

SOLID WASTE FRONT-END PROCESSING WITH MASS-BURN INCINERATION TO RECOVER RECYCLABLE MATERIAL

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ABSTRACT

Most existing mass-burn waste-to-energy facilities do not recover recyclable materials from delivered mixed municipal solid waste ("MSW") prior to incineration. Community recycling programs typically rely on source separation to recover materials for recycling. However, recent legislative initiatives and community efforts to maximize the recovery of recyclable materials from MSW may result in the need to consider other options such as recovering recyclable material from MSW with a front-end processing system added to a new or existing mass-burn waste-to-energy facility. This paper discusses several issues that should be considered when evaluating and planning front-end process systems for mass-burn waste-to-energy facilities, including: potential material recovery rates; worker health and safety; capital and operating costs; and impacts on mass-burn facility performance.

INTRODUCTION

Currently, the separation of specific MSW components for recycling primarily occurs at the source of its generation (source separation). Mechanical processing of MSW to recover recyclable material at waste-to-energy facilities has largely, with a few exceptions, been limited to refuse-derived-fuel (RDF) facilities. Mass-burn facilities typically have not included recovery of

recyclables other than ferrous metal from incinerator ash residue.

Although the recovery of certain recyclable material is typical for RDF facilities, most successful facilities today recover only a single material for recycling: ferrous metal. Other potentially recyclable materials such as aluminum beverage containers, corrugated paper, high density polyethylene (HDPE) containers, polyethylene terephthalate (PET) beverage bottles, are typically not recovered today at RDF facilities. Front-end processing systems for RDF facilities focus on refining the waste to meet size specifications (shredding) and separating non-combustibles to produce a more homogeneous fuel, rather than recovering recyclables.

Facilities using mass-burn grate technologies, by definition, do not require front-end processing or preparation of MSW before incineration. Actual operating procedures, however, typically include some basic front-end separation of oversized materials and unacceptable waste on a tipping floor with a front-end loader, or in a storage pit with a crane and grapple system. Additional front-end processing is possible as long as the MSW is not processed to the point where the fuel bed becomes too dense and impervious, causing underfire air flow channelling and incomplete combustion on the mass-burn grate.

When evaluating and planning front-end process systems with mass-burn technologies to recover recyclables, several issues should be considered, including: po-

tential material recovery rates, worker health and safety, capital and operating costs, and impacts on the mass-burn facility performance. This paper briefly discusses these issues using an example front-end process system.¹

SELECTING MATERIAL RECOVERY METHODS

There are many different methods of recovering targeted material from MSW for recycling. These methods may rely on equipment and technologies such as belt magnets, eddy current separators, trommels, air knives, optical sensors and froth flotation tanks. In many cases, the targeted material may require some degree of manual separation. When developing a front-end process system to recover recyclables, available material recovery methods should be evaluated and selected after considering several factors, including:

- (a) Existing and future waste composition.
- (b) Existing and potential recovered material recycling markets.
- (c) Recycling market specifications.
- (d) Quantity of material available for recycling.
- (e) Process system experience and reliability.
- (f) Environmental impacts.
- (g) Worker health and safety.
- (h) Impacts on the mass-burn facility performance.
- (i) Economics of other alternatives.
- (j) Process flexibility to meet changing market conditions.

As an example, available recovery methods for certain materials, such as mixed paper (manual separation), may result in a product which is too contaminated to be marketable. Other recovery methods, such as those available for glass (e.g., froth flotation), may be too expensive.

THE DAKOTA COUNTY FRONT-END SYSTEM EXAMPLE

The Dakota County Study selected the following materials for recovery after evaluating several potential recyclable materials and available recovery methods:

- (a) Ferrous metal.
- (b) Aluminum beverage containers.

- (c) HDPE containers.
- (d) PET beverage containers.
- (e) Corrugated paper.

Although a detailed market study was not conducted as part of this project, it was known that a MSW processing facility located in the area was recovering and marketing these materials (the Reuter Resource Recovery Facility located in Eden Prairie, Minnesota).

Of this list of targeted materials, mechanical recovery systems for a facility the size proposed for Dakota County (800 tons per day) were available for only ferrous metal and aluminum. The recovery method selected for ferrous metals was a belt magnetic separation system. Manual separation was selected for the recovery of aluminum beverage containers over available mechanical methods due to concerns about contamination. Without the option of mechanical recovery, the selected method for recovering the remaining targeted materials, HDPE containers, PET beverage containers, and corrugated paper, was also manual separation.

A schematic of the front-end process system considered for the Dakota County Resource Recovery Project as part of the Dakota County Study is shown in Fig. 1. MSW would be delivered to an enclosed tipping hall where a front-end loader would either feed a conveyor to the front-end processing system, or bypass the front-end system by pushing the waste into the main storage pit directly serving the mass-burn incinerators, bypassing the front-end system. MSW sent to the front-end process system would be conveyed first to a corrugated paper manual picking station. After the corrugated paper station, MSW would be conveyed to a trommel screen used to separate larger and generally lighter material (the "overs" fraction) from smaller generally heavier material (the "unders" fraction), aiding in the recovery process. The screen holes would be large enough to allow aluminum beverage containers to pass-through to the unders fraction and the majority of HDPE containers and PET beverage containers to pass over the screen.

With the exception of corrugated paper, the recyclable materials were expected to be delivered in plastic or paper bags. In order to liberate the recyclables from the bags, the trommel screen would employ sharp knife-like blades protruding radially inward in its first section.

After leaving the trommel, the overs fraction would be conveyed to a manual picking station for recovery of HDPE and PET. The remaining MSW would then pass through a belt magnet ferrous recovery system before being conveyed to the main storage pit serving the mass-burn incinerator.

¹ The background for this paper was largely generated during a study by the authors for Dakota County, Minnesota (the "Dakota County Study") as part of the Dakota County Resource Recovery Facility Project which considered using front-end processing with a proposed 800 tons per day mass-burn facility [1].

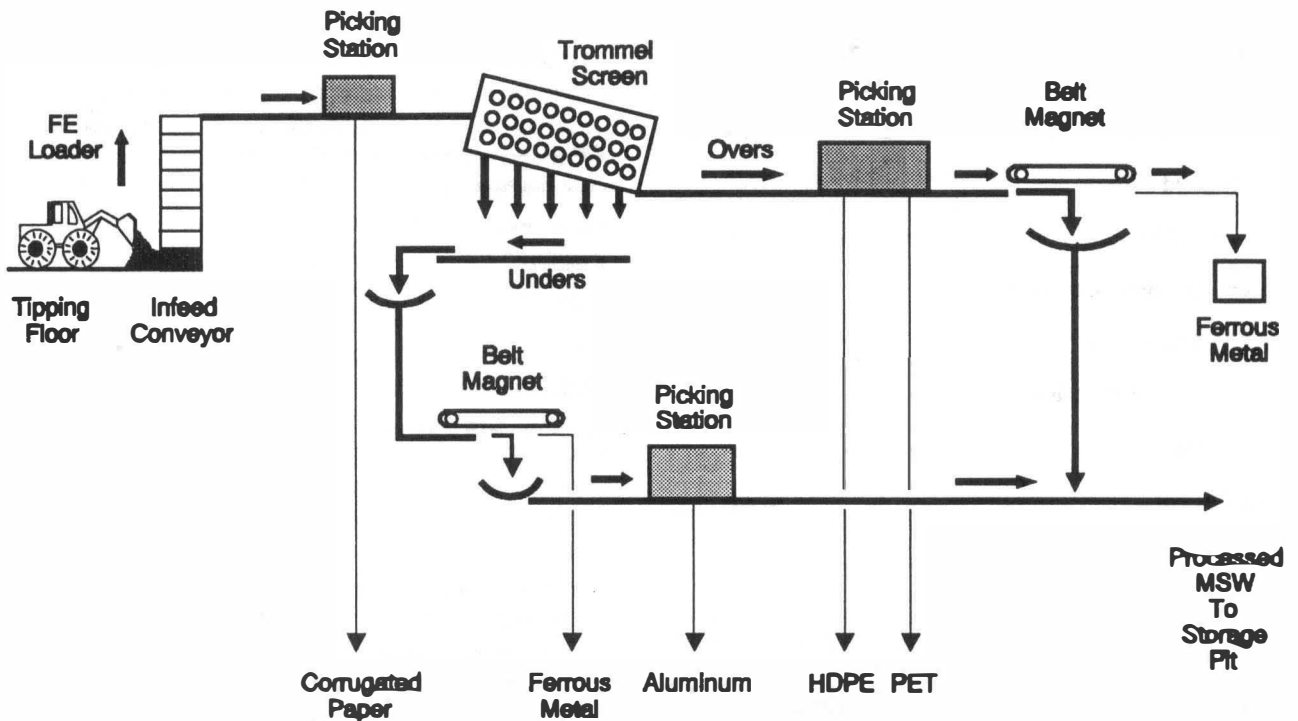


FIG. 1 SCHEMATIC DIAGRAM OF EXAMPLE FRONT-END PROCESS SYSTEM

The unders fraction from the trommel would first pass through a separate belt magnet ferrous recovery system before being conveyed to an aluminum beverage container manual picking station. Upon leaving the aluminum picking station, the MSW would be conveyed to the main storage pit serving the mass-burn incinerator.

The front-end process system evaluated for the Dakota County Facility was conceptually designed to operate two shifts a day, 5 days a week. Two independent processing trains were included; each designed to process a maximum of 43 tons of MSW/hr. The general arrangement of equipment in the Dakota County Study conceptual design provides additional manual separation stations for future recyclables or other targeted materials. The conceptual design also allows the front-end process system to be bypassed in order to maintain the facility's availability. During long periods of downtime, MSW could be dumped directly into the storage pit serving the mass-burn units.

The front-end process conceptual design developed for the Dakota County Study is highly dependent on manual separation. As a result, it is labor intensive, adding significantly to the operating cost of the facility. To date, the number of proven and reliable automated technologies to recover recyclables from MSW is lim-

ited when compared to the number of potentially recyclable materials in the waste stream. Until new automated systems are proven, a front-end process system design using manual separation provides the flexibility to recover a variety of materials, and to expand to recover additional targeted recyclable materials in the future. Manual separation will also allow identification and separation of specific materials which may be targeted because they are significant contributors to hazardous air emissions (e.g., small appliances containing heavy metals), poor ash leachate quality, or maintenance problems with the mass-burn grate/furnace/boiler system [e.g., polyvinyl chloride (PVC) plastic, which contains chlorine].

MATERIAL RECOVERY RATES

Although not included as part of the Dakota County Study, a field sampling program to determine the existing composition of delivered MSW is recommended as a means to determine the content of recyclable materials in the MSW and to estimate recovery rates from a proposed front-end process system. Future waste composition projections should also be considered. Although many communities have recently started source

TABLE 1 ESTIMATED COMPOSITION OF DELIVERED MSW WITH 30% SOURCE SEPARATION RECYCLING

| Item | Composition (% by Weight) |
|------------------------------|------------------------------|
| Corrugated Paper | 10.3 |
| Ferrous Metal | 3.5 |
| Aluminum Beverage Containers | 0.3 |
| HDPE Containers | 1.5 |
| PET Beverage Containers | 0.3 |
| <u>Other Materials</u> | <u>84.1</u> |
| Total | 100.0 |

separation programs, their programs may not have had a chance to mature, and as a result, the existing composition of MSW delivered to the mass-burn facility may change significantly, impacting potential recovery rates and economics of front-end processing.

For the Dakota County Study, an existing source separation recycling rate of 30% was used as a base study case assumption (the definition of recycled material matched that defined in Minnesota Statutes at the time of the study, which included composted yard waste). The net composition after recycling was developed using the gross waste composition results of a 1987 study conducted in the area [2] and assuming specific source separation capture rates for recyclables. Yard waste composting was assumed to account for approximately one-third of the 30% source separation recycling rate. Table 1 shows the projected net composition of delivered MSW to the front-end process system while achieving 30% recycling due to source separation programs in the county.

The total percentage of targeted recyclables remaining in the waste stream after source separation was estimated at 15.9%. Assuming all of this material could be recovered, the total recycling rate in the county (as a percent of gross waste generation which includes source separated recyclables) would increase from 30% to 41.3%. It is unrealistic to expect to achieve this amount from front-end processing, but this exercise provides an indication of the potential range of recovered target material quantities.

To develop a reasonable estimate of the potential quantity of material which could be recovered using front-end processing, more realistic recovery rates for the targeted materials were estimated.

TABLE 2 ANNUAL ESTIMATES OF RECOVERED RECYCLABLES WITH FRONT-END PROCESSING*

| Item | 30% Source Separation (Tons) | 35% Source Separation (Tons) |
|------------------|------------------------------------|------------------------------------|
| Corrugated Paper | 6,019 | 978 |
| Ferrous Metal | 6,339 | 5,887 |
| Aluminum | 280 | 213 |
| HDPE | 925 | 742 |
| PET | 448 | 270 |
| Totals | 14,011 | 8,090 |

* Based on a MSW processing rate of 234,000 tons per year.

For the magnetic separation system selected as part of the Dakota County Study, the recovery rate of ferrous metal was assumed to be between 70% and 80%. The manual recovery rates for the corrugated, aluminum, HDPE and PET picking stations were estimated after evaluating the quantity of material being processed, depth of material on the conveyors, the number and size of materials passing through the picking stations, the potential fraction of material that may not be marketable if recovered, and the selected number of pickers. The selected total number of pickers recovering recyclables in the Dakota County Study was 28 per operating shift.

Table 2 shows the estimated annual quantity of recyclable material recovered while processing 234,000 tons of MSW for the case assumption of 30% source separation recycling. This quantity is approximately 6% of the MSW processed and 5% of the total gross quantity of waste generated in the county (assuming that all MSW not recycled is delivered to the facility and that the gross quantity of MSW in the county is approximately 334,000 tons). Thus, with front-end processing, the county would be capable of increasing their overall recycling rate from 30% to 35%.

Also as part of the Dakota County Study, a sensitivity analysis was conducted to determine the performance of front-end processing with a higher level of source separation recycling. With an as delivered MSW composition derived for 35% source separation recycling, front-end processing was estimated to recover the annual quantities shown in Table 2. The results of this analysis indicated that approximately 3½% of the total waste processed would be recovered as recyclables. This would provide a total county recycling rate of approximately 37%.

WORKER HEALTH AND SAFETY

Some level of manual separation is expected with a front-end process system as a result of the limited number of mechanical systems available to recover recyclable material from MSW. Manual separation of MSW can expose workers to health and safety risks which should be considered during the design and operation of the facility. Chief among these potential health and safety hazards are exposure to biologic aerosols, dust, sharps and chemicals. There is only a very limited amount of quantitative information on the health hazards to workers in MSW processing facilities [3].

The health risk from biologic aerosols, dust and chemicals can be reduced by requiring workers to wear protective clothing and equipment such as: a face mask suitable for filtering out dust and microbiologic aerosols that could be inhaled; gloves which are nonabsorbent and resistant to most chemicals to protect against dermatitis agents; protective eyewear to reduce exposure to potential disease agents; and uniforms which completely cover arms and legs for protection from dermatitis agents. In order to further reduce exposure to biological aerosols and dust, manual separation stations should be in an enclosed area which is well ventilated and equipped with a dust collection system. Worker health risks should be evaluated and addressed during the development of ventilation, dust control, and odor control specifications.

Safety risks from exposure to chemicals and sharps when picking through MSW can also be reduced with protective clothing and process design techniques. One design technique for minimizing worker exposure to sharp objects is to separate these materials before the manual separation stations. Sharps, such as glass and syringes, are relatively small (glass after being broken up through handling with a front-end loader and/or trommel) and can be separated using a trommel screen (unders fraction). The overs fraction of the screen would contain larger paper and plastic materials for recovery in a manual separation station without most of the sharps.

Another design technique that allows a reduction in the safety risks associated with manual separation is to minimize the burden depth and velocity of the waste stream being sorted by workers. This will allow a more clear identification of targeted material in the waste stream, allowing more efficient material recovery. When burden depths are too large, workers will have to search through passing material to identify targeted materials that may be hidden, exposing workers to greater safety risks. High material velocities will re-

quire workers to respond too quickly to recover targeted materials, increasing the potential for accidents.

When using manual separation as part of a MSW front-end process system, it is recommended that a health and safety risk management program be developed before start-up of the facility. This health and safety risk management program could include:

- (a) Worker health criteria for screening applicants.
- (b) Physical examination plan.
- (c) OSHA compliance review plan.
- (d) Required safety equipment and apparel.
- (e) Worker hygiene practices and procedures.
- (f) Hygiene training program.
- (g) Worker safety training program.

CAPITAL AND OPERATING COSTS

One significant issue impacting the decision to add on a front-end process to recover recyclables before mass-burn incineration is cost. The capital cost of the front-end process facility analyzed in the Dakota County Study [4] was estimated to be approximately \$16 million in January 1992 dollars (\$20,000 per installed ton of processing capacity). This cost includes only the additional cost of adding the front-end system described above to a proposed 800 TPD mass-burn incinerator.

The Dakota County front-end system capital cost estimate includes the additional cost of a larger tipping floor and building to receive, store and feed the front-end process in-feed conveyor system. The current design of the Dakota County Resource Recovery Facility also allows MSW to be dumped directly into a storage pit.

The additional cost of two larger storage pit crane/grapple systems were also included to maintain the design furnace charging rate. A large crane/grapple system is required as a result of processed MSW material from the front-end processing facility being conveyed to one end of the storage pit, increasing the average duty cycle time of the crane/grapple system when compared to facilities which receive MSW along the length of its storage pit.

The capital cost estimated for the Dakota County facility does not include any savings that may be realized from a reduction in the size of the mass-burn system, since the design approach in the Dakota County Study was to provide for facility operation with or without front-end processing. The rated capacity of the mass-burn incinerator units and energy recovery system may be reduced somewhat if it is assumed that the front-end process facility recovers 14,011 tons of

recyclable material out of the 234,000 tons/year processed.

If a bond costs sizing factor of 1.25 times the estimated capital costs, an average bond interest rate of 8%, and an amortization period of 20 years is used, the addition debt service required as a result of the front-end process facility would be approximately \$2.0 million per year.

The additional operating and maintenance cost of the front-end processing facility was estimated to be \$2.6 million in January 1992 dollars.² Approximately, 70% of this estimate was due to the cost of labor.

The operating and maintenance cost estimate did not include any cost impacts which might be realized with the mass-burn facility. These cost impacts may include, for example, a change in the cost of maintenance, gross power generation (although the electrical cost of operating the front-end process facility is included in the operating and maintenance cost estimate), and ash disposal costs.

The annual revenue from recovered recyclables in the base case analysis (30% source separation recycling before front-end processing) was estimated to be approximately \$740,000. This estimate may vary substantially, depending on market conditions and the quality of the recovered product.

After adding the estimated annual debt service, and operation and maintenance cost, then subtracting estimated revenues from the sale of recyclables, the total net annual cost of adding the front-end process facility to the Dakota County Resource Recovery Facility was estimated to be approximately \$3.9 million. This would increase the tipping fee at the facility by approximately \$17/ton.

With the system proposed and a delivered waste composition reflecting 30% source separation recycling, the cost of recovering recyclables would be approximately \$280/ton of recyclable material recovered. This cost has not been adjusted to account for the savings in ash disposal, or other economic impacts front-end processing may have on the performance of the mass-burn steam generators.

The cost of recovering recyclables with front-end processing can be compared to the additional cost to the county of achieving the same results with a curbside collection, source separation program. Dakota County estimated that increasing total recycling in the county from 30% to 35% with source separation would cost approximately \$40/ton of additional recyclable mate-

rial captured in 1989 (Dakota County, 1990) or approximately \$45/ton in January 1992 dollars. This incremental cost estimate assumes that all recyclable materials targeted by the front-end process system are already being collected by existing curbside source separation programs. Also, the performance of the source separation program is highly dependent on citizen and commercial participation.

For the front-end process system evaluated as part of the Dakota County Study, it would appear that recovering recyclables with source separation is substantially less expensive than with front-end processing. However, project specific factors other than those assumed in the Dakota County Study may significantly impact the actual economic feasibility of using front-end processing to recover recyclables. For example, the source separation program evaluated in Dakota County already included separate curbside collection for the recyclable materials targeted in the front-end process analysis. Adding materials such as corrugated paper or plastic to an existing curbside collection program would be expected to result in significantly higher incremental costs. Communities which are expanding their source separation programs to include new materials or new collection methods may face incremental costs which are substantially higher than those estimated for Dakota County. Therefore, before dismissing front-end processing due to cost, a project specific economic analysis comparing alternatives should be conducted.

Furthermore, some states have set recycling goals as high as 50% and 60% by the year 2000 (e.g., Minnesota, New Jersey). To achieve these goals, many communities may have to look beyond typical source separation programs to meet these mandated targets. As goals are set higher, more materials will require management, making implementation of recycling programs more difficult and costly. Once a front-end process system has been implemented, the incremental cost to achieve higher community recycling goals with front-end processing may be less than with a source separation program. Therefore, while cost is a significant factor, the application of front-end processing to mass-burn incineration will require a careful evaluation of many factors.

IMPACTS ON MASS-BURN FACILITY PERFORMANCE

Several potential impacts on the performance of the existing or planned mass-burn facility should be considered when planning front-end processing facilities, including: grate mechanical performance, furnace and

² The operating and maintenance costs estimated in the Dakota County Study have been adjusted to include the recovery of only recyclables (no other targeted materials) and higher labor costs.

boiler maintenance requirements, waste energy content, ash generation, ash quality, and air emissions.

Grate Mechanical Performance

Although difficult to quantify, discussions with two experienced grate manufacturers indicated that the mechanical performance of a mass-burn grate is expected to improve with the recovery of recyclables using front-end processing [5, 6]. This is particularly true for the removal of inerts such as aluminum and ferrous metal which may contribute significantly to maintenance problems. Substantial removal of aluminum metals from MSW will reduce the clogging of underfire air distribution ports resulting from the solidification of molten aluminum on the grate bars downstream of the burning zone. If aluminum material other than that recovered for recycling is still causing grate maintenance problems, it could also be considered for front-end recovery and separate disposal. These materials may include lawn mowers, window rims, and small appliances containing aluminum.

Recovery of ferrous metal is expected to reduce grate bar wear and resulting maintenance requirements. Front-end processing also allows better screening of large ferrous appliances, such as water heaters, which may cause unit downtime due to bridging in the grate bottom ash chute or ash discharger.

Removal of significant noncombustible components, such as ferrous metal and aluminum, also offers the potential for better burn-out on the grate. If the grate (and boiler, to the extent that the design heat release rate and gas flows are reduced) is designed based on the expected composition and characteristics of MSW processed with a front-end system, consideration may be given to reducing the total mass residence time of the grate. Reducing the design mass residence time on the grate may result in somewhat smaller, less costly grate.

Furnace and Boiler Maintenance

The removal of materials such as glass and PVC with a front-end process system may have the benefit of reducing furnace and boiler maintenance costs. It may not be economically feasible to recover glass with a mass-burn front-end process system, but its removal from fired MSW would be expected to reduce the potential for slagging in the furnace. Removing glass, a major silica source of incinerator ash, helps raise the fusion temperature of the ash, thereby reducing the potential for slagging. As a result, the maintenance cost associated with deslagging the furnace would be expected to

be reduced. Moreover, a cleaner waterwall furnace with reduced slag deposits leads to more efficient heat transfer, and ultimately, an increase in energy recovery.

A significant contributor to hydrogen chloride formation in the furnace is the presence of PVC in MSW. PVC is made up of approximately 45% (weight basis) chlorine [7]. The removal of PVC for recycling or separate disposal with front-end processing is expected to reduce corrosion in the furnace and boiler, maintenance costs and hydrogen chloride emissions from the facility. Although the recovery of PVC was not included in the front-end process example shown in Fig. 1, the example system could be easily adapted to recover PVC by adding additional picking stations.

Waste Energy Content

The impact of front-end processing on energy content or higher heating value (HHV) of the solid waste fired in the mass-burn incinerator is highly dependent on the materials selected for recovery, the HHV of recovered materials relative to other materials in delivered MSW, and individual material recovery rates. In general, the annual average HHV of delivered MSW ranges from approximately 4800 Btu/lb to 5000 Btu/lb. If for example, only corrugated paper with a HHV of approximately 7000 Btu/lb [8] is selected for recovery, the HHV of the processed waste fired in the mass-burn incinerator would be expected to decrease. On the other hand, if only ferrous metal was recovered, the HHV of processed waste would be expected to increase. Combinations of combustible and noncombustible material recovered using front-end processing may either increase or decrease the HHV of the processed waste.

A comprehensive, moderate source separation recycling program (recycling four to eight materials and achieving 15–40% recycling including yard waste) is generally expected to increase the HHV of MSW based on the typical types of materials recycled and capture rates experienced today. Recovering several recyclables with front-end processing is similarly expected to increase the HHV of fired MSW. The Dakota County Study estimated that the front-end process system discussed above would increase the average HHV of fired MSW by approximately 2% while assuming a source separation rate of approximately 30%. In general, the rate of increase in HHV is expected to be a function of the results of community source separation programs. However, a detailed analysis of the potential impacts of a proposed front-end processing system on HHV is recommended.

While the HHV of the waste may increase, since the total quantity of waste will decrease, the net effect on

existing facilities may actually be a reduction in the amount of energy available for recovery with a limited supply of waste. For example, the 2% increase in HHV reported in the Dakota County Study is offset by the fact that approximately 6%, by weight, of material processed was recovered for recycling, leaving a net reduction in energy released in the furnace of approximately 4%.

Ash Generation

As a result of removing recyclable materials from the waste being fired, the total generation of ash from the facility is expected to be reduced. The ash generation rate (as a percentage of MSW fired), however, may increase or decrease depending on the quantity of noncombustible materials recovered versus the quantity of combustible material recovered with front-end processing. The front-end process system analyzed in the Dakota County Study was estimated to reduce the amount of total ash generated per ton of processed MSW fired by approximately 13%, without taking into account the recovery of ferrous from incinerator ash. If front-end processing was compared to the proposed Dakota County facility, which would include a system to recover ferrous metal from the ash, the estimated ash generation rate (as a percentage of MSW fired) would actually increase by 3–4% with front-end processing. This result from the Dakota County Study was primarily due to the removal of more material with a relatively low ash content (other than ferrous metal), which increases the average ash content of fired waste.

Ash Quality

Ash quality is often defined in terms of the quality of leachate from the ash. Poor quality leachate can contaminate surface or ground water sources unless properly contained and disposed. The quality of actual leachate from ash landfills and tests which predict the quality of ash leachate may determine the disposal requirements for ash generated by waste-to-energy incinerators. Poor quality leachate may result in more costly disposal of ash.

In general, factors that influence ash leachate quality other than the method used to manage the ash include the following:

- (a) Soluble heavy metals concentration.
- (b) pH.
- (c) Organic content.

Of the factors that affect ash quality, both the pH and organic content of the ash are not expected to be significantly impacted by front-end processing.

Front-end processing does provide the opportunity to remove items which contain heavy metals. For example, the largest contributor to lead and cadmium in MSW is reported to be from various types of batteries [9]. The recovery of ferrous metal with an appropriately designed magnetic recovery system is expected to result in the removal of some batteries (although not all) before incineration with front-end processing. Other materials, such as appliances and electronic circuit boards, which contain heavy metals, could also be targeted for removal in the front-end process system.

However, in order to determine the impact of removing materials containing heavy metals with front-end processing on ash quality, a correlation is required between recovered heavy metals and soluble heavy metals left in the ash. The waste materials which contain heavy metals are known, but no data is available on which materials contribute to the most leachable portion of these materials in the ash. For example, will a pound of lead from a battery have a greater propensity to leach out of ash than a pound of lead that was used as a heat stabilizer in plastic? If front-end processing recovered a large percentage of the heavy metals present in delivered MSW, ash quality would be expected to improve. But, more research in this area is needed before the impacts of front-end processing systems can be predicted with certainty.

Air Emissions

In order to predict the impacts of a front-end processing system on air emissions from a mass-burn facility, a correlation between pollutant emissions and materials being removed before incineration is required. With heavy metals for example, the fraction typically volatilized during combustion would have to be known for each type of material removed. The fraction of this volatilized material that would be typically recovered by the facilities air pollution control device would also have to be known. This information is currently not available.

Test data from waste-to-energy facilities have shown total heavy metal emissions and ash concentrations, but the authors are not aware of available test data which identifies the contribution individual materials have towards the volatilized fraction of heavy metals.

Test data are available on recovered heavy metals using modern air pollution control equipment indicating that recovery efficiencies for heavy metals are related to particle size distribution of uncontrolled emissions. If the front-end process removes the portion of heavy metals that the air pollution control equipment can't recover, then there could be significant reductions

in heavy metal emissions. However, given the apparent lack of available data, it is difficult to predict with certainty whether front-end process systems will significantly affect heavy metal air emissions from mass-burn waste-to-energy facilities.

While reviewing a Prevention of Significant Deterioration Application for the Spokane Regional Waste-to-Energy Project in 1989, the United States Environmental Protection Agency similarly concluded that not enough technical data was available to determine the air quality benefits of front-end processing (or source separation) in combination with state-of-the-art air pollution control equipment [10].

SUMMARY

Many factors should be considered when evaluating methods to recover recyclable material from MSW using front-end processing. The recovery of certain materials for recycling may not be technically or economically feasible.

With the limited number of mechanical systems available to recover recyclable material from MSW, some level of manual separation would most likely be required. When manual separation is used, a health risk management program should be developed to address worker health and safety issues.

Material recovery rates of front-end processing systems will be impacted by source separation programs collecting the same materials.

The cost of recovering recyclables with front-end processing may be more expensive than existing average source separation program costs on a dollar per ton of material recovered basis. However, a project specific economic analysis comparing the incremental costs of alternatives should be conducted before dismissing the option of front-end processing due to cost. As community recycling goals are set higher and more materials are targeted, source separation programs are expected to be more costly, potentially improving the economic feasibility of front-end processing.

Several potential impacts on the performance of an existing or planned mass-burn facility should be considered when planning front-end processing facilities. When removing inert material such as aluminum and ferrous metal with front-end processing, the mechanical performance of the mass-burn grate is expected to

improve. The removal of other materials such as glass and PVC may have the benefit of reducing the cost of maintaining the furnace and boiler. The HHV of processed MSW fired in the mass-burn incinerator is, in general, expected to increase, but will be dependent on the type and quantity of materials recovered. Total ash generation will be reduced, but the change in ash generation rate will also be dependent on the type and quantity of materials recovered with the front-end process system. The impacts on ash quality and air emissions may be positive, but it is uncertain whether or not these impacts will be significant.

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- [10] "Order Denying Review, In the Matter of: Spokane Regional Waste-to-Energy Applicant," (PSD Appeal No. 88-12), issued by the Administrator, Washington, D.C.: U.S. Environmental Protection Agency, 1989.