# Recycling Technologies for Both Carbon Dioxide Reduction and Resource Saving

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*OVERVIEW: In the 21st century, as population growth, global warming, and resource depletion become mutually entwined, they will continue to progress in parallel. And while fossil fuels will one day become exhausted, the amount of metallic resources that can be mined out of the ground will also continue to decrease. However, if we change our point of view, it becomes clear that metallic resources are simply moved from the place where they exist underground to above the ground; in other words, it is not that they disappear from the earth's surface all together. Recycling those "terrestrial" resources will become the dominant means in the next generation to save as much of our limited resources as possible. Given that establishing a "recycling-based society living on terrestrial resources" has been set as an ultimate goal, it has been forecast that the era in which a huge variety of electronic products and machinery are recycled — starting with recycling of home appliances and personal computers — is approaching. With eyes fixed on these future prospects, the Hitachi Group is actively promoting research and development on recycling of home appliances with the aim of contributing to reducing $CO_2$ emissions and creating a recycling-based society.*

## INTRODUCTION

THE "Law for Recycling of Specified Kinds of Home Appliances" — stipulating recycling of specified household appliances — was enacted in Japan in April 2001 and presently targets four kinds of products: refrigerators/freezers, washing machines, air-

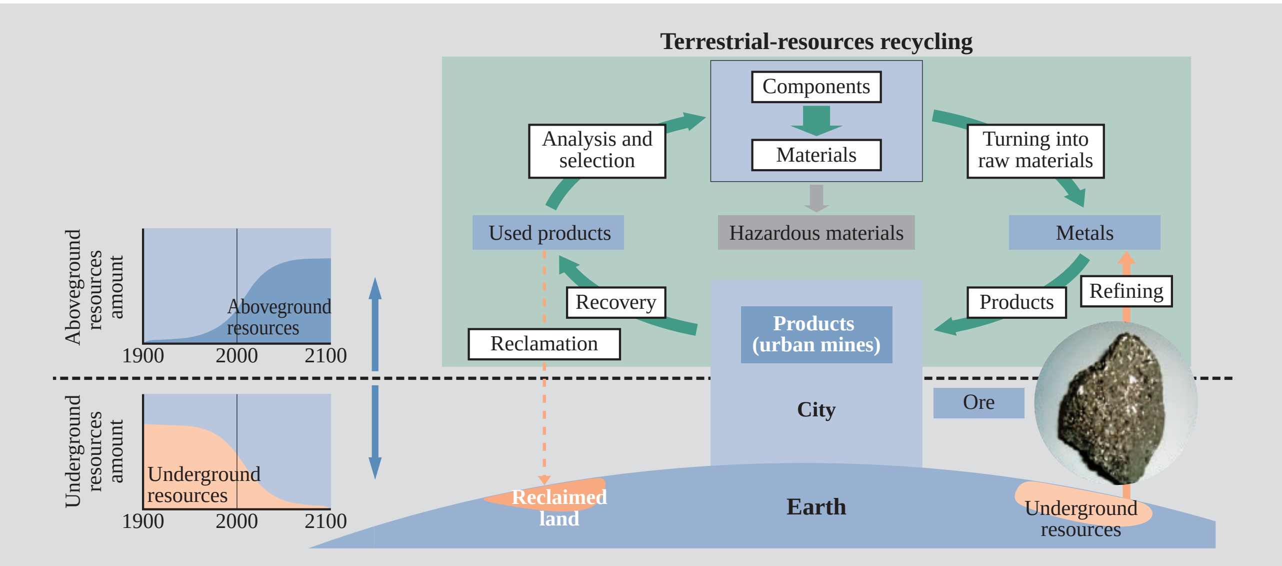



*Fig. 1—The Concept of Recycling Terrestrial Resources.*
*As for the underground-resource-dependent civilization of the 20th century, underground resources were mined, products were manufactured, and used products became rejected waste. The 21st century has become the era in which resources transferred to above ground are circulated. Resources buried in urban areas are recovered, analyzed, and selected, and at the same time while components and materials are produced, harmful products are eliminated. By applying this cycling process, we are helping to build a sustainable society.*

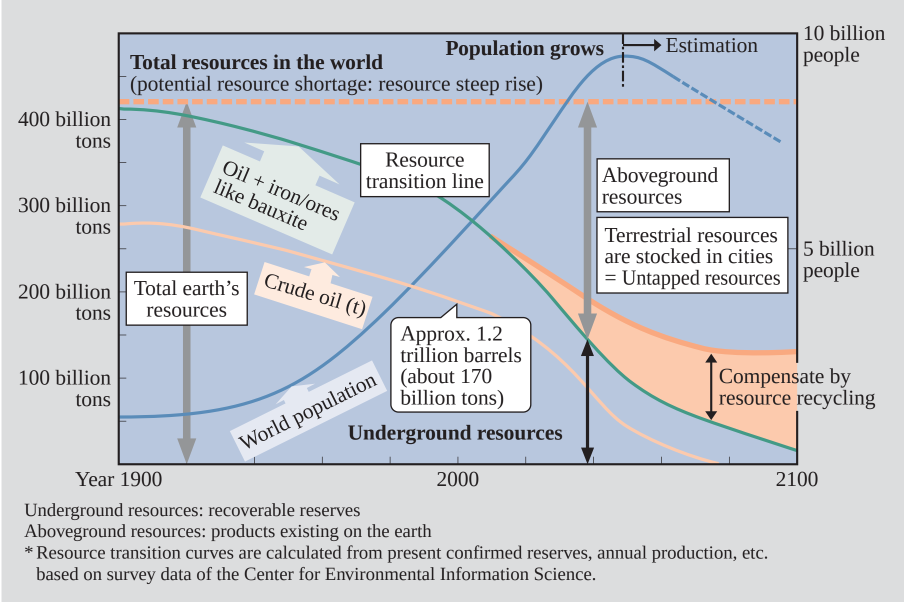



*Fig. 2—The Concept of Transition of World Population and Underground Resources.*
*As the world population grows, development drilling for underground resources will press ahead, and raw materials are forecast to follow a one-way path to depletion.*

conditioners, and televisions (cathode-ray-tube type). Explicitly aimed at the resource recycling, this law, for the first time in Japan, placed the responsibility for recycling and recovery of disposed-of products on manufacturers as part of their product liability. From now onwards, it is expected that FPDs (flat panel displays) and cloths driers will be added to the list of products covered by the law and, accordingly, the need for resource recycling will grow stronger and stronger.

To establish a society that can sustain limited resources, recycling of resources is essential (see Fig. 1). In consideration of a hundred years from now, growth of the world's population is inevitable (see Fig. 2). Moreover, as shown by the decay curve for reserves of crude oil and metallic resources (i.e. iron and bauxite ore), underground resources are being rapidly depleted. Other metals, for the most part, only have an RLI (reserve life index) of several tens of years left[(1)]. However, although underground resources are disappearing, resources shifted to "above ground" (hereafter, referred to as terrestrial resources) sit dormant in urban areas. For that reason, to extend the life of resources, there is no alternative but to reduce the amount of mining underground and compensate that reduction by recycling terrestrial resources.

According to the National Institute of Materials Science, the total amount of terrestrial resources in Japan consists of approximately 1.2 billion tons of iron, 60 million tons of aluminum, and 40 million tons of copper[(2)]. And the greater part of that total is amassed in urban areas as manufactured products. In the case of natural-resource-poor Japan, supplies of almost all natural resources are dependent on overseas, so from now onwards, it is necessary to prepare for problems like skyrocketing prices and curbs on import volumes. Up until now, the Hitachi Group — a consumer of resources in an "arterial industry" — has been aiming at businesses that also combine the role of a recycler of resources (i.e. in a "venous industry") and actively implementing recycling of household appliances. The rest of this report describes recycling technologies being developed by Hitachi with the aim of creating a "recycling society" while reducing $CO_2$ (carbon-dioxide) emissions.

## CONSUMER-ELECTRONICS RECYCLING TECHNOLOGY AND BUSINESS OPERATIONS OF HITACHI

### Technological Development and Business Operations

As one of the first to undertake recycling of household appliances from 1991 onwards, and while gaining cooperation and guidance of the government and business community, Hitachi has been implementing technical developments in addition to participating in our own recycling businesses. The framework of the household-appliance recycling process used in Japan, based on technologies developed and implemented mainly by Hitachi, is covered by a large number of basic patents. As it stands now, this framework has become widespread across Japan as the prevailing recycling process, and it is achieving a recycling ratio that surpasses all legal requirements (see Fig. 3).

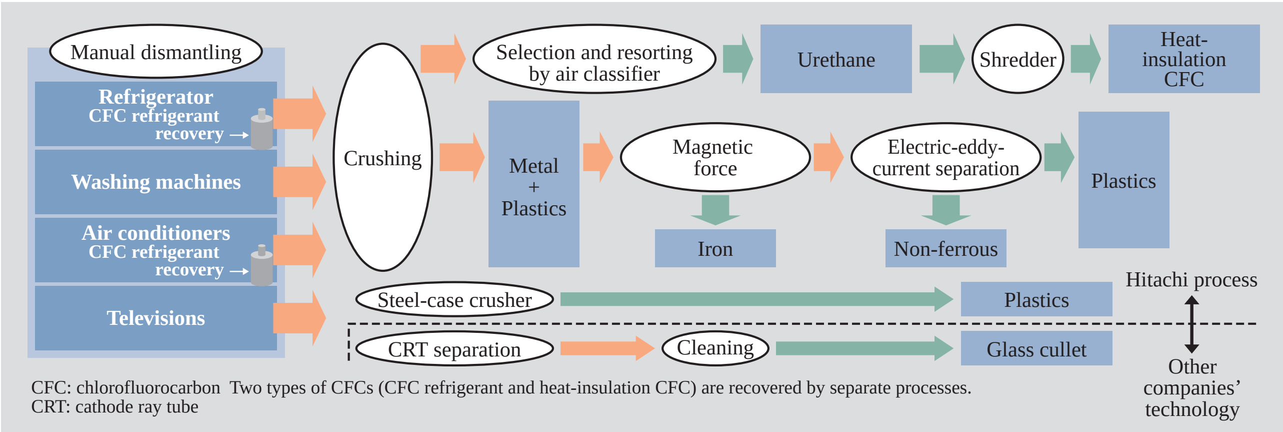



*Fig. 3—Consumer-goods Recycling Process (Tokyo Eco-Recycle).*
*Home appliances are processed by balancing manual dismantling and mechanical selection. The fundamental process has been developed by the Hitachi Group.*

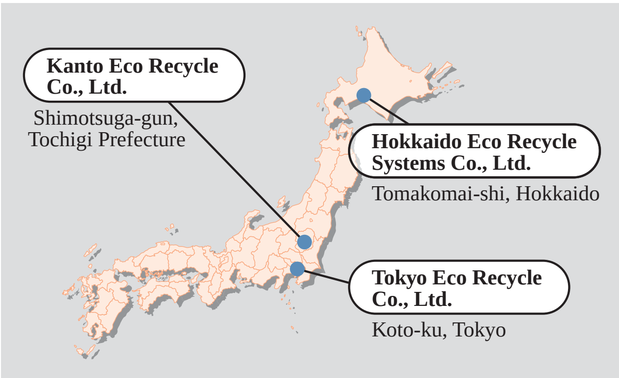



*Fig. 4—Locations of Electrical-appliance Recycling Plants of Hitachi.*
*The locations of Tokyo Eco Recycle Co., Ltd., Kanto Eco Recycle Co. Ltd., and Hokkaido Eco Recycle Systems Co. Ltd. as electrical-appliance recycling bases are shown.*

To positively comply with the “Law for Recycling of Specified Kinds of Home Appliances,” Hitachi has established the Tokyo Eco Recycle Co., Ltd. (hereafter simply referred to as Tokyo Eco), Kanto Eco Recycle Co., Ltd., and Hokkaido Eco Recycle Systems Co., Ltd. (see Fig. 4 for locations). The total amount of material handled by these three companies is 50,000 t annually, which accounts for about 11% of the total recycled weight (about 447,000 t) of the four kinds of household electrical appliances targeted in Japan.

### Comparison with WEEE Directive of the EU

The total recycled weight (about 447,000 t) of the four kinds of household electrical appliances targeted nationally converts to 3.5 kg per person in Japan.

Although the EU’s WEEE (“Waste Electrical and Electronic Equipment”) directive (which came into force in February 2003) targets a separated collection weight of 4 kg per EU citizen from among 98 kinds of electrical and electronic devices, the bulk of those items are covered by the four items specified in Japan for recycling. In the case of the 98 items covered by WEEE (i.e. vacuum cleaners, electric shavers, video cameras, etc.), the material composition ratio and structure of each are different. However, the main structural components of these WEEE-specified items are ferrous and non-ferrous metals and plastics, so even if the target range of resource recycling covers other electrical household appliances and electrical equipment, our experience and know-how of appliance recycling can be applied and arrangements to handle WEEE items can be made on the spot.

## CONTRIBUTION TO A RESOURCE-RECYCLING SOCIETY

### Compressor Separator

Household appliances are composed of a great many components; however, as one of these components, compressors are important because they contain large amounts of copper and aluminum. Used in refrigerators and air conditioners, compressors are fitted with motors in a steel shell composed of thick welded iron. To recover the valuable motor, the shell has to be removed, so a device for breaking up the shell is needed.

Conventionally, although melt cutting by methods like gas-flame cutting has been used, ignition of machine oil and generation of oily smoke are major problems. Moreover, there are two types of compressors, reciprocating and rotary, so a cutting device that can handle both types is needed.

Accordingly, in collaboration with Hitachi Plant Technologies, Ltd., Tokyo Eco developed a “compressor-dismantling device” that addresses the above-described problems and needs. A bird’s eye view of the device, along with an image of a dismantled compressor, is given in Fig. 5. Note that this compressor is widely used in cars and automatic vending machines. Development of an automatic machine for separating compressors from these products in this manner will become even more important when the WEEE directives are extended to cover for suitable components.

## Effect of Resource Recycling

In regard to processes for mining ores from mineral deposits and refining them, a large amount of energy is used up. That means that “re-producing” (i.e. recovering) metals by means of recycling resources is directly linked to energy saving. For the example of iron products, the process flow up to finished products is shown in Fig. 6. It is clear that by means of recycling resources, the amount of processing, and thus the energy consumed, can be cut. If the iron is recycled, the process is completed with one third of the energy consumption, one seventh of the copper, and one twentieth of the aluminum compared to the case of producing iron from ore. Resource recycling in this manner has the effect of cutting the energy used in metal production. Furthermore, the purity of iron and aluminum obtained by the recycling process is more than 99%, which is much higher than the purity obtainable from iron ore (50–65%).

Since recycling manufactured products composed of metallic and plastic components is useful for conserving resources and saving energy, from now onwards, even items other than those covered by regulations will be recycled voluntarily on a trial basis.

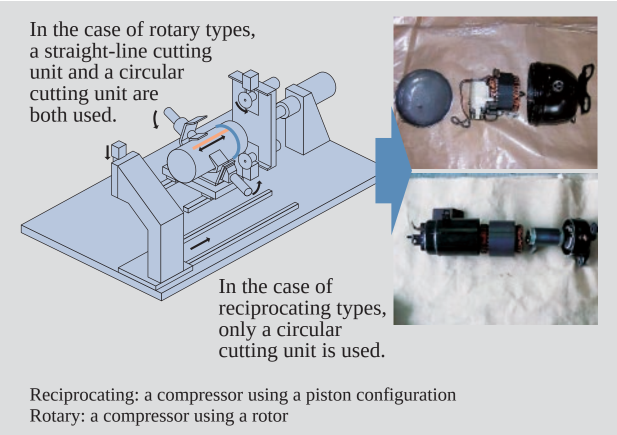



*Fig. 5—Features of Compressor Separator.*
*Either reciprocating or rotary types can be broken up and separated on a single machine. Moreover, the power source is electrical—which generates little $CO_2$.*

## Recovery of Rare Metals

Different kinds of advanced electronic devices, like FPDs, cannot be manufactured without rare metals. Schemes for their recovery and recycling are thus being tested by governments. In line with such schemes, focusing mainly on our own products, Hitachi will assess the possibility of economically recovering rare metals.

# EFFECT OF $CO_2$-EMISSION REDUCTION

## Life-cycle Assessment

Recycling of household appliances contributes not only to the resource recycling but also to reduction of

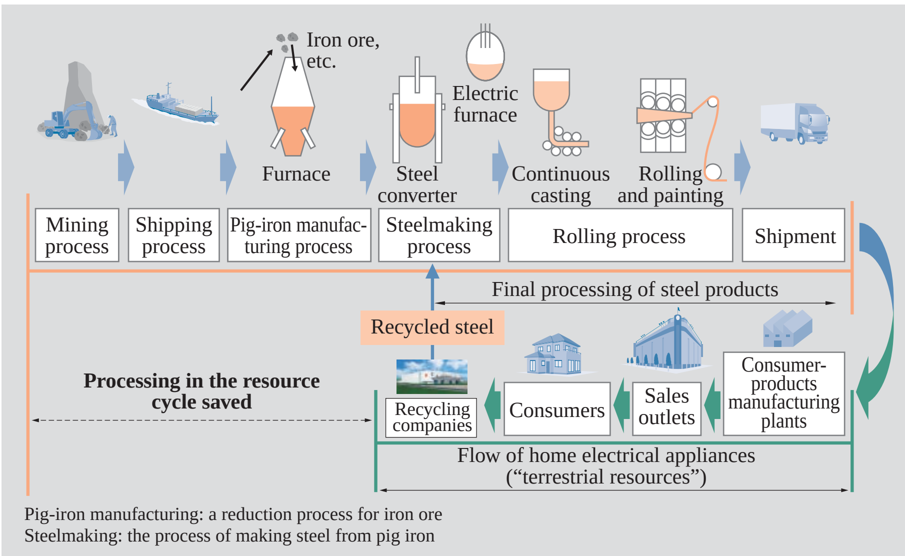
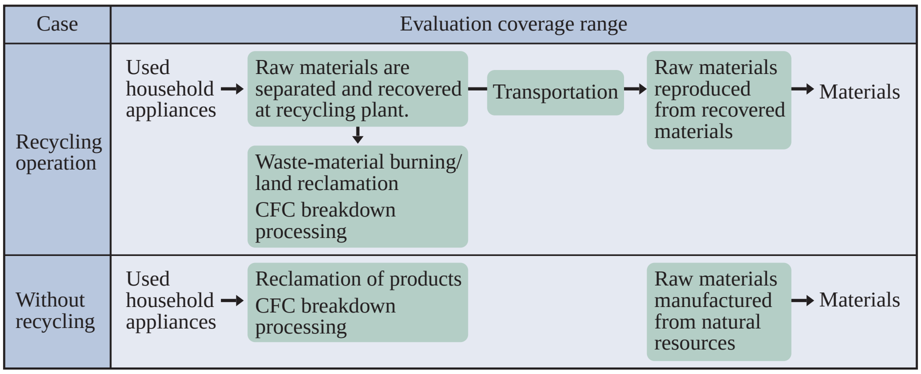



*Fig. 6—Resource (Iron) Recycling Process.*
*The resource cycle consists of several efficient measures from the viewpoint of a scarce-natural-resource Japan.*




Recycling operation: Recovered material processed from household electrical appliances is reproduced as raw materials.
Without recycling: Equivalent materials are manufactured from natural resources.

*Fig. 7—Method for Evaluating Effects of $CO_2$ Emission Reduction by Recycling.*
*The difference between the recycling case and the no-recycling case is the amount of $CO_2$ emission reduced by recycling.*

$CO_2$ emission. Tokyo Eco, for example, calculated the effect of $CO_2$ emission by recycling. Taking the example of recycling of household goods presently in operation, they estimated the amount of $CO_2$ emission by LCA (life-cycle assessment)[5]. Following the progression of steps from processing to manufacturing, LCA aggregates the amount of resources consumed and the amount of $CO_2$ emission produced and evaluates its impact on the environment. According to the technique used by LCA for aggregating emission amounts, called “inventory analysis,” the $CO_2$ emission amount was evaluated.

## Evaluation Method

Tokyo Eco accepts and processes 350,000 units (about 13,000 t) of used household electric appliances per year and separates all their components and recovers their materials. The bulk of these recovered materials are further treated at the shipping destination and eventually reused as materials.

The method for evaluating the effect of reducing $CO_2$ emission is shown schematically in Fig. 7. The amount of $CO_2$ emission covering the target period (that is, processing of household appliances by Tokyo Eco, further processing at the shipping destination to which the recovered materials and components were transported, and eventual re-production as raw materials) is summed up. Moreover, in the no-recycling case (i.e. using the used appliances as landfill), the amount of $CO_2$ emission for manufacturing the same amount of material from natural resources is also summed up. The difference in the emission amounts for the two cases represents the reduction in $CO_2$ emission due to recycling.

$CO_2$ emission amount for Tokyo Eco was calculated by multiplying by a $CO_2$ emission factor given in the consumption data for electricity and fuel for 2006. $CO_2$ emission amount involved in processing of recovered materials at the shipping destination and in materials production from natural resources, was calculated according to public data in Japan.

## Effect of Reducing $CO_2$-emission Volume

The evaluation results on reduction of $CO_2$ emission amount are plotted in Fig. 8. It is clear from the graph that in comparison with the no-recycling case (i.e. producing equivalent material from natural resources), recycling household appliances and recovering all their materials reduce $CO_2$ emission amount by about 12,000 t annually.

Furthermore, of the whole $CO_2$ emission amount (i.e. starting from processing of household appliances to recovery of materials), the proportion accounted for by operation of recycling plants is 10%. However, production starting from natural resources is unnecessary (since materials are separated and recovered in a recycling plant); therefore, from the

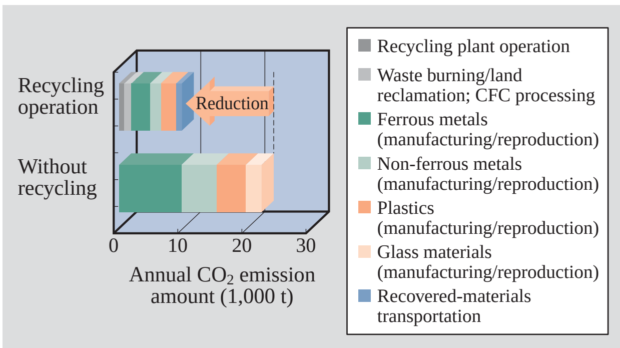



*Fig. 8—Effect of Reducing $CO_2$ Emissions by Recycling Household Appliances.*
*Reusing materials recovered by Tokyo Eco cuts annual $CO_2$ emission amount by about 12,000 t.*

viewpoint of the whole system, $CO_2$ emission amount is reduced by half. It is thus concluded that such a recycling plant makes a significant contribution to reducing $CO_2$ emission of the whole material-circulation system.

## CONCLUSIONS

This report described recycling technologies being worked on by Hitachi — aiming at reducing $CO_2$ emission and creating a "recycling-based society." It is forecast that while underground resources are being depleted, the need to create resources by recycling "terrestrial resources" will grow stronger and stronger. Taking recycling of household appliances as a specific example of the response to this need (in particular, the calculated effect on $CO_2$ emission), we found that if one ton of appliances is recycled by Tokyo Eco Recycle Co.'s recycling process, $CO_2$ generation of about 0.92 tons can be reduced [i.e. 12,000 t ($CO_2$ reduction) ÷ 13,000 t (recycled amount)]. From now onwards, the Hitachi Group is aiming to expand the application scope of this recycling technology so that it covers a broader range of items and can be applied to recover rare metals.

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