SYSTEMIQ

INDUSTRY PRINCIPLES FOR SUSTAINABLE BATTERY RECYCLING

The 10 principles outlined below provide practical recommendations for the recycling industry, in order of value chain steps. Industry participants should actively encourage their partners to adhere to these principles to ensure sustainable battery recycling across their value chain.

RECYCLING OPERATIONS

1 **Safe operations:** Prioritise stringent health and safety standards in recycling operations

Commit to the highest health and safety standards, ensuring that workers are appropriately trained and provided with high-quality protective equipment. For example, adhere to ISO 45001 – an international standard for health and safety at work – or relevant ILO standards and guidance on occupational health and safety in industrial operations. Ensure fair working conditions through regulated and licensed economic activity along the entire recycling value chain to rule out exploitative practices. This should take priority above all.

2 **Technology selection and process design:** Incorporate sustainability impact assessments into the selection of battery recycling technologies and processes

Recycling processes differ according to local situations, inputs and desired outputs; and no one process has a clear sustainability advantage in all dimensions. To make informed decisions, conduct in-depth data driven analyses of recycling routes, considering the advantages, disadvantages and trade-offs of the recycling flowsheet from a cradle-to-gate perspective and considering all inputs.

3 **High-ambition recycling:** Maximise material recovery and carbon efficiency, and prioritise recycling to high-grade materials

Optimise recycling operations for maximum recovery of key materials and minimum carbon footprint. This includes recovering energy during discharge and reclaiming non-active materials during disassembly and mechanical processing. Aim for high-purity secondary materials which allow for repeated reuse and recycling. Recovery of active and critical materials should take precedence. However, each material has its own optimal recovery rate, considering overall material yields and energy consumption. To determine the optimal material recovery rates, comprehensive evaluations comparing recycled and newly mined materials across various sustainability aspects are needed. To facilitate high-purity recycling, optimise disassembly and pre-processing steps and explore innovative recycling technologies.

4 **Water management:** Adopt best practices for water reduction and wastewater management

Aim to implement a closed water loop within recycling facilities – that is, a system that consumes no more water than is lost through evaporation or oxidation, and that recycles and purifies water processes. If this is not feasible, establish treatment systems to ensure that the quality of water entering the facility matches that of the water leaving it and minimise overall water consumption.

5 **Minimal waste:** Design and operate recycling processes to minimise waste streams and ensure that all waste is treated and disposed of in accordance with international standards

Minimise solid waste generation by exploring reuse options wherever possible – for example, repurposing hydrometallurgy sulphate by-products for the detergent industry or using slag produced in pyrometallurgy for road construction. Where this is not feasible, ensure that responsible disposal practices are in place, adhering to the highest environmental and safety standards – for example, ISO 14001 on environmental management systems, including waste management procedures; and ISO 24161 on waste collection and transportation management.

6 **Energy usage and GHG emissions:** Decarbonise recycling operations

Reduce the overall energy intensity of operations to the minimum. Ensure that the electricity used is sourced from renewable sources. Consider investing in renewable energy generation infrastructure such as photovoltaic systems or wind turbines. If complete electrification is not feasible for certain operations, transition to low-carbon fuel alternatives. For any unavoidable air emissions, employ reduction and control measures that align with the strictest carbon, environmental and health standards. Where feasible, minimise the direct release of GHGs – for example, by implementing effective capture methods.

RECYCLING VALUE CHAIN

7 **Auxiliary materials:** Minimise consumption and GHG emissions of used chemicals, gases and other input materials

Reduce the auxiliary materials consumption of recycling processes. If possible, recycle or regenerate the inputs – for example, recover used acids via regenerative chemistry or scrub and reuse inert gas used in shredding. Procure auxiliary materials such as chemicals with low environmental footprints – including considerations such as climate (eg, carbon footprint), freshwater and land impacts – in alignment with the planetary boundaries.

8 **Supplier engagement:** Apply sustainability assessment criteria and robust controls to ensure that suppliers of auxiliary materials adhere to internationally accepted environmental, social and labour standards

When procuring end-of-life batteries, black mass or auxiliary materials, conduct rigorous due diligence on suppliers to ensure that their materials have not caused adverse social and environmental impacts. Adhere to established international safety and environmental standards, follow due diligence regulations and refer to guidance such as the OECD's Due Diligence Guidance for Responsible Business Conduct. Verify supplier provenance to prevent materials from uncertified or problematic sources – ideally through established certification schemes.

BROADER VALUE CHAIN

9 **Transport:** Optimise transport routes and electrify modes of transportation

Prioritise the decarbonisation of all transportation relating to recycling operations, extending this effort beyond primary suppliers whenever feasible. Optimise transport routes to minimise distances and enhance the efficiency and scalability of dismantling and recycling networks. Invest in comprehensive training and equip personnel to uphold strict transport protocols, ensuring safety and environmental responsibility. When outsourcing transportation services, hold partners to these same high standards, including by requesting relevant certifications.

10 **Data availability:** Implement digital tools and enhanced traceability in line with the digital ecosystem along the value chain

Deploy digital tools such as battery passports, battery analytics and intelligence software to access information about battery history and composition. This will also enhance the recovery rates of valuable materials and facilitate sustainable recycling processes.