LCA Study of home appliance recycling systems
–Evaluation for avoided environmental load comparing different recycling systems–

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A home appliance recycling system, called “thermal elutriation system (TES)” has the following advantages: saves time and problem for disassembly, utilizes melted plastics as energy, collects fine grade for non-shredding, and extracts all CFCs. In this study, the environmental impact of TES was compared to a general recycling system “shredding” sifting out the steel from shredded home appliance. The recycling processes of treated metals and plastics are included in the assessment as avoiding the production impact from virgin materials and energy. In steel recycling, it was assumed that dilution process with iron or fine ore was applied to make the steel quality of TES and the shredding system comparable (shredded steel contains more impurity). Steel from the shredding is recycled in an electric arc furnace with dilution of copper and steel from TES is recycled in an oxygen converter without dilution. TES showed less contribution in all impact categories since TES distracts all CFCs and takes out metals with lower impurity. Even though the shredding collects 90% CFC and 70% thermal insulating CFC, its GWP and ODP were still considerably higher. The dilution process made the big effect in all impact categories.

Keywords: LCA, Home appliance recycling, Metal recycling

I. INTRODUCTION
Expansion of production and consumption and diversification of life style with economic development have increased the waste emission from electric machinery in Japan.1 Meanwhile, we are facing a difficulty to acquire waste treatment system for rising demand for environmental protection and surging land prices. Ebara, Toshiba and Sankyu developed a home appliance recycling system “thermal elutriation system (TES)”, eluting plastics from home appliance, under IMS international cooperation research program This system has the following advantages compared with a shredding
system;
- Save time and problem for disassembly
- Utilize melted plastics for energy
- Collect fine grade metals by non-shredding,
- Collect all CFCs.

In this study, environmental impact of TES was evaluated comparing with a shredding system. GaBi3 LCA software and database, developed by IKP and PE Product Engineering GmbH, were used as the assessment tool and the data source.

II. EVALUATION PROCEDURE
II-A. Outline of treatment systems
Thermal Elutriation System (TES):
Figure 1 shows TES treatment process. The operation processes of TES and the shredding systems is defined as "treatment" instead of "recycling" in order to distinguish from "recycling" process of treated materials. Home appliances, removed board and some plastic parts, are heated at 600–700 degrees and the rest of plastics is eluted down. A part of the plastics is gasified and utilized as thermal energy in the plant. CFCs is extracted in combustion system at over 850 degrees.

Shredding system:
Figure 2 shows Shredding treatment process. This treatment system is commonly used in Japan. After removing motor, compressor, thermal converter, cooling CFC and cooling oil, home appliances are treated in two shredding processes. 90% cooling CFC and 70% of thermal insulating CFC extraction are assumed. Copper and aluminum are not collected. Collection ratio of steel is presumed as 65%.

II-B. Functional Unit
The environmental impact of 1t home appliances (refrigerators and washing machines) from transportation for collecting, treatment, recycling processes was assessed. Plant construction and disposal were not included. In the recycling process, collected steel, aluminum, copper and plastics were estimated as avoided impact.

II-C. Avoided impact
Treated metals and plastic of home appliances are collected and recycled as secondary metals and thermal energy. Therefore, the environmental impact of recycling process should be added into the evaluation process. In this study, the difference of environmental load between virgin material production and recycling and between thermal energy production and plastic incineration is included in the evaluation as avoided impact.

According to blast furnace steel manufacturer, non-shredded steel scrap is able to be recycled in oxygen converter whereas the shredded one is recycled in electric arc furnace for containing more impurity.

It was therefore assumed that dilution process with iron or fine ore was applied to make the qualities equal between treated steels. Steel from the shredding is recycled in electric arc furnace diluting copper from 0.2% to 0.15% and steel from TES is recycled in oxygen converter without dilution.

Oxygen converter mainly utilizes thermal energy for fusion while electric arc furnace uses electric...
power. Since thermal energy has about 3 times higher efficient for energy conversion, it is considered that there would be shown a big difference of environmental impact between their recycling processes. Aluminum and copper are assumed to be recycled to secondary materials. Plastic is assumed to be recycled as thermal energy.

III. RESULTS AND DISCUSSION

III-A. Primary Energy Consumption

Comparing only treatment processes, TES showed 1.6 times higher for PE consumption. TES in total, however, avoided 7 times higher PE consumption due to the steel recycling. There are two reasons considered for the decisive contribution. The first reason would be steel dilution. The copper in riddled steel is diluted from 0.2 to 0.15% to adjust the functional unit to TES. It leads additive energy consumption to apply the environmental load from iron or fine ore production. It is considered for the second reason that the shredded steel is recycled in electric arc furnace utilizing electric power while the steel from TES is fused in oxygen converter utilizing thermal energy. The different efficiency of energy conversion between thermal energy and electric power (thermal energy has 3 times higher efficient) leaded to the contribution higher.

III-B. Global Warning Potential

At the shredding system, the emission of 10% cooling CFC and 30% thermal insulating CFC mostly contributed for GWP. Second contribution was from CO2 emission of plastics incineration. It, however, is still relative small contribution comparing with CFCs emission. The contribution, especially from CFCs emission caused the impact considerably higher than TES. TES avoided the impact overall because of avoiding a big contribution from steel recycling.

III-C. Acidification Potential

TES showed the impact reduction 13 times bigger than that of the shredding system due to the steel and copper recycling. Sulfur is removed at sintering process of steel refinery. This is due to that sulfur has a detrimental effect for steel. NOx is also emitted at refinery process. Therefore steel recycling relatively contributes to the impact reduction. Copper recycling also avoids the impact relatively high since copper refinery emits high concentration of sulfur dioxide.

III-D. Ozone Depression Potential

CFCs emission showed a overwhelming contribution for the impact at the shredding system even though thermal recovery from plastics and steel recycling avoided the impact. The total contribution for the impact was avoided at TES.
while transportation showed a high contribution for the impact. It is mainly for the steel recycling. Comparing two systems, the shredding system showed relative higher contribution.

III-E. Sensitivity Analysis

TES showed less contribution in all impact. It is mainly for the difference of steel and CFCs recycling. Therefore, we examined how contribution would be varied when CFCs are all collected at shredding system and steel at TES is recycled in electric arc furnace. In this analysis, the impact from installation of CFCs collection device is not considered. In both assumption, the contribution to the impact were highly varied. ODP even showed the higher impact avoidance than that at TES when CFCs are all collected at shredding system, the contribution of impacts for GWP and ODP are highly reduced. It is highly suggested for further study to consider the all factor together and discuss suitable amount of CFCs collection.

IV. CONCLUSION

In this study, we compared the contribution of environmental impact between two waste home appliance systems, TES and shredding system. Shredding system showed higher contribution in all impact categories. It was mostly influenced for following reasons.

Steel recycling at shredding system was evaluated with dilution of iron. It leaded the effect of avoiding impact smaller than that at TES.

EAF consumes energy 3 times bigger than OC since EAF utilizes electric power for steel melting. It highly affected in all impact categories.

In this study, we assumed that 90% of cooling CFCs and 70% of thermal insulating CFC are collected while all CFCs is collected at TES. It relatively contributed to GWP and ODP.

Since collected steels between the systems have different impurity, dilution process was applied to make the qualities comparable, but it would cause a limitation in the market to keep cascade recycling from dilution in future. This emphasized the importance of collecting steel with high degree of purity from both environmental and technical aspects. When we made an assumption to collect all CFCs at shredding system, the contribution of impacts for GWP and ODP are highly reduced. It is highly recommended in future to discuss the suitable collecting ratio of CFCs considering all factors together.

REFERENCES


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