Resource Recycling for Sustainable Industrial Development

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OVERVIEW: Manufacturing is the foundation of industry. People manufacture products using resources mined from the ground such as plastics made from crude oil or metals refined from ores. However, the resources in the Earth are not inexhaustible and will run out if we continue to use them at our current pace. Also, because reserves of rare earth metals are not widespread, security of supply is becoming difficult. In response, Hitachi is developing techniques for collecting and recycling rare earth metals from used products. Other measures include commercializing systems for on-site recycling of rubble from construction sites that can turn it into a useful resource, collecting used products and recycling them with the option of carbon offsets, and improving the proportion of plastics that are recycled.

INTRODUCTION

THE mined resources (crude oil, mineral ores, and so on) that are essential to manufacturing are rapidly heading toward exhaustion[1] (see Fig. 1). Meanwhile, rare earth metals are recognized as groundbreaking materials with the potential to support future improvements in energy and resource use, but bottlenecks in their importation threaten to impede the production of the products in which they are used (particularly high-performance electric motors that use rare earth magnets). This highlights how important security of resource supply is to manufacturing.

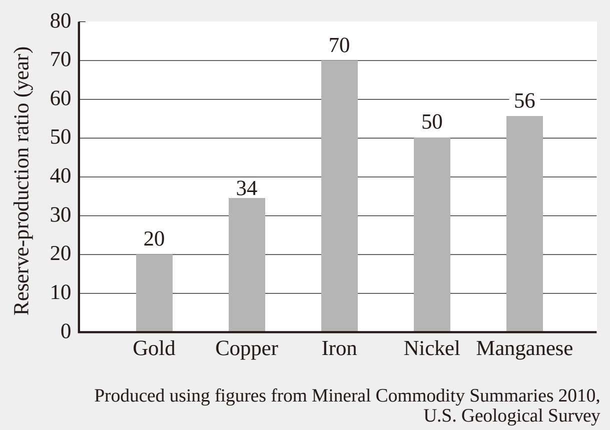


Fig. 1—Reserve-production Ratio of Major Metal Commodities (Based on the Fiscal Year 2009 Data).
Reserve-production ratio at current levels of production (in-ground reserves/annual production) of gold, copper, iron, nickel, and manganese is shown.

As a nation poor in natural resources, Japan is necessarily an importer of these commodities. Any inability to import resources will see industry shifting to resource-producing nations and speed up the hollowing out of manufacturing in Japan.

However, Japan is a country so full of “urban mines” (above-ground resources contained in products) that it rivals the world’s leading resource-rich nations. Estimates by the National Institute for Materials Science[2] suggest that the quantity of these above-ground resources in Japan is approaching one tenth of the world’s in-ground resources, including about 7,000 t of gold and 38,000 t of copper, for example. When this fact is taken into account, making effective use of these urban mines becomes an important issue.

Hitachi embarked on the development of product recycling technology in 1991 and has been contributing to the recycling of resources in Japan. This includes work on recycling rubble and other by-products of construction.

This article introduces some examples of what Hitachi is doing in this field: (1) rare earth recycling technology, (2) on-site recycling of rubble and other by-products of construction, (3) IT (information technology) equipment recycling, (4) recycling of PCs (personal computers) with carbon offsets, and (5) technology for separating plastics. In the case of rubble recycling, the intention is that it also be utilized to deal with the rubble that has become a problem in the cleanup following the recent major earthquake.

DEVELOPMENT OF TECHNOLOGY FOR RECYCLING RARE EARTHS

Japan is vulnerable to a sudden fall in the import volume of rare earth metals, something that is exacerbated by the fact that the world's deposits of these materials are concentrated in a few locations. The rare earths are a group of 17 elements including neodymium, dysprosium, cerium, and ruthenium. Because obtaining reliable supplies of the neodymium and dysprosium used to make magnets for products such as high-performance motors has become difficult, it is hoped that measures such as recycling will provide a reliable source of supply.

Rare earth magnets are used in the high-performance motors fitted in products such as PC HDDs (hard disk drives) or air conditioner compressors. Taking note of the current situation in which rare earth magnets are used in everyday situations and ultimately thrown away, Hitachi has been working on the development of techniques for separating and collecting the rare earth magnets from end of life products, and on researching environmentally conscious techniques for recycling the collected magnets.

The following sections give some examples of this work.

Technique for Recovering Magnets from HDDs

The conventional approach to recycling electronic parts and equipment is first to use a crusher after which the iron, copper, aluminum, and other materials are sorted and collected automatically. Unfortunately, because rare earth magnets are sintered objects (fused into a solid by raising a powder to a high temperature), if this method is used for recycling components that contain them, the impact of the crusher causes the magnets to disintegrate back into fine particles that retain some of their magnetic properties but are difficult to recover. This means that gathering the rare earth magnets from an HDD requires that it be carefully disassembled part by part (see Fig. 2).

Study by Hitachi has found that a person can disassemble HDDs manually at a rate of about 12 per hour. To make the process economic, this needs to be increased to more than 100 per hour. Because the fastening screws used in HDDs have different shapes for different parts, models, and manufacturers, using robots or other machines to mechanize this process is likely to be difficult. In response, Hitachi has developed a machine that works automatically, subjecting the HDD to shaking and other impacts to remove the screws used to fasten each of its component parts.

Because the economic viability of the process will be impaired if the costs such as the machine itself or its running costs are too high, it was designed to be as simple and robust as possible. As a result, the system is able to disassemble most of the components into their respective parts and materials. Although the performance differs depending on the HDD design, the system is able to achieve a result comparable to manual disassembly during the roughly 30-minute residence time each HDD spends in the machine (see Fig. 3).

The machine is designed with the capacity and configuration to process 100 HDDs at a time which gives it a theoretical capacity of 200 HDDs per hour. A feature of the machine is that it is designed such that the sintered magnets can be sorted out and collected as soon as they are separated from the HDD and therefore they can be recovered without the magnets being crushed (reduced to powder).

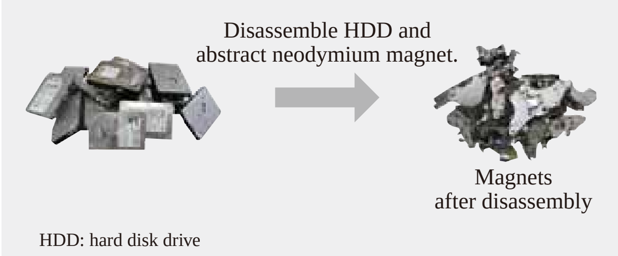


Fig. 2—Recovery of Rare Earth Magnets from HDDs.
In the past, HDDs needed to be disassembled manually to collect the rare earth magnets because the magnets are difficult to recover if crushed.

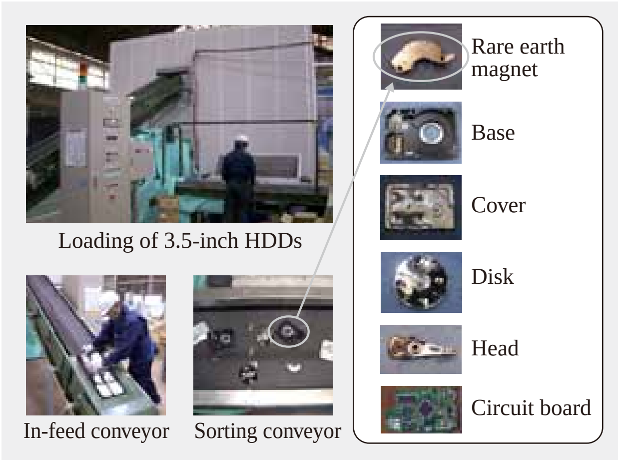


Fig. 3—Overview of HDD Disassembly Machine.
The HDDs are loaded into the machine via an in-feed conveyor where they are disassembled into their component parts and ejected. The parts are sorted on the conveyor and collected individually.

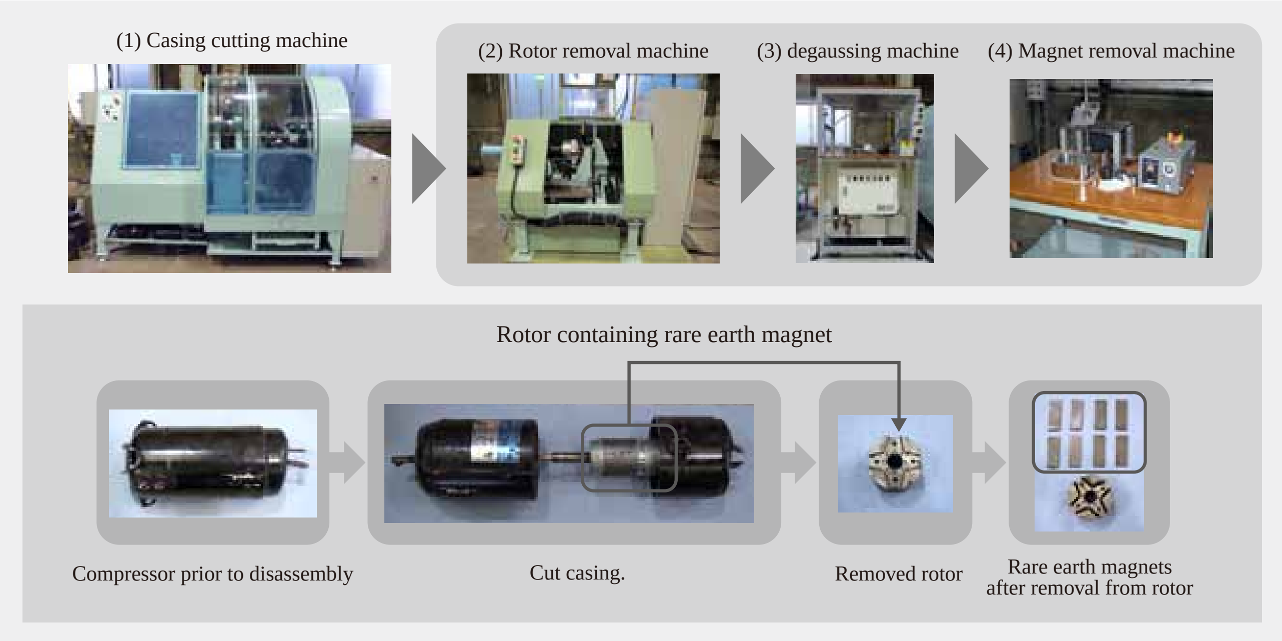


Fig. 4—Process for Recovering Rare Earth Magnets from Compressors.
The magnet recovery process consists of four sequential steps in which the casing is cut, the rotor removed and degaussed, and then the magnets removed.

Technique for Recovering Magnets from Compressors

As compressors are housed in a steel casing to which couplings are welded, they cannot be disassembled using ordinary tools[3]. For this reason it is necessary to cut open the casing to remove the internal components. The problem with this, however, is that the cutting position is different depending on factors such as the manufacturer, year, or model. Accordingly, Hitachi has developed a machine for cutting compressor casings automatically in which all the operator needs to do is specify the cut position.

The machine goes on to remove the rotor from the casing and then degauss (demagnetize) the rare earth magnets embedded in the rotor so that the entire process up to the safe removal of the magnets can be mechanized. Fig. 4 shows the process sequence.

As the rotor is made from steel plate (iron), the magnetic attraction between it and the embedded rare earth magnets makes the magnets difficult to remove while they retain their magnetism. Accordingly, the process includes a step in which the entire rotor is degaussed. Whereas degaussing is commonly achieved by heating (in which the magnet is raised to a temperature at which its crystal structure changes), because this leads to problems such as melt-solidification of adhesives and the need to deal with the resulting oil smoke, a room temperature degaussing method[4] (in which the magnetic field direction is disordered by a resonance current) was chosen instead. Because the entire rotor is able to be degaussed, the magnet removal unit (the final step in the process) is able to work on the simple principles of hammering and gravity. This also improves the safety of magnet removal.

Environmentally Conscious Technologies for Magnet Recycling

Neodymium and dysprosium are valuable materials and their combined concentration in the rare earth magnets collected by this method is around 30%, about 1,000 times higher than in mined ores.

Abstraction of the rare earths from used magnets could be done using the current “wet process” method. However, because this method involves dissolving the magnets in acid, the large amount of metal-containing waste fluid it produces means it places a heavy burden on the environment. For this reason, Hitachi directed its attention toward “dry processes” for rare earth abstraction that do not use water solutions.

Although there are a number of candidate abstraction media with a strong affinity for rare earths, Hitachi chose one that has a low melting point (about 700°C). A rare earth alloy is formed by reacting the rare earths against the molten abstraction medium. The Fe (iron) which is the main component of the magnets does not react with the abstraction medium and therefore is easily separated. The rare earth alloy

Nd: neodymium Dy: dysprosium

Fig. 5—Rare Earth (Nd, Dy) Alloy Abstracted from Magnets.
The rare earth alloy shown here was recovered by melting together with an abstraction medium with a strong affinity for rare earths and then raising the temperature to evaporate the abstraction medium.

is then further heated to above 1,000°C to evaporate the abstraction medium and recover the high purity rare earth metal (see Fig. 5).

Because this method recycles the abstraction medium and does not produce any waste fluid, it recycles the rare earth metals without any negative effects on the environment. Also, it has demonstrated a very high 95% recovery rate in beaker-level experiments. Hitachi plans further work aiming at bringing it into practical use.

ON-SITE RECYCLING OF CONSTRUCTION BY-PRODUCTS

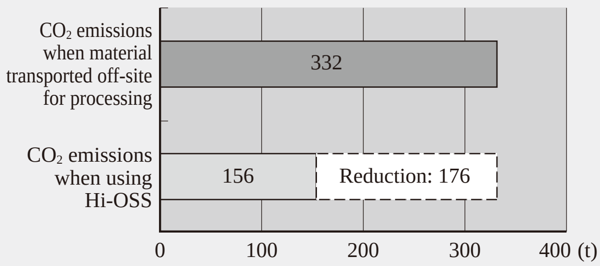
In addition to rare earths, another urgent issue for recycling is how to deal with the rubble produced at construction sites. Hitachi's answer to this challenge is the Hi-OSS (Hitachi on-site screening & solution) which provides a processing system with an optimum combination of self-propelled machinery to suit the nature of the site. A feature of Hi-OSS is that it can reduce both cost and environmental impact in a range of different fields from civil engineering to agriculture and forestry or post-disaster reconstruction.

By installing an on-site system able to process construction by-products to the point where they are reusable, on-site recycling has major benefits for CO_2 (carbon dioxide) emission reduction compared to the case when material is transported off-site for processing.

At a particular housing construction site, Hitachi installed a system for sorting soil left over from construction mixed in with other material such as concrete waste (fragments of concrete) and plastic. Because the system was able to reuse separated soil at the same site as fill and to crush concrete waste to the desired size for use as coarse base material, it succeeded in recycling 93% of the total quantity of waste for use as various types of material on-site.

Also, transportation of waste to an intermediate processing facility or other destination without first performing on-site sorting results in the emission of CO_2. Because Hi-OSS separates the waste into different materials for reuse, this off-site transportation is not required and in one case the reduction in CO_2 emissions was about 53% (mainly as a result of reduced transportation) (see Fig. 6).

In another example involving improvement work preparing the ground for factory construction, the rocks from the site, which included hard basalt, were crushed, sorted, and reformed so that all of the material could be recycled for use in the building foundations. This achieved an approximate 20% reduction in cost compared to the initial plan for the work which involved removing the rocks from the site and trucking in additional soil (soil brought in from off-site). By using on-site closed recycling, the CO_2 emissions associated with transportation (haulage to and from the site) are also reduced. Because the system combines a number of self-propelled machines



Composition of rubble used for above calculation

Quantity of material		18,500 m^3
Proportion	Soil	52.0%
	Concrete waste	40.5%
	Plastic	4.5%
	Wood	1.9%
	Iron scrap	1.1%

CO_2: carbon dioxide Hi-OSS: Hitachi on-site screening & solution

Fig. 6—Comparison of CO_2 Emissions when Material Transported Off-site for Processing versus Using Hi-OSS.
The figure shows a comparison of CO_2 emissions when material transported to an off-site processing facility versus performing similar processing on-site.

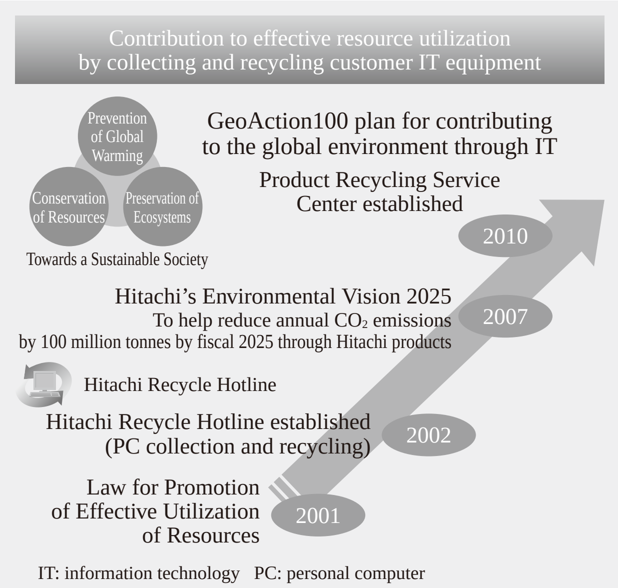


Fig. 7—IT Equipment Collection Initiatives.
In addition to the collection and recycling of PCs, Hitachi established Product Recycling Service Center which also purchases reusable components.

allowing the layout to be changed as work progresses, it can operate with a good level of efficiency.

In this way, Hi-OSS is an effective means of cutting CO_2 emissions and costs and Hitachi intends to expand its use further in the future to help reduce the burden on the global environment.

IT EQUIPMENT COLLECTION INITIATIVES

In response to the Law for Promotion of Effective Utilization of Resources implemented in 2001, Hitachi in 2002 established the Hitachi Recycle Hotline and started a service for the pickup and collection of used PCs and other products designated as specified resources-reconverted products.

In 2010, Hitachi formulated its GeoAction100 plan for contributing to the global environment through IT and established Product Recycling Service Center to promote recycling, particularly of IT equipment (see Fig. 7).

Support Services for Product Collection

The Product Recycling Service Center handles inquiries from customers and formulates plans for the collection of used products (see Fig. 8).

A collection plan sets out how to go about collection based on the customer's requirements. The options include: (1) collection based on industrial waste regional accreditation scheme (a scheme whereby a manufacturer is permitted under the Waste Management

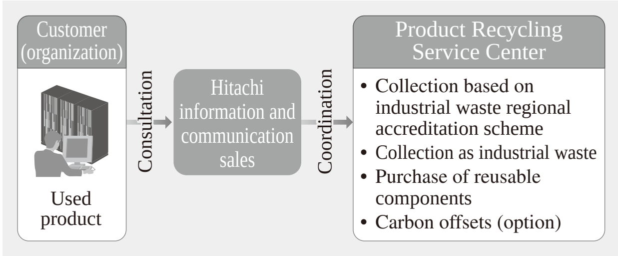


Fig. 8—Product Collection Support.
The Product Recycling Service Center produces collection plans to suit customer requirements. Carbon offsets are also available.

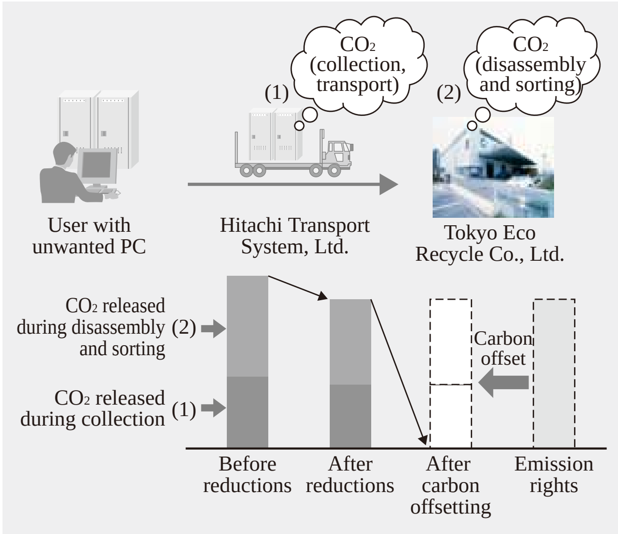


Fig. 9—Overview of Recycling with Carbon Offsets.
The CO_2 released by collection, transport, disassembly, and sorting during recycling of used IT equipment discarded by companies is offset using carbon credits.

and Public Cleansing Law to process waste in a number of different jurisdictions without needing permission from the respective local authorities), (2) collection as industrial waste, (3) purchase of reusable components, and (4) carbon offsets.

Recycling of PCs and Servers with Carbon Offsets

Hitachi runs a service for recycling PCs and servers in the Tokyo metropolitan district to contribute to reducing greenhouse gas emissions as well as reuse of resources.

The concept of carbon offsets involves seeking in the first instance to reduce as far as possible the release of greenhouse gases that inevitably results from activities such as commerce and daily life and then to compensate for (offset) those remaining unavoidable greenhouse gas emissions by purchasing emission rights (known also as "carbon credits") generated by reducing greenhouse gas emissions in some other location.

Hitachi's recycling service uses carbon credits to offset the volume of CO_2 (one type of greenhouse gas) emitted in two different ways: (1) fuel consumed by trucks used to collect used PCs, servers, and other IT equipment from companies for recycling, and (2) energy consumed by forklifts and other machinery used for their disassembly and sorting (see Fig. 9).

The advantage of the service for customers is that it increases the benefits of their environmental CSR (corporate social responsibility) activities by contributing to reuse of resources, global warming prevention, and other good causes. The CO_2 offset by the service also counts toward Japan's greenhouse gas reduction targets under the Kyoto Protocol.

ADVANCES IN HOME APPLIANCE RECYCLING TECHNOLOGY

The quantity of home appliances recycled has grown steadily over the 10 years since the Law for Recycling of Specified Kinds of Home Appliances was introduced. In addition to its work on technology for rendering materials such as CFCs (chlorofluorocarbons) harmless, Hitachi has been seeking to increase the quantity of useful resources that are recycled.

As an example, this section describes what Hitachi is doing to recycle the plastics that make up around 30 to 40% of the parts in home appliances.

When appliances such as refrigerators and washing machines are recycled, parts made of a single material that can easily be separated manually (such as washing machine lids or refrigerator vegetable bins) are removed in the initial stage of processing at the recycling center. The route for recycling these materials is already well established. In the case of complex parts such as interior walls that are not easy to disassemble and sort by hand, however, these need to be fed into a crusher so that they can fall away from parts that contain a mix of materials. The result is that the material comes out of the crusher as a mix of iron, copper, aluminum, wire, plastic, and other fragments. Although technologies already exist for separating and collecting ferrous and non-ferrous metals (such as copper), the remaining plastic residue still contains other materials such as copper wire which prevents it from being recycled.

In response, Hitachi has installed plastics sorting technology at its home appliance recycling plant, Kanto Eco Recycle Co., Ltd.

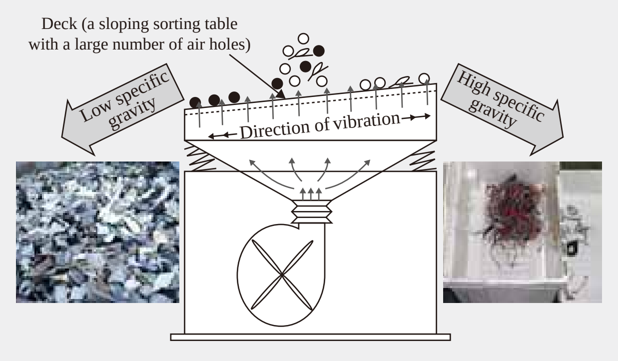


Fig. 10—Specific Gravity Sorting Machine for Mixed Plastics. The machine uses air pressure and vibration to sort materials with different specific gravities based on the difference in frictional force.

Fig. 10 shows the part of the system that sorts plastic residue. Air is blown up through a vibrating deck that contains small air holes. This causes material with high specific gravity to move up the slope due to the friction induced by the vibration while material with low specific gravity is partially suspended by the blown air which reduces friction and therefore causes this material to move down the slope. Continuing this process over a period of time results in the material being sorted by specific gravity. The result is that the presence of urethane, electric wire, metals, and other unwanted material in the plastic residue is reduced (by 33%) and the quality of the plastic improved.

This mechanism was originally used for the removal of materials with high specific gravity such as rock and metal from grain. Hitachi worked with the company that developed the mechanism[5] to adapt the machine for use in recycling of home appliances. For the future, Hitachi intends to expand use of the machine to other home appliance recycling centers.

CONCLUSIONS

This article has described progress on developing a technique for recycling rare earth metals and the menu of services provided by Hitachi's current resource recycling activities.

When compared against all of the products handled by Hitachi in terms such as their categories and quantities, the scope of recycling technology development is still limited and the number of products collected remains low. In view of factors such as rising demand in emerging nations and that the reserve-production ratios of materials such as gold and copper range between about 20 and 34 years, it is essential for Japan that it both establishes new resource recycling schemes and develops recycling technology for the benefit of the next generation, even for resources that are routinely available at present.

For the future Hitachi intends to take the initiative in promoting the recycling of precious resources to help sustain industrial society.

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