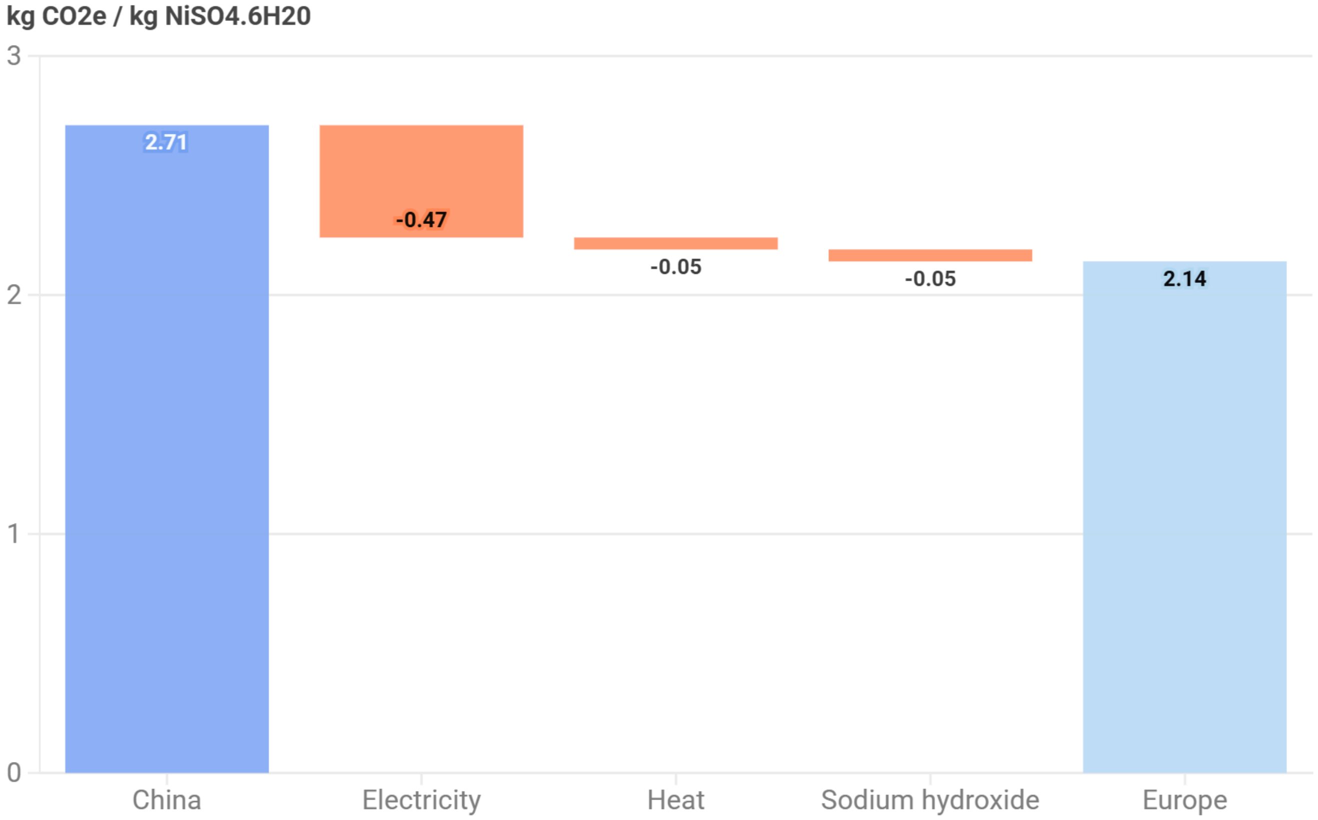


Source: Minviro; T&E analysis • Cradle-to-gate life cycle assessment using an economic allocation approach for the recycling routes

The graph below depicts the main drivers of the emission gap between China and Europe. Electricity is the main driver of emissions reduction in this scenario comparison contributing about 18% to the overall 21% reduction. This is followed by sodium hydroxide and emissions from heat.

Electricity is the main contributor to emissions reductions for recycled nickel sulfate hexahydrate

Made in Europe vs Made in China hydrometallurgy scenarios



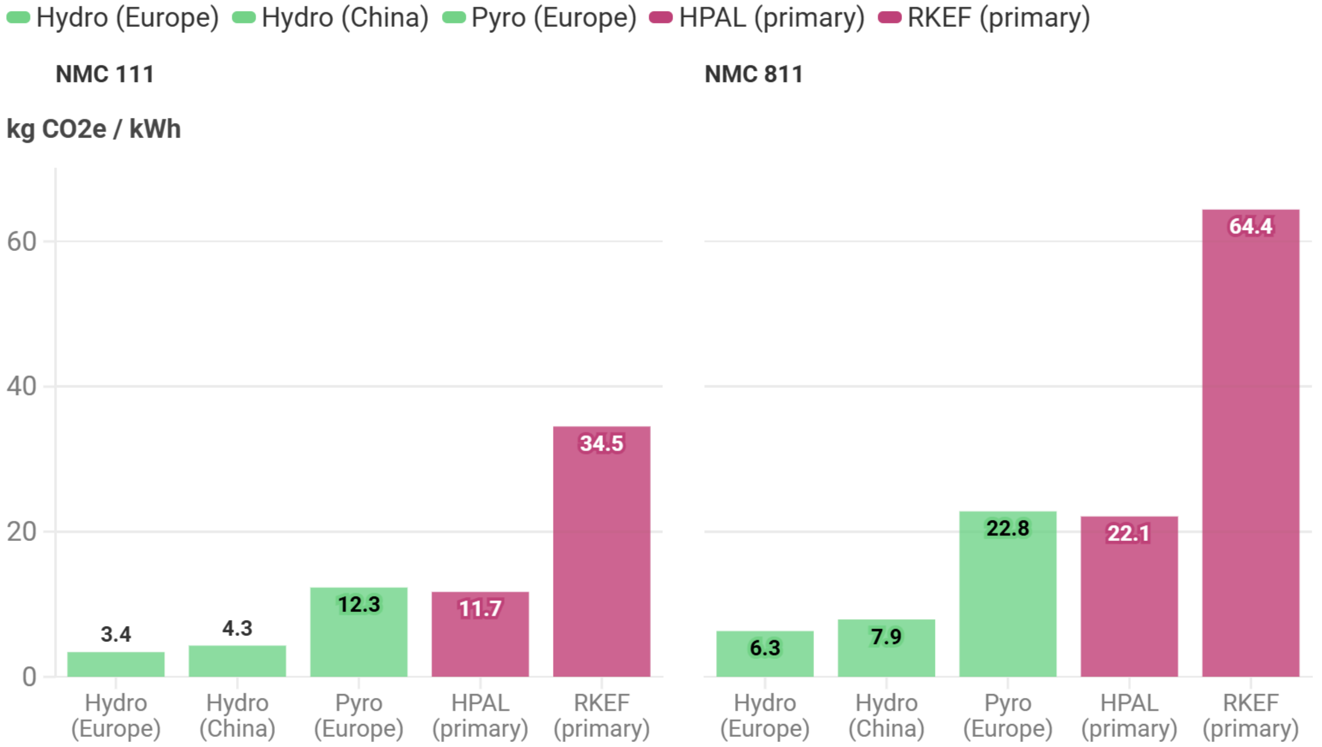
Source: Minviro and T&E analysis • Cradle-to-gate life cycle assessment using an economic allocation approach for the recycling routes

3.3 Choice of nickel sulfate source can greatly impact a battery's carbon footprint

Depending on the chemistry, different proportions of nickel are required, from low nickel containing NMC 111 to higher nickel containing NMC 811 and NMC 955. Nickel sulfate can be very carbon intensive which can have a significant impact on a battery's total emissions. The figure below shows that, depending on chemistry, the overall impact at the battery level can vary significantly. For a typical 77 kWh VW ID4 using a NMC 811 battery, European recycled nickel sulfate hexahydrate can achieve savings of 1200kg CO_2e if used instead of nickel produced via the most common primary HPAL route. The figure below illustrates the battery level emissions stemming from different sources of nickel sulfate.

European hydrometallurgical recycling can result in substantial battery level emissions savings

Nickel sulfate hexahydrate's contribution at the battery level



Source: T&E analysis

4. Conclusions and policy recommendations

We show recovering nickel from batteries has a lower carbon footprint than primary nickel. Nevertheless, the recycling route, and other factors such as plant location, can have a huge impact on the overall carbon emissions of the final nickel sulfate produced. Whilst nickel sulfate produced via pyrometallurgic routes is less carbon intensive than some primary production routes, such as via RKEF, the analysis shows that hydrometallurgical routes in Europe can significantly reduce the carbon intensity of nickel sulfate compared to almost all primary production. Electricity emissions constitute a large proportion of emissions for hydrometallurgy routes and the location of the battery recycler employing this technology can result in significant reductions in total emissions. With a comparatively cleaner grid, Europe can lead the way in low carbon hydrometallurgical recycling, producing cleaner nickel, contributing to greener batteries.

Given the potential for recycling in Europe, in particular for hydrometallurgy, and the expected feedstock of waste batteries containing nickel to become available, now is the time to ensure Europe has the needed recycling capacity. Nevertheless, the existing recycling capacity across

Europe is 10 times below where it needs to be in 2030, with almost half of Europe's battery recycling plans at risk. Europe will need to significantly scale up its recycling capabilities in order to unlock its capacity to power new vehicles with secondary materials. As part of this, ensuring the scaling of low-emission technologies, such as hydrometallurgical recycling, will be key.

In order to scale effective and low-emissions recycling in Europe, and develop a truly European Single Recycling market, T&E recommends:

- **Mainstream and prioritise circularity across policy areas and funding streams:** Recycling should be considered as any other clean tech. The EU Innovation Fund, InvestEU, the European Investment Bank (EIB), the future European Competitiveness Fund and national state aid should provide similar Capex and Opex support to recycling and circularity projects as cleantech, focusing on commercialisation and technology gaps. A focus on recycling technologies such as hydrometallurgy will be important.
- **Ban or significantly limit waste material shipment outside the EU via the upcoming Circular Economy Act (CEA):** To ensure sufficient feedstock for EU recyclers, including nickel, the CEA must prevent material leakage from end-of-life batteries, black mass and related waste products such as scrap. This should preferably be achieved via export bans, more harmonised waste criteria, or levied export fees, which would make exporting to third countries more expensive and burdensome.
- **Simplify intra-EU waste shipment rules to cut costs and administrative burden**: The CEA should further simplify the Waste Shipment Regulation, including allowing simplified information procedures when dispatching battery waste shipments. The CEA should harmonise waste definitions - including for by-products and shipment classifications - and create recycling partnerships or 'recycling clusters' where multiple actors in the same waste stream are treated as a single entity for administrative purposes.
- **Implement circularity targets in the EU Batteries Regulation and ensure they benefit EU recyclers:** Recovery and recycling targets should be quickly implemented and under no circumstances be weakened. The CEA should amend the EU Battery Regulation on recycled content in new batteries to introduce a local preference. Compliance with the battery recycled content targets for lithium, nickel, cobalt and copper should prioritise - and later only allow - secondary material that has been recycled in Europe.

Further information

Michael Carron

Battery and Materials Researcher

T&E

Michael.carron@transportenvironment.org