Survey of Metal Recovery in the
U.S. WTE Industry

Werner Sunk
Department of Earth & Environmental Engineering,
Henry Krumb School of Mines,
Columbia University, New York, NY 10027
(ws2172@columbia.edu)

Abstract

Part of the WTERT effort to increase the amount of metals recovered by the U.S. Waste-to-Energy industry was a survey to determine the type of equipment used for metal recovery and the quantities of ferrous and non-ferrous metals recovered, and the distribution in percent between front- and back-end recovered metals. A questionnaire was sent to the headquarters of the three major WTE companies and fifty three WTE plants responded with data for the year 2004. As mass burn and RDF plants were examined separately, a comparison of metal recovery by means of these two technologies was possible.

The ways to recover metals in the U.S. WTE industry range from only manual separation of large objects at the tipping floor at mass burn facilities, to front-end recovery at RDF plants, to metal separation from the ash at the back-end of the WTE process or at a regional metal recovery facility.

Accordingly, the amounts of metals recovered range from very little to over 40,000 tons per year. Comparison of the collected with estimated averages of ferrous (5%) and non-ferrous (0.7%) metals in U.S. MSW, indicated that 48% of ferrous and 9% of non-ferrous metal input are recovered at these 53 WTE facilities every year. The remainder is landfilled and represents a revenue loss that may be as high as $160 millions per year, including the payment of tipping fees for landfilling metals.

Mass burn facilities recover an average of 43% of the ferrous and 5% of the non-ferrous metals, while RDF plants recover 71% of ferrous and 30% of non-ferrous of the assumed metal input. However, the metal input in some WTEs may differ from the U.S. average because of effective metal recycling practice in the community.

Analysis of the front- and back-end recovery at mass burn and RDF plants shows that the former recover only 1% of the ferrous metal at the front-end and 99% from the bottom ash. In comparison, RDF plants recover 88% of the ferrous metal at the front-end and only 12% after combustion. Mass burn plants recover 94% of the non-ferrous metal at the back end. It is interesting to note that RDF plants also recover most of their non-ferrous metals (98% of the total) at the back-end.

Our analysis shows that there is room for increasing metal recovery of both ferrous and non-ferrous metals at selected mass burn facilities that presently recover less than 10% of the input ferrous metals. Non-ferrous metal recovery is very low for mass-burn and low for RDF plants. Since the value of WTE metals has increased appreciably recently, due to increased consumption in China, it is a good time to consider plant modifications that will help increase metal recovery. Some of the most likely WTEs for implementing such modifications have been identified and discussions are under way for effecting plant retrofits at some facilities.

A current objective is to obtain similar data from the nearly 30 facilities that were not included in the first part of this survey. We are also trying to determine how metal recycling practice in the communities that supply various WTE facilities correlates with the metal recoveries attained by these facilities.
1 Introduction
Fifty three Waste-to-Energy plants all over the U.S. participated in a WTERT survey of metal recovery. The objective was to determine the amounts of metals in MSW that are recovered in the WTE process – at the front-end from MSW (before combustion) or at the back-end (after combustion) from the ash. A questionnaire was developed and sent to the WTE facilities.

2 The Questionnaire
The questionnaire [1] was developed to determine
- The overall amount of metals (ferrous and non-ferrous) recovered the WTE plant,
- The percentage of this amount of metals recovered at the front- and back-end,
- The equipment used to recover metals at the front- and back-end,
- The quality of the metals recovered and the further processing on-site or off-site at a regional metal recovery facility to increase the market value and marketability.

The questionnaire was sent to the headquarters of the major WTE companies in the U.S. The complete questionnaire as it was sent to the WTE facilities is shown in Appendix 1.

3 State of metal recovery in the U.S. WTE industry [2]
The possibilities to recover metals in the U.S. WTE industry are manifold and range from manual separation of chunky parts at the tipping floor at mass burn facilities, to front-end recovery at RDF plants of ferrous and non-ferrous metals, to metal separation from the ash at the back-end of the WTE process or at a regional metal recovery facility. The U.S. WTE facilities can be categorized regarding metal recovery as follows:

- **Mass burn plants without metal recovery equipment**: Neither ferrous nor non-ferrous metals are separated systematically. Large objects (not only metals) are separated at the tipping floor to avoid damage of the furnace grate, boiler, ash quench and the following ash conveying system. As the separated material is a mixture of all different kinds like tree stumps, steel beams, concrete blocks, etc. it is shipped usually to a recycler, or is landfilled.

- **Mass burn plants with on-site metal recovery at the back-end**: These facilities separate bulky pieces at the tipping floor to avoid damage. After combustion, the ash is quenched and conveyed to the metal recovery equipment. Typically, a grizzly scalper is operated in front of the magnetic separation to avoid damage of the following equipment, although, some plants operate a magnetic separation, only. The fraction separated by the grizzly scalper not necessarily consists exclusively of metals. All pieces bigger then about 8 inches are separated, which might include unburned tree trunks, concrete blocks, etc. This fraction is collected separately and shipped to a recycler or to a landfill while the -8" ash stream is conveyed to the magnetic separation system. Some plants operate two magnets (drum- or belt magnets) to collect different grain sizes of ferrous metals and some have only one magnet. Typically, there is no further processing of the recovered metals or the ash stream on-site the WTE plant. The metals are sold to regional metal recovery plants for further cleaning and processing while the ash is shipped to a landfill. As the metal market has become much more favorable in the last couple of years, many WTEs that are already recovering ferrous metal are considering, or have already installed equipment for non-ferrous metal separation.

- **RDF plants**: RDF plants recover metals at the front-end, from shredded MSW, and at the back-end, from the ash. While the back-end metal recovery from the ash is comparable to the recovery at mass burn plants, the RDF front-end metal recovery process is more advanced and very complex. It usually includes shredding in a hammer mill, several steps of screening in trommel screens and, in between, several magnetic separations. The advantage of front-end metal recovery is that the metals are of better quality due to the absence of ash adherences and less oxidation by combustion and quenching. The WTE front-end metal scrap is in some ways comparable to traditional shredder scrap (i.e. no ash adherence, no oxidation). However, the RDF front-end metal scrap is contaminated with plastic and paper because of its edged and beaked shape. Therefore, this recovered scrap must be shipped to a regional metal recovery facility (scrap processing plant) for cleaning. The main disadvantage of the RDF process are the high costs for building, operating and maintaining the front-end of the plant (shredder, etc.), although advantages such as homogenization of the MSW fuel and more efficient combustion could compensate the disadvantages.

- **WTE plants that cooperate with a regional metal recovery facility**: The cooperation of a WTE facility with a regional metal recovery plant might
start at several stages in the WTE process. Basically, the possibilities for a cooperation are:

1. At the front-end of an RDF-WTE plant: Although, this concept is unusual, it could be possible that the equipment used for metal recovery at the RDF process is operated by a regional metal recovery facility as it is done at the back-end at mass burn plants. Shredding, screening, cleaning, and even baling of the front-end recovered metals could be necessary to meet the market specifications.

2. At the back-end of any WTE plant:
   a) shipping of the ash directly to an off-site regional metal recovery facility to recover ferrous and non-ferrous metals,
   b) after basic ferrous recovery at the WTE plant, the ferrous metals pulled out at the front-end and the bottom ash are shipped to the regional metal recovery facility for further processing and non-ferrous recovery, respectively,
   c) conveying the unprocessed ash to the on-site but separate metal recycler that processes the ash as in a),
   d) a metal recycler designs and/or operates equipment for metal recovery as an integrated part of the WTE plant, and
   e) a metal recycler "mines" the metals, from the ash that a WTE plant has deposited over past years in a landfill.

In a) to e) the depth of the cooperation depends on the contract. The contracts can be exclusive or not and bind the WTE facility and the metal recycler to each other or allow the metal recycler to receive pre-recovered metals or ash from other WTE plants or companies.

Another typical arrangement is that the metal recycler's additional responsibility is the marketing of the recovered metals. The WTE plant is compensated for their effort with a certain percentage of the revenue gained from the sale of the metals.

All the above mentioned configurations of metal recovery were addressed in the responses to the WTERT questionnaire.

5. Influence of quality, market value, marketability of the metals and contracting on the metal price

The quality, market value and marketability of the recovered metals increase with the complexity of the metal recovery system. Therefore, metals that meet the narrow specifications of the market regarding metal impurities (e.g., copper) and contaminations (e.g., ash, plastics, paper, wood) would command higher prices than just pulled out unprocessed metals.

In general the metal prize depends on the international metal trade, as metals are dealt at institutions (e.g., London Metal Exchange LME) like stock exchanges but on a monthly base. This contemplated price is affected by the quality and the content of impurities, respectively, of the recovered metals. This means, the closer the market specifications of the recovered metals are met, the closer the price for the recovered metals will be to the published "official" price.

Furthermore, the contracting with the purchaser (could be the affiliated county or a scrap dealer that processes the metals to meet the specifications of the market) is of great importance. The contracting is often very complex, because third parties like a county could be involved. This applies for ferrous recovery, especially, as many counties order to recover ferrous metals by law. On the non-ferrous side such regulations do not exist, typically. As the county is not involved, the whole profit can be shared between the WTE plant the metal recycler, accordingly to the contract. This is one reason why non-ferrous recovery is more profitable for the WTE facility as ferrous recovery.

There are several WTE plants in the U.S. that get rates for their magnetically pre-separated metals from their contractors that vary up to 400% to 500%. However, the situation in the metal market has changed in the last couple of years and the WTE facilities that have to separate ferrous metals because of state or county regulations now get money from the contractor for on-site recovered metals instead of paying the contractor to take their metals away, as in the past. This new market encourages many WTE facilities in the U.S. to recover ferrous metals, if they not already do, and even install additional equipment to separate non-ferrous metals, as the market value of aluminum, copper and stainless steel is now more then ten times higher (again: depending on the quality) then for ferrous metals.

6. Analysis of the questionnaire

The questionnaire asked each WTE facility to describe the equipment they use for metal recovery, the amounts of the total metals recovered and the distribution in percent between front- and back-end recovered metals at their facility.

As this survey focuses on the amounts of metals recovered and not on where and by whom the metals
are recovered (as long as the metals originate from this particular WTE plant), equipment that is operated by a contractor of the WTE plant (e.g., regional metal recycler) was considered as equipment operated by the WTE plant. Otherwise, these WTE plants would appear as not recovering plants, which would distort the analysis. Such WTE plants recover metals but have chosen to cooperate with a regional metal facility to outsource metal recovery.

In the following analysis, mass burn and RDF plants were examined separately. This allows a more accurate analysis and a comparison of these two technologies regarding metal recovery.

6.1 Metal Recovery at Mass Burn plants

6.1.1 Recovery of ferrous and non-ferrous metals at the front-end

More than 60% of the responding mass burn plants reported to recover either manually or by crane some ferrous and/or non-ferrous metals at the front-end. The amounts of recovered metals were either not specified or very low. Only one plant reported a considerable amount of non-ferrous metals recovered (399 t/yr) at the tipping floor, without using any shredding or eddy current equipment. According to our calculations, this plant recovers 15.6% of the non-ferrous metal input in MSW which is more than other WTE plants reported to recover at the back-end by operating an eddy current separator.

Nevertheless, it can be concluded that the manual separation and the separation by cranes at the tipping floor mainly serves the separation of bulky objects (e.g., white goods, wood, etc.), of whatever material, so as to prevent clogging of the chute or damage to the grate and following equipment, and not for the purpose of recovering metals from the waste stream and prevent damage of the equipment. This separated bulky fraction might contain metal parts but this operation is not at all focused on metal recovery. This situation is supported by the fact that the metal recovery rates are very low.

6.1.2 Recovery of ferrous and non-ferrous metals at the back-end

90% of the responding mass burn plants recover ferrous metals at the back-end after combustion. The remaining WTE plants do not recover metals at all, either at the back- or the front end. The minority of the recovering WTE plants cooperates with contractors and either ship pre-separated ferrous metals or the unprocessed ash to their contractor where the metals are recovered by shredding, several screening steps (e.g. grizzly scalpers, finger screens and trammels) and magnetic-, eddy-current- and manual (stainless steel, copper) separation.

At WTE plants shredders are usually not installed at the back-end to process the ash or the metals before conveying the ash to screening devices and metal recovery equipment. 80% of the responding mass burn plants operate a magnetic separator and only at the back-end. Of these, 60% operate a screening device before the magnetic separation for more efficient separation and equipment protection.

25% of the responding WTE plants are equipped with an eddy current system to separate non-ferrous metals. All of them operate a magnetic separation in front of the non-ferrous separation.

6.2 Equipment used for metal recovery at RDF plants

6.2.1 Recovery of ferrous and non-ferrous metals at the front-end

As expected, all RDF plants that responded to our survey shred the received MSW in a hammer mill shredder to reduce particle size and break up material interconnections. In addition, shredding results in a higher bulk density of the recovered metal that helps to meet certain market scrap specifications.

Most of the responding RDF plants operate additional equipment like trommel screens and bag openers or report manual separation or separation by crane.

As mentioned above, the recovered metals are contaminated with plastics, paper, etc. For this reason one RDF plant reports cooperating with a regional metal recovery facility that cleans the separate metals and markets them.

None of the 5 RDF plants in this survey reported recovery of non-ferrous metals at the front-end.

6.2.2. Recovery of ferrous and non-ferrous metals at the back-end

60% of the responding RDF plants reported that they recover both ferrous and non-ferrous metals at the back-end from the ash by operating magnetic and eddy current separators. The remaining 40% do not recover either ferrous or non-ferrous metals at the back-end and therefore have no such equipment.

One RDF plant that recover metals from the ash by cooperating with a regional metal recovery facility (scrap dealer) that increase the quality of the pulled out scrap by further processing.

6.3 Metal recovery in figures
The 53 reporting WTE facilities processed a total of about 25 million tons of MSW in 2004, which represents approx. 10% of the total MSW generated regarding the Environmental Protection Agency (EPA) of 2003 in the U.S [3]. Furthermore, this amount of MSW represents approximately 86% of the total capacity of the U.S. WTE industry reported by IWSA in 2004 [4].

Table 1 shows the overall recovery rates of ferrous and non-ferrous metals at the 53 WTE facilities.

### Table 1: Generation of ferrous and non-ferrous metals in MSW and recovery rates at the WTE facilities

<table>
<thead>
<tr>
<th>Nr. Of WTE plants</th>
<th>Total tons MSW processed</th>
<th>Ferrous metals</th>
<th>Nonferrous metals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total tons ferrous generated in MSW at 5.0%</td>
<td>Total tons ferrous recovered</td>
<td>Percent ferrous metals recovered</td>
</tr>
<tr>
<td>All</td>
<td>24,736,420</td>
<td>1,236,821</td>
<td>596,163</td>
</tr>
<tr>
<td>Mass Burn</td>
<td>20,377,274</td>
<td>1,018,864</td>
<td>439,868</td>
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<td>RDF</td>
<td>4,359,146</td>
<td>217,957</td>
<td>156,295</td>
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In this study it was assumed that MSW contains approx. 5% ferrous and 0.7% of non-ferrous metals (aluminum, copper, brass, and stainless steel) [3].

Our calculation demonstrates that approx. 48% of the ferrous in the MSW that is processed by the WTE plants is recovered and 52% is discarded in landfills. On the non-ferrous side, only 9% are recovered and the biggest part (91%) is lost in landfills.

It should be noted that not all metals in MSW are recoverable and marketable, especially after combustion, because of the low quality of very small and thin metal pieces. A regional metal recovery facility estimates that only 75% of the recovered metals are marketable. In addition, the metal content in MSW varies by region and season and in communities where there are rigorous source separation programs the metal input in the MSW to WTEs may be lower than the estimated metal content of 5% for ferrous and 0.7% for non-ferrous that we used in our calculation. However, examples in our survey show that the metal recovery rate at some facilities reaches the estimated value of 80% to 90% metal recovery.

Table 2 summarizes the ferrous and non-ferrous recovery rates at the front- and back-end. Our survey shows that most (78%) of the total amount of ferrous recovered (Table 1) is recovered at the back-end from the combustion ash - only 22% are recovered at the front-end from the MSW feed to the WTE. On the non-ferrous side, the situation is even worse, with 96% nearly off the non-ferrous metals recovered at the back-end.

### 6.3.1 Metal recovery at mass burn and RDF plants

Dividing the 53 WTE plants that participated in this survey to mass-burn and RDF WTE plants results in a more accurate picture. Table 1 summarizes the amounts of MSW processed either at mass burn plants or RDF plants and the amounts of ferrous and non-ferrous metals recovered at these two types of plants.

It is shown that less than half (43%) of the ferrous input and only 5% of the non-ferrous metals are recovered at mass burn plants at this time. At RDF plants, the metal recovery is much higher. 72% of the ferrous metals and 30% of the non-ferrous metals are recovered at RDF plants.

### 6.3.2 Metal recovery at the front- and back-end of mass burn and RDF plants

Table 3 summarizes the metal recovery at the front- and back-end at both mass burn and RDF plants. It can be seen that 99% of the ferrous metal recovery of mass burn plants occurs at the back-end. Only 1% is recovered at the front-end, which consist of metals that are too bulky for combustion and could damage equipment. On the non-ferrous side, 94% are recovered after combustion from the ash and 6% before combustion at mass burn plants.

At RDF plants, the situation regarding ferrous recovery is the reverse. Table 3 shows that 88% of the ferrous metal input is recovered at the front-end and only 12% is recovered after combustion from the ash. Although, the rates of front-end recovered ferrous metals are very high at RDF plants, as compared to mass burn facilities, the front-end recovery of non-ferrous is very low at only 2%.

### Table 2: Recovery rates of ferrous and non-ferrous metals at the front- and back-end of a WTE plant

<table>
<thead>
<tr>
<th>Nr. Of WTE plants</th>
<th>Total tons MSW processed</th>
<th>Ferrous metals</th>
<th>Nonferrous metals</th>
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</table>
The total amount of non-ferrous metals recovered at RDF plants is much higher than at mass burn facilities.

7 Conclusions

The analyzed data showed that about 596,000 tons of ferrous (48% of estimated input) and 15,900 tons of non-ferrous metals (9% of estimated input) were recovered in 2004 at the 53 WTE facilities that participated in the WTERT survey. This means that 641,000 tons (52%) of ferrous and 157,000 tons (91%) of non-ferrous were landfilled.

If we assume that the recovery of metals in WTE plants could be increased from current levels to 75% of the total metal discarded in MSW according to EPA estimates, approx. 481,000 tons of valuable ferrous and 118,000 tons of valuable non-ferrous metals are lost in landfills by these 53 WTE plants every year. These quantities of landfilled ferrous and non-ferrous metals correspond to a current market value of about $48 million (at $100/ton) for ferrous and about $94 million (at $800/ton) for non-ferrous metals. It must be noted that these metal market values are conservative and for well processed WTE scrap (shredded, screened, cleaned, baled, etc.) could reach $180/ton [5] for ferrous and over $1000/ton [6] for non-ferrous metals. Based on the same figures we calculated a metal value of over $7.8 per ton of MSW that was processed by the responding WTE facilities. Further calculations show that the value added by recovering metals represent less than 30% of the value added it could be with more extensive metal recovery.

At the same time, the WTE industry has to pay tipping fees to landfill the same quantities of recoverable and marketable metals that were sent to landfills. If we estimate a national average tipping fee of $34/ton [7], the 53 WTE plants would save approx. $20 millions per year (shipping costs to the landfill are not included) on paying tipping fees. Therefore, the total revenue loss because of the sale of the recoverable metals and the savings on tipping fees could be $162 millions per year for the U.S. WTE industry.

While mass burn plants recover an average of 43% of the ferrous and 5% of the non-ferrous metals in MSW, RDF plants recover with an average of 71% of ferrous and 30% of non-ferrous metals significant more metals from the MSW input. In fact, all the RDF plants recover, according our calculations, more than 50% of the ferrous input while only 16 of the 48 mass burn plants reported equally high recoveries.

However, these 16 mass burn facilities demonstrate that high metal recovery rates are feasible for the mass burn technology.

More interesting results are obtained if we consider front- and back-end recovery of metals at the 53 mass burn and RDF plants. At mass burn plants 1% only of the total recovered ferrous metals is recovered at the front-end, 99% are recovered from the ash after combustion. In comparison RDF plants recover 88% of the ferrous metals input at the front-end and only the remaining 12% are recovered after combustion. On the non-ferrous side, the recovery is higher at the back-end than at the front-end for both the RDF and mass burn technology. The analysis shows that 94% of the ferrous metal input is recovered at the back-end of mass burn plants. At RDF plants, 98% of the non-ferrous metal is recovered at the back-end and the total amount of recovered non-ferrous metals is higher for the 5 RDF plants than the total non-ferrous recovery for the 48 mass burn plants.

Table 3: Recovery rates of ferrous and non-ferrous metals before and after combustion at mass burn facilities

<table>
<thead>
<tr>
<th>Type of WTE plant</th>
<th>Nr. Of mass burn plants</th>
<th>Total tons MSW processed</th>
<th>Ferrous metals</th>
<th>Non-ferrous metals</th>
<th>Ferrous metals</th>
<th>Non-ferrous metals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total tons ferrous metals recovered</td>
<td>Total tons nonferrous metals recovered</td>
<td>Percentage ferrous metals recovered bc</td>
<td>Percentage nonferrous metals recovered bc</td>
</tr>
<tr>
<td>Mass burn</td>
<td>48</td>
<td>20,377,274</td>
<td>439,668</td>
<td>6,714</td>
<td>1%</td>
<td>6%</td>
</tr>
<tr>
<td>RDF</td>
<td>5</td>
<td>4,359,146</td>
<td>156,295</td>
<td>9,164</td>
<td>88%</td>
<td>94%</td>
</tr>
</tbody>
</table>

1 before combustion
2 after combustion
Our analysis shows that there is much room for improvement in ferrous metal recovery at several of the mass-burn WTEs that participated in our survey. The non-ferrous metal recovery is low for both mass-burn and RDF plants. In fact, two of the five responding RDF plants do not recover non-ferrous metals at all.

Not long ago, WTE plants had to pay the metal recycler to accept ferrous and even non-ferrous metals that were recovered at the WTE because of state law or contract agreements with the county. Therefore, WTE metals did not generate sufficient revenues to warrant capital investment in metal recovery equipment. This situation has changed drastically, as metal prices in the global scrap markets of both ferrous and non-ferrous scrap have increased appreciably. Therefore the ROI on the investment for the necessary equipment is very high.

The changed circumstances have encouraged many WTE facilities to consider installing additional equipment for increasing ferrous metal recovery and also starting to recover non-ferrous metals. The author of this study visited recently two WTE plants that participated in the WTERT survey and are pursuing the installation of equipment for metal recovery. One of these plants is in the stage of verifying the metal content in their ash and MSW respectively and the other is negotiating with an equipment supplier who will also be responsible for operating the equipment and marketing the recovered metals.

8. Ongoing research

At this time there is a study in progress to address the question, if metals recovered at the front-end are more valuable than back-end recovered metals. This research effort is a university-industry joint project that includes physical and chemical analysis of ferrous and non-ferrous metal samples and characterization of different quality grades of WTE scrap. This may increase the acceptance and therefore the marketability of metals recovered at WTE facilities. In addition, the question of whether combustion decreases the quality and marketability of WTE metals by oxidation and ash adherences will be addressed. At this time, it appears that front-end recovered metal is comparable to traditional shredder scrap or source collected food and beverage cans. Another question to be answered is the effect of combustion on the quality and quantity of marketable non-ferrous metals.

Another interesting issue in this research project is to determine how contracts between the WTE operator and the MSW provider (e.g. county) may affect the will to improve an existing metal recovery system. For example, let us assume that a WTE facility has a contract with the county that commits the plant to recover ferrous metal. The contract stipulates that the revenues from the sale of the recovered metals have to be split between the parties at ratio of e.g. 70% for the county and e.g. 30% for the WTE plant. However, the additional costs for installing, operating and maintaining new equipment must be covered by the WTE plant alone. Such a situation will not encourage the WTE operator to increase metal recovery.

9. References


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