Special Feature 2

A Vision for Growth in the Circular Economy

～The Role of the JX Nippon Mining & Metals Group in Building a Recycling-Oriented Society～

The risk of resource depletion has become as serious a social issue as climate change.
As an organization closely connected to these resources, the JX Nippon Mining & Metals Group has set contributing to the realization of a recycling-oriented society as one of its key priorities.
With a clear policy of contributing to resource recycling leveraging our technological capabilities, we have created a vision for our growth in a recycling-oriented society.

A Necessary Shift Toward a Circular Economy

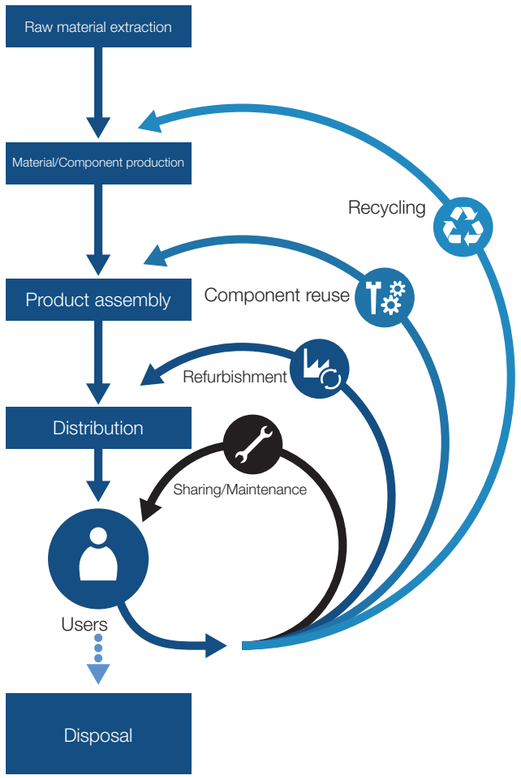
Unlike the traditional linear economic system of “take, make, and waste” for mined resources, the circular economy works to build an ongoing system of maximal use of mined resources, without discarding them, though re-circulation on a variety of levels. This can include sharing, reusing, and recycling.

In recent years, demand has risen for mineral resources alongside development of emerging economies. In the next 10 years, with the spread of electric vehicles and the advent of the data-driven society, the demand for copper and rare metals is expected to increase rapidly, causing great concern about the supply of resources. This has led to calls for a circular economy given the recognition that single use and disposal of the world’s limited resources will impede society’s future development.

Leveraging Strengths in Material Recycling Technology to Pursue Resource Efficiency

At the Group, we believe that the mission of players involved in the materials industry is to minimize resource final disposal through an ongoing cycle while maintaining the maximum value of these resources. In order to realize a circular economy system as shown in the diagram on the right, the Group will begin by putting greater focus on business and technology development in material recycling, the last bastion of resource circulation and an area where we have been making great effort for many years. This will also reduce waste in resources and energy in the supply chain by improving the yield of mining and smelting production processes. In addition, through the supply of advanced materials with high functionality and quality, we will contribute to greater durability and reusability of final products and components, as well as to the spread of digital infrastructure supporting recycling-oriented businesses.

Concept: The Circular Economy



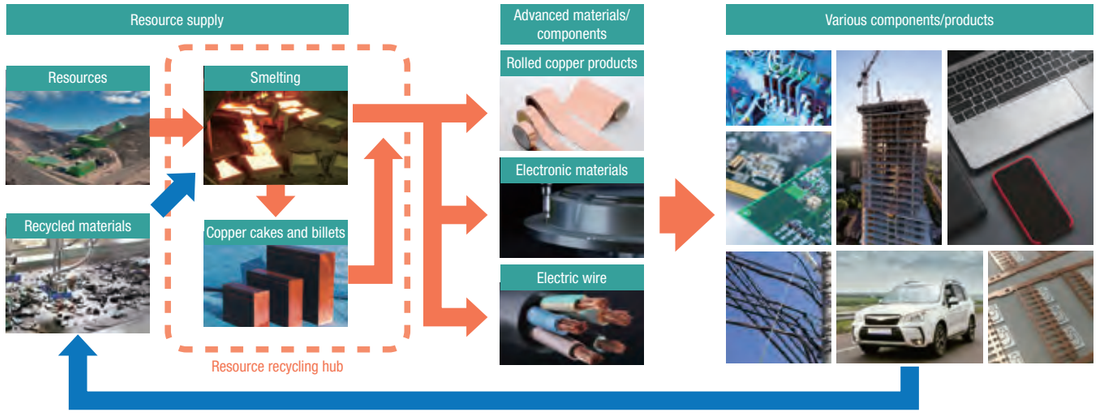
The smallest loop represents the cycle of sharing and maintenance among consumers. If these are difficult to achieve, then resources are circulated to the next larger loop, and so on until the manufacturer refurbishes the product, recovers and reuses components, or reuses these as materials. The “circular economy” refers to an economic system that maximizes the use of limited resources by ensuring this kind of multi-stage loop. The above diagram only covers worldwide circulation for industrially produced materials constrained to our current business domains (technosphere).

Priority Activity 1 **Enhancing Recycled Raw Materials Ratios in Copper Smelting**

Developing Technology for “Hybrid Smelting” to Significantly Increase the Ratio of Recycled Raw Materials

Demand for copper and other metals is expected to continue to grow in response to advancement in the information society and the trend toward decarbonization, but despite that, the development environment for copper natural resources continues to deteriorate, including a decline in the average ore grade. Meanwhile, demand for nonferrous metals is expected to continue growing as renewable energy and electric vehicles become more prevalent. Against this backdrop, the Group has set a goal of significantly increasing the ratio of recycled materials in copper smelting to 50% of total by further improving the highly efficient material recycling technology that we have cultivated over the years, and in order to make significant contributions toward the realization of stable materials supply and of a resource recycling-oriented society.

The Saganoseki Smelter & Refinery of JX Metals Smelting Co., Ltd. uses the flash smelting furnace method for copper smelting. In this method, copper concentrate and oxygen-enriched air are blown into the furnace, and the heat from oxidation of the sulfur contained in the copper concentrate breaks down the entire material and separates impurities, producing copper anode. Since this requires nearly no external heating, it allows the creation of high quality refined copper with little energy consumption. In addition, since there is plenty of generated heat left over in this process, recycled materials can be fed into this process alongside copper concentrate and smelted together. By taking advantages of the particularities in this smelting method, we recover copper, precious metals, and rare metals. Our target is to further evolve this method of simultaneous smelting and recycling to achieve a “hybrid smelting” method in which the ratio of recycled materials is significantly increased. As of the end of fiscal 2020, the ratio of recycled materials was approximately 12% (by input weight), and we aim to increase this ratio in stages to 50% by 2040. In order to develop this technology, the Group established the Saganoseki Branch of the Technology Development Center in October 2020, and integrated the Smelting Technology Department and the Recycling Technology Department in April 2021 to establish a full-scale technology development system for hybrid smelting. In 2021, in order to strengthen our collection and treatment capabilities for recycled materials, we also expanded the Changpin Recycle Center in Taiwan and established the Oita Recycling Logistics Center of JX Metals Smelting Co., Ltd., located in the city of Oita, where JX Metals Smelting has its Saganoseki Smelter & Refinery. We will take on these goals in cooperation with the various Group companies handling the pre-treatment processes for recycling.



Quantitative Understanding of CO_2 Generated Through Life Cycle Assessments

In parallel with developing recycling technology, the Group is also conducting life cycle assessments (“LCAs”) to quantitatively understand the amount of CO_2 generated in the copper production process. In LCAs, we analyze not only the amount of CO_2 generated within the Group, but also those generated by emissions from the supply chain, including in the production of various raw materials purchased and in outsourced logistics. This allows us to comprehensively analyze and assess CO_2 generation for the copper production process using primary and secondary (recycled) raw materials.

Taking advantage of our business model that is vertically integrated from upstream to downstream operations, the Group is currently setting up an appropriate LCA assessment process and constructing highly reliable LCA data. As we leverage the results of these LCA analyses, we will take a macro view and contribute to cutting CO_2 emissions, resource recycling, and a stable supply of materials in society as a whole.

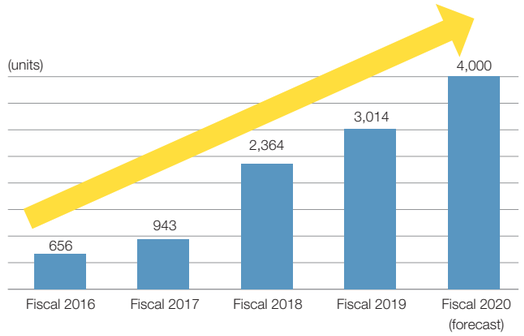
Priority Activity 2 **Establishing Closed-Loop Recycling Technology for LiBs**

A Race to Develop LiB Recycling Technology in Preparation for an Era of Mass Disposal of EV Batteries

The world's leading countries show a striking trend in that they are encouraging widespread use of electric vehicles (EVs) to combat global warming. This has led to concerns that rare metals and other resources required for the lithium-ion batteries ("LiBs") powering these EVs will face depletion and soar in price. Meanwhile, LiBs reaching end of life (EoL) are expected to be disposed of in mass quantities, necessitating a recycling system that can recover resources safely and efficiently. The EU, which is promoting the circular economy as part of core policy programs, has come up with a plan to strengthen EoL LiB recycling by establishing regulations mandating recovery and high recovery rate recycling of EoL LiBs and the minor metals they contain; the EU's plan is to apply this Batteries Regulation (as proposed) beginning in 2022.

We are one of the world's pioneers in launching projects for recovering rare metals from recycling LiBs, and have been operating demonstration trials at the Tsuruga Plant since 2009. As of 2020, we introduced bench-scale equipment (ongoing small-scale testing equipment) at Hitachi Works' Technology Development Center to establish the technology for recovering high-purity metallic salts from EoL automotive LiBs, with the aim of realizing "closed-loop recycling" where we recover resources from these LiBs and use them once again as LiB raw materials. To this end, we have introduced new processes based on this bench-scale equipment at the Tsuruga Plant, and launched verification testing for nickel sulfate recovery in the first half of 2021.

EoI LiBs Recovered Over Time in Japan



Source: "The status of disposed and recycled of new energy vehicle" (August 2020, Japan Automobile Manufacturers Association)

Bench-scale equipment at Hitachi Works

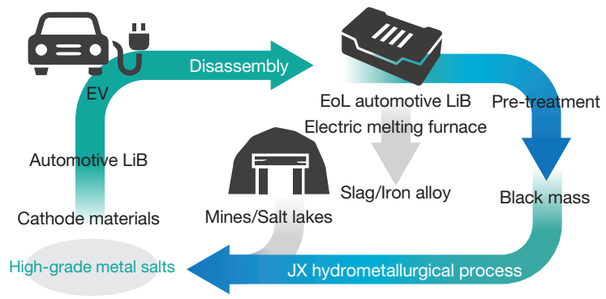
Demonstration testing equipment at Tsuruga Plant

Recycling Focused on Resource Value, Not Measurable by Purely Economic Considerations

Two considerations exist for waste EoL automotive LiBs: minor metal resource utilization and toxicity. Until now, treatment for these waste LiBs has primarily targeted detoxification at low cost, and even when rare metals are recovered from LiBs, they are mainly reused as alloys in so-called "downcycling." However, if we consider the oncoming era of mass automotive LiB disposal, expanding demand for LiBs with the spread of EVs, and the ensuing tight supply of rare metals such as nickel, cobalt, and lithium, we must seek to achieve "closed-loop recycling" where the rare metals in LiBs are used again as raw materials for batteries. For this reason, we have established a process to recover high-purity metallic salts from LiBs based on the unique hydrometallurgical technology we have cultivated. In addition, in order to recover the best raw materials (black mass) in our hydrometallurgical recycling process, we established a new test furnace at Hitachi Works in 2020 and are currently developing optimal pre-treatment technology.

In May 2021, we established a new company, JX Metals Circular Solutions Co., Ltd., to accelerate the development of these technologies. In August 2021, we established the Battery Material & Recycling Promotion Office and integrated the Battery Materials Group within the Technology Development Center to accelerate commercialization by consolidating internal battery-related resources. This has also resulted in a new structure pursuing synergies, such as improving the quality of recycled materials by leveraging our materials development technology and developing technologies with a view to the entire supply chain. In addition, we have established JX Metals Circular Solutions Europe GmbH in Germany to conduct verification testing with the purpose of achieving the commercialization of EoL automotive LiB recycling as soon as possible, in cooperation with automakers and other parties, and to promote comprehensive efforts including materials development.

Conceptual Diagram: LiB Closed-Loop Recycling



An optimal combination of pre-treatment technology and hydrometallurgical direct recovery of metal salts enables resource recycling from battery to battery. Compared to smelting from ores, this process uses less energy to produce raw battery materials, safeguarding resources and contributing to CO_2 reduction.

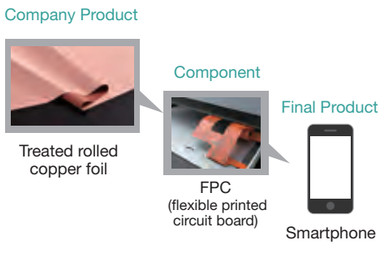
Contributing to the Circular Economy through Product Functionality

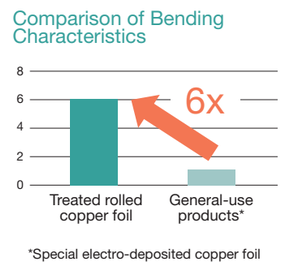
The use of information technologies like AI and IoT is essential for solving global issues, and nonferrous materials like copper and rare metals are becoming increasingly important. As a result, the Group faces strong calls to enhance its production efficiency and recycling of resources, as well as to contribute to enhanced functionality and longer lifespans for products such as electronic devices by making materials more functional.

For example, if the lifespan of electronic components used in information technology devices, automobiles, and other products can be further extended, we can increase the potential for their long-term use through maintenance, higher utilization rates through sharing, and reuse of components through remanufacturing. In this way, the Group's highly durable and highly functional electronic components and materials can contribute to extending the lifespans of these components and final products, as well as to resource conservation. The Group will also continue its efforts as a leader in the development and production of materials that fit into the circular economy.

As one of our measures to promote these efforts, the Group is also promoting industry-academia collaboration and open innovation with external research institutions. In April 2021, we established the JX Nippon Mining & Metals Joint Research Chair for Circular Economy Promotion with Osaka University to study production processes and processing technologies that will contribute to the formation of a circular economy.

- Example Contributions from the Group's Main Products
  - Functional Materials (e.g. Treated Rolled Copper Foil)
    Our highly functional copper products enable smaller and more energy-efficient electronic devices, such as smartphones, through greater design flexibility, and contribute to resource and energy conservation by improving yields in supplier manufacturing processes.
  - Thin Film Materials (e.g. Sputtering Targets)
    Our supply of high-quality materials contributes to improving the production yield for our customers, and to shrinking the physical and resource footprint of electronic devices.
  - Metal Powders for 3D Printers
    We contribute to the reduction of material consumption during manufacturing.





*Special electro-deposited copper foil

Message from the General Manager of the Technology Group

Sugawara Shizuo
Director, Member of the Board, and Deputy Chief Executive Officer
Assistant to the President (Technology, General)
General Manager, Technology Group
JX Nippon Mining & Metals Corporation

In order to build a sustainable society, it is important to achieve both decarbonization and resource recycling. Since our Group is engaged in the entire supply chain for nonferrous metals, from resources and smelting to electronic material products and recycling, our aim is to build a more appealing supply chain for the global environment and society as a whole by utilizing viewpoints like LCA and material flow analysis. We are also working diligently to develop technologies to achieve this goal, and will accelerate our efforts with a view to contributing to the SDGs. Amid the expansion of treatment volume of recycled materials, we have already developed an automatic sorting technology leveraging AI image analysis technology as one technical solution to the problem of pre-sorting items to separate resins from metals. In addition, we have largely established processes for treatment in recycling EoL LiBs for EVs and are now in the process of examining various issues ahead of mass production. On the other hand, the treatment process for recycled materials requires the use of fossil fuels and the incineration of resins contained in scrap. We also need to take on the challenge of establishing recovery technologies and methods for controlling the CO_2 that is generated in this process.

One other particularity about the Group is that we have already earned strong assessments in the market for our advanced electronic materials, which contribute to the data-driven society. As mentioned previously, copper and other nonferrous materials will continue to play an important role in the spread of EVs and renewable energy. As an example, semiconductors are an essential element for control of EVs and renewable energy. In addition, the expansion of businesses oriented toward the circular economy, such as advanced energy management and sharing businesses, will require high-speed information communication over networks, which will not only increase the demand for communication devices, but will also make semiconductors for information processing essential. By supplying materials to this field of advanced electronic materials, our Group will contribute to the formation of a sustainable society. We will also proactively aspire to the development of technologies, such as artificial photosynthesis, that contribute to society with the goal of achieving a carbon-neutral society.

The Group will work as one to become a leader in the decarbonization of the nonferrous metals industry.