2008 Technology demonstration project for CO2-saving recycling and other equipment.

(Demonstration project for a low-carbon recycling system for used lithium-ion batteries for automotive and other applications).

(written) report

28 February 2019

Taiheiyo Cement Corporation

Table of Contents

Figure Table of contents

Table Table of contents

List of abbreviations

In this report, the following abbreviations are used to unify the abbreviations.

abbreviation

Notation in this report.	formal name	Meaning etc.
LIB	Lithium-ion Rechargeable Battery	lithium-ion rechargeable battery
hr.	hour	Hours.

(Summary)

1. Background and issues

The project aims to demonstrate a low-carbon recycling system for used lithium-ion batteries ('LIBs')

The technological development of recycling processes that has been pursued so far has mainly targeted small LIBs and has lagged behind in addressing large LIB packs/modules. However, with the spread of next-generation vehicles, there is now a need to develop recycling technologies for large LIB packs and modules.

Large LIB packs are dismantled and processed in the form of LIB modules after removing the exterior base metal, etc. Heat treatment is essential as direct crushing of LIB modules risks ignition, leading to plant accidents. However, heat treatment requires a large amount of energy, and the recovery of rare metals such as lithium, cobalt and nickel contained in the LIB modules is problematic. At present, electric furnaces and stationary furnaces are available as treatment methods for LIB modules, but in electric furnaces, only iron is recycled and other base metals and rare metals are not recovered, while in stationary furnaces, base metals and rare metals are recovered, but they are in an oxidised state at high temperatures, so there are issues with their integrity.

There are three main recycling issues to be resolved for used large LIB packs

(i) Low-carbon ... Development of systems that enable the reduction of energy consumption in the heat treatment process.

(ii) Resource recycling ... Development of processing technology for highly efficient recovery of metal resources (rare metals and base metals such as lithium) by material.

(iii) Improvement of other environmental impacts.. . Development of a low-cost detoxification system for hydrogen fluoride gas generated in the heat treatment of LIB modules.

2. Objectives and implementation of the project

With the aim of recycling used large LIB packs in a low-carbon treatment scheme, this demonstration project will continue from the previous year to conduct demonstration experiments to recover high-grade metal resources from large LIB packs and modules using a roasting furnace. The treatment targets are a wide variety of large LIB packs and modules for automotive, stationary and other applications.

The objectives of the project are as follows.

① Low carbon ... Design of a system in which the roasting furnace is located next to the cement calcination furnace and the waste heat from the cement calcination process is used to reduce the energy consumption of the LIB roasting process.

(ii) Resource recycling ... Verification of roasting conditions that do not oxidise metal resources (rare metals & base metals such as lithium) and recover each metal

resource in high concentration.

(iii) Other environmental impact improvements ... Design of a low-cost detoxification system for hydrogen fluoride gas generated in the heat treatment of LIB modules, using an adjacent cement calcination furnace.

As the number of types of LIB packs used in the demonstration was small last year, the number of types to be used this year will be increased.

The number of roasters will be increased and the roasting conditions will be verified under conditions close to those in actual operation. In addition, the roasting temperature and time will be increased from the previous year in order to study roasting conditions that enable more efficient recovery of lithium compounds as a solution to the problems of the previous year.

In addition to verifying the kerosene consumption by setting up a more detailed specification, verifying the kerosene consumption with and without input and residual power, and mass processing in continuous operation for practical use, the issues to be improved will be identified and sorted out.

By adjusting the roasting temperature, only the combustible content and adhesives are burnt, while preventing melting and oxidation of the metal, facilitating the recovery of metal resources. By crushing and sorting the roasted LIB modules, not only base metals but also rare metals such as lithium are concentrated to a recoverable concentration for metal recycling.

In addition, the waste heat from the cement calcination process is effectively utilised to save energy, and by utilising existing waste treatment know-how, the aim is to build a treatment system that enables the recycling of all large LIB packs and modules at a lower cost than other technologies.

3. Results of the demonstration project

The implementation details and main results of this demonstration project are described below. The used large LIB packs and modules used in the verification experiment were vehicle-mounted LIB packs from domestic and foreign automobile manufacturers and stationary LIB modules from domestic battery manufacturers.

(i) Separation and manual dismantling of used LIBs

With the aim of reducing the amount of roasting treatment and recovering base metal and plastic resources, used LIB packs were collected, sorted and dismantled by hand, and the amount of resources recovered was measured. Note that manual dismantling was only carried out for vehicle-mounted LIBs discharged as packs, but not for stationary LIBs discharged as modules. The results of the manual dismantling showed that the LIB packs used this year had a higher weight ratio of modules to packs than those used last year, and that the composition ratio of ferrous, non-ferrous and plastic was different for each LIB pack.

② Roasting of spent LIBs

Comparative verification of the roasting temperature range and heating time showed that the combination of 500°C - 4 hours had the highest recovery of base and rare metals, as well as the best lithium distribution to recovered material less than 1 mm, and also used the least amount of paraffin per unit.

A comparison of kerosene consumption by input volume confirms that the higher the input volume, the less paraffin is used per input volume.

Regarding the effect of residual power on roasting, a comparison of kerosene consumption with and without discharge of the LIB module showed that kerosene consumption per unit was lower without discharge. This could be due to the contribution of residual power as fuel.

In the case where a large number of various LIB modules were mixed and roasted in continuous operation, the base metal was recovered at a high efficiency as targeted, but the rare metal recovery rate was approximately 50%, the same as in the previous year. When compared to the case where multiple types of LIB modules were roasted individually, the recovery rate varied, which led to the finding that the recovery rate of rare metals differs depending on the LIB module. The behaviour of lithium, including in the flue gas, was also checked and it was confirmed that lithium was not distributed in the flue gas at any input level.

(iii) Crushing and sorting of roasted LIBs

Highly efficient recovery of base metal and pole powder (<1 mm) containing lithium and other elements from roasted materials.

Therefore, shear crushing was followed by sieve sorting. Metal analysis was carried out on the recovered electrode powder less than 1 mm and on the recovered material of 1 mm or more to check the material balance of the metal resources contained in the LIB module, and found that more than 80% of the lithium could be recovered in the electrode powder, depending on the input level.

(iv) Overall design of the treatment scheme.

Based on the results of the demonstration tests, the overall design of the recycling process for used LIB packs was carried out and the material balance of the recycling flow was calculated.

In the treatment flow of used LIB packs, LIBs in pack form are dismantled by hand, the base metal and plastic are recovered, the LIBs are made into modules and then roasted. The roasted materials are crushed by shearing and sieved, and the recovered electrode powder of less than 1 mm is recycled as rare metals such as lithium, while the recovered materials of 1 mm or more are recycled as copper.

The scale of the treatment scheme was calculated to be around 4,600 t/year of spent LIB packs to be treated, based on a roasting throughput of 3,000 t/year (10 t/day), and the resources to be recovered to be 744 t/year of polar powder and 3,140 t/year of base metals in total.

With regard to energy saving effects, as per last year's design, the annual kerosene consumption in the roasting furnace is expected to be reduced by about 30% by utilising the exhaust heat from the cement calcination process, and the combustible exhaust gas generated from the roasting furnace will be used effectively in the cement calcination process, replacing about 0.1% of the coal required for cement production. The project is expected to replace approximately 0.1% of the coal required for cement production.

4. Environmental improvement effects

In the calculation of the carbon dioxide reduction effect of the project scheme, the technology to be compared was set to incineration in a stationary furnace. As it was difficult to obtain data relating to the energy consumption of the treatment processes before and after incineration in stationary furnaces, the hydrogen fluoride treatment process was excluded from the scope of calculation, as it was assumed to be identical to the project as a more conservative calculation. For the recycling effect, only the amount of resources actually assessed was included in the calculation.

The results of the estimation showed that the carbon dioxide reduction effect of processing a mixture of various types of LIB packs was 434 kg-CO2/LIB pack. Based on the results of this year's demonstration, it is expected that the amount of kerosene used can be reduced to a lower level than in the previous year, resulting in a greater reduction effect. For a processing scale of 3,000 t/year of roasting, the carbon dioxide reduction effect was calculated to be 1,986 t-CO2/year.

The actual resource recycling effect of the assessed resource volume only was calculated to be between 30% and 40%. The decrease from the previous year is thought to be due to the different amounts of ferrous and non-ferrous materials that make up the LIB packs. It was found that the resource recovery rate of LIB packs depends on the content of the constituent materials, but as the recovered materials that are not evaluated as metal are recycled by cement recycling, the amount of landfill disposal for any LIB packs is zero and therefore the recycling rate in this recycling system is 100%.

The behaviour of halogen elements (fluorine) in LIB packs was verified for the low-cost detoxification of exhaust gases (containing hydrogen fluoride): more than 80% of the halogen elements (fluorine) in all LIB packs were distributed in the polar powder less than 1 mm. The remainder was distributed in the roasting exhaust gas, which is sent to a cement calcination furnace for detoxification. Measurements of the final flue gas from the cement production plant confirmed the detoxification treatment of fluorine.

5. economic evaluation

A comprehensive assessment of the economics of LIB pack processing in the project was carried out by calculating the valorisation of the recovered resources and the costs of transport and treatment facilities, labour costs, consumables costs, etc. The valorisation of the rare metals among the recovered resources was based on the concentration of the recovered material; any recovered material larger than 1 mm was considered to be copper valued.

The results of the estimation showed that the costs of all LIB packs were higher than the resource assessment, and the overall assessment was calculated to be around -JPY 150,000/t. The reason for the cost increase over the previous year is thought to be due to the different material composition of the LIB packs. The cost of LIB packs increased overall due to an increase in the costs of transporting and roasting LIB modules, especially when the amount of base metal in the LIB packs decreased and the amount of LIB modules increased. The cost of LIB packs differs depending on the material composition, and we would like to reflect this in the cost setting for actual operation.

In order to reduce costs, the company considered cost reduction through more efficient transport and mass processing, and decided to set up a system where roasting, crushing and sorting are carried out at a single location, tripling the processing volume to 30 t/day, which received a comprehensive evaluation.

The cost is expected to be reduced to around -¥100,000/t. As transport costs account for more than 1/3 of the total costs, it will be necessary to consider the consolidation and scaling up of treatment facilities as well as the selection of dismantling sites in the future.

6. Future challenges and commercialisation timelines

LIB packs have a wide variety of structures and material compositions. As a result of dismantling and roasting a wide variety of LIB packs in this project, it became clear that the resource recovery rate and the cost of treatment differ greatly depending on the material composition of each LIB pack. These findings will be utilised in actual operations, for example by adjusting roasting conditions to increase the resource recovery rate.

In addition, it is necessary to improve the structure of the packing and handling equipment and baskets used in the collection, manual dismantling, roasting, crushing and sorting processes in order to make them more efficient and labour-saving in practical use.

The schedule for the future is to establish a mass treatment system from 2019, to save labour for input and discharge, to obtain permits for demonstration facilities, etc., and to commercialise the system from 2021.

Executive Summary

1. Backgrounds and challenges

This project aims to demonstrate a low-carbon recycling system for used lithium-ion rechargeable batteries (hereinafter abbreviated as "LIB").

While the development of recycling techniques has been focused on compact lithium-ion batteries, those for large-sized LIB pack modules have yet to be fully developed. With next-generation vehicles entering the market, however, there is a growing need to develop recycling techniques for large-sized LIB pack modules. LIB pack modules.

Large-sized LIB packs are stripped down to modules, with their exterior (base metals, etc.) removed, for recycling purposes. Such heat treatment, however, requires a massive amount of energy while recovery of rare metals (lithium, lithium alloys, etc.) is required. LIB modules can be heated either in an electric furnace or in a stationary furnace; the former recovers only iron with other base metals and rare metals wasted, whereas the latter recovers them but oxidation at oxidation is difficult. The latter recovers them but oxidation at high temperatures causes quality problems.

Challenges in recycling used large-sized LIB packs can be summarised as follows.
1) Low carbon: Development of systems that require less energy for heat treatment.
2) Resource recycling: development of techniques to individually recover metal resources (base metals and rare metals such as lithium) in an efficient manner.
3) Other environmental impact reductions: development of systems that efficiently detoxify hydrogen fluoride gas generated by heating LIB modules.

2. Project objectives and outlines

Following last year's demonstrations, this project demonstrates the recovery of high-quality metal resources from large-sized LIB pack The targets are large-sized LIB pack modules for various automobile and stationary use. The targets are large-sized LIB pack modules for various automobile and stationary use.

The project objectives are:.
1) Low carbon: Development of systems that reduce energy consumption from roasting processes, with a roasting furnace installed beside a cement kiln to Low carbon: Development of systems that reduce energy consumption from roasting processes, with a roasting furnace installed beside a cement kiln to make use of the waste heat from the latter.
2) Resource recycling: Testing of roasting conditions for recovering each metal resource (base metals and rare metals such as lithium) at high concentrations without oxidising it.
3) Other environmental impact reductions: designing of systems that efficiently detoxify hydrogen fluoride gas generated by heating LIB modules, using a neighboring cement kiln.

As last year's demonstrations involved limited types of LIB packs, the project deals with a

Variety of types this year, with roasting conditions tested under near-commercial conditions. roasting temperatures and time, moreover, are adjusted More finely to test roasting conditions so that lithium compounds can be recovered more efficiently - i.e., solutions to last year 's problems - while examining the consumption of kerosene according to the amount of input and with/without the residual electricity, and implementing large-scale continuous treatment for commercialisation purposes, all designed to identify and list what needs to be improved.

Roasting temperatures are adjusted to exclusively burn combustibles and adhesives while preventing oxidation of metals without melting, thereby At the same time, roasted LIB modules are crushed and segregated to increase the concentrations of base metals and rare metals such as lithium, which enables their recovery and, by extension, metal recycling.

In addition, the waste heat from a cement kiln is used to reduce energy consumption, with existing waste treatment techniques mobilised to develop treatment systems that fully recycle large-sized LIB pack modules at lower costs.

3. Demonstration results

The following provides how the demonstrations were conducted and turned out. for automobile use (domestic and foreign made) and LIB modules for stationary use (made by domestic battery manufacturers).

1) Segregation and manual dismantling of used LIBs.

Used LIB packs were collected, segregated and manually dismantled, followed by measurement of the amount of recovered resources, to reduce the amount of Only LIB modules for automobile use discarded as packs were manually dismantled, which was not the case with LIBs for stationary use discarded as modules. The results of manual dismantling show that the modules are much heavier than the packs, compared with last year's results, compared with last year's results, compared with last year's results, compared with last year's results. The results of manual dismantling show that the modules are much heavier than the packs, compared with last year's results, while the composition ratio of iron, non-ferrous metals and plastics differs from pack to pack.

2) Roasting of used LIBs

The roasting temperature range was compared with the roasting time; base metals and rare metals were recovered most effectively when roasted at 500°C for The roasting temperature range was compared with the roasting time; base metals and rare metals were recovered most effectively when roasted at 500°C for four hours; the lithium distribution ratio in recovered materials smaller than 1 mm was highest and its consumption of kerosene per unit was lowest.

Comparison of kerosene consumption by the amount of input shows that the consumption per input decreases as the input increases.

With respect to the impact of residual electricity on roasting, a comparison of kerosene consumption with/without discharge from LIB modules shows that the consumption per unit decreases when there is no discharge, which suggests that residual electricity functions as fuel.

Large amounts of various LIB modules were mixed and roasted continuously; base metals were recovered efficiently as originally planned while the Individual roasting of each LIB module, meanwhile, resulted in fluctuations in the recovery rate, which indicates that the recovery rate of rare metals differs from module to module. In addition, the test results of the lithium-ion batteries were recovered efficiently as originally planned while the recovery rate of rare metals remained at about 50% as in the case of last year's demonstrations. In addition, the test results of lithium behaviour in exhaust gas, etc., show that lithium does not exist in exhaust gas at any input level.

3) Crushing and segregation of roasted LIBs

Roasted LIBs were shredded, crushed and screened to efficiently recover electrode particles (smaller than 1 mm, containing base metals, lithium, etc.). .). Recovered electrode particles (smaller than 1 mm) and other recovered materials (1 mm or larger) were then analysed to determine the material balance of Recovered electrode particles (smaller than 1 mm) and other recovered materials (1 mm or larger) were then analysed to determine the material balance of metal resources contained in LIB modules; lithium consists of more than 80% of electrode particles at certain input levels.

4) Treatment scheme design

On the basis of the demonstration results, the recycling of used LIB packs was designed and the material balance of a recycle flow was calculated.

As a treatment flow of used LIB packs, LIBs in the form of packs were manually dismantled into modules, with base metals and plastics recovered, followed by Roasted materials were then shredded, crushed and screened to recover electrode particles (smaller than 1 mm, containing lithium and other Roasted materials were then shredded, crushed and screened to recover electrode particles (smaller than 1 mm, containing lithium and other rare metals) and other materials (1 mm or larger, containing copper). Given that 3,000 tonnes of LIBs are roasted per year (10 tonnes/day), the amount of used LIB packs to be treated is estimated at about 4,600 tonnes/year, which Given that 3 000 tonnes of LIBs are roasted per year (10 tonnes/day), the amount of used LIB packs to be treated is estimated at about 4 600 tonnes/year, which results in a recovery of 744 tonnes/year of electrode particles and 3 140 tonnes/year of base metals.

As for the energy-saving effect, the consumption of kerosene for roasting can be reduced by about 30% per year by using waste energy from a cement kiln, as As for the energy-saving effect, the consumption of kerosene for roasting can be reduced by about 30% per year by using waste energy from a cement kiln, as designed last year, while about 0.1% of coal used for cement production can be substituted by feeding the combustible exhaust gas from a roasting furnace to a cement kiln.

4. Environmental improvement effect

Comparison was made with incineration in a stationary furnace to calculate the CO_2 reduction effect of the project. As data on the energy consumption of treatment before and after the incineration was hardly available, a conservative estimate was made, where the consumption is considered the same as that As for the recycling effect, only the amount of resources to be evaluated was included in the calculation. As for the recycling effect, only the amount of resources to be evaluated was included in the calculation.

The CO_2 reduction effect of an integrated treatment of various LIB packs was calculated to

The results of this year's demonstrations indicate that the kerosene consumption can be reduced from last year 's levels, which leads to a greater CO_2 reduction effect; 1,986 tonnes/year of CO_2 can be reduced given that 3,000 tonnes/year of LIBs are roasted .

The recycling effect of resources to be evaluated is calculated somewhere between 30% and 40%, which is lower than last year's levels. While the resource recovery rate of LIB packs has proved to be dependent on their component makeup, materials that are not recovered as metals are recycled as cement materials. This means that all LIB packs This means that all LIB packs result in zero landfill, which brings the project's recycling rate to 100%.

The behaviour of halogens (fluorine) contained in LIB packs was examined with respect to low-cost detoxification of the exhaust gas containing hydrogen The behaviour of halogens (fluorine) contained in LIB packs was examined with respect to low-cost detoxification of the exhaust gas containing hydrogen fluoride, the results of which indicate that more than 80% of them exists in electrode particles smaller than 1 mm, with the rest distributed in the cement kiln. Incidentally, the detoxification of fluorine was verified through analysis of the exhaust gas from a cement kiln. Incidentally, the detoxification of fluorine was verified through analysis of the exhaust gas from a cement kiln.

5. Cost-effectiveness evaluation

The overall cost-effectiveness of the project's LIB pack treatment was evaluated based on the calculation of valuables in recovered Of recovered resources, rare metals were evaluated for their value Of recovered resources, rare metals were evaluated for their value while those equal to or larger than 1 mm were evaluated as copper.

As it turns out, the overall cost outweighs the value of recovered resources, with the loss calculated at around ¥150,000/ton. In particular, a decrease in the amount of base metals in LIB packs and an increase in the In particular, a decrease in the amount of base metals in LIB packs and an increase in the amount of LIB modules boosts the costs of LIB module transportation, roasting, etc., which results in a higher overall cost. The makeup of components differs from pack to pack and so does the cost, which will be reflected in the calculation of commercial operation costs. The makeup of components differs from pack to pack and so does the cost, which will be reflected in the calculation of commercial operation costs.

Cost reduction measures such as streamlined transportation and a high-volume treatment were therefore reviewed; centralised crushing and As the transportation cost accounts for more than one-third of the overall cost, treatment facilities should be centralised and expanded, and dismantling centres were therefore reviewed; centralised crushing and segregation, and a treatment of 30 tons/day (three times the current level) would reduce the loss to around ¥100,000/ton. As the transportation cost accounts for more than one-third of the overall cost, treatment facilities should be centralised and expanded, and dismantling centres should be located properly.

6. Challenges to be addressed and the commercialisation timeline

The structure and component makeup of LIB packs differ significantly from pack to pack. Meanwhile, show that the resource recovery rate and treatment cost fluctuate significantly due to differences in the component makeup of LIB packs. These findings will be taken into account in implementing commercial operations while roasting conditions will be adjusted to increase the recovery rate. These findings will be taken into account in implementing commercial operations while roasting conditions will be adjusted to increase the recovery rate.

In addition, improvements should be made in packing styles for procurement, manual dismantling, roasting, crushing and segregation, and in the In addition improvements should be made in packing styles for procurement, manual dismantling, roasting, crushing and segregation, and in the structures of handling facilities and baskets to streamline commercial operations and reduce their energy consumption.

The development of a high-volume treatment system will start in FY 2019 and commercial operations are scheduled to commence in FY 2021, with the input and The development of a high-volume treatment system will start in FY 2019 and commercial operations are scheduled to commence in FY 2021, with the input and output processes streamlined and the licence obtained for demonstration facilities, etc.

Project implementation system

■ Implementing entities		
Taiheiyo Cement Corporation	Deputy General Manager, Environmental Business Unit Leader, Sales Planning Group	field of early-blooming (or ripening) rice consideration
	Director in charge of the Environmental Business Unit Sales Planning Group	Hanada Takashi
	Environmental Division Counsellor, Sales Planning Group	Fukuda Seiji
	Environmental Division Assistant Manager, Sales Planning Group	Kenichi Mori
	Environmental Division Sales Planning Group Principal Officer	Suzuki cool
	Environmental Division Sales Planning Group Principal Officer	Uesugi court (national) mourning
	Central Research Institute, Research Department 3 Separation Technology Team Leader	Ishida Yasuyuki
	Central Research Institute, Research Department 3 Senior Researcher, Separation Technology Team	City Village Central China
	Central Research Institute, Research Department 3 Senior Researcher, Separation Technology Team	Hon. Kenichi
	Central Research Institute, Research Department 3 Researcher, Separation Technology Team	Takemoto. Tomonori
	Central Research Institute, Research Department 3 Researcher, Separation Technology Team	Nakamura Mitsushi
	Central Research Institute, Research Department 3 Researcher, Separation Technology Team	Komatsu Kohei

	Central Research Institute, Research Department 3 Researcher, Separation Technology Team	Takizawa valiant
■ Re-consignee.		
Matsuda Sangyo Co.	Environmental Solutions Division Deputy General Manager, Solutions Sales Department	boundary Kenichiro
	Environmental Solutions Division Planning and Promotion Division section manager	Yano man of valor
	Production Headquarters Technical Development Section Assistant Section Chief	Urata Yasuhiro
	Production Headquarters Technical Development Section technical assistant	Akihiro Okochi
Cleco Labs Ltd.	representative director (i.e. someone chosen by the board of directors from among the directors to represent the company)	Kozu Seiroku
	manager (e.g. of a business, an idol, etc.)	Wakabayashi Shiko

1. Implementation of demonstration projects

1.1 Overview of the demonstration project

1.1.1 Objectives, background, issues, etc.

The project aims to demonstrate a low-carbon recycling system for used lithium-ion batteries ('LIBs'). The technological development of recycling treatment that has been promoted so far has mainly targeted small LIBs and has lagged behind in dealing with large LIB packs/modules. However, with the spread of next-generation vehicles, there is now a need to develop recycling technologies for large LIB packs and modules.

Heat treatment is essential for LIB modules because of the risk of ignition and plant accidents if they are crushed directly. However, heat treatment requires a large amount of energy, and the recovery of rare metals such as lithium, cobalt and nickel contained in LIB modules is problematic. At present, electric furnaces and stationary furnaces are available as treatment methods for LIB modules, but in electric furnaces, only iron is recycled and other base metals and rare metals are not recovered, while in stationary furnaces, base metals and rare metals are recovered, but they are in an oxidised state at high temperatures, so there are issues with their integrity.

In order to recycle used large LIB packs and modules in a low-carbon treatment scheme, this demonstration project aims to demonstrate the recovery of high-quality metal resources from large LIB packs and modules using a roasting furnace. The treatment targets are a wide variety of large LIB packs and modules for automotive, stationary and other applications. The ultimate goal is to recover and recycle lithium, which has not been recovered so far. The objectives, background and issues are shown in the diagram below.

Objective.

- Recycling of lithium ion batteries (LIBs) in **low-carbon processing schemes.**
- The ultimate goal is to **recover and recycle previously unrecovered lithium compounds**

<Low carbon

Design of systems that **utilise waste heat from the cement calcination process to reduce energy consumption in the roasting process.**

<Resource

Selection of treatment processes to **recover metal resources (rare metals and base metals such as lithium compounds) respectively.**

target waste

<Other environmental impact remediation>.

Design of a **low-cost detoxification** system for the **treatment of hydrogen fluoride gas** generated in the heat treatment of LIB **in a cement calcination furnace.**

background

Automotive and stationary LIBs

- The spread of next-generation vehicles requires the development of **recycling technologies for a wide variety of large LIBs.**
- Increased demand for **lithium due to the** widespread use of LIBs has created demand for **lithium recycling.**
- Direct crushing of LIBs without heating can lead to ignition and plant accidents. Heat treatment is essential, but requires a lot of energy consumption.
- Metal recycling, as detoxification in electric furnaces can only recover iron, while in stationary furnaces the metal is oxidised. (base metals and rare metals) have challenges.
- High environmental impact of exhaust gases, such as the generation of difficult-to-treat hydrogen fluoride gas when heated.

H29 Outcome.

Three types of LIBs were used in the roasting experiments: one for vehicle-mounted use (domestic and international) and one for stationary use.

The two temperature zones of 450°C and 600°C were compared and verified, with the result that 450°C was preferable.

The heating time was compared between 3 hours and 6 hours at 450 °C. The results showed that 6 hours was preferable.

- **The structure of LIBs varies widely, and the effective roasting conditions etc. depend on the material of the frame (iron, resin).**

CO_2 emissions in the heat treatment process are expected to be **reduced by approximately 70%** (comparison: stationary furnace).

FY30. enforcement agenda

(i) Roasting a wide variety of LIBs and testing effective methods.

Roast a wide variety of LIBs in terms of type, total weight, remaining total power, etc., and compare and verify **roasting conditions that can be applied to a wider range of LIBs**.

(2) Verification of roasting conditions (temperature and time) for high effective recovery of lithium compounds.

In order to study **roasting conditions that enable higher effective ❹ recovery of lithium compounds**, Conducting **temperature zones, time zones, etc.,** were **set in detail**, and the specific

(iii) Verification of operational requirements, etc. for continuous operation for practical use.

Investigate **operational** methods **to quadruple** the **daily throughput compared to last year's results** and **to ensure continuous operation in high-volume processing.**

Verify **operational requirements for commercialisation (e.g. mass processing, stable operation)**, identify and organise improvement issues

Figure 1-1. Objectives, background and issues of this demonstration project

1.1.2 implementation system

A diagram of the project's implementation structure is shown in Figure 1-2. In implementing the project, Pacific Cement, Creco

Regular meetings were held at the beginning of each month at Labo, Matsuda Sangyo and other three companies to confirm monthly progress and to check, share and discuss issues such as implementation items and targets for the following month.

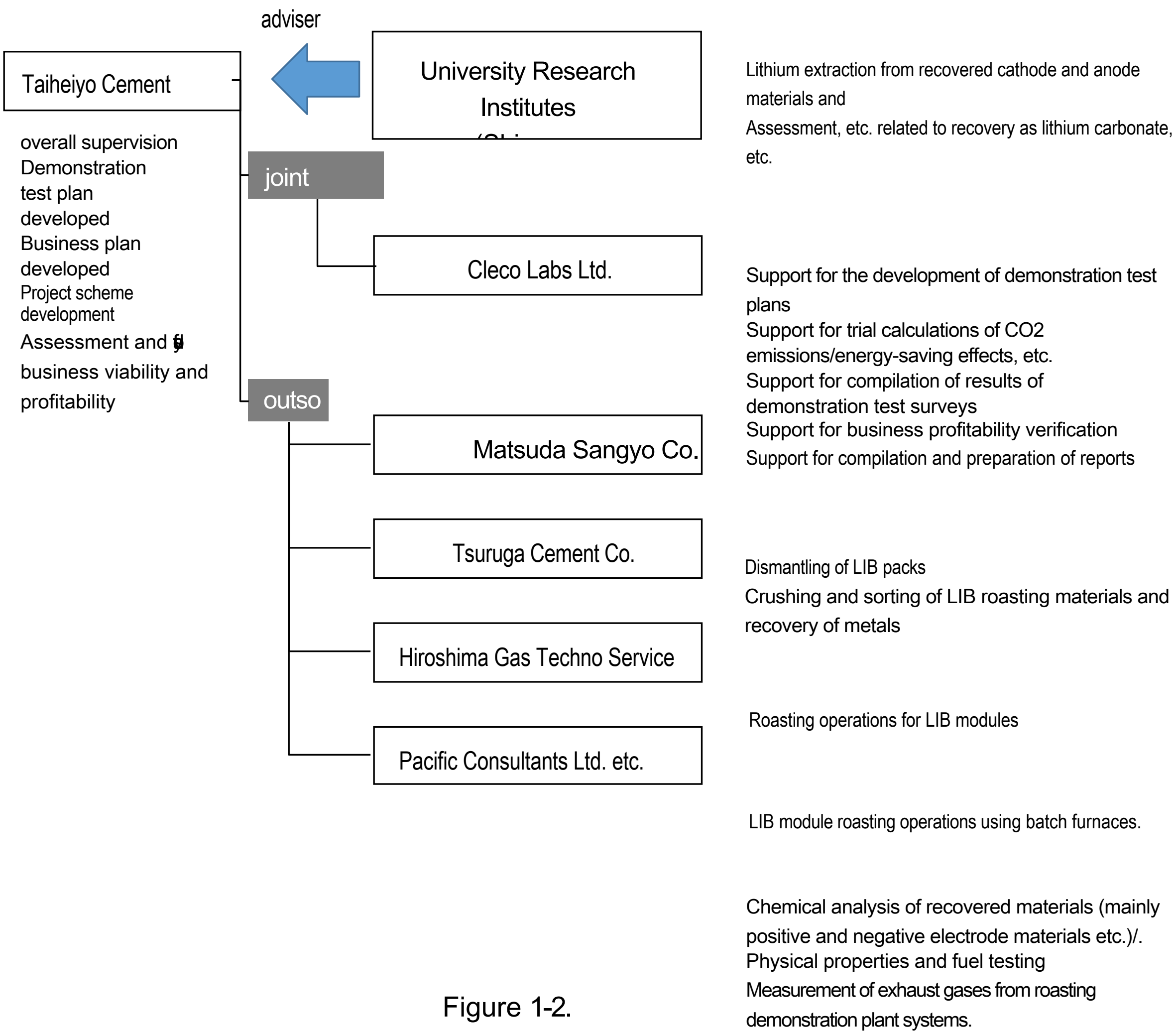


Figure 1-2. Implementation structure diagram

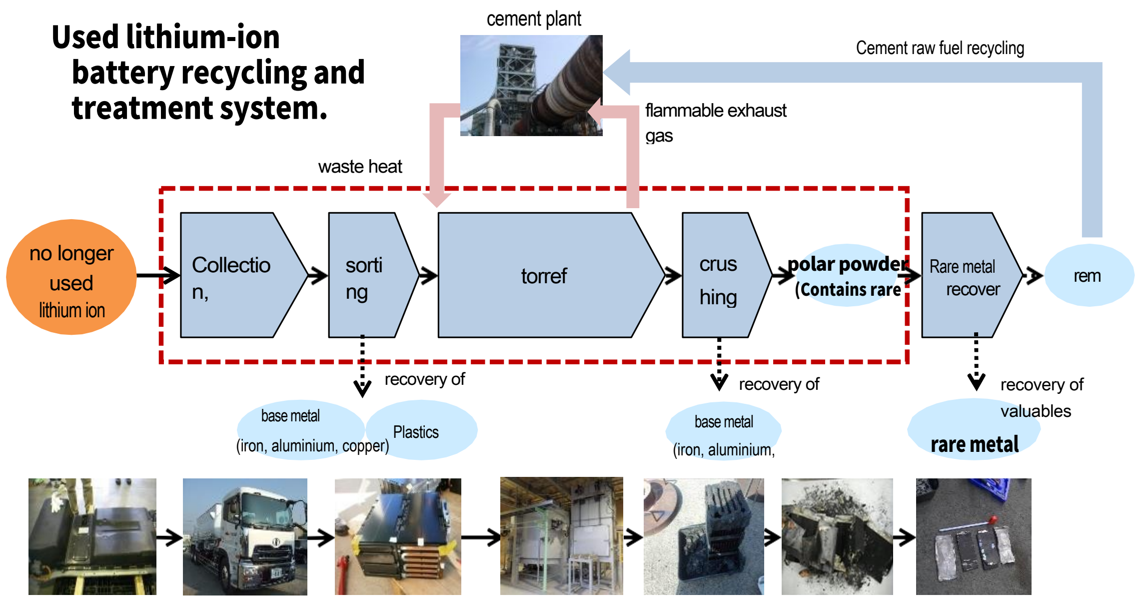
1.1.3 System of demonstration projects

In this demonstration project, the roasting temperature is adjusted to prevent melting and oxidation of the metal, while only combustible content and adhesives are roasted to facilitate recovery of metal resources. By crushing and sorting the roasted LIB modules, not only the base metals are recovered, but also rare metals such as lithium are concentrated to a concentration that enables recovery of the materials, thereby facilitating metal recycling.

Furthermore, as an energy-saving measure, the roasting furnace is located next to the cement calcination furnace and the exhaust heat from the cement calcination process is used in the roasting furnace, thereby reducing the amount of energy consumed for roasting. In addition, the exhaust gas containing flammable gases generated by roasting is returned to the cement calcination process and used as a fuel substitute, and the difficult-to-treat hydrogen fluoride contained in the exhaust gas is treated by the cement calcination furnace at low cost. The aim is to build a treatment system that enables the recycling of all LIB packs and modules at a lower cost than other technologies.

The concept of the roasting process is characterised by the fact that the spent LIB modules are placed in a metal container (basket) and fed into the roasting furnace, which has a double structure. This creates low-oxygen conditions and prevents a rapid temperature rise due to the combustion of the LIB and the melting and oxidation of the metal, while also allowing the roasting conditions to be set according to the input material. Furthermore, the plant is located adjacent to a cement calcination furnace, and hydrogen fluoride gas generated by the roasting of spent LIB modules is returned to the cement calcination furnace, enabling low-cost fluorine detoxification treatment and energy saving in the cement calcination process through the effective use of heat from the roasting exhaust gases.

The concept of the crushing and sorting process is the recovery of electrode powder with a high concentration of rare metals such as lithium, and is characterised by the pursuit of economic efficiency by increasing the metal recovery rate and the realisation of 100% recycling by turning the residues into cement resources.



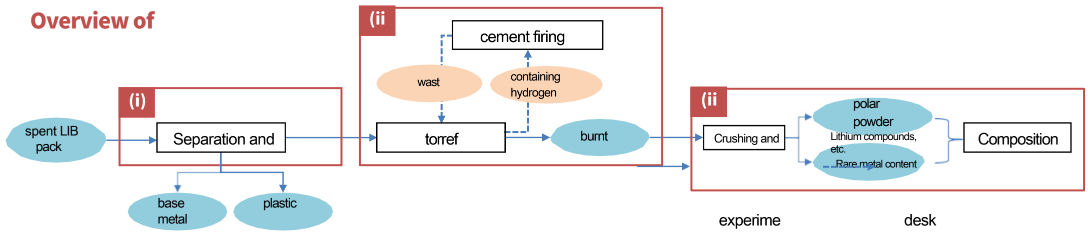
Collection/transport of waste battery packs Battery pack dismantling Roasting furnaces Roasting materials Shredding and sorting

Resource sorting

Figure 1-3. System of the project

1.1.4 Implementation flow of the demonstration project

The implementation items, studies, objectives and results of each step of this demonstration are shown in the diagram below.



enforcement agenda	Details of implementation	Objectives /outcomes .
(i) of used LIB packs. Separation and manual demolition	• Hand dismantling of a **wide variety of** used LIB packs • Weighing of recovered resources • **Measurement of voltage, current, etc.**	• **Capturing disposal status data in a wide variety of LIB packs** • **Obtaining data on the amount of resources collected in a wide variety of LIB packs**
(ii) Roasting of spent LIB modules	• Detailed verification of roasting conditions for dismantled LIB modules H29: 450°C, 600°C/3hr-6hr **H30: 400-550°C/4hr-8hr** • Investigation of the effect of dismantled LIB modules on the roasting process. H29: Small quantity (2 baskets/day), 3 species **H30: High volume (8 baskets~/day), multiple species, total weight, total remaining power, etc.** • Measuring the behaviour of rare metals (e.g. Li) and fluorine. H29: Roasting ware **H30: Roasting and exhaust gases.** • Energy savings from the effective use of waste heat from the cement calcination process and exhaust gases from roasting furnaces. trial calculation	• **More detailed roasting conditions for higher effective ❹ recovery of lithium compounds. study** • **A wide variety of LIB module types, unit throughput, remaining power, etc. Comparison of roasting of LIB modules** • Measurement of the recovery accuracy of **rare metals (e.g. Li) in the** roasting process **(checking the overall behaviour including roasting and flue gas).** • **Estimated energy savings from** the effective use of exhaust heat from the cement calcination process and exhaust gas from roasting furnaces, using cement calcination furnaces at **different levels of roasting conditions, etc.**
(iii) Roasted LIB Modjes Recovery of resources from the	• Pre-processing for resource recovery (crushing and sorting (shearing type (with particle size adjustment function)) • **Analysis of resource recovered materials by level of roasting conditions, etc. (Measurement of Li, Co, Ni, Cu, Fe, Al)**	• Shredding and sorting processes for resource recovery • **Comparative verification of resource recovery effectiveness.**
④ Treatment schemes. Overall design and economics Re-examination of the	• Overall design of treatment and recycling schemes • Consideration of roasting conditions • Material balance creation • Waste heat from the cement calcination process and roasting furnace exhaust gas, utilising the adjacent cement calcination furnace. Study of design and operation methods for a low-carbon system that makes effective use of • Verification of economic efficiency in the design flow. • Business scheme business competitiveness estimates from collection to treatment in a hypothetical model.	• Overall design of LIB pack treatment and recycling flow. • **Can be used with a wide variety of LIB modules, and has better resource recovery efficiency. Investigation of roasting conditions, etc.** • Material balance in treatment and recycling flows. • Design and operation methods for low-carbon systems that make effective use of waste heat from the cement calcination process by placing the cement calcination furnace and roasting furnace next to each other, detoxify fluorine-hydrogen gas in the exhaust gas from the roasting furnace, and use flammable exhaust gases as alternative fuel. • **Planning of economically feasible treatment schemes.** • Organisation of future issues and development of business plans

Figure 1-4. Overview of the implementation of this demonstration project

(1) Experiments on separation and manual dismantling of used LIBs

As a pre-treatment for the roasting process, the LIB packs were dismantled by hand as required. The LIB packs used are for on-board use. Dismantling of stationary LIB packs was not carried out as it was not necessary. Weights etc. were measured before and after dismantling and a material balance was prepared.

Pre-dismantling LIB packs (vehicle-mounted) | Dismantling operations | LIB module insulation work | Recovered resources

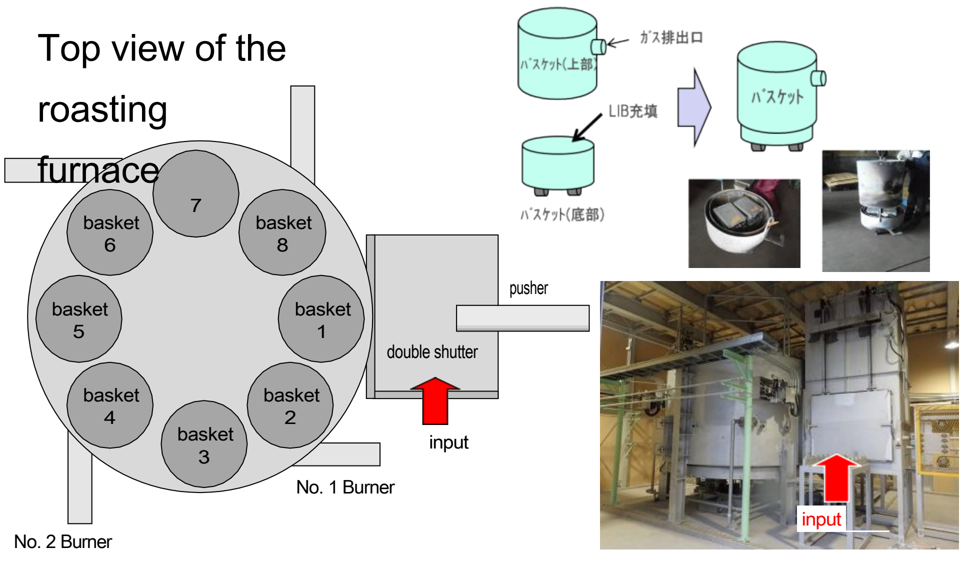
Figure 1-5. Disassembly and manual disassembly of used LIB packs in this demonstration project

(2) Experimental roasting of spent LIBs

The dismantled LIB modules are fed into a roasting furnace (test furnace) and the heating temperature range and time are selected to suit metal recovery. The roasted material produced (e.g. pole powder) is used for crushing and sorting in the next process. In addition, the fuel substitution effect of the effective utilisation of the flue gas containing combustible gases generated from the roasting furnace in the cement calcination process is estimated.

The roasting furnace used in this experiment is a project subsidised by the Ministry of Economy, Trade and Industry (*) and installed at Tsuruga Cement Co.
1) a rotary bed continuous roasting furnace (test furnace) introduced for the purpose of lithium-ion battery recycling and 2) a small fixed incinerator (test furnace) of Hiroshima Gas Techno Service Co. The roasting furnace of Tsuruga Cement was mainly used, and the furnaces of both Tsuruga Cement and Hiroshima Gas Techno Service were used to confirm the impact of residual power.

1 Subsidy for the development of practical industrial technology in 2014 (Resource Recycling Demonstration Project).
2014 Subsidy for the development of practical industrial technology (Demonstration project for the recovery



of rare metals with recycling priority).

Figure 1-6. Roasting furnace in this demonstration project (Tsuruga Cement)

(Remark: the size of the furnace interior is Φ3,400 mm, height 1,500 mm)

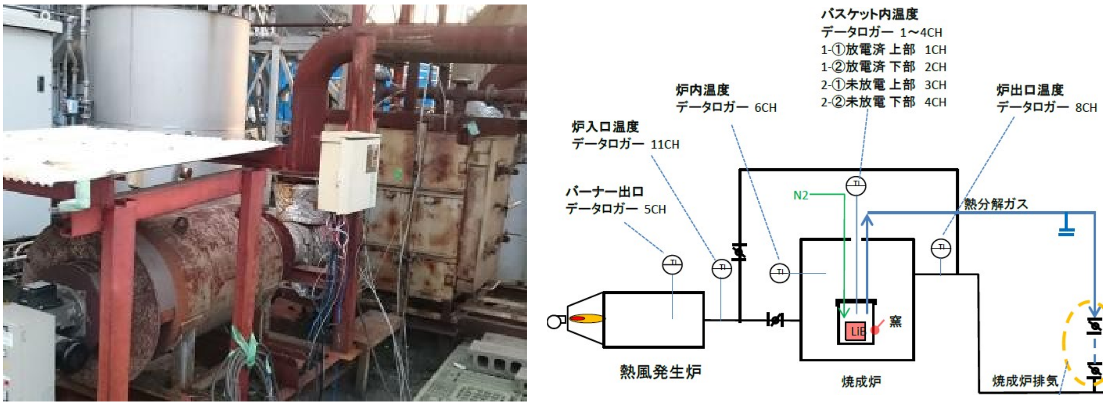


Figure 1-7. Roasting furnace in this demonstration project (Hiroshima Gas Techno Service)
(Remark: the size of the furnace interior is 560 mm (W) x 1000 mm (D) x 900 mm (H))

(3) Experiments in crushing and sorting roasting materials

Shear crushing and sieve sorting are used as methods to recover lithium and other materials from roasted materials (e.g. electrolyte powder) generated in a roasting furnace with high efficiency. In the scope of this demonstration, the recovery and component analysis of the electrode powder containing lithium, etc. will be carried out.

Figure 1-8. Crushing and sorting equipment in this demonstration project

1.2 Results of the demonstration project

1.2.1 Experiments on separation and manual dismantling of used LIBs

In this demonstration project, a wide variety of LIB packs were dismantled by hand as a pre-treatment for the roasting process. This year, 10 types of LIB packs (modules for stationary use) were dismantled, compared to three types last year. Only vehicle-mounted (domestic and foreign) LIBs discharged in packs were dismantled by hand.

As a result of manual dismantling, an average of approximately 40% (by weight) of metal and plastic material was recovered per vehicle LIB pack, both nationally and internationally.

Table 1-1. Breakdown of samples used (unit: pcs)

	cathode material					cell shape		
	NCM	NCM (Mn Rich).	LMO	NCM+. LTO	LFP	corner (e.g.	laminate	cylinder

		Cell housing material			Unit weight (weight/number of modules)		
		aluminium	stainless steel	iron	Less than 10 kg	10 kg or more Less than 20 kg	20 kg or more
For in-vehicle use	outside the country	26	0	0	0	16	10
	domestic	204	322	8	162	364	8
for stationary use	outside the country	0	0	0	0	0	0
	domestic	79	0	0	64	15	0

(Remark: for vehicle-mounted applications, the LIB is in LIB packs; for stationary applications, the LIB is in LIB modules).

Table 1-2. Material balance and residual voltage etc. in LIB packs

basic information			Modular structure				pack (Number of pieces)
LIB Type	manufacturer	Type.	cathode material	cell shape	Cell housing material	Module size (㎜)	
For in-vehicle use	outside the country	PHEV	NCM	corner (e.g. desk, pavement)	aluminium	400*180*110	6
		EV	NCM (Mn rich).	corner (e.g. desk, pavemen	aluminium	410*300*150	3

basic information			Residual Power Measurement	
LIB Type	manufacturer	Type.	Voltage (V)	Current (mA)[1)]
For in-vehicle use	outside the country	PHEV	58.5	81.3
		EV	46.7	64.8
	domestic	PHEV	56.5	78.4
		PHEV	34.8	48.3
		EV	7.3	10.1
		EV	32.5	45.1
		HV	98.1	136.2
		HV	166.5	231.3
		(HV)	0	0
for stationary use	domestic	–	0	0
		–	0	0

1) Connect an electrical resistance of 720 Ω and carry out current measurements.

basic information			packed and dismantled yerba maté ballat					use
LIB Type	manufacturer	Type.	module	iron	non-ferrous	plastic	total amount	
For in-	outside the country	PHEV	72.3%	4.8%	22.3%	0.2%.	99.7%.	October Roasting trials (discharged, undischarged)
		EV	81.4%	2.8%.	15.8%.	–	100.0%.	October Roasting trials

vehicle use	domestic	PHEV	44.7%	35.4%	12.1%	7.8%	100.0%.	October Roasting trials
		PHEV	74.6%	4.8%	19.0%	1.7%	100.0%.	October Roasting trials
		EV	65.9%.	31.1%	2.9%.	0.1%	100.0%.	October Roasting trials
		EV	73.5%.	2.6%	19.1%	4.8%	100.0%.	July-October Roasting trials (discharged, undischarged)
		HV	67.6%	24.3%	8.1%	–	100.0%.	October Roasting trials
		HV	41.9%.	48.4%	8.0%	1.3%	99.6%.	October Roasting trials
		(HV)	100.0%.	–	0.0%	–	100.0%.	October Roasting trials
for stationary use	domestic	–	53.1%	36.6%	10.1%	0.2%.	100.0%.	October Roasting trials
		–	53.1%	36.6%	10.1%	0.2%.	100.0%.	October Roasting trials

1.2.2 Experimental roasting of spent LIBs

Roasting treatment experiments were conducted on the dismantled LIB modules by dividing them into type, unit throughput, remaining total power, etc., to verify the effect of different LIB modules on the roasting treatment. The verification items of the project are listed below.

Table 1-3. Verification items in the roasting process of LIB modules

<table>
<tr><th colspan="2"></th><th>implementation level</th><th>evaluation technique</th><th>summary chapter</th></tr>
<tr><td>(1)</td><td>Roasting conditions
Exploring the</td><td>Union of roasting temperatures and roasting times
Level-specific roasting experiments by
(4-8 baskets per level)

<Level of implementation>.
<table><tr><th></th><th>4 hours.</th><th>6 hours.</th><th>8 hours.</th></tr><tr><td>400°C</td><td>××-mark (used to indicate an incorrect answer in a test, etc.)</td><td>symbol used as a placeholder (either because a number of other words could be used in that position or because of censorship)</td><td>symbol used as a placeholder (either because a number of other words could be used in that position or because of censorship)</td></tr><tr><td>450°C</td><td>××-mark (used to indicate an incorrect answer in a test, etc.)</td><td>symbol used as a placeholder (either because a number of other words could be used</td><td>symbol used as a placeholder (either because a number of other words could be used</td></tr></table></td><td>Component analysis
Checking paraffin consumption.
Exhaust gas component analysis
Measurement of temperatures in the furnace, exhaust gases, etc. during roasting.</td><td>(1) Search for roasting conditions</td></tr>
</table>

(1) Exploration of roasting conditions

For the recovery of high concentrations of base and rare metals, more precise comparative verification was carried out on the roasting temperature range and heating times that do not melt the aluminium and copper of the electrode materials, burn off only the adhesive and have good recovery rates of the rare metals.

Last year, a combination of 450°C-6hr was considered suitable, but a more detailed comparison with a more detailed verification temperature range resulted in the highest recovery of rare metals below 1 mm and base metals above 1 mm at 500°C-4hr.

The distribution ratio of lithium between the recovered material after crushing and sorting and the flue gas also showed that the highest amount of lithium was recovered at 500°C-4hr to less than 1 mm. The amount of paraffin used per treatment volume was also lowest at 500°C-4hr. From these results, 500°C-4hr was judged to be the optimum roasting condition.

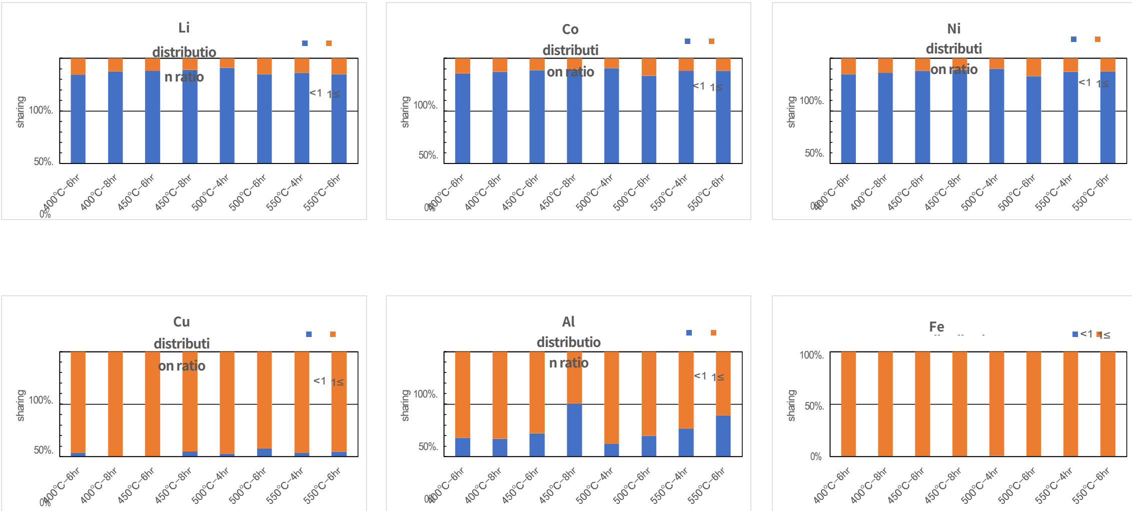


Figure 1-9. Distribution of recovered resources by roasting temperature and roasting time

Table 1-4 Amount of lithium per tonne of LIB module by level (distribution ratio)

level	Less than 1 mm (%)	More than 1 mm (%)	Exhaust gas (%)
400°C-6hr.	85	15	0
400°C-8hr.	88	12	0
450°C-6hr.	88	12	0
450°C-8hr.	89	11	0

Table 1-5. Kerosene consumption by level

level	Roasting conditions		Paraffin consumption		Temperature measurement	
	Set temperature (°C)	Hours. (hr)	Kerosene consumption per unit time (L/hr)	Per unit module volume Paraffin consumption (L/kg-LIB)	Furnace temperature (°C)	Exhaust gas temperature (°C)
400°C-6hr.	400	6	23	0.55	409	401
400°C-8hr.	400	8	23	0.74	410	394
450°C-6hr.	450	6	27	0.65	459	438

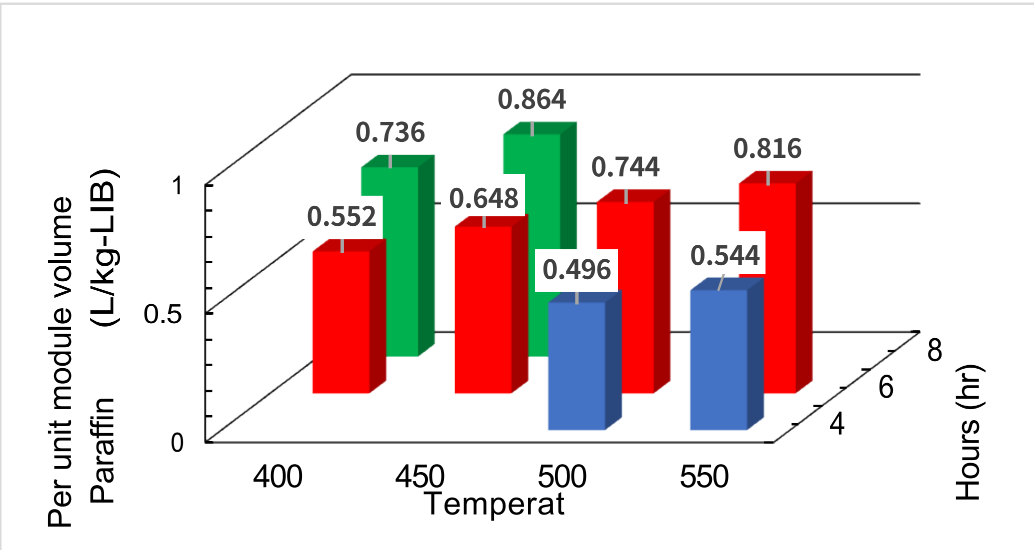


Figure 1-10. Kerosene consumption per unit module volume by level

(2) Confirmation of impact on fuel use per input.

A comparison of kerosene consumption by input volume confirms that increasing the input volume reduces kerosene consumption.

Table 1-6. Kerosene consumption per input

level (Input). (kg)	Roasting conditions	Paraffin consumptio n		Temperature measurement	
		Kerosene consumption per unit time (L/hr)	Kerosene consumption per unit module volume [illegible]	Furnace temperat ure	Exhaust gas temperatur

(3) Check residual power impact.

In order to confirm the effect of residual power in the LIB module on roasting, roasting tests were conducted with and without discharge, and the temperature inside the basket and the amount of paraffin used during roasting differed depending on whether the LIB module was discharged or not, confirming that differences in residual power (with or without discharge) had an effect on the roasting process. This confirmed that the difference in residual power (with and without discharge) had an effect on the roasting process.

In addition, a comparison of paraffin consumption showed that paraffin consumption was lower without discharge. This is presumably due to the contribution of residual electricity as fuel.

Table 1-7 Photographs of LIB module roasting experiments with and without discharge

	
pre-roasting (left: discharged, right:	after roasting (Top: discharged, bottom:

(Note: Filmed at Hiroshima Gas Techno Service).

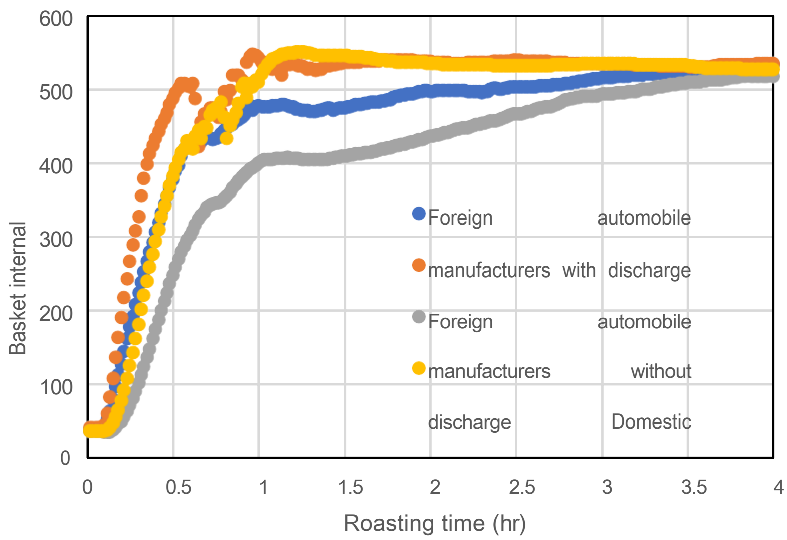


Figure 1-11. Temperature inside the basket with and without discharge

(Remarks) The roasting temperature is 500°C.

Table 1-8. Kerosene consumption by presence of discharge

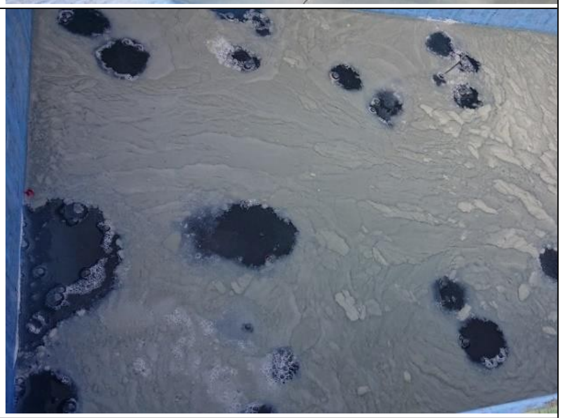
level	input (kg)	Roasting conditions	during normal operation	
			Kerosene consumption per unit time (L/hr)	Kerosene consumption per unit module volume (L/kg-LIB)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

(Reference) Submerged test results of LIB modules.

In order to discharge the LIB modules, domestic and foreign automobile manufacturers ☆ LIB modules ☆ ☆ were submerged in water. When the submerged treatment was carried out, bubbles were generated immediately after submergence, and white or yellow turbidity covered the water surface.

Wastewater ☆ Component analysis showed that effluent standards ☆ were exceeded for six items (BOD, COD, F, Cu, Zn and Cr). This ☆ indicates that submerged treatment of LIB modules must be carried out in a facility equipped with wastewater treatment facilities ☆.

Table 1-9. Photographs of spent LIB modules submerged in water

Domestic automakers	foreign automobile manufacturer
	
	

(4) Confirmation of the influence of LIB module type and continuous roasting furnace operation with a wide variety of LIB modules.

In order to confirm the ☆ influence on the roasting process by the LIB module ☆ type, and to confirm the ☆ roasting results in the continuous roasting furnace operation using many kinds of ☆ LIB modules, a demonstration experiment was conducted using various kinds of ☆ LIB modules. As a result, a large amount of base metals could be recovered at 1 mm or more as targeted regardless of the type of LIB module ☆ but the recovery of rare metals remained at around 50 % as in the previous year.

☆ operational know-how was gained, such as not mixing ☆ and bad ☆.

When paraffin consumption was compared between roasting a single ☆ type and roasting a mixture of many different types, ☆ paraffin consumption per unit was lower when roasting in the mixed state.

☆ ☆ ☆ Other lithium ☆ behaviour was confirmed in a continuous roasting furnace operation using many types of ☆ LIB modules, and it was confirmed that the lithium ☆ did not fly into the exhaust gas.

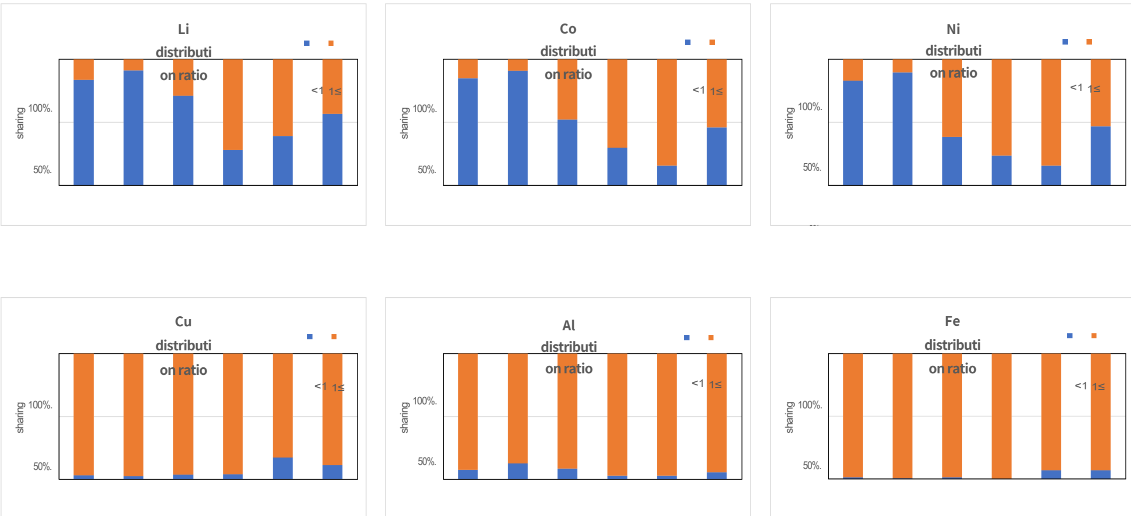


Figure 1-12. Percentage distribution of recovered resources by LIB module type

(Remarks: Roasting conditions: 500°C-4hr)

Table 1-10. Kerosene consumption by LIB module type and in continuous operation

level	Manufacturer used	cathode material	cell shape	Cell housing material	Module size (mm)	Operating conditions (batch or continuous, roasting time)
For in-vehicle use 1	outside the country	NCM (Mn rich).	corner (e.g. desk, pavement)	aluminium	410*300*150	Batch, 4hr.

level	Manufacturer used	Kerosene consumption per unit time (L/hr)	unit module quantity Paraffin consumption per (L/kg-LIB)	Furnace temperature (°C)	Exhaust gas temperature (°C)
For in-vehicle use 1	outside the country	26	0.41	511	489
For in-vehicle use 2	domestic	31	0.50	505	494
Automotive 3	domestic	32	0.63	507	486
Automotive 4	domestic	25	0.38	521	500
fixed	domestic	28	0.45	518	496
mixture (wide variety)	mixture	11	0.09	541	503

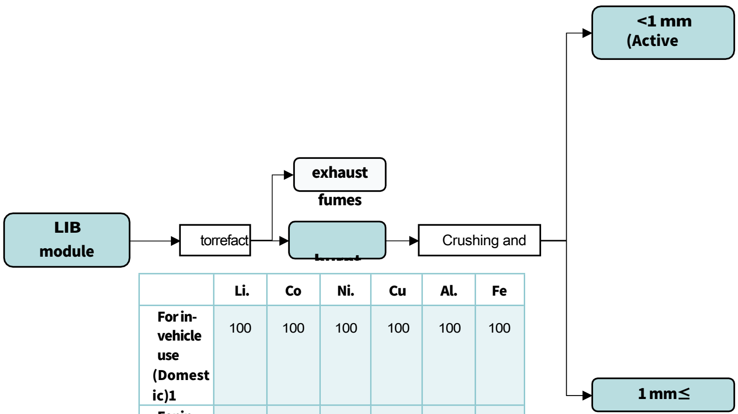
Table 1-11. Lithium distribution rates by LIB module type and in continuous operation

level	Manufacturer used	Amount of lithium per tonne of LIB module (distribution ratio)		
		Less than 1 mm (%)	More than 1 mm (%)	Exhaust gas (%)
For in-vehicle use 1	outside the country	84	16	0

1.2.3 Experiments in resource recovery from roasting and burning materials.

For highly efficient recovery of base metal and polar powder (<1 mm) containing lithium and other materials from roasted materials.

As ☆ suitable crushing and sorting methods, shear crushing and sieve sorting, which were selected in last year's demonstration project, were used.LIB modules ☆ by type ☆ recovered metal ☆ material balance is shown below. Last year, the average ☆ lithium recovery rate was about 50%, but this year, depending on the input level, more than 80% ☆ lithium was successfully recovered in less than 1 mm. Highly efficient rare metal recovery is considered to be possible by devising the LIB module ☆ configuration to be fed.



	Li.	Co	Ni.	Cu	Al.	Fe
For in-vehicle use (Domestic)1	100	100	100	100	100	100
For in-vehicle use (Domestic)2	100	100	100	100	100	100
For in-vehicle use	100	100	100	100	100	100

<1 mm:

	Li.	Co	Ni.	Cu	Al.	Fe
For in-vehicle use (Domestic)1	84	85	83	3	8	1
For in-vehicle use (Domestic)2	91	91	90	3	13	1
For in-vehicle use (Outside the country) 3	71	52	38	4	9	1
For in-vehicle use (Domestic)4	28	30	24	4	3	0
fixed (Domestic)	39	16	16	17	3	7
consecutive (Mixed)	57	46	47	11	6	7

Last year:
Automotive (domestic) Li, Co, Ni = 53,53,54
Automotive (outside Japan) Li, Co, Ni = 53, 78, 50

1 mm≤:

	Li.	Co	Ni.	Cu	Al.	Fe
For in-vehicle use (Domestic)1	16	15	17	97	92	99
For in-vehicle use (Domestic)2	9	9	10	97	87	99
For in-vehicle use (Outside the country) 3	29	48	62	96	91	99
For in-vehicle use (Domestic)4	72	70	76	96	97	100
fixed (Domestic)	61	84	84	83	97	93
consecutive (Mixed)	43	54	53	89	94	93

Figure 1-13. Material balance of recovered metals by LIB module type

Table 1-12. Photographs of roasting and recovered material after crushing and sorting by

terms and conditions	<1 mm	1 m m≤
400°C 6hr.		
400°C 8hr.		
450°C 6hr.		
450°C 8hr.		

terms and conditi ons	<1 mm	1 m m≤
500°C. 4hr.		
500°C. 6hr.		
550°C 4hr.		

550°C 6hr.		

Table 1-13. Photographs of roasted LIB modules by type and recovered material after crushing

Type.	<1 mm	1 m m≤
For in-vehicle use 1		
For in-vehicle use 2		
For in-vehicle use 3		
For in-vehicle use 4		

Type.	<1 mm	1 m m≤
for station ary use		
mixtur e (Wide variety . Diverse)		

(Remarks: Roasting conditions: 500°C-4hr)

1.3 Overall design of treatment and recycling schemes

Based on the results of the demonstration experiment, the overall design of the spent LIB pack ☆ recycling flow was carried out and the recycling flow ☆ material balance was calculated. As a treatment flow for used LIB packs☆ , the LIBs in the pack state are dismantled by hand, the base metal and plastic are recovered, the LIBs are made into modules, and then roasted. The roasted materials are crushed by shearing, sieved, and the sorted and collected materials (less than 1 mm) are sorted and collected.

☆Polar powder is recycled as lithium and other ☆rare metal recycling, while ☆more than 1 mm is recycled as copper recycling. The scale of the ☆ processing scheme is based on the ☆ experimental data from this year, with a roasting processing volume of 3,000t/year (10t/day) as the axis.

The total amount of used LIB packs to be processed is estimated to be about 4,600 t/year, while the resources to be recovered are 744 t/year of polar powder and a total of about 3,140 t/year of base metals.

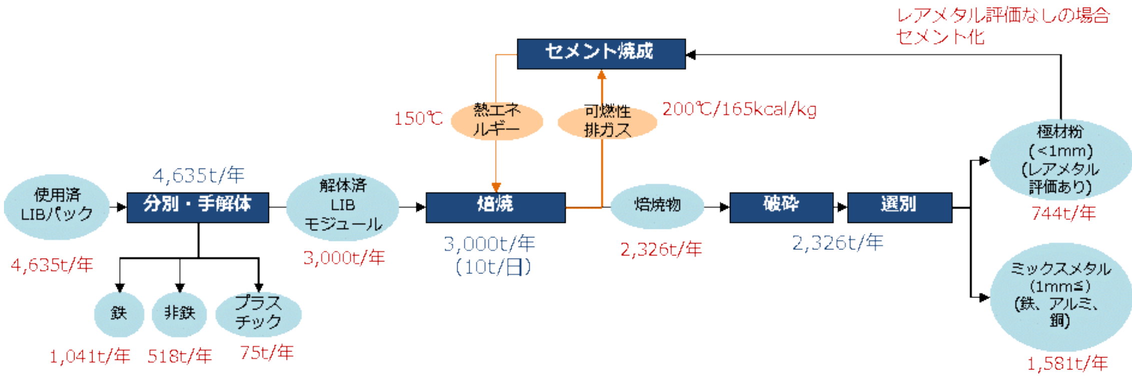
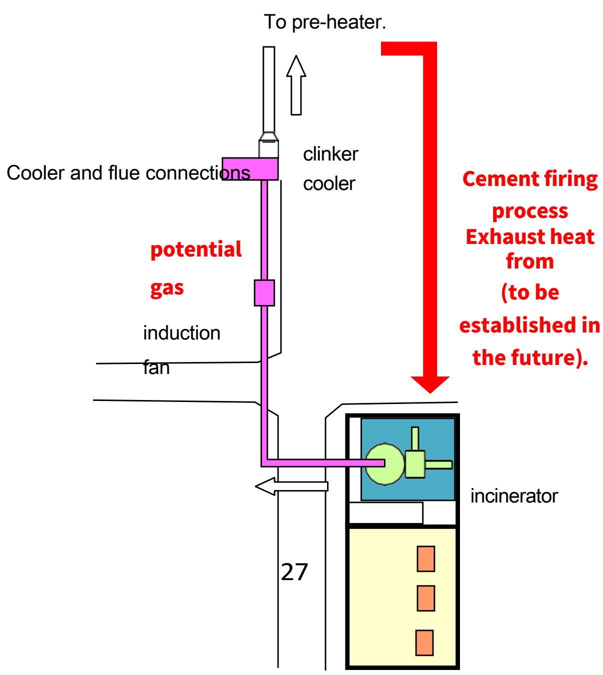


Figure 1-14. Overall design of treatment and recycling schemes

(Remark: LIB pack ☆ Material balance is a ☆ value for a mixture (of many varieties).

Roasting furnace to cement calcination furnace ☆ Combustible gas ☆ Properties 200°C/165 kcal/kg and cement calcination furnace to roasting furnace ☆ Thermal energy 150°C are based on the results of last year's study).



incinerator
flue gas
flue

LIB storage facilities

Figure 1-15. Design and operational approach for a low-carbon system using an adjacent cement calcination furnace.

2. Verification of environmental impact reduction benefits.

2.1 Examination of the effects of resource recycling

The recycling effect of the actual resource recovery from the content concentration is shown below. The resource recovery rate was approximately 30% for the Automotive 2, approximately 48% for the Automotive 4 and approximately 38% for the Mixed. This difference is not due to the recovery rate of rare metal ☆, but to the material composition ratio of LIB packs ☆.

In the previous year, the rate was approximately 61% for vehicle-mounted (average) use. The reason for the decrease in the resource recovery rate ☆ is thought to be due to the different amounts of ferrous and non-ferrous ☆ that make up the LIB packs. Therefore, the resource recovery rate of LIB packs ☆ is considered to depend on the ☆ content of the materials that make up the LIB packs.

In the case of rare metal recovery ☆ ☆ ☆ pole powder that is not expected to be recycled, it should be recycled as cement, or it should be recycled as a waste material. The recycling rate is 100%, as in the previous year, because the amount of landfill for any ☆ LIB packs in the project is zero.

Table 2-1. Results of the evaluation of resource recycling effects in the project

Unit: t/t		throughput	iron	non-ferrous (Aluminium)	plastic	Li.	Co	Ni.	Cu	(resource) recovery rate	recycling rate
For in-vehicle use LIB	Automotive 2 (domestic) - EVs	1.00	0.03	0.19	0.05	0.00E+00	0.00E+00	0.00E+00	0.07	33.2%.	100.0%.
	Automotive 4	1.00	0.24	0.08	0.00	9.77E-04	3.09E-03	6.67E-04	0.15	48.0%.	100.0%.

Unit: t/year		LIB pack throughput	iron	non-ferrous (Aluminium)	plastic	Li.	Co	Ni.	Cu	Volume of resources recovered
For in-vehicle use LIB	Automotive 2 (domestic) - EVs	4,083	107	781	195	0	0	0	272	1,355
	Automotive 4 (domestic) - HV	4,435	1,077	359	0	4	14	3	672	2,129
Mixed (wide variety)		4,573	1,019	481	81	0	0	0	151	1,732

(Note: Non-ferrous metals are assumed to be aluminium rated).

Table 2-2. Results of evaluation of resource recycling effects in H29 projects (indicative)

Unit: t/t		throughput	iron	non-ferrous (Aluminium)	plus chick	Li.	Co	Cu	(resource) recovery rate	recycling rate
Automotive LIBs	domestic	1.00	0.32	0.21	0.05	7.68E-04	1.94E-03	0.11	68.8%.	100.0%.
	outside the country	1.00	0.02	0.35	0.04	0.00E+00	0.00E+00	0.11	52.5%.	100.0%.
	average	1.00	0.17	0.28	0.05	7.19E-04.	3.37E-03	0.11	61.0%	100.0%.
Stationary LIB		1.00	–	–	–	2.39E-03	4.90E-03	6.80E-04	1.3%	100.0%.

Unit: t/year	throughpu	iron	non-ferrous (Aluminium	plus chick	Li.	Co	Cu	Volume of

		t		)					resources recovered
Automotive LIBs	domestic	7,000	2,222	1,444	333	5	14	799	4,818
	outside the country	5,111	111	1,778	222	0	0	574	2,685
	average	5,908	1,002	1,637	269	4	20	669	3,602
Stationary LIB		3,000	–	–	–	7	15	2	40

2.2 Study of the effects of reducing CO

In calculating the ☆ carbon dioxide reduction effect of the project scheme, the ☆ incineration process in a stationary furnace was set as the technology to be compared. Since it was difficult to obtain data on ☆ energy consumption in the ☆ treatment process before and after incineration in a stationary furnace, the hydrogen fluoride treatment process was excluded from the scope of calculation, assuming it to be the same as in the Project as a more conservative calculation. The recycling effect was included in the calculation only for the amount of resources ☆ that is actually assessed.

As a result of the trial calculation, the CO_2 emission reduction effect per tonne of LIB packs was calculated to be 171 kg-CO_2/t in the case of 2 ☆ for vehicle use, 242 kg-CO_2/t in the case of 2 ☆ for vehicle use and 434 kg-CO_2/t in the case of mixed (various types of) packs. Last year, the average value for vehicle-mounted LIB packs (average) was approximately 300 kg-CO_2/t, and therefore, for mixed (diverse)

emissions ☆ reduction results due to a reduction in kerosene use ☆ compared to

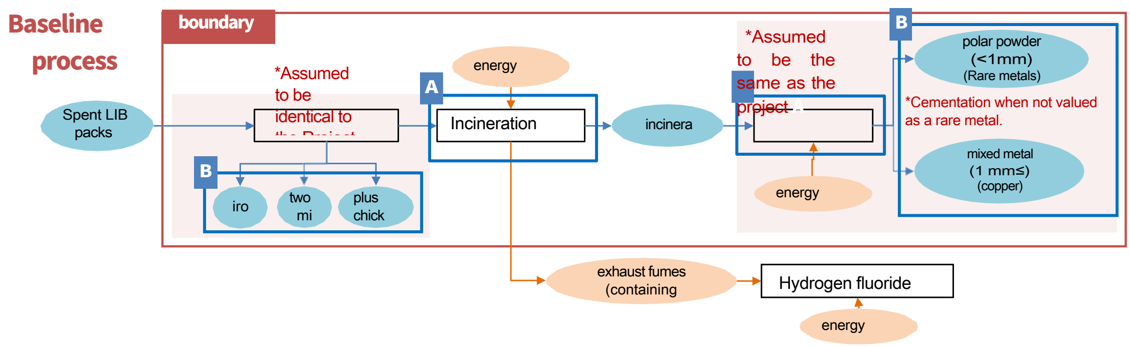


Figure 2-1. Baseline process (stationary furnace treatment)

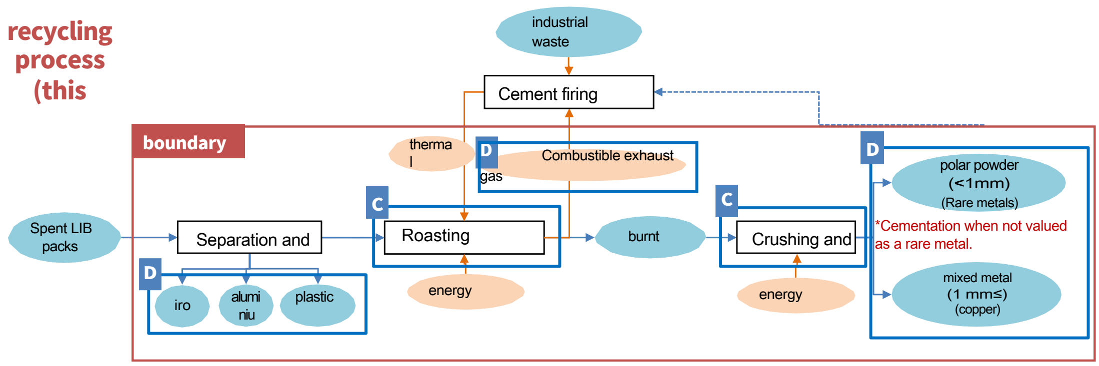


Figure 2-2. Recycling process of this demonstration project

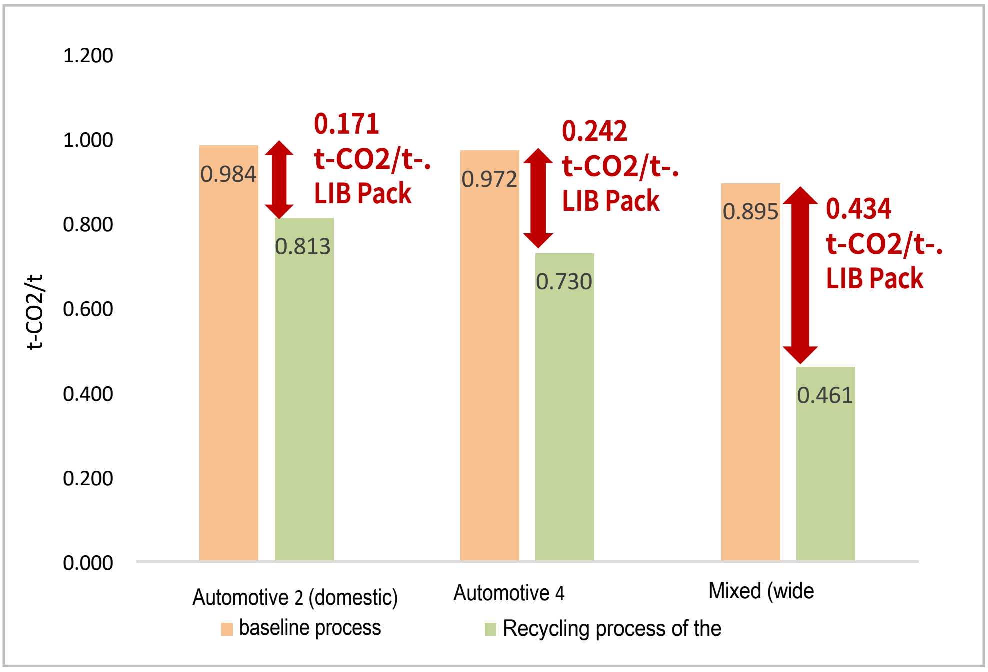


Figure 2-3. Comparison of CO2 emissions per tonne by LIB pack

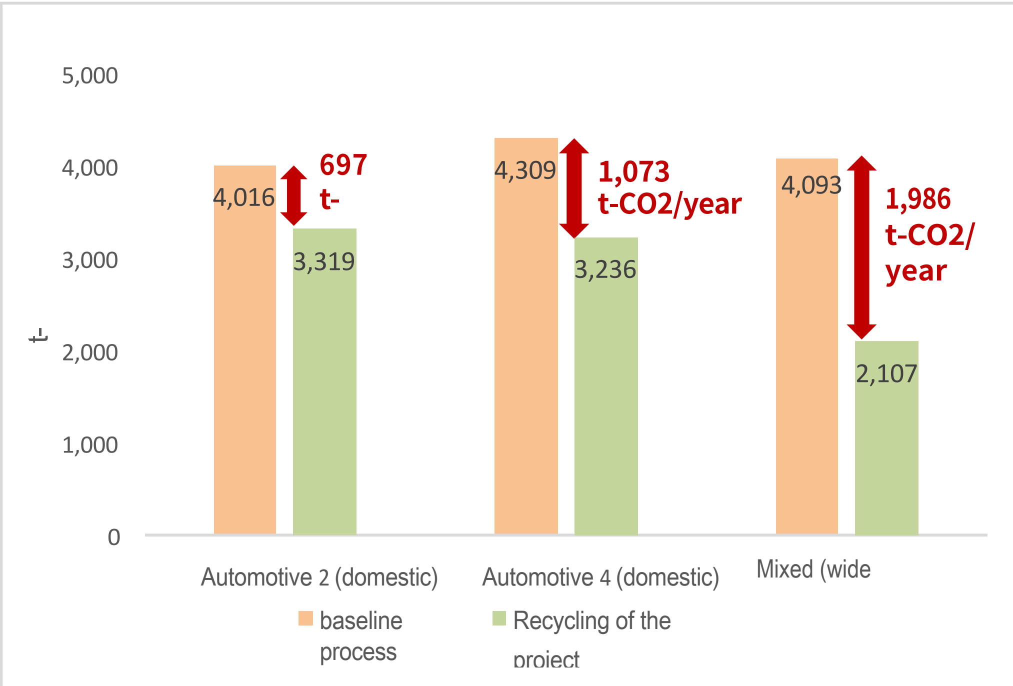


Figure 2-4. Comparison of CO2 emissions per unit of annual throughput by LIB pack

Table 2-3. CO2 emission reductions compared to the project and stationary furnace treatment (per tonne of LIB pack)

process	category	(data) item	Contents	Automotive 2 (domestic) emission (e.g. of CO2, etc.) t-CO2/t-LIB pack		Automotive 4 (domestic) emission (e.g. of CO2, etc.) t-CO2/t-LIB pack		Mixed (wide variety) emission (e.g. of CO2, etc.) t-CO2/t-LIB pack	
baseline process	A	process	Incineration (stationary furnaces)	0.953	0.985	0.945	0.973	0.868	0.896
			Crushing and sorting	0.032		0.028		0.028	
	B	recycling effect	Iron, aluminium and plastics	0.001	0.001	0.001	0.001	0.001	0.001
			Rare metals, copper	0.000		0.001		0.000	
	C	process	Roasting (roasting furnaces)	0.822	0.854	0.740	0.768	0.469	0.497
			Crushing and sorting	0.032		0.028		0.028	

Table 2-4. CO2 emission reductions compared to the project and stationary furnace treatment (per year of treatment)

process	category	(data) item	Contents	Automotive 2 (domestic) emission (e.g. of CO2, etc.) 4,083 t/year t-CO2/year		Automotive 4 (domestic) emission (e.g. of CO2, etc.) 4,435 t/year t-CO2/year		Mixed (wide variety) emission (e.g. of CO2, etc.) 4,573 t/year t-CO2/year	
baseline process	A	process	Incineration (stationary furnaces)	3,891	4,020	4,192	4,315	3,969	4,096
			Crushing and sorting	129		123		128	
	B	recycling effect	Iron, aluminium and plastics	3	4	2	6	3	3
			Rare metals, copper	1		3		0	
	C	process	Roasting (roasting furnaces)	3,357	3,487	3,282	3,405	2,147	2,274
			Crushing and sorting	129		123		128	

Table 2-5. Activity and CO_2 emissions intensity of stationary furnace treatment (per tonne of 2 (domestic) LIB packs for on-board use)

baseline process

category	NO	process	activity level			emission intensity			emission (e.g. of CO_2, etc.) (tCO_2/t)
			item name	numerical value	unit	atomic unit name	numerical value	unit	
A	1	Incineration (stationary furnaces)	Recycled heavy oil B consumption per tonne of LIB pack	0.184	kL/t-LIB pack	CO2 emission factor for the use of recycled heavy oil B.	3.000000	tCO2/kL	0.551087
	2		Per tonne of LIB packs initially fed Amount of waste plastic treated in the process concerned.	0.158	t/t-LIB packs	CO2 emission factors for the combustion of waste plastics.	2.550000	tCO2/t	0.401881
	3	Crushers (shearing type)	Electricity consumption per tonne of LIB pack	44.443	kWh/t-LIB pack	CO2 emission factor for electricity use.	0.000512	tCO2/kwh	0.022755
	4	dust collector	Electricity consumption per tonne of LIB	16.161	kWh/t-LIB pack	CO2 emission factor for electricity use.	0.000512	tCO2/kwh	0.008274

Baseline process recycling effectiveness.

category	NO	process	activity level			emission intensity			emission (e.g. of CO_2, etc.) (tCO_2/t)
			item name	numerical value	unit	atomic unit name	numerical value	unit	
B	1	iron recovery (Crude steel alternative)	Iron recovery per tonne of LIB packs	0.026	t/t-LIB packs	CO2 emissions per tonne of crude steel produced	0.001190	tCO2/t	0.000031
	2	aluminum recovery (Aluminium recycled ingot substitute)	Amount of aluminium recovered from 1t of LIB packs	0.191	t/t-LIB packs	CO2 emissions per tonne of recycled aluminium ingot produced amount	0.003130	tCO2/t	0.000599
	3	plastic (plastics) recovery (PP banding alternative).	Collected from 1t of LIB packs. plastic volume	0.048	t/t-LIB packs	CO2 emissions per tonne of PP banded production.	0.000446	tCO2/t	0.000021
	4	lithium recovery (Electric lithium alternative)	Amount of lithium recovered from 1 tonne of LIB packs	0.000	t/t-LIB packs	CO2 emissions per tonne of electric lithium production	0.082300	tCO2/t	0.000000
	5	cobalt recovery (Electric cobalt substitute)	Amount of cobalt recovered from 1t of LIB packs	0.000	t/t-LIB packs	CO2 emissions per tonne of electrolytic cobalt production	0.018800	tCO2/t	0.000000
	6	Nickel recovery (Electric nickel alternative)	Amount of nickel recovered from 1t of LIB packs	0.000	t/t-LIB packs	CO2 emissions per tonne of electrolytic nickel produced	0.007980	tCO2/t	0.000000
	7	copper recovery (Electrolytic copper alternative)	Amount of copper recovered from 1t of LIB packs	0.068	t/t-LIB packs	CO2 emissions per tonne of electrolytic copper produced	0.003670	tCO2/t	0.000251
	total amount								**0.001**

Table 2-6 Activity and CO2 emissions intensity of stationary furnace treatment (per tonne of vehicle-mounted 4 (domestic) LIB packs)

baseline process

category	NO	process	activity level			emission intensity			emission (e.g. of CO2, etc.) (tCO2/t)
			item name	numerical value	unit	atomic unit name	numerical value	unit	
A	1	Incineration (stationary furnaces)	Recycled heavy oil B consumption per tonne of LIB pack	0.169	kL/t-LIB pack	CO2 emission factor for the use of recycled heavy oil B.	3.000000	tCO2/kL	0.507282
	2		Per tonne of LIB packs initially fed Amount of waste plastic treated in the process concerned.	0.172	t/t-LIB packs	CO2 emission factors for the combustion of waste plastics.	2.550000	tCO2/t	0.437878
	3	Crushers (shearing type)	Electricity consumption per tonne of LIB pack	38.859	kWh/t-LIB pack	CO2 emission factor for electricity use.	0.000512	tCO2/kwh	0.019896
	4	dust collector	Electricity consumption per tonne of LIB pack	14.130	kWh/t-LIB pack	CO2 emission factor for electricity use.	0.000512	tCO2/kwh	0.007235
	5	Sorting (sifting)	Electricity consumption per tonne of LIB pack	1.060	kWh/t-LIB pack	CO2 emission factor for electricity use.	0.000512	tCO2/kwh	0.000543
	total amount								**0.973**

Baseline process recycling effectiveness.

category	NO	process	activity level			emission intensity			emission (e.g. of CO2, etc.) (tCO2/t)
			item name	numerical value	unit	atomic unit name	numerical value	unit	
B	1	iron recovery (Crude steel alternative)	Iron recovery per tonne of LIB packs	0.243	t/t-LIB packs	CO2 emissions per tonne of crude steel produced	0.001190	tCO2/t	0.000289
	2	aluminum recovery (Aluminium recycled ingot substitute)	Amount of aluminium recovered from 1t of LIB packs	0.081	t/t-LIB packs	CO2 emissions per tonne of recycled aluminium ingot produced	0.003130	tCO2/t	0.000253
	3	plastic (plastics) recovery (PP banding alternative).	Collected from 1t of LIB packs. plastic volume	0.000	t/t-LIB packs	CO2 emissions per tonne of PP banded production	0.000446	tCO2/t	0.000000
	4	lithium recovery (Electric lithium alternative)	Amount of lithium recovered from 1 tonne of LIB packs	0.001	t/t-LIB packs	CO2 emissions per tonne of electric lithium production	0.082300	tCO2/t	0.000070
	5	cobalt recovery (Electric cobalt substitute)	Amount of cobalt recovered from 1t of LIB packs	0.003	t/t-LIB packs	CO2 emissions per tonne of electrolytic cobalt production	0.018800	tCO2/t	0.000051
	6	Nickel recovery (Electric nickel alternative)	Amount of nickel recovered from 1t of LIB packs	0.001	t/t-LIB packs	CO2 emissions per tonne of electrolytic nickel produced	0.007980	tCO2/t	0.000005

	7	copper recovery (Electrolytic copper alternative)	Amount of copper recovered from 1t of LIB packs	0.158	t/t-LIB packs	CO2 emissions per tonne of electrolytic copper produced	0.003670	tCO2/t	0.000580
	total amount								**0.001**

Table 2-7 Activity and CO2 emissions intensity of stationary furnace treatment (per tonne of mixed (multi-species) LIB packs)

baseline process

category	NO	process	activity level: item name	activity level: numerical value	activity level: unit	emission intensity: atomic unit name	emission intensity: numerical value	emission intensity: unit	emission (e.g. of CO2, etc.) (tCO2/t)
A	1	Incineration (stationary furnaces)	Recycled heavy oil B consumption per tonne of LIB pack	0.164	kL/t-LIB pack	CO2 emission factor for the use of recycled heavy oil B.	3.000000	tCO2/kL	0.491999
	2		Per tonne of LIB packs initially fed Amount of waste plastic treated in the process concerned.	0.147	t/t-LIB packs	CO2 emission factors for the combustion of waste plastics.	2.550000	tCO2/t	0.375785
	3	Crushers (shearing type)	Electricity consumption per tonne of LIB pack	39.165	kWh/t-LIB pack	CO2 emission factor for electricity use.	0.000512	tCO2/kwh	0.020052
	4	dust collector	Electricity consumption per tonne of LIB pack	14.242	kWh/t-LIB pack	CO2 emission factor for electricity use.	0.000512	tCO2/kwh	0.007292
	5	Sorting (sifting)	Electricity consumption per tonne of LIB pack	1.068	kWh/t-LIB pack	CO2 emission factor for electricity use.	0.000512	tCO2/kwh	0.000547
	total amount								**0.896**

Baseline process recycling effectiveness.

category	NO	process	activity level: item name	activity level: numerical value	activity level: unit	emission intensity: atomic unit name	emission intensity: numerical value	emission intensity: unit	emission (e.g. of CO2, etc.) (tCO2/t)
B	1	iron recovery (Crude steel alternative)	Iron recovery per tonne of LIB packs	0.223	t/t-LIB packs	CO2 emissions per tonne of crude steel produced	0.001190	tCO2/t	0.000265
	2	aluminum recovery (Aluminium recycled ingot substitute)	Amount of aluminium recovered from 1t of LIB packs	0.105	t/t-LIB packs	CO2 emissions per tonne of recycled aluminium ingot produced amount	0.003130	tCO2/t	0.000330
	3	plastic (plastics) recovery (PP banding alternative).	Collected from 1t of LIB packs. plastic volume	0.018	t/t-LIB packs	CO2 emissions per tonne of PP banded production.	0.000446	tCO2/t	0.000008
	4	lithium recovery (Electric lithium alternative)	Amount of lithium recovered from 1 tonne of LIB packs	0.000	t/t-LIB packs	CO2 emissions per tonne of electric lithium production	0.082300	tCO2/t	0.000000
	5	cobalt recovery (Electric cobalt substitute)	Amount of cobalt recovered from 1t of LIB packs	0.000	t/t-LIB packs	CO2 emissions per tonne of electrolytic cobalt production	0.018800	tCO2/t	0.000000

	6	Nickel recovery (Electric nickel alternative)	Amount of nickel recovered from 1t of LIB packs	0.000	t/t-LIB packs	CO2 emissions per tonne of electrolytic nickel produced	0.007980	tCO2/t	0.000000
	7	copper recovery (Electrolytic copper alternative)	CO2 emissions per tonne of electrolytic copper produced	0.004	tCO2/t	CO2 emissions per tonne of electrolytic copper produced	0.003670	tCO2/t	0.000013
	total amount								**0.001**

Table 2-8 Activity volume and CO2 emissions intensity of the project (per tonne of 2 (domestic) LIB packs for on-board use)

Recycling process for demonstration projects.

category	NO	process	activity level item name	numerical value	unit	emission intensity atomic unit name	numerical value	unit	emission (e.g. of CO2, etc.) (tCO2/t)
C	1	incinerator	Kerosene consumption per tonne of LIB pack	0.153	kL/t-LIB pack	CO2 emission factor for paraffin use.	2.490000	tCO2/kL	0.380730
	2		Per tonne of LIB packs initially fed Amount of waste plastic treated in the process concerned.	0.158	t/t-LIB packs	CO2 emission factors for the combustion of waste plastics.	2.550000	tCO2/t	0.401881
	3	ventilation fan	Electricity consumption per tonne of LIB pack	77.593	kWh/t-LIB pack	CO2 emission factor for electricity use.	0.000512	tCO2/kwh	0.039728
	4	Crushers (shearing type)	Electricity consumption per tonne of LIB pack	44.443	kWh/t-LIB pack	CO2 emission factor for electricity use.	0.000512	tCO2/kwh	0.022755

Recycling effectiveness of the recycling process in the demonstration project.

category	NO	process	activity level item name	numerical value	unit	emission intensity atomic unit name	numerical value	unit	emission (e.g. of CO2, etc.) (tCO2/t)
D	1	iron recovery (Crude steel alternative)	Iron recovery per tonne of LIB packs	0.026	t/t-LIB packs	CO2 emissions per tonne of crude steel produced	0.001190	tCO2/t	0.000031
	2	aluminum recovery (Aluminium recycled ingot substitute)	Amount of aluminium recovered from 1t of LIB packs	0.191	t/t-LIB packs	CO2 emissions per tonne of recycled aluminium ingot produced amount	0.003130	tCO2/t	0.000599
	3	plastic (plastics) recovery (PP banding alternative).	Collected from 1t of LIB packs. plastic volume	0.048	t/t-LIB packs	CO2 emissions per tonne of PP banded production.	0.000446	tCO2/t	0.000021
	4	lithium recovery (Electric lithium alternative)	Amount of lithium recovered from 1 tonne of LIB packs	0.000	t/t-LIB packs	CO2 emissions per tonne of electric lithium production	0.082300	tCO2/t	0.000000
	5	cobalt recovery (Electric cobalt substitute)	Amount of cobalt recovered from 1t of LIB packs	0.000	t/t-LIB packs	CO2 emissions per tonne of electrolytic cobalt production	0.018800	tCO2/t	0.000000
	6	Nickel recovery (Electric nickel alternative)	Amount of nickel recovered from 1t of LIB packs	0.000	t/t-LIB packs	CO2 emissions per tonne of electrolytic nickel produced	0.007980	tCO2/t	0.000000
	7	copper recovery (Electrolytic copper alternative)	Amount of copper recovered from 1t of LIB packs	0.068	t/t-LIB packs	CO2 emissions per tonne of electrolytic copper produced	0.003670	tCO2/t	0.000251

	8	exhaust fumes	Replacement rate per tonne of LIB pack	0.017	t/t	CO2 emission factor in coal (general coal).	2.330000	tCO2/t	0.040096
	total amount								**0.041**

Table 2-9 Activity volume and CO2 emissions intensity of the project (per tonne of vehicle-mounted 4 (domestic) LIB packs)

Recycling process for demonstration projects.

category	NO	process	activity level: item name	activity level: numerical value	activity level: unit	emission intensity: atomic unit name	emission intensity: numerical value	emission intensity: unit	emission (e.g. of CO2, etc.) (tCO2/t)
C	1	incinerator	Kerosene consumption per tonne of LIB pack	0.107	kL/t-LIB pack	CO2 emission factor for paraffin use.	2.490000	tCO2/kL	0.265591
	2		Per tonne of LIB packs initially fed Amount of waste plastic treated in the process concerned.	0.172	t/t-LIB packs	CO2 emission factors for the combustion of waste plastics.	2.550000	tCO2/t	0.437878
	3	ventilation fan	Electricity consumption per tonne of LIB pack	71.425	kWh/t-LIB pack	CO2 emission factor for electricity use.	0.000512	tCO2/kwh	0.036570
	4	Crushers (shearing type)	Electricity consumption per tonne of LIB pack	38.859	kWh/t-LIB pack	CO2 emission factor for electricity use.	0.000512	tCO2/kwh	0.019896
	5	dust collector	Electricity consumption per tonne of LIB pack	14.130	kWh/t-LIB pack	CO2 emission factor for electricity use.	0.000512	tCO2/kwh	0.007235
	6	Sorting (sifting)	Electricity consumption per tonne of LIB pack	1.060	kWh/t-LIB pack	CO2 emission factor for electricity use.	0.000512	tCO2/kwh	0.000543
	total amount								**0.768**

Recycling effectiveness of the recycling process in the demonstration project.

category	NO	process	activity level: item name	activity level: numerical value	activity level: unit	emission intensity: atomic unit name	emission intensity: numerical value	emission intensity: unit	emission (e.g. of CO2, etc.) (tCO2/t)
D	1	iron recovery (Crude steel alternative)	Iron recovery per tonne of LIB packs	0.243	t/t-LIB packs	CO2 emissions per tonne of crude steel produced	0.001190	tCO2/t	0.000289
	2	aluminum recovery (Aluminium recycled ingot substitute)	Amount of aluminium recovered from 1t of LIB packs	0.081	t/t-LIB packs	CO2 emissions per tonne of recycled aluminium ingot produced	0.003130	tCO2/t	0.000253
	3	plastic (plastics) recovery (PP banding alternative).	Collected from 1t of LIB packs. plastic volume	0.000	t/t-LIB packs	CO2 emissions per tonne of PP banded production	0.000446	tCO2/t	0.000000
	4	lithium recovery (Electric lithium alternative)	Amount of lithium recovered from 1 tonne of LIB packs	0.001	t/t-LIB packs	CO2 emissions per tonne of electric lithium produced	0.082300	tCO2/t	0.000070
	5	cobalt recovery (Electric cobalt substitute)	Amount of cobalt recovered from 1t of LIB packs	0.003	t/t-LIB packs	CO2 emissions per tonne of electrolytic cobalt production	0.018800	tCO2/t	0.000051

	6	Nickel recovery (Electric nickel alternative)	Amount of nickel recovered from 1t of LIB packs	0.001	t/t-LIB packs	CO2 emissions per tonne of electrolytic nickel produced	0.007980	tCO2/t	0.000005
	7	copper recovery (Electrolytic copper alternative)	Amount of copper recovered from 1t of LIB packs	0.158	t/t-LIB packs	CO2 emissions per tonne of electrolytic copper produced	0.003670	tCO2/t	0.000580
	8	exhaust fumes	Replacement rate per tonne of LIB pack	0.016	t/t	CO2 emission factor in coal (general coal).	2.330000	tCO2/t	0.036909
	total amount								**0.038**

Table 2-10 Activities and CO2 emissions intensity of the project (per tonne of mixed (multi-species) LIB packs)

Recycling process for demonstration projects.

category	NO	process	activity level: item name	activity level: numerical value	activity level: unit	emission intensity: atomic unit name	emission intensity: numerical value	emission intensity: unit	emission (e.g. of CO2, etc.) (tCO2/t)
C	1	incinerator	Kerosene consumption per tonne of LIB pack	0.023	kL/t-LIB pack	CO2 emission factor for paraffin use.	2.490000	tCO2/kL	0.058160
	2		Per tonne of LIB packs initially fed Amount of waste plastic treated in the process concerned.	0.147	t/t-LIB packs	CO2 emission factors for the combustion of waste plastics.	2.550000	tCO2/t	0.375785
	3	ventilation fan	Electricity consumption per tonne of LIB pack	69.273	kWh/t-LIB pack	CO2 emission factor for electricity use.	0.000512	tCO2/kwh	0.035468
	4	Crushers (shearing type)	Electricity consumption per tonne of LIB pack	39.165	kWh/t-LIB pack	CO2 emission factor for electricity use.	0.000512	tCO2/kwh	0.020052
	5	dust collector	Electricity consumption per tonne of LIB pack	14.242	kWh/t-LIB pack	CO2 emission factor for electricity use.	0.000512	tCO2/kwh	0.007292
	6	Sorting (sifting)	Electricity consumption per tonne of LIB pack	1.068	kWh/t-LIB pack	CO2 emission factor for electricity use.	0.000512	tCO2/kwh	0.000547
	total amount								**0.497**

Recycling effectiveness of the recycling process in the demonstration project.

category	NO	process	activity level: item name	activity level: numerical value	activity level: unit	emission intensity: atomic unit name	emission intensity: numerical value	emission intensity: unit	emission (e.g. of CO2, etc.) (tCO2/t)
D	1	iron recovery (Crude steel alternative)	Iron recovery per tonne of LIB packs	0.223	t/t-LIB packs	CO2 emissions per tonne of crude steel produced	0.001190	tCO2/t	0.000265
	2	aluminum recovery (Aluminium recycled ingot substitute)	Amount of aluminium recovered from 1t of LIB packs	0.105	t/t-LIB packs	CO2 emissions per tonne of recycled aluminium ingot produced amount	0.003130	tCO2/t	0.000330
	3	plastic (plastics) recovery (PP banding alternative).	Collected from 1t of LIB packs. plastic volume	0.018	t/t-LIB packs	CO2 emissions per tonne of PP banded production.	0.000446	tCO2/t	0.000008
	4	lithium recovery (Electric lithium alternative)	Amount of lithium recovered from 1 tonne of LIB packs	0.000	t/t-LIB packs	CO2 emissions per tonne of electric lithium production	0.082300	tCO2/t	0.000000

	5	cobalt recovery (Electric cobalt substitute)	Amount of cobalt recovered from 1t of LIB packs	0.000	t/t-LIB packs	CO2 emissions per tonne of electrolytic cobalt production	0.018800	tCO2/t	0.000000
	6	Nickel recovery (Electric nickel alternative)	Amount of nickel recovered from 1t of LIB packs	0.000	t/t-LIB packs	CO2 emissions per tonne of electrolytic nickel produced	0.007980	tCO2/t	0.000000
	7	copper recovery (Electrolytic copper alternative)	Amount of copper recovered from 1t of LIB packs	0.037	t/t-LIB packs	CO2 emissions per tonne of electrolytic copper produced	0.003670	tCO2/t	0.000136
	8	exhaust fumes	Replacement rate per tonne of LIB pack	0.015	t/t	CO2 emission factor in coal (general coal).	2.330000	tCO2/t	0.035797
	total amount								**0.037**

Table 2-11. List of sources of emission factors used in the estimation of CO

data item	process	
CO2 emissions per tonne of crude steel produced	Iron recovery (crude steel replacement)	CFP Programme 'Database of common intensity of CO2 conversion'.
CO2 emissions per tonne of recycled aluminium ingot produced	Aluminium recovery (recycled aluminium ingot substitute)	
CO2 emissions per tonne of electrolytic copper produced	Copper recovery (electrolytic copper replacement)	
CO2 emissions per tonne of electric lithium produced	Lithium recovery (electric lithium replacement)	
CO2 emissions per tonne of electrolytic cobalt production	Cobalt recovery (electro-cobalt substitution)	
CO2 emissions per tonne of electrolytic nickel produced	Nickel recovery (electro-nickel substitution)	
CO2 emissions per tonne of PP banded production.	Plastic recovery (alternative to PP banding)	
CO2 emission factor for the use of recycled heavy oil B.	Incineration (stationary furnaces)	Ministry of the Environment, 'List of calculation methods and emission factors in the calculation, reporting and publication system'.
CO2 emission factor for paraffin use.	incinerator	
CO2 emission factor for electricity use.	ventilation fan	'List of emission factors by electric utility (H29 results - alternative values)' - H29 results Published by the Ministry of the Environment and the Ministry of Economy, Trade and Industry on 27.12.H30
	Crushers (shearing type)	
	dust collector	
	Sorting (sifting)	

2.3 Study of CO2 emissions from the collection of used LIB packs

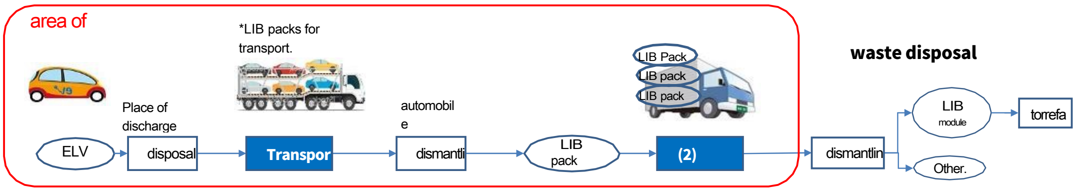
A model case was also set up to calculate the amount of CO The calculation range was defined as the period from the disposal of the vehicle at the dealership to the vehicle dismantler, where the LIB packs are removed and taken to a manual dismantling yard.

For the ☆ loading situation during transport, two patterns were set up: ideal loading and inefficient loading ☆. The ☆ closest to the current ☆ reality is the ☆ inefficient loading ☆ one.

As for the vehicles to be transported, a 9-tonne trailer was set for transport 1), which is brought from the dealer to the auto dismantler, and for transport 2), which is brought from the auto dismantler to the manual dismantling yard, a 2-tonne truck and a 4-tonne truck were used ☆ Two patterns were set for transport 2).

As a result of the calculation using the improved ton-kilometre method, ☆ CO2 emissions per tonne of LIB packs were reduced to about 50 kg under ideal loading, but 128 kg and 167 kg under the current ☆ inefficient loading, which is almost the same as the CO2 emissions for processing a single type of ☆ LIB packs.

Draft model for studying CO2 emissions from LIB pack collection.



	Scope of calculation	cargo	transport vehicle	loading conditions	loading capacity	mileage
ideal load	transport (i)	ELV		6 ELVs per trailer. (6 LIB packs)	6 units	50 km
	transport (ii)	LIB Pack	 	Maximum loading on transport vehicles (4t, 2t) *1	4t: max 50 pcs. 2t: 25 max.	100 km
inefficient product 10^4 4	transport (i)	ELV		1 ELV per trailer. (1 LIB pack)	one (object)	50 km
	transport (ii)	LIB Pack	 	Minimum loading on transport vehicles (4t, 2t) *2	4t: 1 pc. 2t: 1 piece	100 km

*1: Maximum loading capacity taking into account pallet size and safe transport configuration; LIB packs are assumed to be of medium size.
*2: This is set as the minimum loading capacity, as car dismantlers do not have a covered storage area and therefore carry out the removal from one vehicle.

Figure 2-5. Model to study CO2 emissions from the collection of used LIB packs
(Remark: assuming ELVs 1.5 t/unit and LIB packs 50 kg/unit)

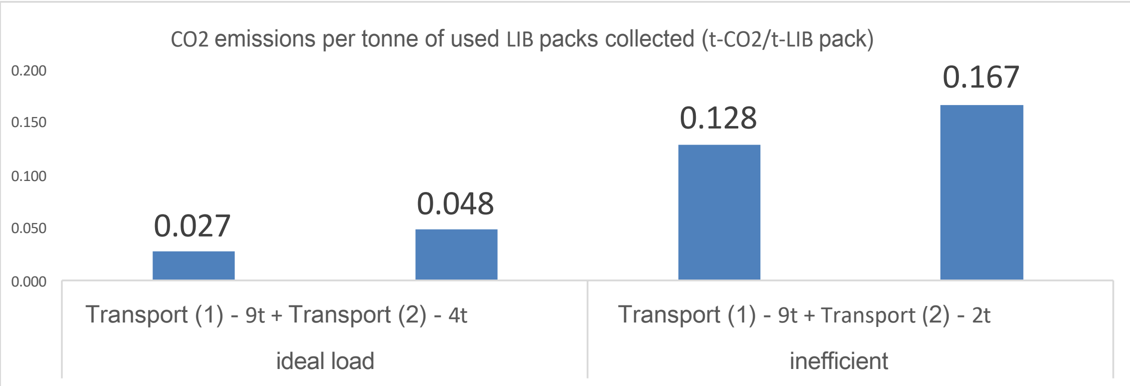


Figure 2-6. CO2 emissions from the collection of used LIB packs

◆ Ideal loading

Table 2-12. Basis for calculation of CO2 emissions from collection of used LIB packs

category	process	Activities /units of activity	reference number	data item	numerical value	unit	Formula, description.	source (e.g. quotation)
Transport ①. 9t trailer	Transport ①.			ELV loading weight of trucks (trailers)	9	t/unit.	1.5t x 6 vehicles	estimated value
				ELV loading rate of trucks (trailers)	100%.	%/unit	6 units/unit	estimated value
				LIB packs as a percentage of the loaded weight of the truck (trailer)	0.3	t/unit.	50 kg/unit x 6 units	estimated value
				Volume of transport of Transit Distance	50	km/turn	movement within the prefecture	estimated value
		activity level	C001	Quantity transported per tonne of ELV	450	tkm	Loaded weight x transport distance	
		intensity		CO2 emissions intensity of diesel oil	2.5800	tCO2/kL	Emissions intensity	1)
		intensity	C002.	Fuel (diesel) consumption per tkm	0.039	L/tkm	Median 9t vehicle, 100% load factor	2)

category	process	Activity/. intensity	reference number	data item	numerical value	unit	Formula, description.	source (e.g. quotation)
Transport (ii) 4t truck.	(2) Transportation			Truck (4t) LIB pack loading weight	2.5	t/unit.	Prerequisite.	estimated value
				Truck loading rate	63%.	%/unit	4t	estimated value
				Transit Distance	100	km/turn	movement within the prefecture	estimated value
		activity level	C001	Quantity transported per tonne of ELV	250	tkm	Loaded weight x transport distance	
		intensity		CO2 emissions intensity of diesel oil	2.5800	tCO2/kL	Emissions intensity	1)
		intensity	C002.	Fuel (diesel) consumption per tkm	0.0867	L/tkm	Median 5t vehicle, 60% load factor	2)

category	process	Activity/. intensity	reference number	data item	numerical value	unit	Formula, description.	source (e.g. quotation)
Transport (ii) 2t truck	(2) Transportation			Truck (2t) LIB pack loading weight	1.0	t/unit.	Prerequisite.	estimated value
				Truck loading rate	50%.	%/unit	2t	estimated value
				Transit Distance	100	km/turn	movement within the prefecture	estimated value
		activity level	C001	Quantity transported per tonne of ELV	100	tkm	Loaded weight x transport distance	
		intensity		CO2 emissions intensity of diesel oil	2.5800	tCO2/kL	Emissions intensity	1)
		intensity	C002.	Fuel (diesel) consumption per tkm	0.1680	L/tkm	Median 3t vehicle, 40% load factor	2)

◆ inefficient

category	process	Activity/. intensity	reference number	data item	numerical value	unit	Formula, description.	source (e.g. quotation)
Transport ①. 9t trailer / Transport (ii) 4t truck.	Transport ①. / Transportation			ELV loading weight of trucks (trailers) / Truck loading rate	1%	t/unit / %/unit	1.5t x 6 vehicles / 4t	estimated value
				ELV loading rate of trucks (trailers) / Transit Distance	100	%/unit / km/turn	6 units/unit / movement within the prefecture	estimated value
		activity level	C001	Quantity transported per tonne of ELV	5	tkm	Loaded weight x transport distance	
		intensity		CO2 emissions intensity of diesel oil	2.5800	tCO2/kL	Emissions intensity	1)
		intensity	C002.	Fuel (diesel) consumption per tkm	0.3710	L/tkm	Median 5t vehicle, 10% load factor	2)

category	process	Activity/. intensity	reference number	data item	numerical value	unit	Formula, description.	source (e.g. quotation)
Transport (ii) 2t truck	(2) Transportation			Truck (2t) LIB pack loading weight	0.1	t/unit.	Prerequisite.	estimated value
				Truck loading rate	3%.	%/unit	2t	estimated value
				Transit Distance	100	km/turn	movement within the prefecture	estimated value
		activity level	C001	Quantity transported per tonne of ELV	5	tkm	Loaded weight x transport distance	
		intensity		CO2 emissions intensity of diesel oil	2.5800	tCO2/kL	Emissions intensity	1)
		intensity	C002.	Fuel (diesel) consumption per tkm	0.5190	L/tkm	Median 3t vehicle, 10% load factor	2)

(Remark: emission factors etc. ☆ Source: ☆ below.

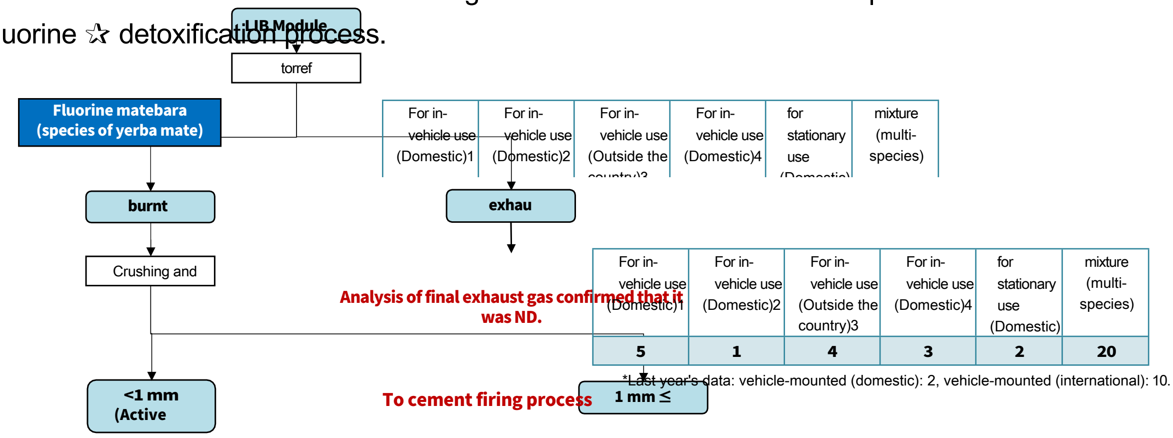
1) Ministry of the Environment, 'List of calculation methods and emission factors for calculation, reporting and publication systems (Reference 1)'.

2) Ministry of Economy, Trade and Industry (METI), Ministry of Land, Infrastructure, Transport and Tourism (MLIT), 'Joint Guidelines for Calculating CO_2 Emissions in the Logistics Sector Ver.

3.1 (July 2016)'

2.4 Study of the effect of reducing environmental impact due to exhaust emissions.

Exhaust gases (containing hydrogen fluoride)✰Low-cost detoxification treatment✰The behaviour of halogen elements (fluorine) in LIB packs was verified, and most of them were transferred to the polar powder less than 1 mm ✰. Some of it was transferred to the roasting exhaust gas, but this ✰ exhaust gas is sent to the cement calcination furnace for detoxification treatment. The results of the measurement of the final exhaust gas from the cement calcination plant ✰ confirmed the fluorine ✰ detoxification process.



For in-vehicle use (Domestic)1	For in-vehicle use (Domestic)2	For in-vehicle use (Outside the country)3	For in-vehicle use (Domestic)4	for stationary use (Domestic)	mixture (multi-species)	For in-vehicle use (Domestic)1	For in-vehicle use (Domestic)2	For in-vehicle use (Outside the country)3	For in-vehicle use (Domestic)4	for stationary use (Domestic)	mixture (multi-species)
95	99	96	97	98	80	0	0	0	0	0	0

Figure 2-7. Material balance of fluorine in the project

3. Verification of project feasibility through economic feasibility assessment

3.1 Economic evaluation of used LIB packs under the project scheme.

☆ per tonne of LIB packs ☆ The results of the balance of payments based on resource assessment and cost assessment are shown.

From the material balance by LIB module, lithium ☆ recovery efficiency at less than 1mm was good (2 for automotive/domestic) bad (4 for automotive/domestic) mixed (various types) ☆ 3
☆ Estimates were made in the ☆ case.

As a result of the trial calculation, Co and Ni in the automotive 4 ☆ pole powder (<1mm) were evaluated as valuable. On the other hand, neither the 2 ☆ pole powders for automotive use nor the mixed ☆ pole powder (<1 mm) were valorised and were judged to be used as cement raw materials.

The value of the rare metals in vehicle-mounted 4 was calculated to be ☆ about 40,000/t, but the cost of ☆ such as labour costs is expected to be ☆ about 180,000/t, resulting in a balance of ☆ -130,000/t.

In last year's ☆ result, the overall evaluation was expected to be around ▲100,000 ☆, but in this project it was calculated to be around ▲150,000 ☆. This is thought to be due to the different material composition ratio of LIB packs ☆, which changed the cost calculation result. In particular, when the amount of base metal in LIB packs decreased and the amount of LIB modules increased, LIB module ☆ transportation costs and roasting treatment costs increased, resulting in an overall increase in costs. The ☆ knowledge that the cost of LIB packs for vehicle-mounted LIBs varies greatly depending on the type of LIB, should be reflected in the setting of ☆ costs in actual operation.

The ☆ reduction in paraffin consumption this year was expected as a result of the demonstration results. Based on this ☆ reduction effect, we compared the economic evaluation of last year's ☆ LIB packs and modules before and after, and calculated that a cost reduction effect of ¥2,000/t ☆ could be achieved. We would like to continue to examine measures to reduce equipment costs and consumables costs ☆ for better economic evaluation.

Table 3-1. Overall economic evaluation of used LIB modules by type of resource value and cost

(Unit: yen/t)

		scrap metal		plastic	<1 mm					1 mm≤	resource assessment total	cost account	comprehensive evaluation
		iron (H2)	non-ferrous (Aluminium Gala)		Li.	Co	Ni.	Rare metal recovery decisions	actual amount	Cu			
Automotive LIBs	Automotive 2 (domestic) - EVs	570	22,000	-4,780	××-mark (used to	××-mark (used to	××-mark (us	××-mark (use	-5,600	9,990	22,160	-185,500	-163,000

(Remarks:

- Resources recovered by manual dismantling were quoted as H2 for ferrous metals and aluminium galas for non-ferrous metals, while plastics were recycled in view of the current situation.
- <1mm was assumed to be smelted at Co and Ni ☆ content concentrations, and Li was also recovered if either one was valued. (From smelting hearings).

- Li, Co, Ni ☆ For metal values, LME ☆ market valuation was used for Co and Ni (smelting costs taken into account) Li was excluded from the monetary valuation for the above ☆ setting reasons. (From smelting hearings)
- If the concentration was not assessed as valuable but metal recovery was possible, the material was classified as low-value valuable, and if the concentration was such that metal recovery was not possible, the material was classified as cemented (treatment costs required).
- 1 mm≤ was defined as copper assessment (iron and aluminium mixed) and the assessed amount was the amount of copper contained in the 1 mm≤ recovered amount, not the 1 mm≤ recovered amount.
- In terms of costs, labour costs, transport costs (modules, packs and roasting materials) equipment costs and consumables costs were considered.
- In the table above, base metals and plastics are in the last digit, rare metals and costumers are in the last two digits, and overall ratings are in the last two digits.
  3 digits ☆ truncated).

Table 3-2. Breakdown of total costs in spent LIB pack disposal schemes

(Unit: Yen)		labour cost	transportation costs	equipment cost	Consumables costs
Automotive LIBs	Automotive 2 (domestic) - EVs	-62,700	-82,300	-32,000	-8,400
	Automotive 4	-57,700	-78,000	-29,400	-7,900

Table 3-3. Comparison of the composition of used LIB packs and overall assessment of income and expenditure for this year and last year

H30.

Unit: t	pack	LIB Module	scrap metal		plastic	burnt offering (i.e. religious	<1 mm	1 mm≤
			iron	Non-ferrous*.				

(Unit: yen/t)		scrap metal		plastic	<1 mm					1 mm≤	resource assessment total	cost account	comprehensive evaluation
		iron (H2)	non-ferrous (Aluminium Gala)		Li.	Co	Ni.	rare metal recovery judgment	actual amount	Cu			
For in-vehicle use LIB	Automotive 2 (domestic) - EVs	570	22,000	-4,780	××-mark (used to indicate an incorrect answer in a test, etc.)	××-mark (used to indicate an incorrect answer in a test, etc.)	××-mark (used to indicate an incorrect answer in a test, etc.)	×x-mark (used to indicate an incorrect answer in a test, etc.)	-5,600	9,990	22,160	-185,500	-163,000
	Automotive 4 (domestic) - HV	5,330	9,300	0	Fat.	Fat.	Fat.	Fat.	5,500	22,730	42,960	-173,100	-130,000
Mixed (wide variety)		4,900	12,107	-1,779	××-mark (used to indicate an incorr	××-mark (used to indicate an incorrect answ	××-mark (used to indicate an incorrect answ	×x-mark (used to indicate an incorrect answer in a test, etc.)	-5,600	4,930	14,540	-170,200	-155,000

				ect answer in a test, etc.)	er in a test, etc.)	er in a test, etc.)						

H29

Unit: t	pack	LIB Module	scrap metal		plastic	burnt offering (i.e. religious animal	<1 mm	1 mm ≤ total
			iron	Non-ferrous*.				

Cases with cost estimates based on H29 assumptions

(Unit: yen/t)		scrap metal		plastic	<1 mm					1 mm ≤ total (Cu)	resource assessment total	cost account	comprehensive evaluation
		iron (H2)	non-ferrous (Aluminium Gala)		Li.	Co	Ni.	rare metal recovery judgment	actual amount				
For in-vehicle use LIB	Domestic - HV	6,980	23,730	-4,760	Fat.	Fat.	×x-mark (used to indicate an incorrect answer in a test, etc.)	Fat.	16,200	17,120	59,340	-128,100	-68,000
	Outside the country - HV	470	40,000	-4,340	×x-mark (used to indicate an incorrect answer in a test, etc.)	×x-mark (used to indicate an incorrect answer in a test, etc.)	×x-mark (used to indicate an incorrect answer in a test, etc.)	×x-mark (used to indicate an incorrect answer in a test, etc.)	-1,100	16,850	51,800	-158,700	-106,000
	Average-HV	3,730	31,860	-4,550	Fat.	Fat.	×x-mark (used to indicate an incorrect answer in a test,	Fat.	0	16,990	48,030	-143,400	-95,000

						etc.)						
Stationary LIB	-	-	-	Fat.	Fat.	Fat.	Fat.	0	100	100	-186,500	-186,000

Cases with cost estimates based on H30 assumptions.

(Unit: yen/t)		scrap metal		plastic	<1 mm					1 mm ≤ total (Cu)	resource assessment total	cost account	comprehensive evaluation
		iron (H2)	non-ferrous (Aluminium Gala)		Li.	Co	Ni.	rare metal recovery judgment	actual amount				
For in-vehicle use LIB	Domestic - HV	6,980	23,730	-4,760	Fat.	Fat.	××-mark (used to indicate an incorrect answer in a test, etc.)	Fat.	16,200	17,120	59,340	-126,800	-67,000
	Outside the country - HV	470	40,000	-4,340	××-mark (used to indicate an incorrect answer in a test, etc.)	××-mark (used to indicate an incorrect answer in a test, etc.)	××-mark (used to indicate an incorrect answer in a test, etc.)	××-mark (used to indicate an incorrect answer in a test, etc.)	-1,100	16,850	51,800	-156,900	-105,000
	Average-HV	3,730	31,860	-4,550	Fat.	Fat.	××-mark (used to indicate an incorrect answer in a test, etc.)	Fat.	0	16,990	48,030	-141,900	-93,000
Stationary LIB		-	-	-	Fat.	Fat.	Fat.	Fat.	0	100	100	-183,500	-183,000

*Each resource assessment in H29 has been revised to align with the unit costs in H30.

3.2 Verification of the possibility of improving the economic efficiency of used LIB packs by reviewing and improving the project scheme.

Used LIB packs ☆ Resource value and processing cost ☆ Comprehensive evaluation of economic efficiency was carried out by reviewing and improving the scheme ☆ to reduce costs and verifying the possibility of ☆ economic efficiency improvement.
Scheme ☆ Review and Improvement ☆ As methods, estimates were made for each of the two methods: reducing treatment costs ☆ by expanding the scale of treatment, and reducing transport costs ☆ by consolidating treatment functions and reducing the number of transports.

As a result of the trial calculation, in the case of pattern (2) ☆☆, the cost is expected to be reduced to around -¥100,000 ☆ at a treatment scale of 30 t/day. In the case of the final target of a fully integrated facility (Pattern 3) ☆ , the cost is expected to be less than ▲100,000 yen from a scale of 20t/day. In order to set a more realistic cost setting for recycling, it is necessary not only to improve technological development ☆, but also to design a concept for the consolidation of bases ☆ and to improve the collection capacity so that the scale can be expanded smoothly after practical implementation.

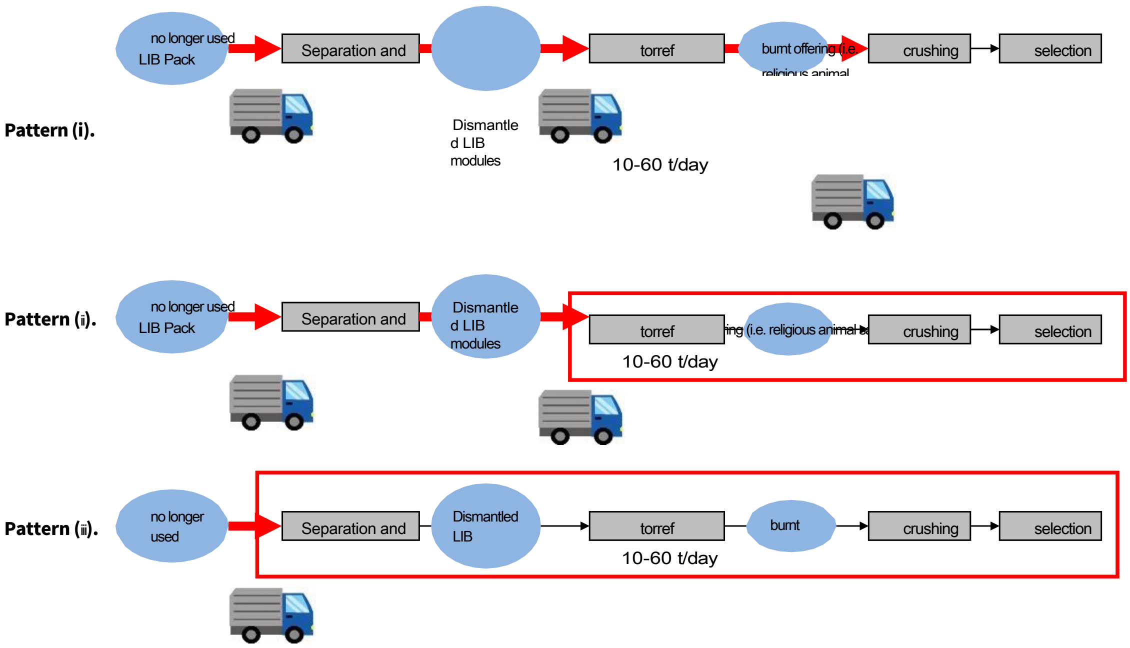


Figure 3-1. Conveyance patterns in the economic evaluation study of the project

Table 3-4. Comparison of overall economic evaluation of spent LIB pack treatment by improving the scale of treatment and number of transports

(Unit: yen/t)

processing scale		10 t/day			20 t/day			30 t/day		
transportation pattern		1	2	3	1	2	3	1	2	3
Automotive LIBs	Automotive 2 (domestic) - EVs	-163,000	-146,000	-118,000	-138,000	-121,000	-94,000	-129,000	-112,000	-84,000
	Automotive 4 (domestic) - HV	-130,000	-115,000	-89,000	-107,000	-92,000	-67,000	-98,000	-83,000	-58,000
Mixed (wide variety)		-155,000	-140,000	-115,000	-133,000	-118,000	-93,000	-125,000	-109,000	-85,000

processing scale		40 t/day			50 t/day			60 t/day		
transportation pattern		1	2	3	1	2	3	1	2	3
Automotive LIBs	Automotive 2 (domestic) - EVs	-127,000	-110,000	-82,000	-123,000	-106,000	-78,000	-123,000	-105,000	-78,000
	Automotive 4 (domestic) - HV	-97,000	-82,000	-56,000	-93,000	-78,000	-52,000	-92,000	-77,000	-52,000
Mixed (wide variety)		-123,000	-108,000	-83,000	-119,000	-104,000	-79,000	-119,000	-104,000	-79,000

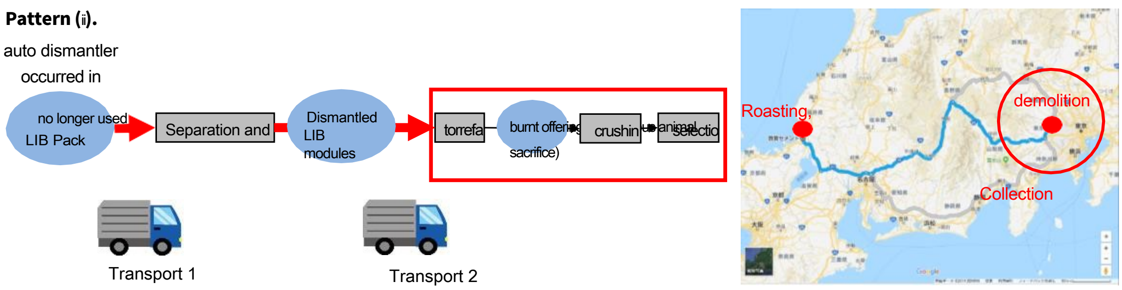
3.3 Model studies to reduce transport costs

The ☆ transportation costs of used LIB packs ☆ were verified in a more detailed model case using the aforementioned ☆ pattern (2) ☆ model. The specific area images, loading capacity and mileage are shown below. [5] to [8] correspond to the ideal loading capacity ☆ model.

As a result of the trial calculation, the model with the lowest transportation costs was [5] ☆☆, which was collected and dismantled in the Nagoya area, where the distance travelled was also small, and transported to Tsuruga. The model also showed that there was almost no difference in cost between the Tsuruga delivery and the Nagoya delivery.

LIB packs ☆ Processing costs ☆ Transportation costs account for more than 1/3 of the processing costs ☆ Selection of sites

☆ Consideration should be given to.



	cargo	transport vehicle	loading conditions	loading capacity	Mileage Patterns
transport 1	LIB Pack	4t truck	minimum loading	50 kg (1 piece)	• 50 km (e.g. metropolitan area → Iruma, Nagoya area) • 350 km (e.g. metropolitan area → Nagoya area)
			maximum payload	2,500 kg (50 pieces)	
transport 2	LIB module	8-tonne truck	maximum payload	3,500 kg (100 pcs)	• 100 km (e.g. around Nagoya → Tsuruga) • 450 km (e.g. Iruma to Tsuruga, Nagoya area to Hiroshima area).

Figure 3-2. Model for reducing transport costs in the project

Table 3-5. Comparison of area image and cost of transporting used LIB packs by transport

pattern	Example of area image			Transport 1		Transport 2		Transport costs per tonne of LIB packs (Yen/t-LIB pack)
	Collection area	demolition yard	Roasting, crushing and sorting facility	Loading capacity (kg)	Distance travelled (km)	Loading capacity (kg)	mileage (km)	
[1]	Nagoya area	Nagoya area	Tsuruga era (1185.8.28-1190.4.11)	50	50	3,500	100	**535,320**

(Note: The haulage vehicles were defined as haulage 1: 4-tonne trucks and haulage 2: 8-tonne trucks. The haulage costs were set at market unit prices by vehicle type and distance travelled.
The LIB pack conversion was calculated based on the ☆ ratio of this year's demonstration project ☆ Mixed

(multispecies) ☆ The LIB pack ☆ weight was set at 150 kg/unit).

4. Business feasibility of this treatment technology.

4.1 Forecasted market size of waste to be received.

As shown in the table below, it is assumed that the processing needs for automotive and stationary lithium-ion batteries will increase in all parts of Japan from 2020 onwards, and in order to meet these needs properly, a recycling system that can make effective use of existing infrastructure in various parts of Japan and respond quickly and economically according to processing needs is required. The system is based on the concept of a recycling system that can respond quickly and economically to the processing needs of each region. This system is considered to make a significant contribution to a recycling-oriented society in the future, as it can reduce the cost of collecting used LIB packs and modules and respond flexibly to the volume of treatment consigned, by using cement plants located in various parts of Japan in a phased manner.

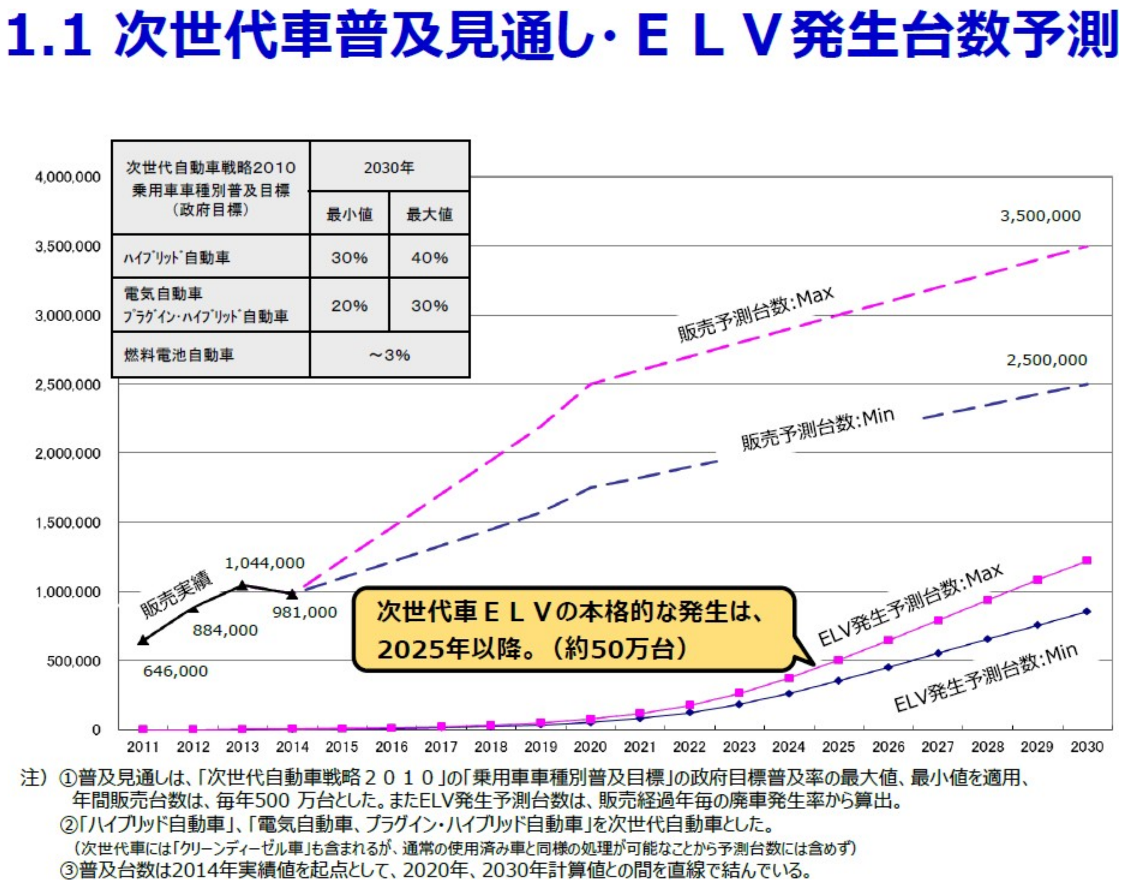


Figure 4-1 Projected disposal of automotive LIBs

(Source: Japan Automobile Manufacturers Association, "Next Generation Vehicles ☆ Appropriate Treatment and Recycling ☆ Status of Efforts", 2018 Sangyo Kaikan and Chukan Kaikan Joint Conference Document Document 3-2 (4 September 2018)).

住宅用／業務用蓄電システム 販売台数予測　　　　（単位：万台）

Figure 4-2 Market size forecast for stationary LIBs

(Source: Seed Planning HP, press release 17 April 2017.

(https://www.seedplanning.co.jp/press/2017/2017041701.htm)

4.2 Horizontal expansion to its own existing facilities

In this scheme, demonstration tests were conducted on LIB packs for vehicle-mounted vehicles, which are difficult to dismantle because they are robust and of unspecified size and are expected to generate a particularly large amount of LIB packs ☆ but it is technically possible to process stationary LIB modules as well. Furthermore, not only large but also small LIBs can be processed, and a wide range of LIB packs and modules for various applications distributed in Japan are planned to be accepted, not limited to those for vehicle-mounted LIBs.

The scheme will also achieve low-carbon recycling through the efficient use of waste heat energy by installing a dedicated treatment plant for used LIB packs and modules within the cement plant.

☆. Not only at Tsuruga Cement's Tsuruga Plant, where the demonstration tests are being conducted, but also at each of the Group's ☆ cement plants (see diagram below), taking into account the LIB pack module collection system, and planning to introduce and deploy the system in stages. Furthermore, the system can also be deployed at overseas ☆ cement production sites, and the possibility of overseas deployment is also being considered.

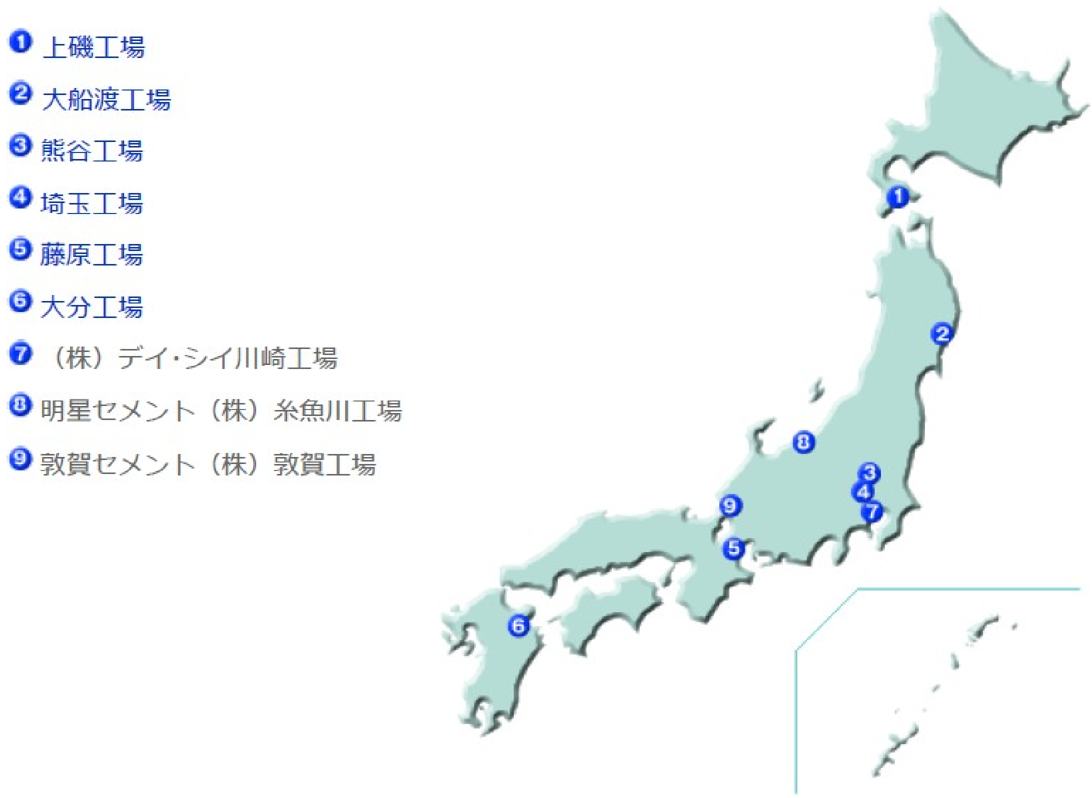


Figure 4-3. Pacific Cement's cement business locations in Japan

(Source: Pacific Cement Corporation HP http://www.taiheiyo-cement.co.jp/company/busi/world/japan-2.html)

(Remark: ☆ in the figure, blue characters indicate the Pacific Cement plant and black characters indicate the plants of Group companies).

4.3 Advantages of the Project.

As for the LIB recycling treatment ☆ system, in addition to this system (cement calcination + rotary bed continuous roasting furnace) ☆ there are also kiln incineration/roasting furnaces, fixed incineration/roasting furnaces, melting furnaces and electric furnaces. The advantages and disadvantages of the main treatment systems ☆ are shown in the table ☆ below.

Table 4-1. Advantages and disadvantages of different treatment systems

processing system	Benefits.	demerit
main, primary system (Cement fired) + (+ rotary floor continuous roasting furnace)	Continuous processing (greater throughput and lower energy costs). ☆ Cement calcination furnaces under high calcium for the treatment of roasting exhaust gases containing fluorine are inexpensive. Roasting temperatures can be controlled and all base and rare metals can be separated and recovered. Energy saving and low CO_2 emissions can be achieved by using the exhaust heat from the cement calcination process and the heat content of the LIB (residual power and combustible content) as a heat source for the roasting process. ... roasting exhaust gases can be used as heat in the cement calcination process. ... because the residues can be converted into cement resources, 100% recyclable. Retrofitting of existing ☆ cement production facilities. be able to install	☆ Difficult to process in packs and need to be dismantled down to the module.
Rotary kiln type Incinerators/roasting furnaces	Continuous processing (large processing capacity, (Energy costs can be reduced).	...usually the inner walls of the kiln have to be dismantled down to a single cell. Difficult to process packs/modules ☆ direct feeding process due to damage Low recyclability of useful metals etc.☆ as they are mixed with a wide variety of waste batteries and waste materials and are contaminated. Costly treatment of fluorine-containing flue gases
fixed type Incineration/roasting furnaces	...packs ☆ can be processed as they are. ☆ Some facilities can be converted from existing ☆ low-concentration PCB treatment furnaces at inexpensive conversion costs.	The number of people who have been treated in a batch process is not continuous (treatment). (Smaller capacity to reason) When disposed of as ☆ packs, the pre-dismantled recovered materials are also incinerated, resulting in a low recycling rate. Costly treatment of fluorine-containing flue gases

As shown in Table 4-1 ☆, this system (cement calcination + rotary bed continuous roasting furnace) is likely to be cheaper than other ☆ treatment systems, as it is easy to increase the treatment volume due to its continuous treatment capability, low energy cost and significant cost reduction in treating exhaust gas containing harmful substances. In addition, the system can be retrofitted to existing ☆ cement plants, making it easy to establish a business by utilising the many cement plants located in Japan and abroad as LIB roasting treatment bases, and so on.

In the future, the rotary bed continuous roasting furnace ☆ basket etc. ☆ will be modified, and LIB packs ☆ will be collected and transported.

☆ We will strive to make our pricing more competitive ☆ by promoting improvement studies.

5. Future challenges and business plans

5.1 Future tasks.

LIB packs/modules have a wide variety of structures and material compositions. When roasting tests were conducted for each type of LIB module ☆ in this year's ☆ demonstration experiment, differences in resource recovery rates were observed. In actual operation, it is necessary to utilise the data accumulated in this demonstration and adjust the roasting conditions to increase the resource recovery rate.

In order to put this project scheme into practical use, it is necessary to improve the packing and handling equipment and basket structures used in the collection, dismantling, roasting, crushing and sorting ☆ processes in order to make the work more efficient and labour-saving. Roasting furnace ☆ We would like to examine structural ☆ improvement proposals that would increase processing capacity, improve energy efficiency ☆ and reduce processing costs ☆, and for those improvement proposals that are considered to be cost-effective ☆, we would like to make prototypes and verify their productivity ☆.

In order to further improve the economic evaluation in the future, it is necessary to study the adjustment of LIB modules ☆ to be fed during roasting ☆ and the setting of collection areas and dismantling sites ☆.

5.2 Future business plans

As for the future ☆ schedule, the construction of a mass treatment system ☆ is to be started in 2019, input emissions ☆ labour-saving, business facilities ☆ permits and licences are to be obtained, and commercialisation is planned to start in 2021.

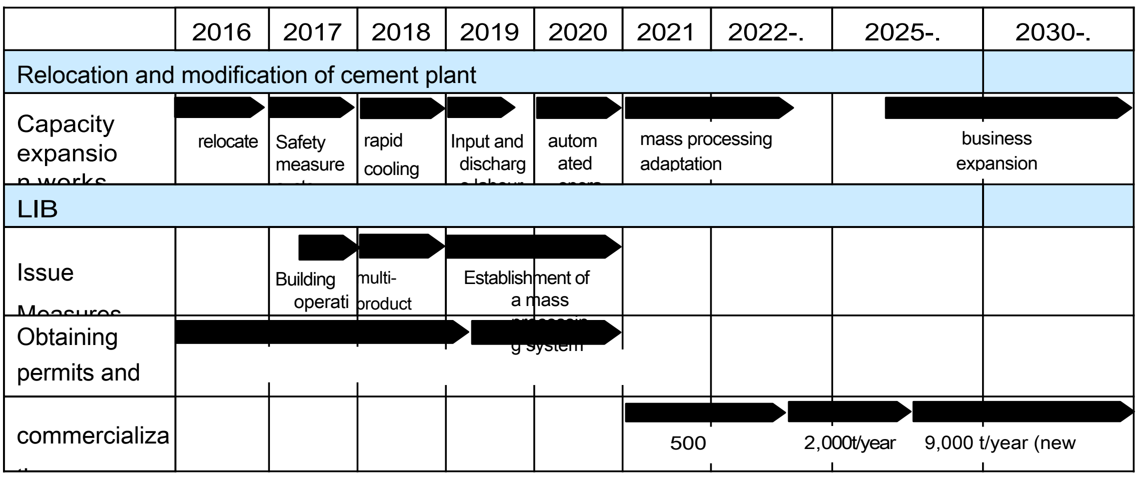


Figure 5-1. Schedule for the future

6. generalise

In order to recycle used ☆ large LIB packs in a low-carbon treatment scheme, this demonstration project continued from the previous year to conduct ☆ demonstration experiments to recover high-grade ☆ metal resources from large LIB packs and modules using a roasting furnace. The treatment targets were a wide variety of ☆ large LIB packs and modules for automotive and stationary applications.

Last year, the number of LIB pack ☆ types used in the demonstration experiment was small, so this year the number of types used was increased and the ☆ roasting conditions were verified under conditions close to those in actual operation. In addition, as a solution to the ☆ issues of the previous year, in order to examine roasting conditions that enable more efficient recovery of lithium compounds, we set the roasting temperature and time more precisely than in the previous year, verified the amount of paraffin used ☆ depending on the input amount and whether or not residual electricity is used, and conducted ☆ mass processing in continuous operation towards practical application, and identified and organised improvement issues.

The implementation details and main results of this demonstration project ☆ are described below. The used large LIB packs and modules used in the verification experiment were LIB packs for vehicles from domestic and foreign automobile manufacturers ☆ and LIB modules for stationary use from domestic battery manufacturers ☆.

(i) Separation and manual dismantling of used LIBs

For the purpose of reducing the amount of roasting treatment ☆ and recovering base metal and plastic resources ☆, used LIB packs ☆ were collected, sorted and dismantled by hand, and the amount of recovered resources ☆ was measured. Manual dismantling was only carried out for vehicle-mounted LIBs ☆ which were discharged in packs, but not for stationary LIBs which were discharged in modules. As a result of manual dismantling ☆, the LIB packs used in this year had a higher ratio of module ☆ to pack weight than those used in the previous year ☆, and each LIB pack had a different composition ratio of iron, non-ferrous and plastic ☆.

② Roasting of spent LIBs

Comparative verification of the roasting temperature range and heating time ☆ showed that the 500 °C - 4 h ☆ combination had the highest base metal and rare metal ☆ recovery rate, the best lithium distribution rate to ☆ recovered material of less than 1 mm, and the lowest ☆ paraffin consumption per unit.

A comparison of paraffin use by input volume confirms that the higher the input volume, the lower the ☆ paraffin use per input volume.

Regarding the effect of residual power on roasting ☆☆, a comparison of paraffin consumption by LIB module ☆☆ discharge with and without discharge showed that ☆☆ paraffin consumption per unit was lower in the case without discharge. This could be due to the contribution of residual power as fuel.

In the case where a large number of various LIB modules were mixed and roasted in continuous operation, the base metal was recovered at high efficiency as targeted, but the rare metal recovery rate was about 50 %, the same level as last year ☆. Compared to the case where multiple ☆ LIB modules were roasted individually, the recovery rate varied, and ☆ knowledge was obtained that the recovery rate of rare metal ☆ differs depending on the LIB module. The lithium ☆ behaviour including the exhaust gas was also confirmed, and it was confirmed that lithium was not distributed in the exhaust gas at any ☆ input level.

(iii) Crushing and sorting of roasted LIBs

Highly efficient recovery of base metal and pole powder (<1 mm) containing lithium and other elements from roasted materials.

The recovered ☆ recovered materials were analysed to check the metal resource ☆ material balance in the LIB module. The recovered electrode powder of less than 1 mm ☆ ☆ and the recovered material of more than 1 mm ☆ were analysed for metal and the metal resource ☆ material balance in the LIB module was confirmed, and more than 80% ☆ lithium could be recovered in the electrode powder depending on the input level.

(iv) Overall design of the treatment scheme.

Based on the results of the demonstration experiment, the overall design of the used LIB pack ☆ recycling treatment ☆ was carried out and the recycling flow ☆ material balance was calculated.

Used LIB packs ☆ As a processing flow, the ☆ LIBs in a pack state are dismantled manually, the base metal and plastic are recovered, and after being made into modules, they are roasted. The roasted materials are crushed by a shearing method, sieved, sorted and collected ☆ less than 1 mm ☆ electrode powder is recycled as lithium and other ☆ rare metals, and the materials collected more than 1 mm ☆ are recycled as copper.

The scale of the treatment scheme ☆ was calculated to be ☆ based on a roasting treatment volume of 3,000 t/year (10 t/day), with approximately 4,600 t/year of used LIB packs to be treated, 744 t/year of polar powder and a total of 3,140 t/year of base metal resources to be recovered.

As for energy saving effects, last year ☆ design ☆ As per last year's ☆ design, the use of exhaust heat from the cement firing process ☆ roasting furnace ☆ is expected to reduce annual kerosene consumption by about 30%, and the use of combustible exhaust gas generated from the roasting furnace for the cement firing furnace will reduce coal ☆ needed for cement production by about 0.1%.

☆ Replacement is expected.

Environmental improvement effects

In calculating the ☆ carbon dioxide reduction effect of the project scheme, the ☆ incineration process in a stationary furnace was set as the technology to be compared. Since it was difficult to obtain data on ☆ energy consumption in the ☆ treatment process before and after incineration in a stationary furnace, the hydrogen fluoride treatment process was excluded from the scope of calculation, assuming it to be the same as in the Project as a more conservative calculation. The recycling effect was included in the calculation only for the amount of resources ☆ that is actually assessed.

The results of the ☆ ☆ estimation showed that the carbon dioxide reduction effect of processing a wide variety of LIB packs in a mixed manner was 434 kg-CO2/LIB pack. From the results of this year's ☆ demonstration, it is expected that the amount of kerosene used can be reduced less than in the previous year, resulting in a greater reduction effect. In the case of an annual roasting volume of 3,000 t/year ☆ processing scale, the ☆ carbon dioxide reduction effect was calculated to be 1,986 t-CO2/year ☆.

The actual assessed resource ☆☆ effect of resource recycling was calculated to be between 30% and 40%. The decrease from the previous year is thought to be due to the different amounts of ferrous and non-ferrous ☆ that make up the LIB packs. It became clear that the resource recovery rate of LIB packs ☆ depends on the content of the materials ☆ that make up the LIB packs, but since the recovered materials that are not evaluated as metal are recycled by cement recycling, the amount of landfill disposal for any ☆ LIB packs is 0, and therefore the recycling rate in this recycling system is 100%.

Exhaust gas (containing hydrogen fluoride)☆ As a result of verifying the behaviour of the halogen element (fluorine) ☆ contained in LIB packs, more than 80% of all ☆ LIB packs were distributed to ☆ polar powder of less than 1 mm. The rest was distributed in the roasting exhaust gas, which is sent to a cement kiln for detoxification. Measurements of the final exhaust gas from the cement production facility ☆ confirmed the fluorine ☆ detoxification process.

economic assessment

The LIB pack treatment ☆ economics of the LIB pack treatment in this project was comprehensively evaluated by calculating the recovered resources ☆ valuables evaluation and the costs for transportation and treatment facilities, labour costs, consumables costs, etc. Among the recovered resources ☆ rare metal ☆ valuables were evaluated based on the ☆ concentration of the recovered materials. 1 mm or more ☆ recovered materials were all evaluated as copper.

As a result of the estimation, the cost of each ☆ LIB pack was higher than the resource assessment, and the overall assessment was calculated to be around -JPY 150,000/t. The reason for the cost increase compared to last year can be attributed to the different material composition ratio of the LIB packs. The reason for the cost increase over the previous year can be attributed to the different material composition of the LIB packs ☆. The ☆ material composition ratio of LIB packs differs depending on the material, and the cost of LIB modules ☆ increased. We would like to reflect this in the ☆ cost setting in actual operation. The results of this year's ☆ demonstration showed that the amount of paraffin used could be reduced by ☆. It was calculated that this would result in a cost reduction of ¥2,000/t ☆. We would like to continue to examine measures to reduce equipment and consumables costs ☆ for better economic evaluation.

In order to reduce costs ☆, we considered cost reduction through more efficient transport ☆ and mass processing, and we decided to set up a system in which roasting, crushing and sorting are carried out in one place, and the processing volume was tripled ☆ to 30t/day ☆ scale, which received an overall evaluation.

The cost is expected to be reduced to around ▲100,000/t. As transport costs account for more than 1/3 of the total cost ☆, it is necessary to consider the selection of ☆ demolition sites as well as the consolidation and scaling up of treatment facilities ☆ in the future.

Future challenges and commercialisation timelines

LIB packs have a wide variety of structures and material compositions. As a result of dismantling and roasting a wide variety of LIB packs in this project, it became clear that the resource recovery rate and the cost of treatment differ greatly depending on the material ☆ composition ratio of each LIB pack. These ☆ findings will be utilised in actual operation, for example by adjusting roasting conditions to increase the resource recovery rate.

In addition, it is necessary to improve the packing, handling equipment and basket ☆ structure used in each process, such as collection, manual dismantling, roasting, crushing and sorting, in order to make the work more efficient and labour-saving when putting the material into practical use.

As for the future ☆ schedule, the establishment of a mass treatment system ☆ will be promoted from 2019, input emissions ☆ labour-saving, demonstration facilities ☆ permits and approvals will be obtained, and commercialisation is planned from 2021.

2008 Technology demonstration project for CO2-saving recycling and other equipment.

Automotive and other ☆ used lithium-ion batteries ☆ low-carbon recycling system demonstration project Report

28 February 2019

Taiheiyo Cement Corporation
Environmental Division