ABSTRACT

COMBS, ANTHONY RUSH. Life Cycle Analysis of Recycling Facilities in a Carbon Constrained World. (Under the direction of Joseph F. DeCarolis and Morton A. Barlaz).

Increased focus on greenhouse gas (GHG) reductions has made recycling an attractive target for landfill diversion of municipal solid waste (MSW). In 2009, recycling of 74 million Mg of MSW led to a 178 million Mg reduction of CO_2-e (EPA, 2010). Costs and energy consumption associated with the recovery of recyclable material from MSW have increased as more programs migrate to single-stream processing, in which all recyclable materials delivered to the material recovery facility (MRF) are mixed (AFPA *et al.* 2004). The objective of this research was to analyze the material recovery process to characterize the relationship between key MRF parameters, total processing cost, and resultant emissions.

Sensitivity and uncertainty analysis conducted on a single-stream MRF model provide insight into which parameters most effectively drive cost and CO_2e reduction. Results are similar between manual and automated facilities. Diesel combustion accounted for the majority of greenhouse gases (GHGs) emitted, while the cost of this fuel represented a primary driver of system cost. The ability to recover materials that are either high value in remanufacturing markets or constitute a significant percentage of MSW composition are identified as the most influential on reductions in system cost.

Life Cycle Analysis of Recycling Facilities in a Carbon Constrained World

by
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BIOGRAPHY

Rush Combs was the first born into a family of four on August 18, 1981. Throughout elementary school he excelled in the sciences, which ultimately culminated in a B.S. in Mathematics with a minor in Computer Science earned in December of 2005. After spending several years working as a freelance software developer, Rush chose to pursue a M.S. in Environmental Engineering in 2009. His research focused on energy and process modeling of environmental systems. Here he will stand in a long lineage of Combs family graduates from the North Carolina State Civil Engineering Department originally started in 1918.

ACKNOWLEDGMENTS

I would like to thank those people whose mentorship provided me with the direction and expertise necessary to complete this body of work. In particular, I would like to thank my committee members: Dr. Joseph DeCarolis, Dr. Morton Barlaz, and Dr. S. Ranji Ranjithan, as well as my colleagues: James Levis and Dr. Anders Damgaard. This effort was also made manageable though the support of my family and friends.

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1 INTRODUCTION & OBJECTIVES

Municipal solid waste (MSW) is characterized as all solid waste that consumers discard, excluding industrial, hazardous, and construction wastes. At the municipal level, this material must be managed and disposed of in a safe and effective manner to prevent threats to human health and the environment. Management of this waste requires that a solid waste management (SWM) program be developed to handle MSW from collection to disposal or beneficial reuse.

Traditionally landfills have been the primary disposal option; however, increasing interest in landfill diversion programs are encouraging beneficial reuse alternatives. This is often accomplished via landfill bans on specific types of waste. Typically these wastes already have alternate means for disposal or reuse, such as recycling. Recycling currently represents a significant portion of SWM across the nation, with per capita MSW generation in 2009 reaching 4.34 lb/person/day and 33.8% of this material being recycled or composted (EPA, 2010). Continuing focus on landfill diversion will likely increase the recycling rate in years to come.

Beneficial reuse alternatives not only allow more material to be diverted from landfills, but also to be repurposed by industry. Further, for many types of waste, recycling lowers GHG emissions, which aids in the mitigation of climate change. After recyclables are collected and sorted, they may be used to offset some amount of virgin material used in the production of new materials. The effective provision of high-purity feedstocks to remanufacturing relies on the efficient sorting of recyclables from the facility's input waste stream.

The separation of recyclables into streams suitable for remanufacturing is accomplished in material recovery facilities (MRFs). Different types of MRFs accept varying levels of sorted material, thus requiring an upstream collection option appropriate for the facility. There are four primary types of MRFs: mixed waste, single-stream, dual-stream, and presorted. MRFs are defined by the amount of presorting as well as the incoming waste composition from which they recover material. Mixed waste facilities receive all MSW, single-stream exclude all non-recyclable material, dual-stream MRFs receive recyclables that have been sorted into fiber and container streams, and a presorted recyclables facility receives recyclables sorted for remanufacturing.

The combination of collection systems and MRF configuration options gives rise to a complex set of management possibilities. For example, if a mixed waste MRF is used, only one collection route would be required to collect MSW, but this also leads to increased cost for separation and decreased quality of recovered material, which would hamper the remanufacturing process. Alternatively, efforts to produce a clean, sorted stream may suggest collecting mixed waste and recyclables separately, which would require the use of a single-stream MRF. As such, an integrated approach is required to analyze the SWM system.

A growing number of management options have added significant complexity to decision making when considering SWM programs. Planning-level tools aid in the selection of effective management techniques by incorporating factors outside the realm of traditional waste management. Incorporating life-cycle assessment techniques allows for inclusion of raw material procurement, energy utilization, and subsequent emissions to the environment, thus providing more comprehensive consideration of costs and environmental burdens.

The objective of this research is to develop models of the four major types of MRFs (mixed waste, single-stream, dual-stream, and presorted) and use life-cycle assessment techniques to quantify costs and emissions associated with the construction and operation of these facilities as a function of waste composition. While the focus of this research concentrated on characterizing MRF operation, these models are developed to be integrated into a suite of models used to analyze SWM. By including the costs and environmental benefits associated with remanufacturing and disposal of residual, a more comprehensive analysis of the SWM system may be conducted. Likewise, upstream costs and savings from collection program augmentation may also be considered.

The MRF models developed for this research are part of a larger effort to create life-cycle unit process models for all of the processes that comprise the waste management system and integrate them into a single SWM system model. Holistic modeling of the solid waste system requires the development of a decision support tool, which may be used to optimize waste management systems based on cost or emissions. The software tool under development, known as the Solid Waste Optimization Life-Cycle Framework (SWOLF), uses an optimization framework that integrates inputs from a number of other unit operation models similar to the MRF to aid policymakers and planners interested in evaluating SWM alternatives. Figure 1.1 illustrates how different materials flow through the system by considering options relevant to recycling.

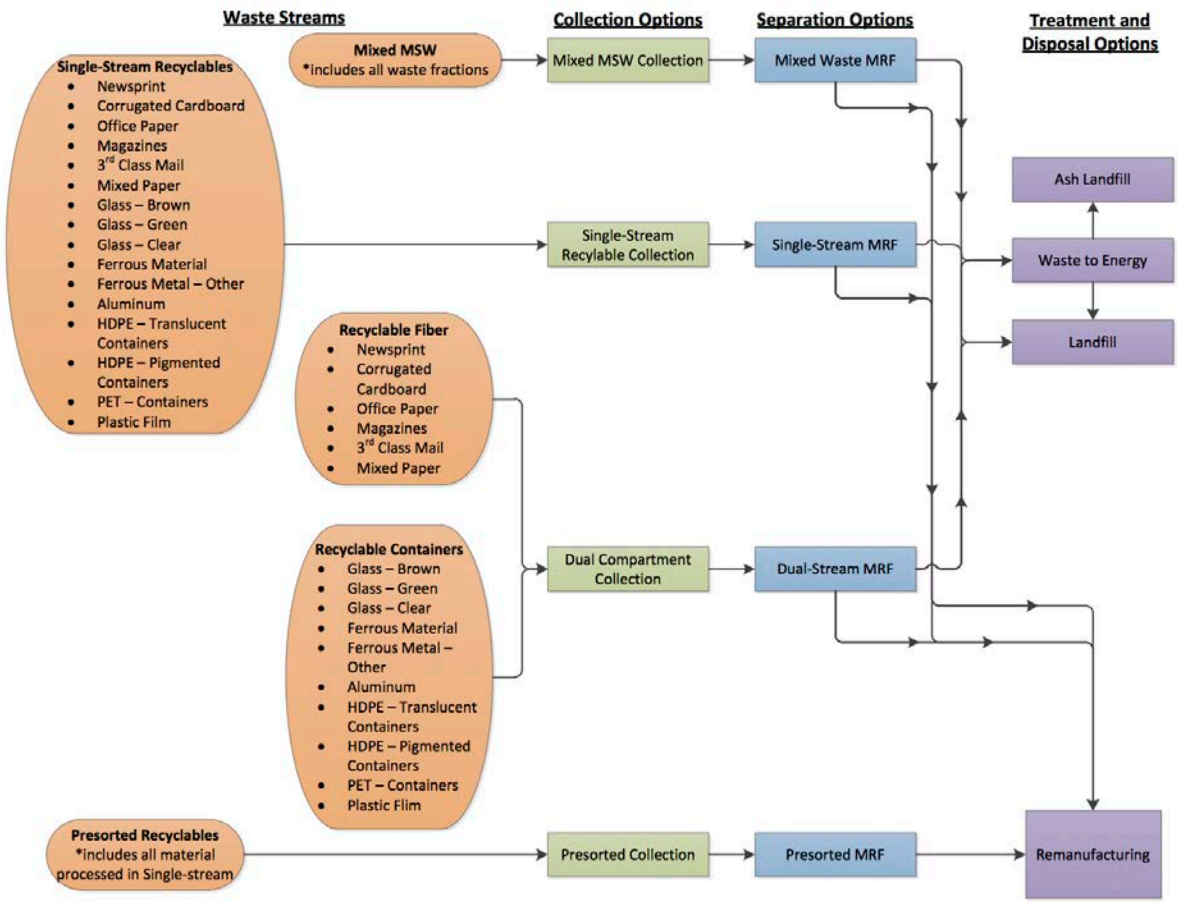


Figure 1.1 Recycling-relevant management alternatives associated with collection, recovery, beneficial reuse, and disposal of MSW.

The thesis is structured as follows: Chapter 2 describes the development of the MRF process models, including documentation and the required data development and results. A comprehensive sensitivity analysis is described in Chapter 3 and the conclusions drawn from results and analysis are discussed in Chapter 4.

2 MODEL DEVELOPMENT

The objective of this chapter is to describe how the 4 different MRF types are modeled to represent emissions and costs associated with the processing of materials into waste streams suitable for remanufacturing. This chapter is divided into two subsections to separate those MRFs requiring material separation from those receiving presorted material. A systems-level view of how material moves through these types of facilities is presented before elaborating on the modeling approach. Calculations required to attribute emissions and costs to material type are then discussed. Finally, each section is concluded with subsections on user input and data development.

The primary focus of the MRF model is to quantify the costs and life-cycle emissions associated with the separation of recyclable materials. A model boundary diagram is provided in Figure 2.1 to outline the consumption of resources as well as the production of revenue and emissions resulting from the separation of recyclables in a MRF.

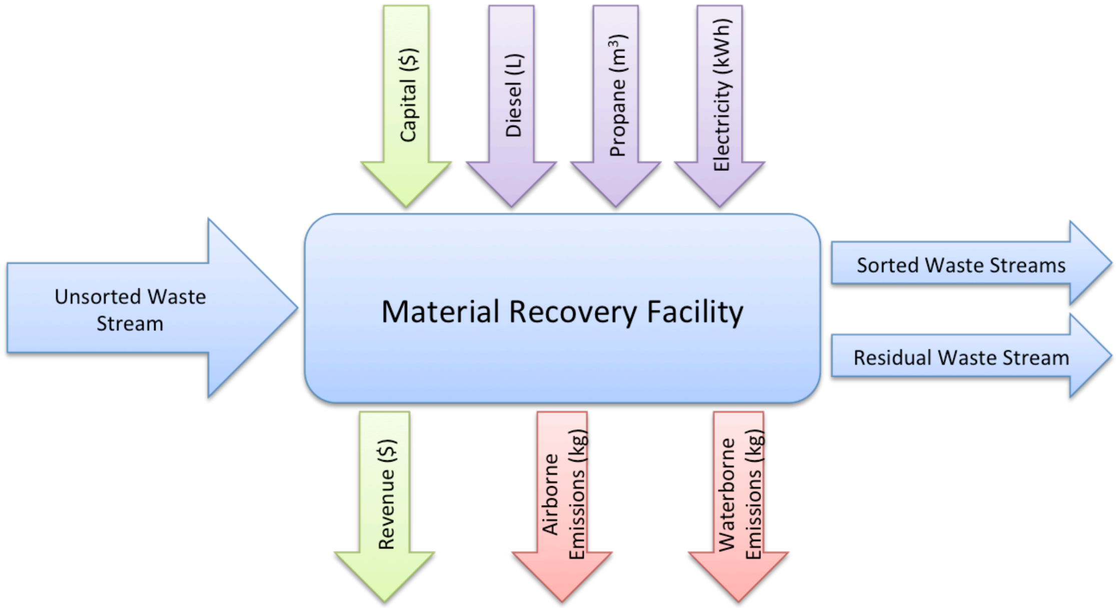


Figure 2.1 Boundary diagram illustrating input and output waste streams in blue arrows. Energy consumed by the facility is shown in purple, while corresponding emissions are shown in red. Cash flow through the system is shown in green.

A goal of model development is to offer flexibility regarding the degree of facility automation while remaining generic enough to handle all recyclable waste streams considered in the model. The generic MRF model developed for single-stream, dual-stream, and mixed waste recovery is illustrated in Figure 2.2 in the form of a process flow diagram (PFD). This process is based on a number of currently operating single-stream MRFs whose individual PFDs are shown in Appendix D. Given the prevalence of single-stream MRFs in the industry, they are the main focus of this research. A dual-stream facility is also modeled wherein the same materials are received, but a slightly higher separation efficiency can be achieved. This increased separation efficiency is due to less cross-contamination of streams, since fiber and containers are collected separately. Despite the current scarcity of mixed waste facilities, they are modeled for the sake of completeness. Mixed-waste facilities receive mixed waste and sort all recyclables, but due to the complexity of sorting, recovery of a high quality product is challenging. At the other extreme, presorted recyclables MRFs receive separate material streams and therefore require no separation, only preparation for shipment to remanufacturing facilities (e.g. baling). A presorted recyclables MRF is also modeled and accepts waste from either household source-separating recyclables or crew-sorted at the curbside. All facilities are modeled empirically, using a top-down approach, while mechanistic approaches are taken where appropriate for certain sub processes. Top-down modeling emphasizes higher-level processes, such as the separation of material, before considering low-level supporting infrastructure, including floor-area and lighting.

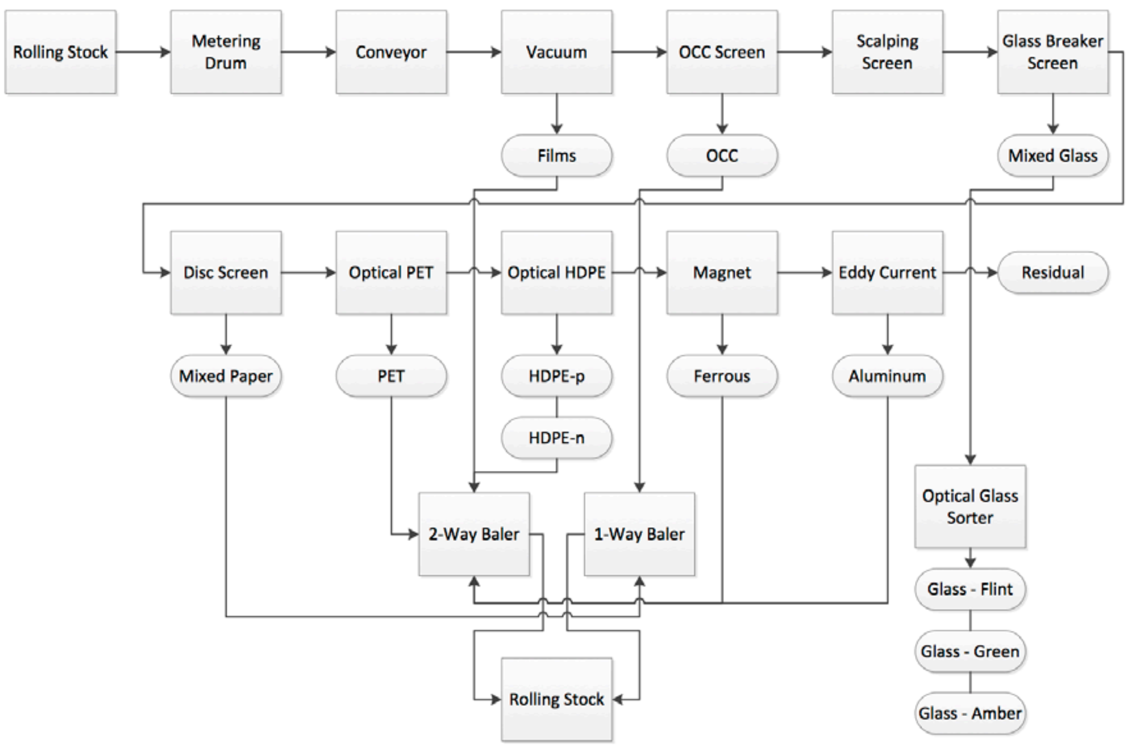


Figure 2.2 Process flow diagram (PFD) of the generic MRF modeled for use in single-stream, dual-stream, and mixed waste MRFs. The state of automation in the MRF industry was captured in this design. Sorting of each material was compartmentalized such that automated sorting may be replaced by manual sorting for any technology.

The emissions inventory accounts for electricity and fuel consumption as well as emissions produced during the fuel production process, also known as pre-combustion emissions. These emissions rates are referred to as life-cycle inventory (LCI) parameters. The cost of fuel and electricity consumption is also considered when accounting for facility operating costs. These costs are considered, along with other MRF construction and operation costs, to capture total system cost of the facility. Attribution of costs and emissions to the individual waste fractions is described in Section 2.1.2.3.

Using 1 Mg (1Mg = 1 metric ton) of incoming material processed by the facility as the functional unit, MSW is classified into 41 distinct waste fractions. For example, mixed waste MRFs are capable of processing all 41 mixed waste fractions, whereas single stream, dual stream and MRFs accepting presorted recyclables only process the 21 recyclables shown in Table 2.1. Thus, the functional unit of a single stream facility is 1 Mg of recyclables, while a mixed waste MRF employs a functional unit of 1 Mg of mixed waste. These waste fractions are provided in Table 2.1 and further described in Section 2.1.2.3. All costs, waste flows, and resulting emissions are allocated to waste fractions to allow for the costs and emissions associated with each fraction to be assessed.

Table 2.1 Assumed Composition of materials flowing into MRFs to Define the Function Unit (based on USEPA, 2010 with yard waste disaggregation from Oshins and Block, 2000). The values in Table 2,1 represents the default waste composition for the analyses presented in this thesis.

Material Type	Composition of Mixed Waste	Composition of Recyclables
Yard Trimmings - Leaves	6.7%	

Table 2.2 Assumed Composition of materials flowing into MRFs to Define the Function Unit (based on USEPA, 2010 with yard waste disaggregation from Oshins and Block, 2000). The values in Table 2,1 represents the default waste composition for the analyses presented in this thesis. (continued)

Material Type	Composition of Mixed Waste	Composition of Recyclables
Yard Trimmings - Grass	5.0%	
Food Waste - Animal	3.5%	
Food Waste - Vegetable	13.8%	
Wood	5.0%	
Wood Other	0.0%	
Textiles	4.4%	
Rubber/Leather	0.5%	
Newsprint	4.9%	13.5%
Corr. Cardboard	14.5%	39.8%
Office Paper	2.6%	7.2%
Magazines	0.8%	2.2%
3rd Class Mail	2.2%	5.9%
Paper - Other #1	0.0%	0.0%
Paper - Other # 2	0.0%	0.0%
Mixed Paper	0.0%	
Paper - Non-recyclable	10.5%	
Glass - Brown	2.7%	7.5%
Glass - Green	1.2%	3.2%
Glass - Clear	0.8%	2.1%
Mixed Glass	0.0%	
Glass - Non-recyclable	0.0%	
Ferrous - Cans	1.1%	3.2%
Ferrous - Other	0.2%	0.6%
Ferrous - Non-recyclable	0.0%	
Aluminum - Cans	0.7%	2.0%
Aluminum - Foil	0.2%	0.6%
Aluminum - Other	0.0%	0.0%
Al - Non-recyclable	0.1%	0.3%
HDPE - Translucent Containers	0.4%	1.1%
HDPE - Pigmented Containers	0.7%	2.0%
PET - Containers	1.3%	3.7%
Plastic - Other #1	0.0%	0.0%

Table 2.2 Assumed Composition of materials flowing into MRFs to Define the Function Unit (based on USEPA, 2010 with yard waste disaggregation from Oshins and Block, 2000). The values in Table 2,1 represents the default waste composition for the analyses presented in this thesis. (continued)

Material Type	Composition of Mixed Waste	Composition of Recyclables
Plastic – Other #2	0.0%	0.0%
Plastic Film	2.0%	5.4%
Plastic - Non-recylcable	5.6%	
Misc. Organic	0.0%	
Misc. Inorganic	3.6%	
E-waste	0.0%	

Development of emissions and costs factors required the attribution of these emissions and costs to the responsible waste fraction, resulting in factors denoted as coefficients. Thus, each coefficient represents the impact associated with the processing of 1 Mg of that fraction through the MRF. These coefficients are multiplied by their respective composition fraction to determine the cost, energy consumption, or emissions associated with the processing of one Mg of unprocessed material at the MRF.

2.1 Single-Stream, Dual-Stream, and Mixed Waste MRF Design

Single-stream, dual-stream and mixed waste MRFs are designed to separate recyclable materials from a mixed stream of material. Incoming waste streams in single and dual-stream facilities should be largely recoverable material with some (<10%) residual, whereas mixed-waste facilities include all components of MSW. While the residential single-stream facilities surveyed typically recover nearly 85-90% of material by mass, mixed waste facilities recover considerably less due to contamination and the limited proportional quantity of recyclables in the incoming product stream (California Environmental Protection Agency, 2006).

Despite their differences, mixed waste, single, and dual-stream facilities separate material using similar techniques. These three MRF types often utilize the same automation technologies, but the specific machines are calibrated differently to process different combinations of waste fractions. Therefore, the equations that describe these MRFs are the same, but different parameter values are required to characterize the different designs. The fraction of an incoming material that is recovered for remanufacturing is described in the model by the separation efficiency, described in Section 2.1.1.2. Due to the low recovery rates experienced in mixed waste facilities, this parameter is the primary metric that differentiates the modeling of mixed waste facilities from others modeled in this section.

Since facilities accepting presorted material do not require any separation, no specialized equipment or sorting labor is required to process the material. Unlike facilities accepting presorted recyclables, modeling of separation occurring in conventional MRFs represents a large portion of how these MRFs are modeled. Therefore, MRFs accepting presorted recyclables require a much simpler model, described in Section 2.2, though these facilities are modeled using similar techniques.

2.1.1 Process Flow Description

This section includes a process flow diagram that may be adapted for each type of MRF by enabling and disabling steps in the process. The order in which material fractions are separated directly affects the efficiency of separation. This model follows the paradigm that volume dictates the precedence in which a material is removed; that is, the highest volume materials are removed first. Typically, the fiber in residential waste streams represents the highest volume, and is therefore removed first. Process flows are defined in the first sub-section. The equations that define these flows follow.

The PFD presented in Figure 2.2 illustrates the process by which a fully automated MRF may operate. The process is typical for the current state of the residential recycling industry. Using this process, automated separation technologies may be disabled in the process model to represent a particular facility, which may rely more on manual recovery. Using manual recovery, automation technologies are replaced by picking lines.

User flexibility to choose between manual recovery and automation is emphasized in this model. Offering users the ability to substitute manual separation for any unit process is necessary to effectively simulate any number of facilities in operation. Further description of the inputs related to automation and grouping of recyclables is provided in Section 2.1.5.

2.1.1.1 Material Flow and Separation

Material is transferred from an area designated for dumping unsorted material, known as the tipping floor, to a conveyor belt by means of rolling stock, which are typically front-end loaders fueled by diesel, though sometimes propane is used. The conveyor is equipped with a metering drum, which regulates the flow of material, so it remains constant. Should facilities opt to collect plastic films, these will be removed in the presort using a vacuum placed between two pickers who will guide the vacuum over films to facilitate their removal. The vacuum will then convey the material to a bunker for baling.

Next, corrugated cardboard (OCC) is removed by a disc screen. Disc screens designed to remove OCC have large gaps between each disc, allowing for all other materials to fall through. These screens are operated at a relatively low incline to facilitate movement of the large OCC across the discs. Material that falls through the disc screens, known as “bottoms”, is conveyed to scalping screens that are used to remove fines prior to glass removal via breaker screens. Scalping screens operate similarly to disc screens, but with smaller gaps between discs and no incline.

The use of scalping screens, also known as fine screens or French screens, enhances the purity of mixed glass cullet by removing fines prior to glass removal. Glass is then crushed by a breaker screen that allows crushed glass to fall between discs, while fiber and remaining containers (plastic, aluminum, metal) pass over the top. Mixed cullet may then be sent to an optical sorter for separation by color. When the target material is detected, a small puff of air deflects the material to a bunker. Currently, the cost of optical sorting technologies for glass is too high for many MRF owners to justify, opting instead to send mixed glass cullet to processing centers that capitalize on economies of scale. In the MRF process models, the separation of mixed color cullet by optical sorting is assumed to occur in the MRF. However, if transportation to a mixed cullet processing facility is required, as is typical, a mileage parameter may be specified to account for the transportation distance to this facility.

Following glass removal, fiber is then recovered using high incline polishing screens. These are disc screens similar to those used in OCC removal; however, their discs are spaced much closer with steeper inclines to allow for plastics, aluminum, and ferrous material to drop through the bottom. Three fiber screens are placed in sequence to allow for an acceptable level of purity. Fibrous material is then baled using either a single-ram or dual-ram baler.

PET, HDPE-t (translucent), and HDPE-p (pigmented) are separated optically if automation is selected. This is completed through the application of two optical sorters. First PET is removed via a single optical sorting machine. The remaining fraction is then sent to an HDPE-t/p sorter that can separate the incoming stream into three output streams: HDPE-t, HDPE-p, and residual ─ this technique is called dual-eject. The residual stream output from the HDPE-t/p sorter is enriched in aluminum and ferrous material. As is the case for optical glass sorters, some owners cannot justify the expense of such a technology, opting to use manual sorting for plastics. A picking line may be used in place of automated plastics separation.

All material responding to a magnetic field may be included in ferrous bales. This includes ferrous cans and other ferrous metals in the SWOLF composition list shown in Table 2.1. Magnetic separation is accomplished by mounting an inverted conveyor perpendicularly above the waste conveyor. The bottom conveyor contains the waste stream, while the top conveyor will eject the ferrous material. This inverted conveyor contains a permanent magnet between the rollers of the belt, which applies enough attractive force to remove material from the bottom conveyor. Once material reaches the end of the upper conveyor, the absence of the magnet allows the material to drop into a bunker. This configuration is known as an overhead self-cleaning magnet.

Automated processing of aluminum is accomplished using an eddy current separator (ECS). Given the prevalence of this technology, it is included by default in all separation facilities. An ECS effectively separates aluminum from the residual stream by inducing a repulsive current, which casts aluminum across a blade, which acts as a divider to direct aluminum into a separate storage bunker.

Material remaining on the conveyor after the ECS is conveyed to a container for residuals, which is hauled to a landfill for final disposal. This represents the residual stream remaining from separation. Disposal costs at the landfill are calculated in a separate landfill process model based on the mass of residuals that require disposal.

2.1.1.2 Separation Equations

The mass of material separated throughout the recovery processes is calculated using specified separation efficiencies. These factors indicate the fraction of a target material that is recovered from a typical incoming waste stream. Therefore separation efficiency has a direct effect on the mass of material recovered. Figure 2.3 illustrates how separation efficiency is used as a factor for modeling separation in the recovery process. Determining the amount of material that can be separated for a particular fraction is necessary to calculate the costs, energy and emissions associated with processing that particular fraction. Separation of incoming mass into recovered material, as opposed to passing as residue, for a particular fraction determines whether that waste stream can provide positive revenue for the MRF.

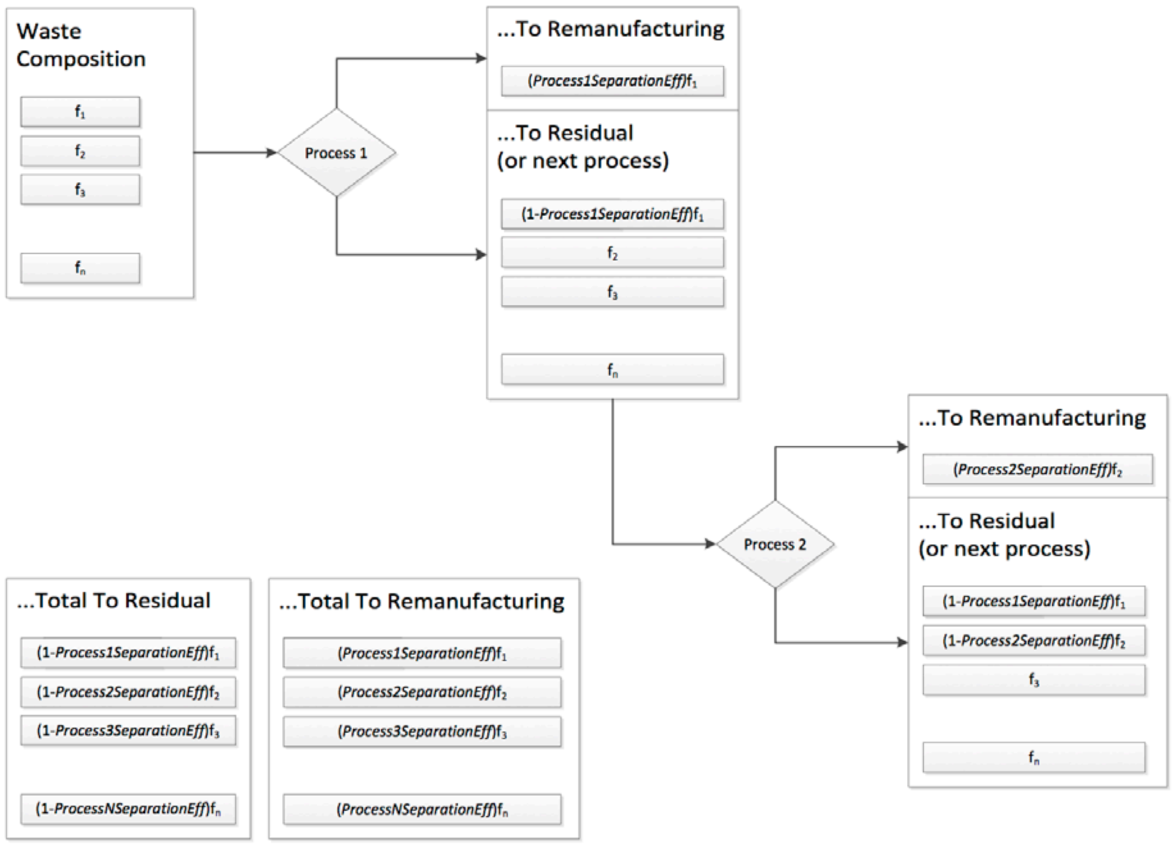
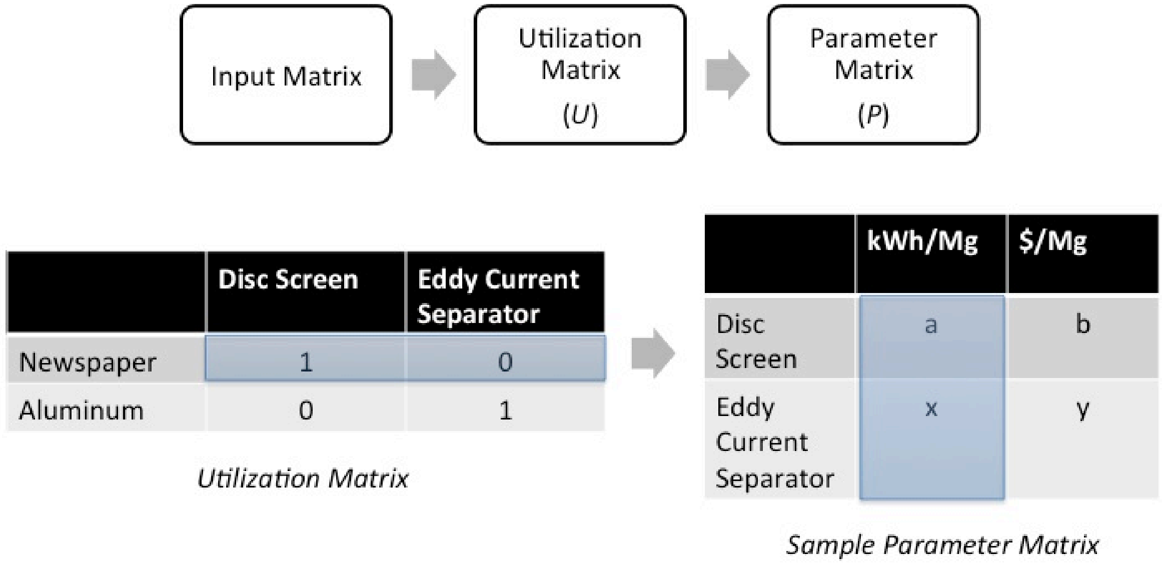


Figure 2.3 Flow diagram showing how separation efficiency is used to calculate the mass of separated material. This figure illustrates how the first two processes in an *n*-process system use the concept of separation efficiency to calculate mass flow through a separation system.

2.1.2 Principles of Model Function

Inputs specified in the graphical user interface (GUI) determine the coefficients of a binary utilization matrix. This matrix characterizes process automation and utilization of different parameters for individual waste fractions. Previous models (Nishtala, 1994) did not require specification at this level of detail since separation technology at that time was dominated by manual separation, but innovation in automated sorting technologies has made their use more common in newer facilities.

The binary utilization matrix is used in combination with a parameter matrix to characterize the utilization of different processes with regard to an individual waste fraction (e.g. kWh of electricity consumed to separate 1 Mg of PET). Each of these matrices is described in further detail in the following two sections. Figure 2.4 shows how these matrixes are utilized to develop a comprehensive characterization of MRF separation technologies. Since this approach is only able to capture parameters associated with separation technologies, combining this technique with the modeling of operations not captured by the utilization matrix provides a thorough assessment of the facility. Other supporting infrastructure may be estimated proportionally to floor area, such as general electricity consumption. Electricity consumed by HVAC, water heating, lighting, refrigeration, and office equipment is estimated using two separate consumption intensities (kWh/m^2) specific to warehouses and offices (USEIA, 2006). Using floor area as a basis, electricity consumption from the office area and processing area are calculated using floor area estimations based on an analysis described in Section 2.1.4.3.



$$U_i \bullet P_j = (1*a) + (0*x) = a$$

Figure 2.4 The user input matrix is used to inform the utilization matrix to determine which waste materials will be sorted out of the incoming waste stream. Further, the input matrix defines which materials will be sorted through automation versus manual sorting. The utilization matrix is a binary matrix, which is used to activate parameters based on their usage as defined in the input. The parameter matrix contains data for all automation technologies used in the model. Using a matrix dot product between these two matrices, appropriate parameters may be assigned to waste materials.

2.1.2.1 Utilization Matrix

The utilization matrix allows different technologies and separation techniques to be enabled for each waste fraction. This matrix is determined by a series of user inputs shown in Table 2.2, wherein the user specifies which fractions are to be separated via an automated process and which via a manual process. This table is described in detail in Section 2.1.5. Each separation technology listed in the utilization matrix has a particular waste material (consisting of one or more fractions) that is useful to separate as shown in Table 2.3. Users may enable automation for a particular waste fraction (or set of fractions). The corresponding automation technology will automatically be enabled by placing a 1 in the cell at the intersection of the waste fraction and the technology as shown in Figure 2.4. Similarly, if manual sorting is specified, the intersection of the waste fraction and the “manual sorting” technology will be specified as a 1. Should “no recovery” be specified with a 0 in the input table, then all technologies will remain disabled with 0’s in the utilization matrix except for the rolling stock necessary to transport waste into the separation system, the metering drum, and the conveyors necessary to transport the waste through the facility. All required technologies (e.g., conveyors) are indicated with 1’s in the utilization matrix.

To illustrate how the user input in Table 2.2 works, consider paper recovery. Suppose the user wishes to perform manual separation of office paper following automated separation of mixed paper. Since automated mixed paper recovery occurs by default, as indicated by a “2” associated with paper automation in the third row, the user does not have to specify an override in the automation column. However, since manual recovery of office paper is required, the user must place a “1” in the Supplementary Recovery override column corresponding to office paper. Once this is done, the “Value” column associated supplementary recovery is automatically updated to indicate manual separation, and the price of material recovery will be automatically updated from the price per unit mass of mixed paper to the price per unit mass of sorted office paper.

Table 2.2 This table specifies all user input required for single-stream, dual-stream, and mixed waste MRFs. User editable fields are indicated with yellow regions, whereas white cells indicate values used in the model. Initially, white cells contain default values, but can be overridden by the user in the corresponding yellow cell. Automated sorting of some material types is determined by its parent material type (e.g. paper, glass, ferrous, HDPE) in instances where automation machinery can only remove a set of material types. Crosshatched cells indicate items that are not applicable for the corresponding material type. Automation is specified as: (0) no recovery, (1) manual recovery, (2) automated recovery in the cells located in the automation column for each recoverable material type. Material may be recovered into an individual material type or as a collection of similar materials (e.g. mixed paper). This level of aggregation recovery is specified in the Supplemental Recovery column: (0) recovery as a mixed product, (1) recovered individually. Material Revenue: sorted sale price per Mg of either mixed or pure stream material, depending on whether the user specifies supplementary recovery.

	Automation		Supplemental Recovery		Material Revenue ($/Mg)
	Value	Override	Value	Override	Value
Paper	2				
Newsprint	2		0		$82.00
Office Paper	2		0		$82.00
Magazines	2				$82.00
3rd Class Mail	2				$82.00
Paper Other #1	0		0		$0.00
Paper Other #2	0		0		$0.00
Corr. Cardboard	2				$115.00
Glass	2		1		
Glass - Brown	2				$20.00
Glass - Green	2				$1.00
Glass - Clear	2				$28.00
Ferrous	2				
Ferrous Cans	2				$140.00
Ferrous Metal - Other	2				$140.00
Aluminum	2				$1,480.00
Aluminum - Foil	2				$1,480.00
Aluminum - Other	2				$1,480.00
Plastics					
HDPE	2				
HDPE - Translucent Containers	2				$500.00
HDPE - Pigmented Containers	2				$330.00
PET	2				$320.00
Plastic Other #1	0		0		$0.00
Plastic Other #2	0		0		$0.00
Films	0				$0.00

The default configuration of a single-stream MRF is very similar to the fully automated facility illustrated in Figure 2.2, but without the vacuum used for film recovery.

recovery was omitted as a default assumption due to its lack of prevalence in the industry; however, the user can change this. Table 2.3 lists each recyclable waste fraction with its associated automation technology. Other technologies included in the utilization matrix are necessary to facilitate recovery of a particular fraction. These technologies include scalping screens, rolling stock, conveyors, and balers. While these technologies are not responsible for the actual separation of material, they are necessary as supporting infrastructure and must be accounted for.

Table 2.3 Waste fractions listed by separation technologies responsible for their separation.

Separation Technology	**Waste Fraction**
Optical Glass Sorting Glass Breaker Screen	• Glass - Brown • Glass - Green • Glass - Clear
OCC Screen	• Corr. Cardboard
Disc Screen	• Newsprint • Office Paper • Magazines • 3rd Class Mail • Paper - Other #1 • Paper - Other #2
Magnet	• Ferrous - Cans • Ferrous - Other
Eddy Current Separator	• Aluminum • Aluminum - Foil • Aluminum - Other
Optical HDPE n/p	• HDPE - Translucent Containers • HDPE - Pigmented Containers
Optical PET	• PET - Containers • Plastic - Other #1 • Plastic - Other #2
Vacuum	• Plastic Film

2.1.2.2 Parameter Matrix

The parameter matrix is developed for use with the utilization matrix. Separation technologies are represented as rows in the parameter matrix, while the columns specify individual parameters associated with these technologies, for example kWh consumed per Mg of aluminum in an eddy current separator. Thus, the number of rows in the parameter matrix must equal the number of columns in the utilization matrix. Eight parameters are specified to determine the costs and emissions associated with processing one Mg of each waste fraction, while an additional fuel consumption parameter must be specified for those technologies requiring transportation to another facility. These seven parameters are shown in Table 2.4.

Table 2.4 Seven parameters used in the parameter matrix are used to quantify costs and emissions on a per Mg basis for all waste fractions processed in each facility.

Parameter	**Unit**
Power	Kilowatt
Investment Cost	$
O&M Cost	$/year
Laborers Required to Operate	Laborer/Hour
Separation Efficiency	unitless
Economic Lifetime	Years
Throughput	Mg/Hour
Utilization Factor	unitless

The parameter matrix serves as the primary data hub for the MRF models, wherein all parameters of separation technologies are entered. This matrix performs intermediate calculations necessary to develop factors required for the calculation of life cycle assessment (LCA) parameters. LCA parameters are normalized on a per Mg of sorted material basis for each separation technology. Intermediate calculations for electricity consumption and costs may then be used to develop cost and emissions coefficients using allocation by the utilization matrix. For example, electricity consumption is divided by throughput to yield an electricity consumption rate (kWh/Mg). A sample parameter matrix is shown in Appendix A.

Investment cost and operations & maintenance (O&M) cost are used in combination with a global discount rate and technology lifetime to calculate the annual cost associated with deployment and operation of each technology. Given a specific throughput, a value for $/Mg is calculated as shown in Equation 2.1. A nomenclature table for variables used in all equations may be found in Appendix C.

Equation 2.1 Annual cost of ownership of a technology.

$$INV_t[\$/Mg] = \frac{(INVCOST_t[\$] \bullet CRF\left[yr^{-1}\right] + FIXOM_t\left[\frac{\$}{yr}\right]}{THROUGHPUT_t\left[\frac{Mg}{hr}\right] \bullet HRS\_PER\_SHIFT\left[\frac{hrs}{shift}\right] \bullet SHIFTS\_PER\_DAY\left[\frac{shifts}{day}\right] \bullet DAYS\_OP\_ANNUALLY\left[\frac{days}{yr}\right]}$$

Where,

INV_t:	Annual cost associated with purchase, installation, and O&M associated with processing a Mg of material for technology, *t*
$INVCOST_t$:	Installed cost of a technology, *t*
CRF:	Capital recovery factor (*A/P*,*i*,*l*) where *i* is the discount rate And *l* is the economic lifetime f the equipment
FIXOM:	Fixed operations and maintenance cost of the equipment
THROUGHPUT:	Hourly throughput capacity of a piece of equipment
HRS_PER_SHIFT:	The number of working hours (paid and operational) in a shift
SHIFTS_PER_DAY:	Number of shifts per day that the MRF operates

DAYS_OP_ANN: Number of days per year that the MRF operates

Electricity consumption due to operation of each technology is calculated using a specified throughput. Power (kW) is divided by a fraction of maximum load to account for the utilization associated with the process and then divided by throughput to calculate the electricity use per unit mass of material as shown in Equation 2.2. Division by utilization allows for inefficiencies in electricity consumption due to underutilization of equipment to be captured. For example, disc screens will consume a constant amount of electricity when in operation, regardless of the amount of material flowing over them.

Equation 2.2 Electricity consumption per Mg processed by each technology

$$ELC\_CONS_{f,t}\left[\frac{kWh}{Mg}\right]=\frac{POWER[kW]}{THROUGHPUT\left[\frac{Mg}{hr}\right]\bullet UTIL\_FRXN}$$

Where,

$ELC\_CONS_{f,t}$: Electricity consumed for fraction, f, by technology, t

POWER: Nameplate power consumption of a piece of equipment

UTIL_FRXN: Fractional utilization of any piece of separation equipment

The number of manual laborers necessary for optimum recovery by each separation technology must be specified. Using the throughput of each technology, the number of laborers per Mg is calculated. This calculation is performed in Equation 2.3. Additional sorters may be required in some cases, such as paper or plastics sorting. Calculations for this parameter and other manual sorting requirements are discussed in Section 2.1.4.2.

Equation 2.3 Calculation of sorters required per Mg for operation and supplemental sorting required for a technology.

$$STRS\_REQ_{f,t}\left[\frac{sorter}{TPH}\right] = \frac{TECH\_MANUAL\_REQ[sorter]}{THROUGHPUT_t\left[\frac{Mg}{hr}\right]}$$

Where,

SRTRS_REQ: Required number of manual laborers

TECH_MAN_REQ: Manual laborers required to support a given separation technology

Fuel consumption is specified per Mg of incoming waste to the facility. This parameter was chosen given that rolling stock is used to handle all incoming waste. Using fuel consumption data collected at MRFs, a default value for fuel consumption is specified. Additionally, the volume of fuel used per mass of material may be specified for those technologies requiring transportation to other facilities. For example, a local glass sorting facility in Raleigh, NC receives mixed glass cullet from other MRFs as far away as Pennsylvania. Fuel consumption for transportation of this material must be considered for accurate accounting of emissions. Since the model assumes that separation is part of the MRF operation, any particular sorting operation can be assumed to be performed offsite, as long as fuel used to transport the material is considered.

2.1.2.3 Fraction Allocation

Fraction allocation is the process of attributing costs, emissions, electricity consumption, and other parameters to the appropriate waste fractions used in SWOLF (Table 2.1). This calculation is performed by taking dot products between vectors in the parameter and utilization matrices. Intermediate calculations in the parameter matrix provide parameters normalized on a per Mg basis, which allow for attribution using the binary utilization variables found in the utilization matrix. Graphical illustration of fraction attribution using this method is outlined in Figure 2.4.

Manual sorting attribution uses values listed in Table 2.5 to specify laborers required for operation of automation equipment because additional sorters may be necessary to sort beyond the capability of the equipment. An additional vector specified outside of the parameter matrix described in Section 2.1.4.2 specifies picker requirements for additional sorting of fiber and plastics based on the fraction being sorted. Should manual sorting be specified with no automated recovery, a similar vector is used, which specifies pickers required per Mg of material recovered.

Table 2.5 Labor required for manual sorting of recyclables (EPA, 1991)

	Recovery Rate (Mg/hr/sorter)		Recovery Efficiency (%)	
	Min	Max	Min	Max
Newspaper	0.68	4.54	60	95
OCC	0.68	4.54	60	95
Glass (mixed/whole)	0.41	0.82	70	95
Glass (by color)	0.20	0.41	80	95
Plastic	0.14	2.72	80	95
Aluminum	0.05	0.05	80	95

Beyond the equipment and laborers required to process material, a certain amount of overhead must be considered. Operational costs associated with administration and management are represented as a fraction of labor costs associated with the processing of each material type. Overhead associated with construction costs and building operation as a whole, including office and processing area overhead electricity consumption, are estimated on a per square meter basis, which is a function of throughput. This approach relies on the simplifying assumption that each processed fraction requires the same amount of overhead per Mg of material. This assumption is justified considering the low impact of overhead-related parameters as illustrated with the results in Section 2.3.1.

2.1.3 Emissions Coefficients

Emissions are separated into two primary categories: airborne and waterborne. Both categories are necessary to account for all combustion and pre-combustion emission attributable to fuels used in the MRF. Electricity consumption also represents a primary driver of emissions produced upstream of the MRF. Combining fossil-related emissions with those generated from electricity required to run the facility provides a comprehensive inventory of emissions produced through facility operation.

Table 2.6 Waterborne and airborne emissions considered in SWOLF.

Airborne Emissions	Waterborne Emissions
• CO_2 – Fossil	• Dissolved Solids
• CO_2 Biomass	• Suspended Solids
• CO_2 - Stored	• BOD
• Methane	• COD
• Nitrous Oxide	• Oil

Table 2.6 Waterborne and airborne emissions considered in SWOLF. (continued)

Airborne Emissions	Waterborne Emissions
• PM-10	• Sulfuric Acid
• Total PM	• Iron
• NO_x	• Ammonia
• Total Hydrocarbons	• Copper
• SO_2	• Cadmium
• CO	• Arsenic
• Ammonia	• Mercury
• Pb	• Phosphate
• HCl	• Selenium
• Mercury	• Chromium
• Benzene	• Lead
• Chloroform	• Zinc
• Carbon Tetrachloride	• Barium
• Ethylene Dichloride	• Silver
• Methylene Dichloride	• Metals (unsp.)
• Trichloroethylene	• Benzene
• Tetrachloroethylene	• Chloroform
• Vinyl Chloride	• Carbon Tetrachloride
• Toluene	• Ethylene Dichloride
• Xylenes	• Methylene Chloride
• Ethylbenzene	• Trichloroethene
• Dioxins/Furans	• Tetrachloroethene
•	• Vinyl Chloride
	• Toluene
	• Xylenes
	• Ethylbenzene
	• Hydrocarbons (unsp.)

2.1.3.1 Airborne Emissions Equations

Two fuels (propane and diesel) are considered when calculating emissions of airborne pollutants listed in Table 2.6. While research has shown that organic dusts in MRFs may be harmful to workers (Gladding *et al.*, 2003), these are not considered in the present work due to insufficient data to characterize pollutant emissions. Therefore, the only direct emissions accounted for within the facility are due to fuel combustion for rolling stock. Fuel combustion in trucks transporting freight to other facilities is also calculated.

Rolling stock is fueled by either propane or diesel, while trucks transporting waste streams to other facilities use diesel. During interviews with personnel at a local glass sorting facility in Raleigh, NC, the plant manager confirmed that trucking is the only way that they are receiving mixed cullet and, to his best knowledge, he is not aware of anyone using barge or rail for this type of transportation (personal communication with Strategic Materials, Jan, 2011). Should mixed glass sorting be performed at a facility outside of the modeled MRF, a transport distance must be specified. This distance is multiplied by a diesel consumption factor of 0.0272 L/Mg-km (NREL, 2006) to transport the glass. The resulting value (L/Mg) is then represented in the parameter matrix. Emissions factors (kg emitted / L combusted) for industrial equipment and trucking combustion drawn from the National Renewable Energy Laboratory (NREL) Life Cycle Inventory Database (NREL, 2010) are used to calculate the associated airborne emissions.

A regional fuel split is used when considering electricity fuel mix. The calculation for emissions associated with electricity generation is based on the North American Electric Reliability Council (NERC) region in which the facility is located. Using fuel splits for the appropriate NERC region, emission factors are calculated on a per kWh basis. Airborne emissions were calculated using Equation 2.4 for each pollutant in Table 2.6 using these emission factors.

Equation 2.4 Calculation of airborne emissions per Mg of each waste fraction processed by the MRF.

$$AIRBORNE\_POLLUTANT_{f,i}\left|\frac{kg}{Mg}\right| = TOTAL\_ELC\_CONSUMPTION_f\left|\frac{kWh}{Mg}\right| \bullet \left(ELC\_AB\_EMISS\_FACTOR_i\left[\frac{kg}{kWh}\right]\right) +$$
$$TOTAL\_DSL\_CONSUMPTION_f\left[\frac{L}{Mg}\right] \bullet \left(\begin{array}{l} DSL\_PRECOMBUSTION\_AB\_EMISS\_FACTOR_i\left[\frac{kg}{L}\right] + \\ DSL\_COMBUSTION\_AB\_EMISS\_FACTOR_i\left[\frac{kg}{L}\right] \end{array}\right) +$$
$$TOTAL\_PROPANE\_CONSUMPTION_f\left[\frac{m^3}{Mg}\right] \bullet \left(\begin{array}{l} PROPANE\_PRECOMBUSTION\_AB\_EMISS\_FACTOR_i\left[\frac{kg}{m^3}\right] + \\ PROPANE\_COMBUSTION\_AB\_EMISS\_FACTOR_i\left[\frac{kg}{m^3}\right] \end{array}\right)$$

Where.

$AIRBORNE\_POLLUTANT_i$: Emission rate of airborne pollutant, i, per Mg of waste fraction, *f* processed by the MRF

$TOTAL\_ELC\_CONS_f$: Total electricity consumption required to process 1 Mg of waste fraction, *f*

$ELC\_AB\_EMISS\_FACTOR_i$: Emission rate of pollutant *i* resulting from 1 kWh of electricity production

$TOTAL\_DSL\_CONS_f$: Total diesel consumption required to process 1 Mg of waste fraction, *f*

$DSL\_AB\_PRECMB\_EMISS\_FACTOR_i$: Diesel airborne emissions of pollutant i resulting from 1L diesel production (i.e. precombustion)

$DSL\_AB\_CMB\_EMISS\_FACTOR_i$: Diesel airborne emissions of pollutant i resulting from combustion of 1L of diesel fuel

$TOTAL\_PROPANE\_CONS_f$: Total propane consumption required to process 1 Mg of waste fraction, *f*

$PROPANE\_AB\_PRECMB\_EMISS\_FACTOR_i$: Propane airborne emissions of pollutant i resulting from 1m^3 of propane production

$PROPANE\_AB\_CMB\_EMISS\_FACTOR_i$: Propane airborne emissions of pollutant i resulting from the combustion of 1m^3 of propane

2.1.3.2 Waterborne Emissions Equations

All waterborne emissions calculated in the MRF model are due to pre-combustion of fuels used for electricity production, rolling stock and transportation. Potential for waterborne emissions found in runoff from facility wash down water was considered; however, due to a lack of water characterization, wash down is not integrated into the model. According to MRF operators interviewed, internal wash down of the facility is performed annually; implying the volume of water would render the amount of pollutants insignificant.

Pre-combustion fuel factors are combined with regional fuel mixes for electricity as calculated for airborne emissions, while diesel and propane fuels use their respective emissions factors to perform calculations found in Equation 2.5 for all waterborne pollutants found in Table 2.6.

Equation 2.5 Calculation of waterborne emissions per Mg of each waste fraction processed by the MRF.

$$
\begin{aligned}
WATERBORNE\_POLLUTANT_{f,i}\left[\frac{kg}{Mg}\right] = {} & TOTAL\_ELC\_CONSUMPTION_{f}\left[\frac{kWh}{Mg}\right]\bullet ELC\_WB\_EMISS\_FACTOR_{i}\left[\frac{kg}{kWh}\right]+\\
& TOTAL\_DSL\_CONSUMPTION_{f}\left[\frac{L}{Mg}\right]\bullet DSL\_PRECOMBUSTION\_WB\_EMISS\_FACTOR_{i}\left[\frac{kg}{L}\right]+\\
& TOTAL\_PROPANE\_CONSUMPTION_{f}\left[\frac{m^3}{Mg}\right]\bullet PROPANE\_PRECOMBUSTION\_WB\_EMISS\_FACTOR_{i}\left[\frac{kg}{m^3}\right]
\end{aligned}
$$

Where,

$WATERBORNE\_POLLUTANT_{f,i}$:	Emission rate of waterborne pollutant, *i*, per Mg of waste fraction, *f*, processed by the MRF
$ELC\_WB\_EMISS\_FACTOR_{i}$:	Emission rate of waterborne pollutant, *i*, associated with 1 kWh of electricity production
DSL_WB_PRECMB_EMISS_FACTOR:	Diesel waterborne emissions of pollutant *i* resulting from 1L diesel production (i.e. precombustion)

PROPANE_WB_PRECMB_EMISS_FACTOR: Propane waterborne emissions of pollutant, i, resulting from 1 m^3 propane production (i.e. precombustion)

2.1.4 Cost Coefficients

Cost coefficients are separated into six groups to simplify accounting. These groups include: equipment, construction, labor, electricity, consumables, and revenue. Groups were then aggregated into one final cost coefficient to represent the cost to process a Mg of a particular waste fraction as presented in Equation 2.6. The following six subsections of the document describe these groups.

Equation 2.6 Calculation of total implementation and operating cost of the MRF

$$TOTAL\_MRF\_COST\left[\frac{\$}{Mg}\right] = TOTAL\_EQUIPMENT\_COST\left[\frac{\$}{Mg}\right] + TOTAL\_LABOR\_COST\left[\frac{\$}{Mg}\right] + CONST\_COST\_RATE\left[\frac{\$}{Mg}\right]$$
$$+ELC\_COST\_RATE\left[\frac{kWh}{Mg}\right] \bullet ELC\_COST\_RATE\left[\frac{\$}{Mg}\right]$$
$$+BALING\_WIRE\_COST\_RATE\left[\frac{\$}{Mg}\right] - MATERIAL\_SALE\_PRICE\left[\frac{\$}{Mg}\right]$$

Where,

TOTAL_MRF_COST: Total cost to implement and operate a MRF per Mg of material processed

TOTAL_EQUIPMENT_COST: Total cost of investment, installation, and maintenance of equipment required to process 1 Mg of recyclables

TOTAL_LABOR_COST: Total labor cost associated with the processing of 1Mg of recyclables

CONST_COST_RATE: Cost of planning and construction of the MRF structure and land acquisition on a per Mg basis

ELC_CONS_RATE:	Cost of electricity associated with processing a Mg of recyclables
BALING_WIRE_COST_RATE:	Cost of baling wire per incoming Mg of material
MATERIAL_SALE_PRICE:	Price per incoming Mg charged by the MRF to remanufacturing for sorted material

Due to inconsistencies and volatility associated with MRF tipping fees, these are not considered in the model. Sale of separated recyclables represent the sole source of revenue to the facility. All MRFs visited during data collection used a different payment structure for incoming recyclables. These structures often differed between commercial and municipal accounts, as well as material type and amount of pre-separation. Residual material sent to a landfill was considered; however, costs associated with disposing in a landfill are calculated in the landfill model.

2.1.4.1 Equipment Cost Equations

Investment cost is the total cost required to purchase and install the equipment, which includes any additional costs associated with integration of the equipment into the facility including conveyance from the last process. Once the machine is installed, there will be a specific O&M cost associated with annual preventative maintenance and replacement of consumable items used by the machine. These O&M costs do not include the actual operating cost of the machine with regard to its fuel consumption, whether it runs on fuel or electricity, as these costs are calculated separately.

Costs associated with each piece of equipment were calculated based on capital cost, O&M cost, lifetime, discount rate, and throughput. Capital recovery factors (CRF) are calculated for each piece of equipment using lifetime and discount rate. The annualized capital cost of the equipment is calculated as the product of the CRF and investment cost. This cost is then combined with an annual throughput to yield a cost per Mg value. Intermediate calculation for each technology is shown in Equation 2.1, while total equipment cost is calculated using Equation 2.7.

Equation 2.7 Calculation of total equipment cost required in the MRF.

$$TOTAL\_EQUIPMENT\_COST\left[\frac{\$}{Mg}\right] = \sum_{f \in FRXN} \sum_{t \in TECH} UTIL_{t,f} \bullet INV_{t,f}\left[\frac{\$}{Mg}\right]$$

Where,

FRXN:	Set of all waste fractions
TECH:	Set of all separation technologies
$UTIL_t$:	Binary utilization of a particular piece of equipment, *t* (0/1)

2.1.4.2 Labor Cost Equations

Several aspects of labor are considered, from operators required to facilitate adequate sorting by the automated processes, to management required to run the facility. The ability to specify manual sorting of a particular fraction requires that additional laborers be substituted for the limited amount required to operate an automated process. This is accomplished using a number of picking rates. These picking rates were taken from ranges specified in The MRF Handbook (EPA, 1991).

Manual picking rates were given as ranges, which account for variation in composition of the incoming stream; engineering judgment was used to specify where these rates fell in the range according to the composition. Ranges for picking rates for each recyclable material were previously listed in Table 2.5. These ranges are used for different facilities, where dual-stream will sort the most efficiently, while mixed waste MRFs will recover the least.

Laborers required to operate machinery are specified as a parameter in the parameter matrix. Automated process laborers are treated as an integral part of the machinery, since they are necessary to achieve the specified throughput and separation efficiency. For example, two workers are assigned to operate a plastic film vacuum removal system. The amount of labor is calculated using material throughput to evaluate the number of pickers required per Mg in an hour. Combining pickers per hour with the number of hours operated per day and operating days per year yields annual cost associated with the processing of a material via automation. Operator requirements for included separation technologies are listed inTable 2.7. The corresponding equation associated with this calculation is specified in Equation 2.8, where requirements for each fraction are calculated using Equation 2.9.

Table 2.7 Manual labor required by each separation technology to achieve a specific separation efficiency.

Separation Technology	Required Labor	Separation Efficiency
Vacuum	2	0.97
OCC Screen	2	0.7
Scalping Screen	0	0.97
Glass Breaker Screen	0	0.97
Optical Glass Sorting	3	0.98

Table 2.8 Manual labor required by each separation technology to achieve a specific separation efficiency. (continued)

Separation Technology	Required Labor	Separation Efficiency
Disc Screen	6	0.91
Optical PET	1	0.98
Optical HDPE n/p	1	0.98
Magnet	0	0.98
Eddy Current Separator	1	0.97
1-Way Baler	1	1
2-Way Baler	1	1
Rolling Stock	1	1

Equation 2.8 Calculation of labor cost associated with all labor in the MRF.

$$TOTAL\_LABOR\_COST\left[\frac{\$}{Mg}\right] = (1+FRINGE\_RATE)\bullet(1+MGMT\_RATE)\bullet \sum_{f\in FRXN}\left(\begin{array}{l}\left(SRTRS\_REQ_f\left[\frac{sorter}{tph}\right]\bullet SRTR\_PAY\_RATE\left[\frac{\$}{sorter-hr}\right]\right)+ \\ \left(UTIL_{f,rollingstock} * DRIVER\_REQ\left[\frac{drivers}{tph}\right] * DRIVER\_PAY\_RATE\left[\frac{\$}{hr-driver}\right]\right)\end{array}\right)$$

Where,

TOTAL_LABOR_COST:	Total labor cost associated with the processing of 1Mg of recyclables
FRINGE_RATE:	Fraction of labor wage paid again as employee overhead
MGMT_RATE:	Fraction of labor wage paid again for administrative and management overhead
$SRTRS\_REQ_f$	The number of sorters required to process 1Mg of waste fraction, *f*
SRTR_PAY_RATE	Hourly wage of each sorter
DRIVER_REQ	Drivers required for rolling stock to process 1 Mg of waste

DRIVER_PAY_RATE Hourly wage of each driver

Equation 2.9 Calculation of the number of sorters required to process a Mg of each fraction.

$$SRTRS\_REQ_f\left[\frac{sorter}{TPH}\right]=\sum_{t\in TECH}\left(UTIL_{t,f}\bullet SRTRS\_REQ_{f,t}\left[\frac{sorter}{tph}\right]\right)+ADTNL\_SRTRS\_REQ_f+MAN\_SRTRS\_REQ_f$$

Where,

ADTNL_SRTRS_REQ$_f$: Number of sorters required for additional sorting of individual waste fractions from a mixed stream

MAN_SRTRS_REQ$_f$: Number of sorters required to pick one Mg per hour of waste fraction, *f*

The total cost associated with labor employment is multiplied by a fringe rate (33%), which accounts for costs associated with the employment of personnel (i.e., costs of leave, employee benefits, pensions, and unemployment benefit plans). Management and administrative overhead is represented as a factor (25%) of all labor.

2.1.4.3 Capital Cost Equations

The primary capital expenditure associated with initial implementation of the MRF is represented as the sum of planning, land acquisition, and construction. The RSMeans Square Foot Costs (R.S. Means Company, 2010) estimating handbook was used to estimate the warehouse construction costs of a corrugated steel structure on a per square meter basis. An engineering factor is applied to this cost for planning and engineering required to implement such a facility (30%). Floor area used for estimating structure construction cost is then used in combination with a factor for land requirement (default value = 300% of floor area) to estimate total land necessary. This total cost is amortized over the lifetime of the facility before dividing by the number of days operated annually to produce a final cost per Mg processed as shown in Equation 2.10.

Equation 2.10 Calculation of the cost of construction per Mg of material processed in the MRF.

$$
\begin{aligned}
&CONST\_COST\_RATE\left[\frac{\$}{Mg}\right] = TOT\_FLOOR\_AREA\left[\frac{m^2}{tpd}\right] \bullet \\
&\left(\begin{aligned}&\left(1 + BUILD\_CONST\_COST\_RATE\left[\frac{\$}{m^2}\right]\right) \bullet (1 + ENG\_COST\_FACTOR[\%]) + \\ &\left(LAND\_REQ\_FACTOR[\%] \bullet LAND\_ACQ\_COST\_RATE\left[\frac{\$}{m^2}\right]\right)\end{aligned}\right) \bullet \\
&MRF\_CRF / DAYS\_OP\_ANN\left[\frac{days}{yr}\right]
\end{aligned}
$$

Where,

CONST_COST_RATE:	Cost of planning and construction of the MRF structure and land acquisition on a per Mg basis
TOT_FLOOR_AREA:	Total floor area required to process one Mg if material
BUILD_CONST_COST_RATE:	Construction costs associated with structure construction per unit floor area
ENG_COST_FACTOR:	Fraction of construction cost associated with engineering and planning of structure
LAND_REQ_FACTOR:	Multiple of indoor floor area to represent required land

LAND_ACQ_COST_RATE: Cost of land per square meter

MRF_CRF: Capital recovery factor (A/P,*i*,*t*), where i is the global discount rate and t represents the economic lifetime of the facility

The required floor area of the facility was estimated using linear regression of floor area in facilities included in surveyed MRFs. Using floor area; data could be combined with office floor area data from Nishtala (1994) to produce a series of six points. Office area from Nishtala (1994) was converted to total floor area by dividing by a median office area percentage of 4% of total floor area found in visited facilities. Floor area was plotted as a function of throughput processed by the facility. Three facilities are considered in case studies and were combined with data compiled on three other facilities found in Nishtala (1994). One case study data point was shown to be an outlier and was removed from the dataset. Presorted commercial material was being sorted in this facility, which increased floor area; however, throughput was only given for this facility's residential processing. A linear trend line was fit to the remaining data where the slope represents m^2 office space per Mg processed per day. The resulting plot using data from Table 2.8 is illustrated in Figure 2.5. An R^2 value of 0.91 indicated a strong correlation between floor area and material processed within the facility. The linear regression indicated 24.4 square meters of indoor floor area were required per Mg per day.

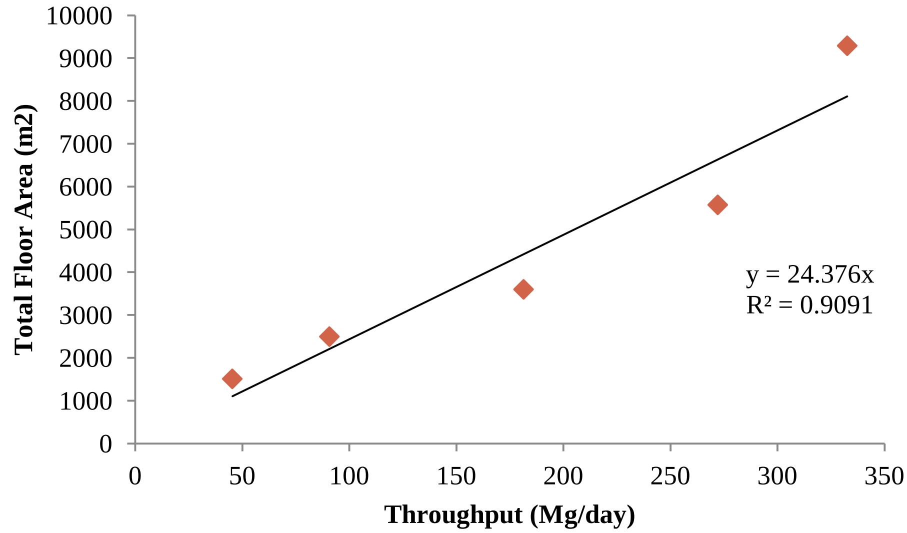


Figure 2.5 Linear regression of total indoor floor area considering five MRFs.

Table 2.9 Indoor floor area data used in linear regression analysis.

	Throughput (Mg/day)	**Total Floor Area (m^2)**
Visited MRF 1	272.1	5574
Visited MRF 2	332.6	9289
Nishtala 1	45.4	1510
Nishtala 2	90.7	2497
Nishtala 3	181.4	3600

2.1.4.4 Electricity Cost Equations

Electricity is categorized into two separate groups to effectively allocate electricity consumption: general electricity and sorting electricity. General electricity consumption includes all electricity required that does not directly contribute to the processing of a waste fraction, while sorting electricity accounts for the remainder.

The MRF includes office areas for administrative and managerial staff. Percentages of total floor area are determined to be approximately 4% according to MRFs visited. Using data from the U.S. Department of Energy Commercial Building Energy Consumption Survey (CBECS) (USEIA, 2006) energy consumption per floor area was given for both warehouses and office areas. These figures were used in combination with floor area per throughput calculations to assess energy consumption of office and warehouse electricity consumption on a per Mg basis.

Sorting specific electricity consumption relates to equipment used in the recovery process. Electricity consumption per Mg processed is provided in the parameter matrix. An example parameter matrix is shown in Appendix A. Calculating the dot product of the row in the utilization matrix for each waste fraction with this parameter column for each technology yields the total electricity required to sort the material fraction. The equation used to perform this calculation is provided as Equation 2.11.

Equation 2.11 Calculation of electricity consumed per Mg of material input into the MRF

$$ELECTRICITY\_CONSUMPTION\_RATE\left[\frac{kWh}{Mg}\right]=\sum_{f\in FRXN}\sum_{t\in TECH}\left(ELC\_CONS_{f,t}\left[\frac{kWh}{Mg}\right]\right)+$$
$$\left(OFFICE\_ELC\_RATE\left[\frac{kWh}{m^2-day}\right]\bullet TOTAL\_FLOOR\_AREA\left[\frac{m^2}{tpd}\right]\bullet\frac{PERCENT\_OFFICE[\%]}{100}\right)+$$
$$\left(WAREHOUSE\_ELC\_RATE\left[\frac{kWh}{m^2-day}\right]\bullet TOTAL\_FLOOR\_AREA\left[\frac{m^2}{tpd}\right]\bullet\left(1-\frac{PERCENT\_OFFICE[\%]}{100}\right)\right)$$

Where,

ELC_CONS_RATE:	Electricity associated with processing a Mg of recyclables
OFFICE_ELC_RATE:	Electricity consumption per unit floor area
PERCENT_OFFICE:	Percent indoor floor area used as office space
WAREHOUSE_ELC_RATE:	Electricity consumption per unit floor area.

Total electricity consumption attributed to each fraction requires logic to determine if general consumption is required for the waste fraction. As described in Section 2.1.2.1, waste fractions are represented by rows in the utilization matrix and any waste fraction processed in the MRF must utilize at least one technology listed in this matrix. Thus, all nonzero rows of this matrix are considered to be processed in the facility and consequently must have general electricity consumption attributed to them. Total electricity consumption is then the general electricity combined with that required for separation.

2.1.4.5 Consumables Cost Equations

Consumables are considered to be those materials required to operate the facility that are required to be replenished at regular intervals. Fuels required for operation of rolling stock include both diesel and propane. Fuel consumption figures are located in the parameter matrix where they are presented on a per Mg basis. Case studies were used to approximate fuel consumption, which is assumed to scale linearly with throughput.

Baling wire is also consumed linearly with throughput; however, more variability is expected across fractions, thus a mechanistic approach was adopted. Data on bale density and bale dimensions were acquired from vendors. Using the amount of wire required per bale and bale density, these figures are combined to estimate wire required per Mg of recyclable fraction. Cost per Mg is calculated for each material using Equation 2.12.

Equation 2.12 Calculation of the cost of baling wire per Mg of each material input into the MRF.

$$BALING\_WIRE\_COST\_RATE_f\left[\frac{\$}{Mg}\right] = \left(\frac{BALING\_WIRE\_COST\left[\frac{\$}{m}\right] \bullet (2 \bullet BALE\_HEIGHT[m] + 2 \bullet BALE\_WIDTH[m] \bullet NUMBER\_STRAPS)}{BALE\_MASS[Mg]}\right)$$

Where,

BALING_WIRE_COST_RATE: Cost of baling wire per incoming Mg of material

BALING_WIRE_COST: Cost of baling wire per unit length

BALE_HEIGHT: The height of a bale

BALE_WIDTH: The width of a bale

NUMBER_STRAPS: The number of bale ties used for one bale of material

$BALE\_MASS_f$: Mass of a bale of material *f*

2.1.4.6 Revenue Cost Equations

Revenue is generated by the MRF in the sale of sorted material. The price paid for these materials is determined in part by the degree they are separated. Inputs described in Section 2.1.5 allow the user to specify what materials are recovered out of separated mixed recyclable streams (e.g. office paper from mixed paper). This information is used to set appropriate pricing on each fraction based on other fractions included in the output stream. Separated recyclable streams with corresponding requirements are set forth by the Institute of Scrap Recycling Industries (2009) and described in Table 2.9. The volatility of the recycling commodity market indicates that prices should be a user specified input.

Separation efficiency is used to calculate the mass flow throughout the system. For any particular fraction there will be an automated technology, or a picking line, which will separate it from the incoming waste stream. Section 2.1.1.2 describes separation efficiency as a fraction of incoming target material able to be recovered in the process. Using this factor, mass flow through the system may be accounted for. As discussed previously, Figure 2.3 illustrates how a material mass may flow through the system with a fraction equal to its separation efficiency being recovered, while the remainder is sent to residual, as described in Section 2.1.1. Though landfill costs for residual material are not considered in this model, they are accounted for in the landfill model.

Table 2.10 Separated recyclable streams as described by ISRI.

Recyclable Name	**Description**
(1) Residential Mixed Paper	Consists of a mixture of various qualities of paper not limited as to type of fiber content, normally generated from residential, multi-material collection programs.
(8) Special News De-ink Quality	Consists of sorted, fresh newspapers, not sunburned, free from magazines, white blank, pressroom over-issues, and paper from other than news, containing not more than the normal percentage of rotogravure and colored sections. This grade must be tear free[1].
(11) Corrugated Containers	Consists of corrugated containers having liners of either test liner, jute, or kraft.

Table 2.9 Separated recyclable streams as described by ISRI. (continued)

Recyclable Name	**Description**
(36) UOP Unsorted Office Paper	Consists of printed or unprinted paper typically generated in an office environment that may include a document destruction process. This grade may contain white, colored, coated, and uncoated papers, manila and pastel colored file folders.
Glass Cullet – Mixed	Soda-lime-silica beverage to food container glass. Cullet may be broken, but not pulverized.
Glass Cullet - Clear	See mixed (95-100% flint)
Glass Cullet - Green	See mixed (95-100% green)
Glass Cullet - Amber	See mixed (95-100% amber, 0-5% green, 0-5% flint, 0-5% other)
Ferrous	Steel can scrap compressed to charging box size and weighing not less than 75 pounds per cubic foot. Cans may be baled without removal of paper labels, but free of other non-metallics. May include up to 5 gallon tin coated containers.
Post Consumer Aluminum Beverage Can Scrap (UBC)	Shall consist of old aluminum food and/or beverage cans. The material is to be free of other scrap metals, foil, tin cans, plastic bottles, paper, glass, and other non-metallic items.
HDPE-n Natural Bottles (P-201)	Translucent (natural) high density polyethylene containers
HDPE-p Pigmented Bottles (P-202)	Pigmented high density polyethylene containers
PET Mixed Bottles (P-100)	Mixed soft drink, liquor, edible oil, etc. bottles
Films (P-020)	Polyethylene bags, cling film, wrapping

2.1.5 Model Inputs

While many parameters may be modified throughout the model to better tailor functionality to user specifications, required user input is fairly trivial. Users must only specify what waste fractions are to be recovered, the degree of automation to be employed, and the resolution associated with product recovery (e.g. office paper vs. office paper present in mixed paper).

User inputs are specified in an input table. Implementation of such an input table is displayed in Table 2.2,

The automation column specifies the degree of automation by which each of the commodities is recovered, thereby providing a user-friendly interface to the utilization matrix. Groups of waste fractions are specified based on the automated technology used to separate them. Mixed paper fibers (OFP, OMG, OCC, TCM, Other #1, Other #2) and mixed glass (green, brown, clear) are sorted by their respective technologies into mixed products.

The recovery column describes which materials may be sorted into individual product streams rather than a mixed product (e.g. mixed paper, mixed glass, etc.). For example, if a 1 is placed next to office paper in the Supplemental Recovery column, then office paper would be sold as a separate product. All other paper types would be baled as mixed paper. Because there is no way to automatically sort office paper, manual sorters would be required. The user must enter a 1 in the automation column to indicate that office paper is to be removed manually.

2.1.6 Data Development

Four MRFs were visited to gather data used to develop defaults, while other data were gathered directly from MRF operators and vendors. A complete listing of the data is presented in Appendix B with PFDs for visited facilities in Appendix D.

Power and investment cost are calculated via linear regression analyses where data were available. Costs and power were gathered for equipment and plotted as functions of their available throughput. For any particular separation technology, data for a number of different throughputs were collected. Using these data, a linear trend line, intersecting zero, is plotted to develop a coefficient of consumption for each technology-specific parameter. The slope of the trend line represents the metric analyzed (kW, $) per unit throughput. For those separation technologies where only two points were gathered, these values were averaged. In some cases the lack of data resulted in single point estimate.

2.2 Model Design for Presorted recyclables MRFs

The objective of this section is to define a MRF that receives presorted recyclables with regard to design and resultant cost and emissions associated with construction and operation. This type of MRF receives recyclables from residential and/or commercial sources that have already been separated into pure streams that may be sent directly to remanufacturing; however, baling and glass crushing are performed to facilitate more efficient transportation. These facilities also perform brokering of sorted recyclables to buyers. Using costs of processing and revenue generated through sale of recyclables, total system costs may be calculated for these facilities.

2.2.1 Material Flow Description

MRFs that receive presorted recyclables, by definition, do not require the separation of recyclables, therefore they represent a much simpler MRF compared to single-stream, dual stream, and mixed waste operations. Given the lack of separation, these facilities are more similar to a transfer station than a conventional MRF. The PFD provided in Figure 2.6 illustrates the limited processing that occurs in facilities processing presorted recyclables.

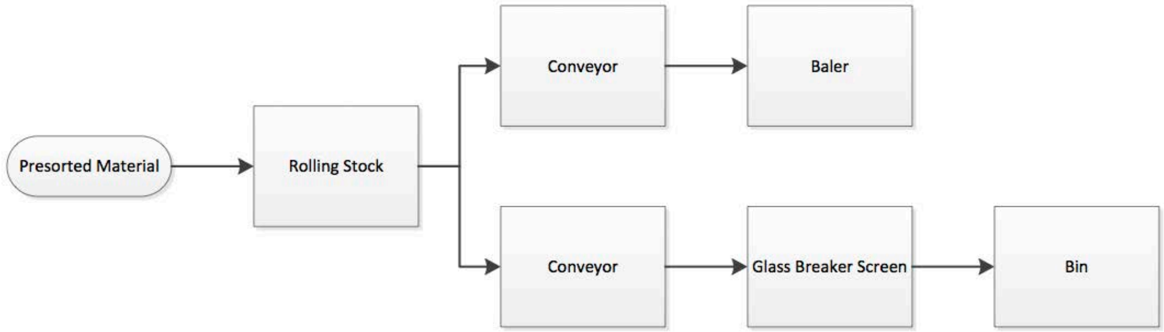


Figure 2.6 Process flow diagram for a presorted recyclables MRF

Front-end loaders are used to manually move material from bunkers acting as tipping floors for the material onto a chain-belt conveyor trough that delivers material to a baler. All material processed at the facility conforms to this flow except for glass. While efforts are made to crush glass during transport and management, the material is not broken into a consistent size. For this reason flint, green, amber, and mixed glass streams are all transported via a front end loader to another conveyor leading to a glass breaker screen, which provides more uniform sizing for glass cullet required for optical separation and subsequent remanufacturing. Bins are then used to store glass cullet before shipment.
The material accepted in these MRFs has been either source-separated, sorted by the collection crew at curbside, or collected as a single recyclable stream from a commercial entity. OCC is the primary fraction of presorted recyclables delivered from commercial entities due to its abundance in the retail industry. Presorted recyclables MRFs are capable of recovering all materials.

2.2.1.1 Fraction Allocation

Emissions and costs are allocated across waste fractions to capture the individual effects on cost and environment emissions as composition changes. Since very little equipment is used in this facility compared to MRFs that process mixed waste or mixed recyclables, there was no need to implement a utilization matrix. Instead, all waste fractions (except for glass) have the following attributed to their processing: building, construction and operation, rolling stock, conveyors, and baler. Since the glass fractions require additional processing into cullet, the cost and emissions associated with the glass breaker are allocated solely to glass while the baler is allocated to all materials except glass.

Costs, electricity consumption, and the number of laborers required are normalized by throughput on a per Mg basis to calculate final cost and emissions coefficients. Equations describing the calculations performed in these operations may be found in the emissions and cost coefficients sections (2.2.2 and 2.2.3).

Beyond equipment and laborers required to process material, a certain amount of overhead must be considered. Operational costs associated with administration and management are represented as a fraction of labor costs associated with the processing of this fraction. Overhead associated with construction costs and operation of the building as a whole, including office and processing area overhead electricity consumption are estimated on a per square meter basis, which is a function of throughput. This relies on the simplifying assumption that each processed fraction requires the same amount of overhead on a per Mg basis to process. This assumption is justified considering the low impact of these parameters as presented in results. No overhead parameters appear in the list of top 5 Spearman rank correlation coefficients from data gathered in the Monte Carlo analyses for either cost or GWP. This indicates low impact relative to other parameters, as Spearman rank coefficients are the metric used to quantify this behavior. Therefore, uniform distribution of overhead resources is appropriate given its ultimately insignificant impact.

2.2.2 Emissions Coefficients

Emissions are separated into two primary categories: airborne and waterborne. These parameters are necessary to account for all combustion and pre-combustion activity of fuels used in the MRF. Electricity consumption represents a primary driver of emissions produced upstream of the MRF. Combining fuel related emissions with those generated from electricity required to run the facility provide a comprehensive inventory of emissions produced due to the operation of the MRF.

2.2.2.1 Airborne Emissions Equations

Propane and diesel fuels are considered in the presorted recyclables MRF when calculating emission levels of airborne pollutants listed previously in Table 2.6. No process level emissions are encountered in MRFs accepting presorted recyclables; therefore, the only direct emissions encountered within the facility are due to fuel combustion in rolling stock.

A regional electricity mix is used when considering emissions resulting from electricity consumption. The calculation for these emissions is based on the NERC region in which the facility is located. In this case the Southeast Electric Reliability Council (SERC) region was chosen. Using the mix of energy carriers for the appropriate NERC region, emission factors were calculated on a per kWh basis. Airborne emissions were calculated for each pollutant in Table 2.6 using emission factors applied to Equation 2.4 similarly to MRFs requiring separation.

2.2.2.2 Waterborne Emissions Equations

All waterborne emissions calculated in the MRF model are due to precombustion of fuels used for electricity production, rolling stock and transportation. Potential for waterborne emissions found in runoff from facility wash down was considered; however due to a lack of water characterization, wash down water was not integrated into the model. According to interviewed MRF operators interviewed, internal wash down of the facility is only done annually, implying the volume of water and associated waterborne emissions included in the analysis would be negligible.

Precombustion emissions were combined with regional electricity mixes as calculated for airborne emissions, while diesel and propane fuels used their respective emissions factors to perform calculations found in Equation 2.5 for all waterborne pollutants found in Table 2.6.

2.2.3 Cost Coefficients

Cost coefficients are separated into six categories to simplify accounting. These categories cover equipment, construction, labor, electricity, consumables, and revenue. Groups were then aggregated into one final cost coefficient to represent the cost to process a Mg of a particular waste fraction. The following six subsections of the document describe these groups.

MRFs receiving presorted recyclables are vulnerable to volatility in tipping fees as those facilities requiring sorting described in Section 2.1.4, thus tipping fees are not considered in this chapter either. Presorted recyclables MRFs use the sale of processed recyclables as their sole source of revenue.

2.2.3.1 Equipment Cost Equations

Equipment costs are calculated as for equipment used in other MRFs described in Section 2.1.4.1; however, less processing machinery is used due to the lack of sorting in these facilities. Five pieces of equipment are used in a presorted recyclables MRF: rolling stock, conveyors, a baler, a glass breaker screen, and bins. Costs associated with each piece of equipment were calculated based on capital cost, O&M cost, lifetime, discount rate, and throughput. Capital recovery factors (CRF) were calculated for each piece of equipment using lifetime and discount rate. The annual payment of the equipment was calculated as the product of the CRF and investment cost. The payment was then combined with an annual throughput to yield a cost per Mg. This calculation is performed using Equation 2.13, while the aggregate equipment cost for all equipment required for recyclables processing is presented in Equation 2.7. Note that technologies in Equation 2.7 differ from those used in facilities that require material sorting; however, costs are calculated in the same manner for the differing set of required technologies.

Equation 2.13 Calculation of cost of ownership for each piece of equipment in the facility.

$$INV_t[\$/Mg] = \frac{(INVCOST_t[\$] \bullet CRF\left[yr^{-1}\right] + FIXOM_t\left[\frac{\$}{yr}\right]}{THROUGHPUT_t\left[\frac{Mg}{hr}\right] \bullet HRS\_PER\_SHIFT\left[\frac{hrs}{shift}\right] \bullet SHIFTS\_PER\_DAY\left[\frac{shifts}{day}\right] \bullet DAYS\_OP\_ANNUALLY\left[\frac{days}{yr}\right]}$$

2.2.3.2 Labor Cost Equations

Several aspects of labor were considered, from operators for various processes to management required to run the facility. Laborers required to operate machinery in a presorted recyclables MRF are specified as a parameter listed under each technology in the model. Automated process laborers are treated as an integral part of the machinery, since they are required to achieve the throughput. The amount of labor is calculated using material throughput to evaluate the number of laborers required per Mg per hour. Combining pickers per hour with the number of hours operated per day and operating days per year yields annual cost associated with the processing of material via automation. Operator requirements for included processing technologies are listed in Table 2.10. The corresponding equation associated with this calculation is specified in Equation 2.14.

Table 2.11 Manual labor required by each technology used in a presorted recyclables MRF

Separation Technology	Required Labor
Rolling Stock	2
Glass Breaker Screen	0
1-Way Baler	1
2-Way Baler	1

Final cost associated with labor is multiplied by a default fringe rate of 33% (IBA, 2009) to account for costs associated with the employment of personnel (i.e., costs of leave, employee benefits, pensions, and unemployment benefit plans). Management and administrative overhead is represented as a default factor (25%) of manual labor as well.

Equation 2.14 Calculation of the labor cost associated with all labor in the MRF

$$TOTAL\_LABOR\_COST\left[\frac{\$}{Mg}\right] = (1 + FRINGE\_RATE[\%]) \bullet (1 + MGMT\_RATE[\%]) \bullet$$
$$\sum_{f \in FRXN}\left(\begin{array}{l}\left(LABORERS\_REQ_f\left[\frac{sorter}{tph}\right] \bullet LABORER\_PAY\_RATE\left[\frac{\$}{sorter - hr}\right]\right) + \\ \left(UTIL_{f,rollingstock} * DRIVER\_REQ\left[\frac{drivers}{tph}\right] * DRIVER\_PAY\_RATE\left[\frac{\$}{hr - driver}\right]\right)\end{array}\right)$$

Where,

LABORERS_REQ$_f$:	Number of laborers required to operate equipment used in processing waste fraction *f*
LABORER_PAY_RATE:	Hourly wage of laborers employed in the MRF

2.2.3.3 Electricity Cost Equations

Electricity is categorized into two separate groups to effectively allocate electricity consumption: general electricity and processing electricity as performed in Section 2.1.4.4. General electricity consumption includes all electricity required that does not directly contribute to the processing of a waste fraction, while processing electricity accounts for consumption associated with processing equipment. General electricity consumption is accounted for as described in Section 2.1.4.4; however processing technologies differ in recycling facilities receiving presorted recyclables.

General electricity consumption represents the same consumption as described previously, although given the absence of a utilization matrix in the presorted recyclables MRF model, attribution is performed differently. Since general electricity consumption is given per Mg this may be directly applied to all recyclables entering the facility, as specified in the input matrix.

Electricity consumption attributed to material processing relates to equipment used in the preparation of sorted recyclables into salable commodities. Electricity consumption per Mg processed is provided for each machine as a quotient of its power and throughput. This consumption is then applied to the waste fractions, which utilize the technology. The equation used to calculate total electricity consumption for a given waste fraction is calculated similarly to material processing in MRFs requiring sorting, and is provided in Equation 2.11.

2.2.3.4 Consumables Cost Equations

Consumables are considered to be those materials required to operate the facility that are required to be replenished at regular intervals. Fuels required for operation of rolling stock include both diesel and propane. Fuel consumption figures are located in the presorted recyclables MRF model section specifying rolling sock parameters, where they are presented on a per Mg basis. Case studies were used to approximate fuel consumption, which is assumed to scale linearly with overall throughput.

Baling wire is also consumed linearly with throughput; however, since a high variability is experienced across fractions on a per mass basis, a mechanistic approach was adopted. Methods employed in facilities requiring sorting were used and is further described in Section 2.1.4.5. Data was acquired from vendors on bale density and bale dimensions. Using the amount wire required per bale and bale density, these figures are combined to estimate wire required per Mg of recyclable fraction. Cost per Mg then is calculated by dividing the cost of wire by the mass of the bale, resulting in Equation 2.12.

2.2.3.5 Revenue Cost Equations

Revenue is generated by the sale of sorted material. The cost of these materials is determined by the composition of the stream. Mixed streams (i.e. mixed paper, mixed glass) will represent less value than their pure constituents. Model inputs described in the following section allow the user to specify the materials received at the presorted recyclables MRF. This information is used to set appropriate pricing on each fraction based on other fractions included in the output stream. For example, office paper in a mixed paper stream will generate less revenue than sorted office paper. Separated recyclable streams with corresponding requirements are set forth by the Institute of Scrap Recycling Industries (2009) and outlined in Table 2.9. The volatility of the recycling commodity market suggests that prices should be a user specified input.

2.2.4 Model Inputs

While many parameters may be modified throughout the model to better tailor functionality to user specifications, required user input is fairly limited. Table 2.11 provides an example of an input table used for the presorted recyclables MRF model. Since no separation is required in presorted recyclables MRFs, degrees of automation need not be specified; however the degree of aggregation of material must be indicated. This is accomplished using a similar form as discussed in Section 2.1.5 for facilities requiring separation. For example, the default model assumption is that glass is separated by color. If the user were to specify mixed glass recovery, the associated revenue would be updated to 0 \$/Mg since the default assumption is that mixed glass cullet has no economic value. .For ferrous, aluminum, and plastics, the user cannot override the default model assumption, which is the receipt of pure streams as specified in Table 2.11. The underlying assumption is that mixed streams would never be received by a presorted facility.

Table 2.12 The user input table for presorted recyclables MRFs is specified similarly to those MRFs at which material is sorted, as shown in Table 2.2. User editable fields are indicated with yellow regions, white cells indicate values used in the model. Initially white cells contain default values, which are changed to update to override values if the user specifies one. Crosshatched cells indicate that cells are not applicable for the corresponding material type. Mixed paper may be received as a mixed paper stream or individual streams. This level of aggregation is specified in the purity column: (0) recovery as a mixed product, (1) recovered individually. All other materials are assumed to be received as individual waste fractions. Material Revenue: sorted sale price per Mg according to aggregation levels specified in the purity column.

	Purity		**Material Revenue ($/Mg)**
	Value	Override	Value
Paper			
Newsprint	0		$82.00
Office Paper	0		$82.00
Magazines	0		$82.00
3rd Class Mail			$82.00
Paper Other #1	0		$82.00
Paper Other #2	0		$82.00
Corr. Cardboard	1		$115.00
Glass	1		
Glass - Brown			$20.00
Glass - Green			$1.00
Glass - Clear			$28.00
Ferrous			
Ferrous Cans			$140.00
Ferrous Metal - Other			$140.00
Aluminum			
Aluminum - Foil			$1,480.00
Aluminum - Other			$1,480.00
Plastics			
HDPE			
HDPE - Translucent Containers			$500.00
HDPE - Pigmented Containers			$330.00
PET			$320.00
Plastic Other #1			$0.00
Plastic Other #2			$0.00
Films			$0.00

2.2.5 Data Development

Equipment vendors were contacted to obtain data (e.g., cost, power consumption) on equipment required to operate presorted facilities. Using these data, an empirical approach was taken for the top-down development of a model as described in Section 2.1.6.

2.3 RESULTS

Both emissions and costs are accounted for in all MRF models with respect to each material type monitored. This section contains descriptions of these coefficients and how they are formulated using a sample composition of waste. First, the coefficients are displayed as total cost of the MRFs and global warming potential from airborne emissions. The following sections illustrate coefficients for default automated MRF configurations with regard to cost and emissions as well as how, using an assumed composition shown in Table 2.1, separate cost and emissions categories contribute to the overall coefficients. The composition of mixed waste is based on waste composition provided in USEPA, 2010, where recyclable composition was derived from applicable materials.

All of the MRFs configured for this table of coefficients are fully automated, recovering all fiber as mixed paper except for OCC. OCC is recovered separately due to ease of recovery and higher sorted sale value. All other recyclable materials are separated into individual waste streams (aluminum, ferrous, PET, HDPE-t, HDPE-p, films, amber glass, green glass, and clear glass).

2.3.1 Final Cost Coefficients

Coefficients describing cost are given in \$/Mg, where mass is given by each material type. For example, cost coefficient *x* for material type *y* would indicate that *x* dollars are spent processing 1 Mg of material *y* in a MRF. A set of coefficients is developed for each MRF type and may be augmented by changing the degree of automation and sorting in the input tables. These tables are described in Sections 2.1.5 for MRFs requiring sorting and 2.2.4 for those receiving presorted recyclables. Table 2.12 provides costs to process a Mg of incoming material for each of the MRFs modeled, where mixed waste MRFs process a Mg of MSW and single-stream MRFs process a Mg of recyclables.

Table 2.13 Final coefficients for all MRFs modeled after applying an assumed composition to measure cost per Mg of material input into each respective facility

	Cost to Process (\$/Mg)	Cost Including Sale of Sorted Material (\$/Mg)
Single-Stream	15.16	-90.93
Dual-Stream	9.72	-96.37
Mixed Waste	11.06	-7.37
Presorted Recyclables	7.77	-130.15

As described in Section 2.2.3, final cost coefficients are broken into five categories during modeling. The composition in Table 2.1 was applied to coefficients generated in the model to form a system of coefficients describing the cost associated with processing 1 Mg of recyclables in a single-stream recycling facility. A graphical representation of final cost coefficients separated into each of these categories is displayed in Figure 2.7.

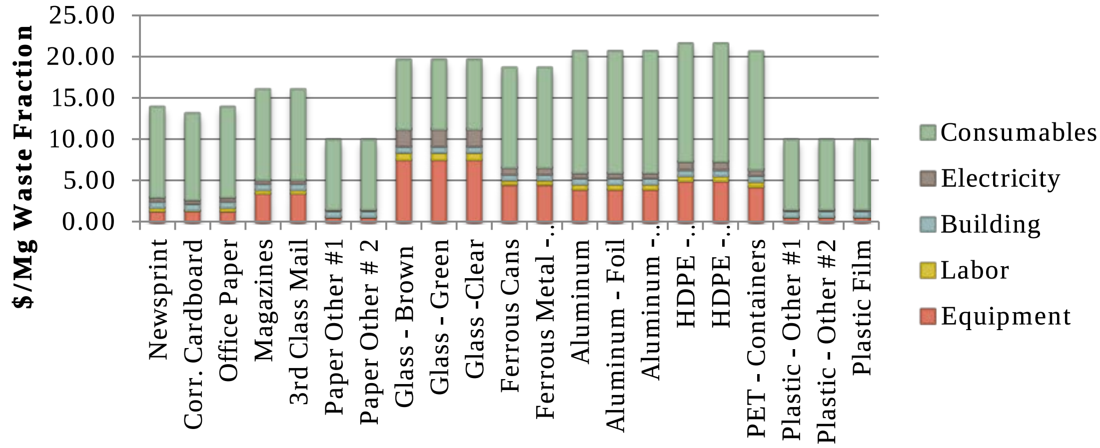


Figure 2.7 Final cost coefficient, characterized by type, to process 1 Mg of recyclables using a sample composition. These costs do not include revenue from sales.

The costs of equipment exhibit significant variation between waste fractions due to the differing equipment required to separate material. Variation in consumables is largely due to differences in material density, and its contribution to the amount of baling wire required. Since glass does not consume baling wire, consumables associated with these fractions illustrate costs associated with fuel requirements in rolling stock. Automation within the facility reduces labor costs to negligible amounts, as with building cost.

2.3.2 Final Emissions Coefficients

Emissions coefficients are calculated similarly to cost coefficients in that they represent specific emissions associated with the processing of a Mg of each waste material. Both waterborne and airborne emissions are calculated and include all pollutants in Table 2.6. Where electricity was used in processing of material, regional fuel splits for the SERC region were used, as opposed to national fuel splits, thus emphasizing the regional service area of a

MRF. Further analysis of fuel split data is described in Chapter 4. Table 2.13 provides CO_2-e resulting from 1 Mg of incoming material into all MRF types modeled in this thesis. Full tables of all emissions modeled in SWOLF at each MRF type are shown in Appendix E.2 and Appendix E.4; however, since GWP was of primary concern in this research, results are presented in terms of nitrous oxide, methane, and fossil-derived CO_2. GWP factors shown in Table 3.1 are applied to these airborne emissions to compute CO_2-e associated with the processing of material and shown in Table 2.13.

Table 2.14 Final GWP coefficients compiled through application of GWP and composition

Incoming Material Composition Type	GWP Associated with Recovery (kg CO_2-e/Mg)
Single-Stream	14.94
Dual-Stream	14.94
Mixed Waste	11.40
Presorted Recyclables	3.62

Figure 2.8 illustrates how GWP associated with each fraction in a single-stream MRF is composed as a product of each contributing pollutant. Elevated GWP of glass processing when compared to other materials illustrates the increased fuel and electricity demand associated with glass recovery.

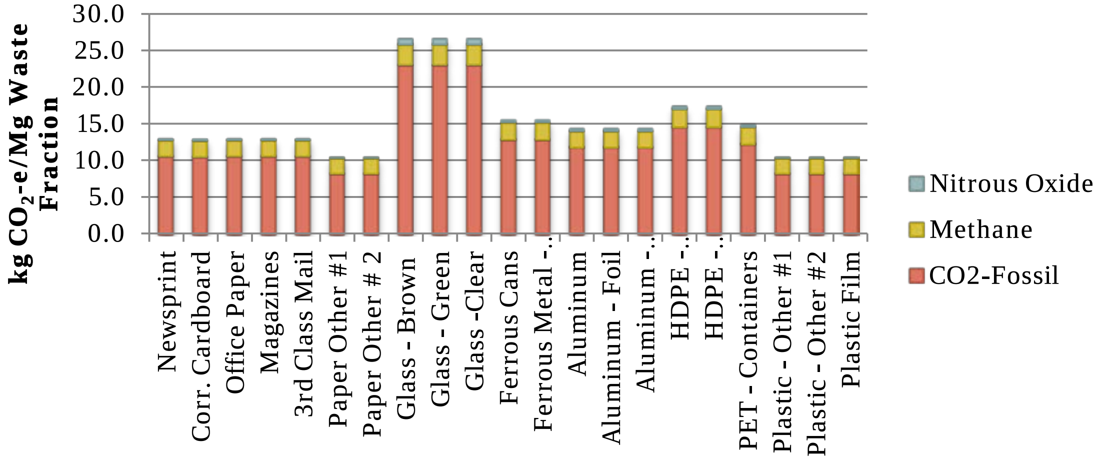


Figure 2.8 Global warming potential by material type.

3 ANALYSIS

3.1 Introduction & Objectives

Single stream recycling programs offer the convenience of collecting all recyclables in one bin at the curbside, thus decreasing collection costs when compared to dual stream programs; however, separation and processing costs are shown to increase (AFPA *et al.* 2004). Despite this increase in processing costs, Figure 3.1 shows the growing trend towards single stream MRFs in the U.S., which is largely driven by an effort to increase participation rate. Given the growing share of single-stream recycling and the associated rise in processing cost, it is critical to identify which steps in the recovery process have the most significant impact on system costs. Some cost reductions can offer environmental benefits as well, such as a reduction in energy consumption.

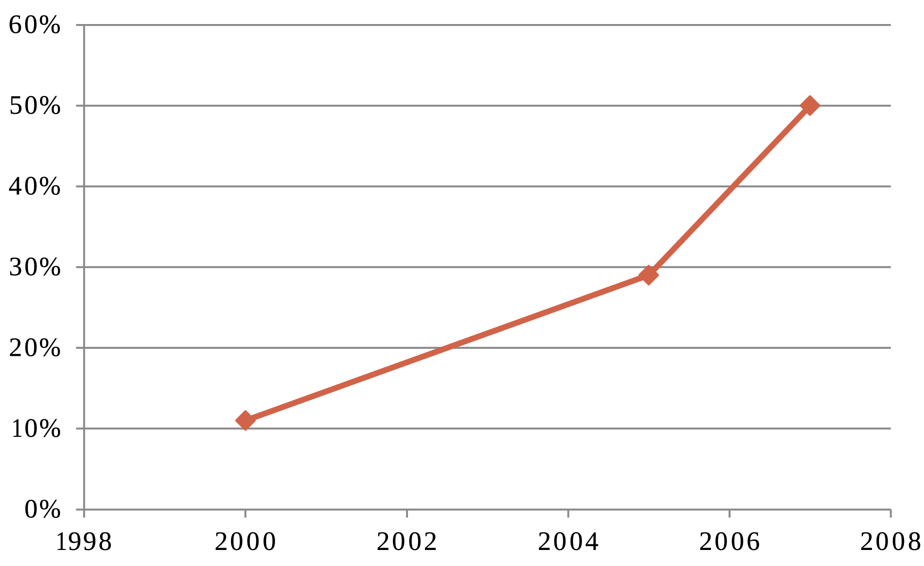


Figure 3.1 Percent of U.S. single-stream MRFs (Morowski, 2010)

Environmental impacts avoided through the implementation of recycling programs include a reduction of GHGs, which is essential for the mitigation of climate change. In 2009, recycling of 74 million Mg of MSW led to a 178 million Mg reduction of CO_2-e (EPA, 2010). Therefore, identification and adjustment of those factors in the recovery process most responsible for GHG production can ultimately aid in the reduction of climate change. Modeling these factors provides a means to examine the process without disrupting current operations within facilities.

Environmental systems modeling involves the simplification of highly complex systems by selecting a small set of representative parameters that best describe them. Parameters used in the modeling of material recovery are highly variable due largely to the variation in the incoming waste composition, flow rate, and organization of these facilities. Uncertainty analysis of key parameters offers a way to quantify how perturbations in this subset of parameters affect output values. Further, parametric sensitivity analysis quantifies the range in resultant cost and GWP in single-stream recycling facilities given a specified range for each input parameter. The objective of this analysis is to determine which parameters produce the greatest response in total cost and GWP.

3.2 Methodology

The analysis was performed on two facilities that represent limiting cases in MRF design: (1) a highly automated facility and (2) a facility with a large degree of manual sorting. Both analyses are similar in execution, but differed in the parameters modeled. In the fully automated facility, 126 parameters are modeled, whereas only 106 were modeled in the manual facility. This decrease in parameters results from the reduction of equipment used in the facility: Fewer parameters are necessary when modeling manual labor compared to those used for automated separation technologies.

The first scenario considers a fully automated facility, which collects all fiber streams as mixed paper, except for OCC. Since OCC can be efficiently machine separated and receives higher prices when sold separately, a screen is implemented to accomplish OCC separation. Furthermore, glass is separated on site optically, as are plastics. A magnet is used to separate ferrous material and an ECS was used for aluminum. The input table for the single-stream model (as described in Section 2.1.5) remained the default.

Following the automated scenario, a lightly automated facility is considered, which incorporates manual sorting of plastics and fiber. Manual recovery is utilized to the extent that it is typically used in industry. All fiber streams are recovered manually as mixed paper, except for OCC. Since OCC is rarely commingled with mixed paper due to its ease of recovery and higher value, this fraction was recovered separately. While not all facilities utilize optical technologies in their recovery process, ECS and magnets have become standards for recovering aluminum and ferrous material, respectively. Default input automation is overridden for both paper and plastic categories in the input table to model the manual sorting in this facility. Detailed explanation of this input table can be found in Section 2.1.5.

Both analyses begin with a Monte Carlo simulation, the outputs of which are used to calculate Spearman rank coefficients. The Spearman coefficients are then used to assess the impact of each of these parameters on MRF GWP and cost. Spearman coefficients measure correlation by quantifying the degree of monotonicity between a monitored output parameter and a given input parameter, thereby providing a quantification of the strength of association between the two variables. An in-depth look at how Spearman coefficients are applied to this analysis is explained in Section 3.2.2. Ranking the Spearman coefficients by their magnitude orders the inputs based on their relative impacts on the output (e.g., GWP, cost). The parameters of highest rank are considered for parametric analysis, where a direct quantification of impact resulting from the modification of one at a time parameter may be calculated. Thus, parametric analyses allow for a clear illustration of how each input parameter in isolation affects the result.

Evaluation of the MRF requires an assumed waste composition, thus allowing output values for all waste fractions to be collapsed into aggregate values for cost and GWP. The composition used in this analysis is presented in Table 2.1. This composition is based on values from USEPA, 2010 where possible; however, engineering judgment is used to further disaggregate some waste fractions requiring higher resolution to fit into the SWOLF composition table. GWP was calculated based on carbon dioxide, methane, and nitrous oxide emissions factors (Franklin, 1998) used in SWOLF. Carbon dioxide was subdivided into three categories (fossil, biogenic, and storage) to facilitate accurate accounting of both sequestered and neutral carbon sources. Fossil CO_2 emissions are those derived from combustion of fossil fuels, which represent a net positive GWP, whereas biogenic emissions are assumed to be negated by the uptake of plants (used to make biomass-based materials) during photosynthesis. Biogenic emissions remain carbon neutral, while CO_2 storage represents sequestration, or net negative production of CO_2. GWP associated with these emissions are listed in Table 3.1. Emissions resulting from electricity generation used the same SERC region fuel splits as described in Section 2.3.2.

Table 3.1 100 year global warming potential for airborne emissions monitored in SWOLF (IPCC, 2007)

Airborne Emissions	**GWP**
CO_2-Fossil	1
CO_2-Biogenic	0
CO_2-Storage	-1
Methane	25
Nitrous Oxide	298

3.2.1 Monte Carlo Simulation

Estimating the effect of changes in inputs on model predictions is conducted with Monte Carlo simulation. Triangular distributions are used for most parameters, while uniform distributions are assigned to parameters with only specified ranges. For example, manual-sorting rates specified by the USEPA (1992) are given as ranges; therefore, they were assigned uniform distributions with minima and maxima specified according to the range. Otherwise, parameter values specified in the MRF model are assumed to be mean values for this simulation, while minima and maxima are calculated as ±25% of the mean to form triangular distributions. Using these values, random sampling across the distributions is used to characterize input parameters as i-element vectors for n parameters. Results of i model runs are then used to develop the corresponding *i*-element output vectors. This analysis performed for i=10,000 model iterations.

3.2.2 Spearman Rank Correlation Coefficients

Data gathered from the Monte Carlo simulation are used to calculate Spearman rank coefficients according to Equation 3.1. These correlation coefficients yield positive values for direct proportionality or negative values to imply inverse proportionality, and the magnitude of the coefficient represents the tendency towards monotonic behavior rather than linearity. Linearity of output based on input parameters was not a concern in this analysis, which is why Spearman coefficients were chosen instead of Pearson; however they are very closely related. Developing Pearson coefficients from the rank of input data forms Spearman coefficients. Those parameters whose Spearman rank correlation magnitudes are nearest to unity have the largest impacts on model output. Parameters with the highest correlation with regard to emissions and cost are considered for further analysis. Full lists of Spearman coefficients calculated in this analysis are provided in Appendix G.1.

$$\rho = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2 \sum_i (y_i - \bar{y})^2}}$$

Equation 3.1 Spearman Rank Correlation Coefficient

Where:

x_i is the rank of the *n*th input parameter in the *i* element vector

$\bar{x}$ is the mean rank of input parameters

y_i is the rank of the nth parameter in the i element vector

$\bar{y}$ is the mean rank of output parameters

The equation used to calculate all Spearman coefficients is given in Equation 3.1. 10,000 samples were taken from each input parameter distribution with total cost and GWP calculated for each sample. Using these data, model input and output values are ranked to establish input values for Equation 3.1, which calculates the Spearman coefficient. All parameters were then ranked according to their Spearman coefficient to determine those with the largest magnitude. Parameters with the largest magnitude were then evaluated in the parametric analysis.

3.2.3 Parametric Analysis

Sensitivity analysis quantifies the effect of changes in inputs on model outputs of interest. This analysis is performed by calculating the percent change in results based on percent change in input values. The five highest ranked parameters, with regard to their Spearman coefficient magnitude, are considered for parametric analysis of cost and emissions. The top five parameters allowed all key parameters to be analyzed in each MRF scenario. For example, only one parameter presents significant impact in manually sorted MRFs when considering GWP; however knowledge of the next most significant impact can provide additional insight. Thus this collection of scenarios and results was presented as a list of top five when considering the magnitude of the Spearman coefficient.

Mean parameter values for input parameters are considered, as well as ±10% and ±25% of these values. Model results are then tabulated for the output parameter being monitored. Figures 3.3, 3.5, 3.7, and 3.9 illustrate percent change in output when input parameters are adjusted by these percentages for the four separate scenarios. Tables providing numerical values for this analysis are found in Appendix G.2.In some cases ±10% and ±25% adjustments to input parameters created infeasible parameters (e.g. efficiency>100%) in which case the cell in the results table for the corresponding analysis will remain empty.

3.3 Results & Analysis

3.3.1 Analysis of Automated Single Stream MRF Model

3.3.1.1 Total System Cost

According to the Spearman correlation coefficients presented in Figure 3.2, and parametric sensitivity analysis results in Figure 3.3, separation efficiency of equipment plays a significant role in determining the overall cost to process recyclables. This is consistent with industry experience, since the ability to recover material dictates the amount of revenue generated by the facility. Separation efficiency is the sole parameter responsible for a piece of equipment’s ability to recover material. Increased separation efficiency increases saleable yield, thus providing a means to offset costs incurred through construction and operation of the MRF. The position of a particular separation technology with regard to others in the rank order of parameters is largely dictated by two other parameters: fraction of the target material in the incoming stream separated by the technology and the sale price of the separated recyclable at the MRF. Thus, the highest impact separation efficiency targets are those representing the greatest composition in the waste stream with the highest prices in remanufacturing markets.

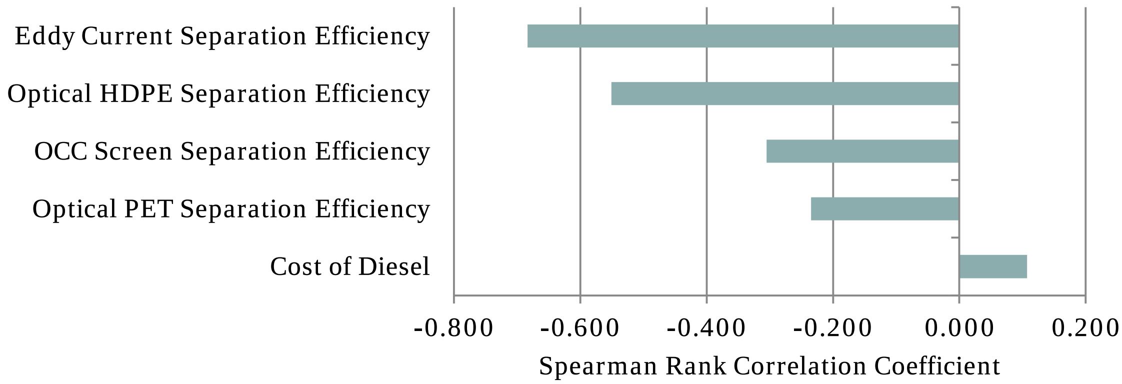


Figure 3.2 The 5 most sensitive parameters based on calculation of the Spearman rank correlation coefficients resulting from the cost analysis of an automated, single-stream MRF.

Due to the prevalence of rolling stock in the recovery process, fuel consumption associated with the operation of this equipment also represents a significant source of sensitivity in the model. The combination of the diesel consumption rate and fuel cost form the primary driving cost associated with rolling stock. Figure 3.2 shows that diesel cost is the only significant parameter driving higher cost, while all other parameters of large Spearman coefficient are inversely proportional to cost. Further quantification of the effects of these parameters is found in Figure 3.3.

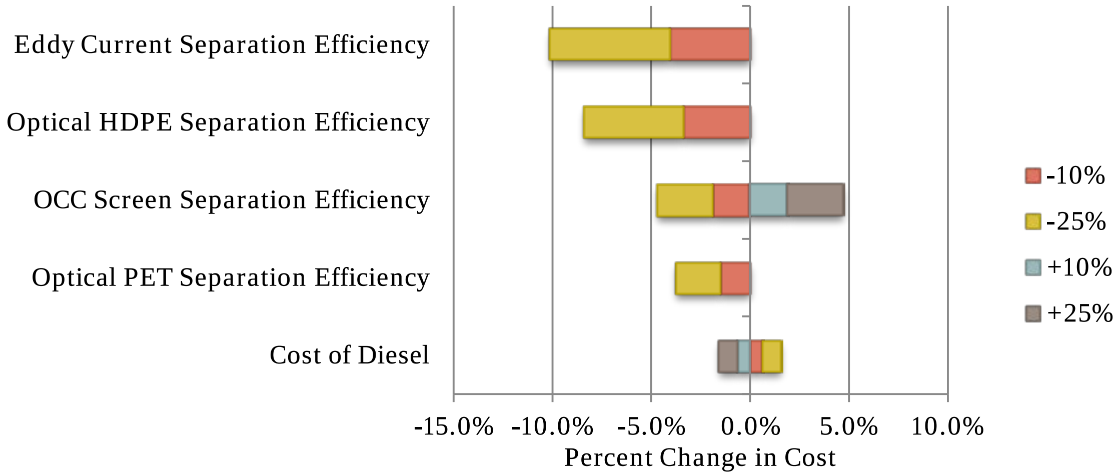


Figure 3.3 Tornado plot illustrating the parametric sensitivity of top ranked Spearman correlation coefficients in an analysis of an automated single-stream MRF considering cost. Horizontal bars are overlaid to show percent change in cost resulting from 10% and 25% reductions in input parameter values, as well as 10% and 25% increases in each parameter value.

Figure 3.3 graphically illustrates the parametric analysis performed on the parameters discussed in this section. Parameters with values absent are due to infeasibility of input values. For example, a 10% increase in ECS separation efficiency would exceed 100% efficiency.

3.3.1.2 Global Warming Potential

Results from the GWP sensitivity analysis as presented in

Figure 3.4 show results in accordance with expectations, with corresponding parametric sensitivity results presented in Figure 3.5. Since rolling stock diesel combustion is the only source of direct emissions within the MRF, diesel consumption is among the top ranked parameters in this analysis. A Spearman coefficient value of 0.98 indicates a nearly perfect correlation between rolling stock diesel combustion and GWP, while all other input parameters are less by an order of magnitude or more.

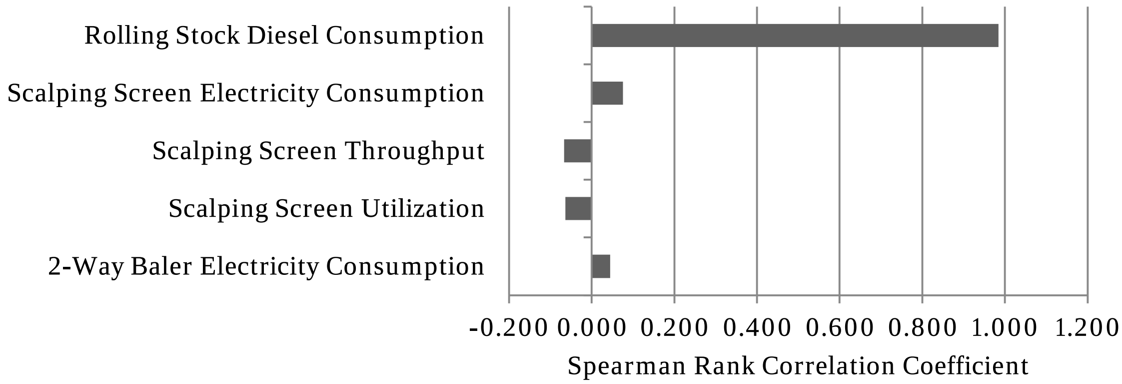


Figure 3.4 The 5 most sensitive parameters based on calculation of the Spearman rank correlation coefficients resulting from the GWP analysis of an automated single-stream MRF.

Secondary emissions from electricity generation are closely tied to the electricity utilization parameter and throughput. These parameters define the utilization and efficiency of the equipment, which determines the overall rate of electricity consumption per Mg of material. Some separation equipment used in facilities consumes a constant amount of electricity regardless of the amount of material processed. This effect is captured by using the utilization parameter, which assesses the utilization of the machine relative to its capacity in order to determine the overall efficiency of operation. Because equipment utilization affects the amount of electricity consumed on a per Mg basis, this parameter is found to have a significant impact on GWP.

Electricity fuel mixes are based on the NERC region where the MRF is located, as mentioned in Section 2.1.3. The MRFs modeled in this section consume electricity generated in the SERC region using the fuel mix shown in Table 3.2. Results from the Single-Stream MRF model described in this section indicate that rolling stock diesel consumption produces far more GHG emissions than those emitted though electricity production. Further, electricity consumption from equipment in the model has relatively little effect on total GWP emissions in comparison; however, resulting GWP would be higher in regions whose fuel mix is more enriched in coal and other fossil fuels.

Table 3.2 NERC Region fossil fuel mixes (%) as ranked by GWP intensity (kg CO2-e/MWh generated), USEPA, 2005.

NERC Region Name	Coal	Oil	Gas	Other Fossil	Non-Fossil
Midwest Reliability Organization (MRO)	70.4	0.87	5.36	0.21	23.2
Hawaiian Islands Coordinating Council (HICC)	13.7	77.3	0.00	1.77	7.25
Southwest Power Pool (SPP)	62.5	0.23	25.8	0.22	11.2
Reliability First Corporation (RFC)	64.4	0.54	6.54	0.71	27.9
Southeast Electric Reliability Council (SERC)	56.9	0.84	14.1	0.28	27.9
Florida Reliability Coordinating Council (FRCC)	26.9	9.23	47.3	0.62	16.0
Northeast Power Coordinating Council (NPCC)	14.7	4.92	26.7	0.00	53.7

Table 3.2 NERC Region fossil fuel mixes (%) as ranked by GWP intensity (kg CO2-e/MWh generated), USEPA, 2005. (continued)

NERC Region Name	Coal	Oil	Gas	Other Fossil	Non-Fossil
Texas Regional Entity (TRE)	34.4	0.37	49.5	0.87	14.9
Western Electricity Coordinating Council (WECC)	30.1	0.4186	31.379 2	0.38	37.7
Alaska Systems Coordinating Council(ASCC)	9.4	14.8062	56.697 2	0.00	19.1

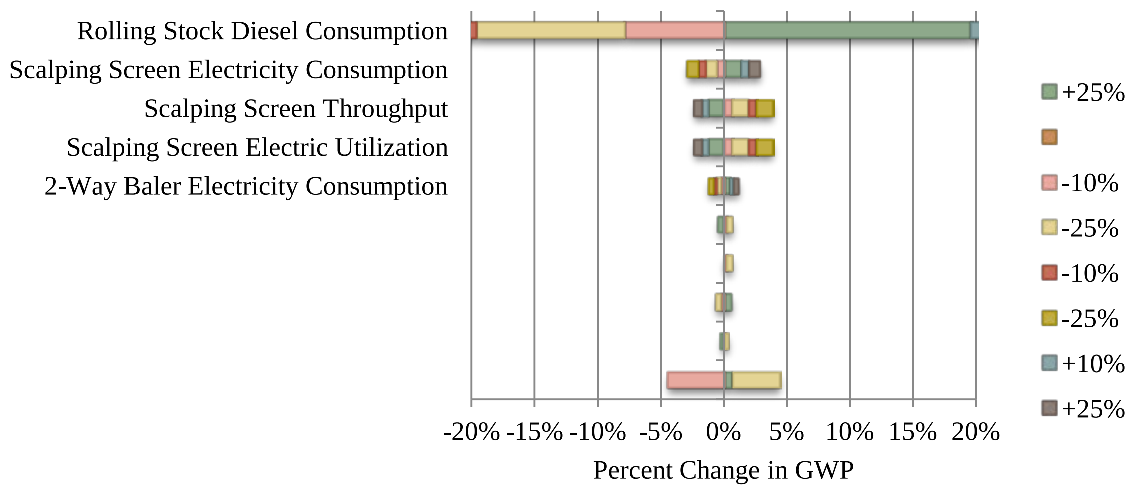


Figure 3.5 Tornado plot illustrating the top ranked Spearman correlation coefficients in the analysis of an automated single-stream MRF considering GWP.

As implied by sensitivity analysis, very little effect is shown by input parameters other than diesel consumption in the parametric analysis depicted in Figure 3.5. All other parameters exhibit less than a 5% change when considering GWP in automated sorting in single-stream MRFs.

3.3.2 Analysis of Manual Single Stream MRF Model

3.3.2.1 Total Cost

Results from Spearman coefficient calculations are provided in Figure 3.6 with the corresponding parametric sensitivity analysis in Figure 3.7. A strong correlation between separation efficiency and MRF costs are illustrated in these results. Separation efficiency indicates the percentage of material to be recovered within the MRF process, which offsets costs by generating more revenue through the sale of recyclables. Therefore, the percentage of the waste fraction in the composition and the sale price of the sorted material further bolster the effects of this parameter. Figure 3.6 presents a very high negative Spearman coefficient for ECS separation efficiency, indicating strong reductions in system cost when separation efficiency is increased. Further, the importance of eddy current separation efficiency indicates that the high purchase price of aluminum is a key driver of MRF revenue despite the relatively low percentage of aluminum in the waste stream. Similarly, HDPE and PET maintain high value as sorted materials. While OCC is significantly cheaper, it represents a higher percentage of the waste stream, thus maintaining high impact on the total MRF cost. Sale prices are specified as a user input as shown in Table 2.2 for MRFs requiring sorting and Table 2.11 for presorted recyclables MRFs. This analysis used default values shown in input tables.

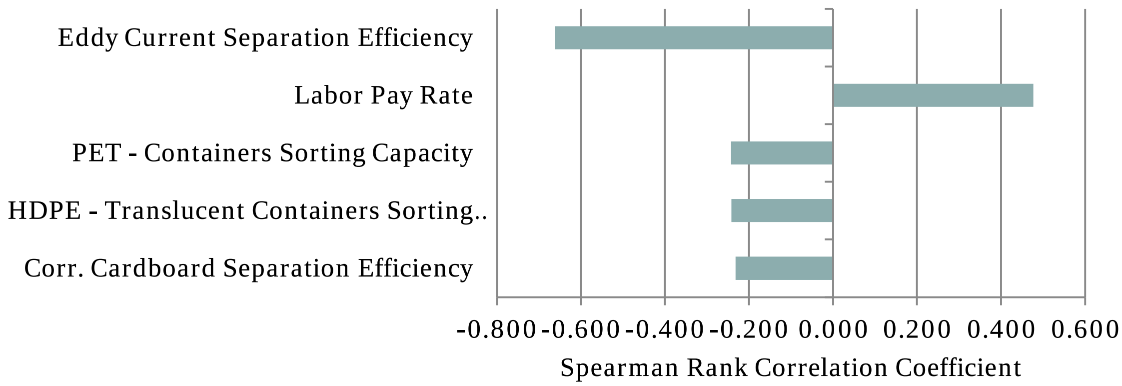


Figure 3.6 The 5 most sensitive parameters based on the calculation of the Spearman rank correlation coefficients resulting from the cost analysis of a single-stream MRF using manual sorting.

The significance of the labor pay rate can be attributed to the increased labor requirement in MRFs using manual recovery. Since sorters for all recovered fractions are being compensated at this rate, modification of this parameter will affect all materials requiring processing.

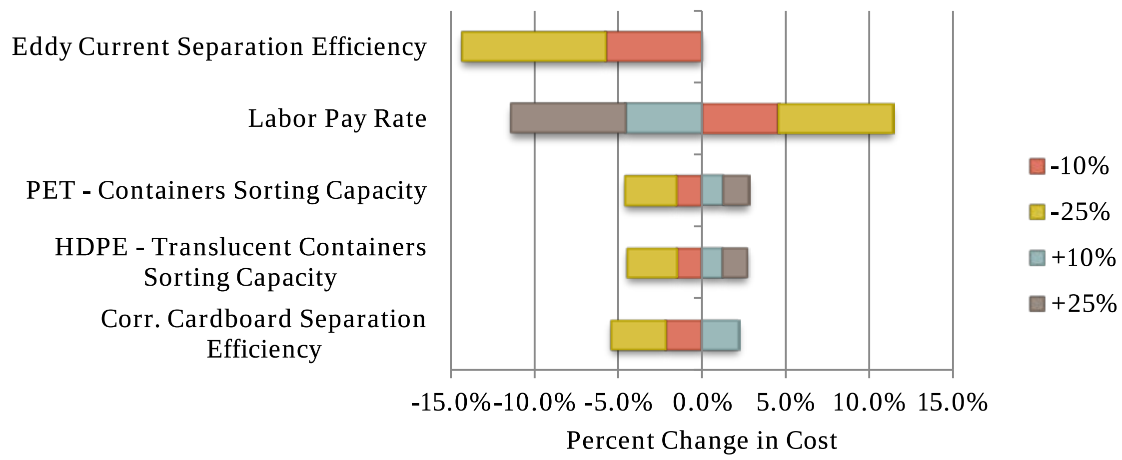


Figure 3.7 Tornado plot illustrating the parametric sensitivity of top ranked Spearman correlation coefficients in a manually sorted single-stream MRF considering cost.

Those parameters not mirrored across the y-axis at 0% indicate nonlinear responses associated with those parameters. This phenomenon is illustrated by sorting capacities listed in Figure 3.7. Nonlinear parameters such as these justified the use of Monte Carlo analysis, as opposed to a simpler linear parametric analysis. As outlined above, it is clear that larger cost impacts are experienced with reductions to these non-symmetric parameters when compared to increases.

3.3.2.2 Global Warming Potential

Results from the GWP sensitivity analysis are presented in Figure 3.8 and yield results in accordance with expectations. Similar to automated facilities, MRFs that manually sort material near-exclusively contribute to GWP through rolling-stock diesel emission.

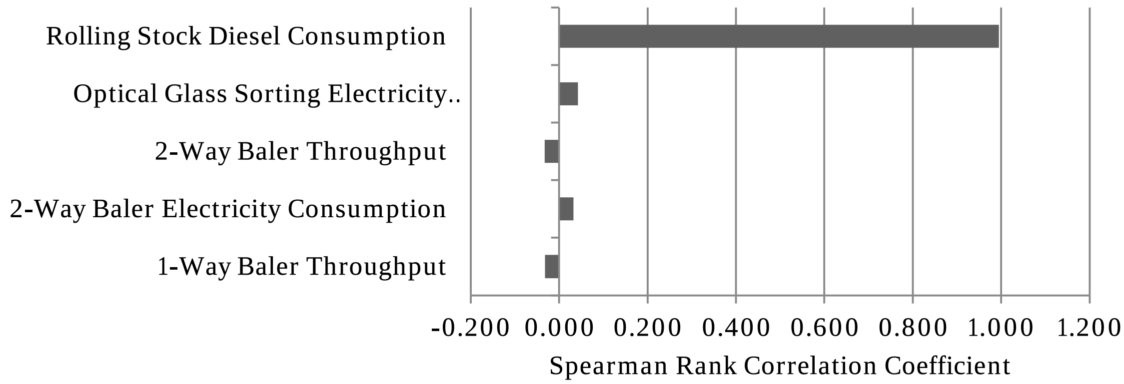


Figure 3.8 The 5 most sensitive parameters based on the calculation of the Spearman rank correlation coefficients resulting from GWP analysis of a single-stream MRF using manual sorting.

Parametric analysis is presented in Figure 3.9. Considering that rolling stock diesel combustion is the only source of direct emissions within the MRF, diesel consumption was hypothesized to be among the top ranking parameters in this analysis. This was mainly due to the inefficiencies in rolling stock operation when compared to heavily optimized electricity production facilities. A Spearman coefficient value of 0.98 indicating a near direct correlation was observed between rolling stock diesel combustion and GWP, thus supporting this hypothesis.

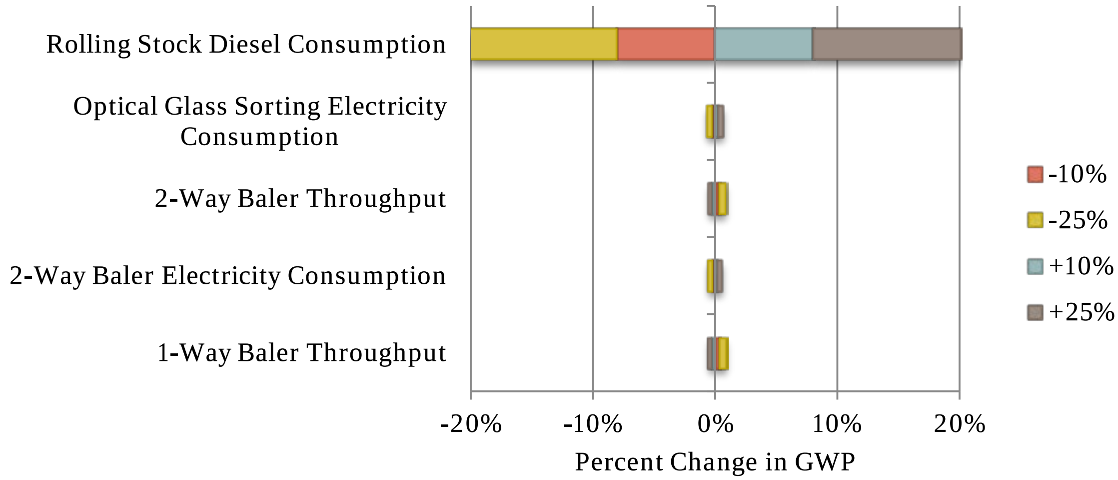


Figure 3.9 Tornado plot illustrating the parametric analysis of top ranked Spearman correlation coefficients in a manually sorted single-stream MRF considering GWP.

Secondary emissions are encountered from electricity generation and are related to the electricity utilization parameter. This parameter defines the utilization of the equipment. For many pieces of equipment, electricity consumption remains constant despite variations in material throughput. Since equipment utilization governs the amount of electricity consumed on a per Mg basis, the equipment utilization factor in turn affects GWP.

Using production figures from Toyota lift trucks used in local facilities (7FDU18), a similar electric lift truck (7FBCU18) was used for comparison to explore potential GWP reduction resulting from fleet conversion. Criteria for selection of an equivalent electric-powered lift truck was based on lift capacity and power. Through computation of energy used per hour a comparison of GWP was made in the SERC grid region. The diesel powered lift truck used 13L/hr, whereas the electric powered truck used 6.34kW/hr. Calculations using default parameters described in Appendix B.3. These calculations indicated a reduction in GWP from 24.57 kg CO_2-e in diesel lift trucks to 5.05 kg CO_2-e in electric lift trucks.

4 CONCLUSIONS

As noted in Section 3.3.1.2, electricity consumed by processes in material processing use a fuel mix specified by the SERC region. This region is slightly less than the mean (within one half of the standard deviation) when considering GWP intensity, therefore the effect of electrical energy consumption would be higher in a region with a higher GWP intensity. Considering electricity generation for recyclables processing in the SERC region did not prove to have a significant impact on GWP when compared to rolling stock fuel combustion, an effective target for GHG reduction may lie in the deployment of electrified rolling stock, rather than use of conventional internal combustion engines. Further analysis of a fleet conversion from diesel lift trucks to electric propulsion in Section 3.3.2.2 indicates that an 80% reduction in GWP is possible.

Separation efficiency for technologies is a primary driver for costs. This is due largely to the multiple impacts of changes to separation efficiency. Increases in separation efficiency decrease the cost of material recovery (per Mg), while increasing revenue. Revenue from the sale of sorted material played a role in determining the cost sensitivity of parameters related to sorting equipment. Specifically, those materials representing significant sources of revenue (per Mg) maintained a strong cost offset. For example, the sorted aluminum sale price contributed to the importance of aluminum separation efficiency as a cost driver compared to other materials with significantly higher fractions in the incoming waste stream. Therefore materials with high economic value can have a large impact on cost sensitivity despite representing a disproportionately small share in the incoming waste stream.

A number of simplifying assumptions were made in an effort to construct a linear model able to be integrated into the SWOLF framework. This framework required that a series of linear coefficients associated with cost and emissions be developed. While these requirements may be limiting due to the nature of automated material processing, this model was developed with 24-50 Mg/hr MRFs in mind. Given that MRFs optimal operating conditions require throughput near its design capacity for a specific composition, further research may investigate different modeling techniques to explore nonlinearities associated with divergence from optimal design conditions.

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APPENDICES

Appendix A Parameter Matrix

	Power (kW) [POWER]	Investment Cost ($) [INVCOST]	Fixed O&M Cost ($/yr) [FIXOM]	Number of Laborers [TECH_MANUAL_REQ]	Diesel Consumption (L/Mg) [TOTAL_DSL_CONSUMPTION]	Propane Consumption (m^3/Mg) [TOTAL_ELC_CONSUMPTION]	Separation Efficiency [SEP_EFF]	Throughput (Mg/hr) [THROUGHPUT]	Economic Lifetime (yrs) [l]	Fractional Utilization [UTIL_FRXN]	Capital Recovery Factor [CRF]	Average Cost of Ownership ($/Mg) [INV]	Electricity Consumption Rate (kWh/Mg) [ELC_CONS]	sorters/Mg [SRTRS_REQ]
Drum Feeder	15	150000	10000	0			1	30	10	1	0.130	0.12	0.50	0.00
Conveyor	5	50000	10000	0			1	30	10	0.85	0.130	0.10	0.20	0.00
Vaccuum	20	150000	1000	2			0.97	10	10	0.85	0.130	0.36	0.59	0.02
OCC Screen	7.5	270000	100000	2			0.75	45	10	0.85	0.130	0.50	0.22	0.00
Scalping Screen	10	280000	100	0			0.85	7	10	0.85	0.130	0.96	1.68	0.00
Glass Breaker Screen	30	220000	10000	0			0.97	9	10	0.85	0.130	0.79	3.92	0.00
Optical Glass Sorting	69	825000	45000	3	0		0.98	5	10	0.95	0.130	5.07	14.53	0.07
Disc Screen	8.5	400000	130000	6			0.94	21	10	0.85	0.130	1.60	0.31	0.03
Optical PET	13	225000	5000	1	0		0.98	5	10	0.85	0.130	0.63	1.53	0.01
Optical HDPE	40	450000	10000	1	0		0.98	5	10	0.85	0.130	1.26	4.71	0.01
Magnet	4	35000	5000	0			0.98	2.25	10	0.85	0.130	0.88	2.35	0.00
Eddy Current	9	128000	5000	1			0.97	10	10	0.85	0.130	0.33	0.88	0.01
Manual Sorting	5	50000	10000	0			0.98	2	10	0.85	0.130	0.60	1.76	0.00
1-Way Baler	63	550000	5000	1			1	51	10	1	0.130	0.28	1.24	0.00
2-Way Baler	59	530000	5000	1			1	30	10	1	0.130	0.45	1.97	0.00
Rolling Stock	0	350000	5000	1	10	0	1	24	10	0.85	0.130	0.39	0.00	0.00

Figure A.1: The parameter matrix contains all equipment specific data. All figures to the right of the double line are calculated from figures on the left and data contained in the miscellaneous section Appendix B.3. Figures on the left side of the double line are described in Appendix B.1. Variable names contained in brackets are those used in model equations. Descriptions of these variable names are contained in Appendix C.

Appendix B MRF Model Parameter Data

Appendix B.1 Equipment

Source: Process Engineer, Van Dyk Baler

Equipment	Material Throughput (Mg/Hr)	Separation Efficiency (%)	Power (kW)	Investment Cost ($)	Required Laborers (Mg/hr)
Drum Feeder	30	100	15	142,000	0
OCC Screen	45	70	7.5	272,000	2
DiscScreen	21	94	8.5	409,000	6
Scalping Screen	7	85	10	280,000	0
Glass Breaker Screen	9	97	30	217,000	0
Eddy Current	3	97	16	120,000	1

- These technologies were designed for a 24 Mg/hr single stream MRF
- Material Throughput and Separation Efficiency are estimated by the expert opinion of Peter Van Dyk
- Above values are used as single-point estimates for parameter matrix in Appendix A

Source: Process Engineer, Bollegraf/Van Dyk Baler

	Material Throughput (Mg/hr)	Separation Efficiency (%)	Power (kW)	Investment Cost ($)	Required Laborers (Mg/hr)
Conveyor	30	100	5	50,000	0
Vacuum	10	97	20	150,000	2
Optical PET Sorting	5	98	13	225,000	1
Optical HDPE	5	98	40	450,000	1

-Conveyors are assumed to consume the same electricity for 24-72” conveyors using a 5HP motor

-Air pressure required to eject HDPE is greater than PET, resulting in a 25 HP compressor being used in place of the 15.

-Optical HDPE sorting requires the use of 2 optical sorters to maintain adequate purity, figures above combine the two (98%)

- Above values are used as single-point estimates for parameter matrix in Appendix A

Optical Glass Sorting (Source: MSS, Inc.)

	Investment Cost ($)	**Required Power (kW)**	**Fixed O&M ($/yr)**	**Throughput (TPH)**
Glass Sort	200,000	2	0	5
25 HP Compressor	25,000	16	1500	5

Optical Glass Sorting (Source: MSS, Inc.) (continued)

	Investment Cost ($)	Required Power (kW)	Fixed O&M ($/yr)	Throughput (TPH)
Infeed conveyor	50,000	5	0	5
Single Setup	275,000	23	1500	5
Green/Amber/Flint Installation	825,000	69	4500	5

-The optical glass sorter requires the use of a 25 HP compressor to provide air pressure for target material ejection
-3 instances of this setup are required to sort mixed glass into green, amber, and flint cullet to 98% purity, which is required to ensure the absence of ceramics in the product
-Parameter matrix uses values for an installation for facilities requiring glass sorting into Green, Amber, and Flint stream with 3 laborers picking ceramics from the feed conveyor.

Magnet (Source: Ereiz Magnetics)

	Investment Cost ($)	Required Power (kW)	Throughput (TPH)
Self-Cleaning Overhead Permanent Magnet A	20,000	3	0.9
Self-Cleaning Overhead Permanent Magnet B	50,000	5	3.6
Average	35,000	4	2.25

- Data provided from correspondence with sales associates at Ereiz Magnetics
- Since no electricity is required to power the magnet, only overhead conveyer required electricity
- Engineering judgment was used to estimate 98% separation efficiency of the magnet

Eddy Current Separator (Source: Ereiz Magnetics) -

	Investment Cost ($)	Required Power (kW)	Throughput (Mg/hr)
24” TYPE-M REO ECS	80,000	8	1.8
60” TYPE-M REO ECS	175,000	10	18.1
Average	127,500	9	9.95

- Data provided from correspondence with sales associates at Ereiz Magnetics and product literature
- Power consumption includes electricity consumed by motor required to spin ECS.
- A single laborer is specified in the parameter matrix to illustrate the post-bale sort to meet a 97% purity.

Rolling Stock (Sources: Toyota, Caterpillar, Surveys)

	Investment Cost ($)	Diesel Consumption (L/hr)	Throughput (Mg/hr)
Toyota 7FDU18	110,000	11.4	11
Caterpillar 924H	140,000	18.9	22
Total	360,000	41.7	22

-Interviews with MRF operators indicated that these were representative front-end loaders (924H) and lift trucks (7FDU18). These facilities also indicated that two lift trucks (7FDU18) and a front-end loader (924H) were necessary to perform daily operations.
-Throughputs were based on utilization in surveyed facilities (13-22 Mg/hr) using one front-end loader and two lift-trucks in their operations. In other words, two lift trucks are required to match the 22 Mg/hr capacity of one front-end loader. Thus, the overall capacity of rolling stock is 22 Mg/hr.
-Total diesel consumption in the plants from respondents in surveys averaged to approximately 10L/Mg so this empirical figure was used in lieu of manufacturers figures in an effort to gain a more accurate assessment of consumption.

Appendix B.2 Baler Data

Single Ram Baler Data (Source: International Press and Shear)

	Investment Cost ($)	Required Power (kW)	Throughput (TPH)
180HS-100S	499,800	50	39
180HS-200S	596,400	76	63
Average	548,100	63	51

- Single ram balers are able to handle more throughput compared to dual-ram which is important considering high fibrous material fractions.
- Single ram balers are not able to effectively bale metals, thus these balers were only used for fibrous material in the model.
-A single laborer is specified in the parameter matrix as a baler operator.

Dual Ram Baler Data (Source: Harris Baler via Catawba Baler)

	Investment Cost ($)	Electricity Consumption (kWh)	Average Throughput (TPH)
Centurion-150	517,000	54	29
Centurion-200	550,662	64	31
Average	533,831	59	30

- Dual ram balers are capable of baling all material processed in all MRFs.
-A single laborer is specified in the parameter matrix as a baler operator.

Source: Harris Baler (Dual Ram), International Press and Shear (Single Ram)

		Dual-Ram	Single-Ram
Bale Width	m	1.14	1
Bale Length	m	1.63	2
Bale Height	m	0.79	1
Straps Per Bale	N/A	6	5

Baling Wire Properties

Wire Length Per Unit Mass	m/kg	13.44
Cost of Baling Wire	$/kg	2.11

- Market cost is given by mass. Using the length per mass, cost per meter may be used to apply to material densities and balers to estimate cost of baling wire per Mg of each material.

		Single-Ram	Dual-Ram
Required Wire	m	23.16	20.00
Wire Cost Per Bale	$/bale	3.63	3.13

Baled Densities

	lb/ft^3	kg/m^3
Bulk OCC	33	528
Newsprint	38	608
Whole Aluminum Cans	28	448
Steel Cans	51	817
Plastic	32	512

Appendix B.3 MRF Parameters

Labor Parameters

Labor Management Rate		.25	Nishtala, 1994
Labor Pay Rate	$/Sorter-hr	7.25	H.R.2, 2007
Driver Pay Rate	$/Driver-hr	8.25	H.R.2, 2007
Fringe Rate	% of Pay Rate	34	Office of the Independent Budget Analyst, 2009
Paid Hours in Shift	hrs/shift	9	surveys
Number of Shifts Per Workday	shifts/day	2	surveys

Electricity and Fuel Parameters

Electricity Consumed in Offices	kWh/m^2	1.607	USEIA, 2006
Electricity Consumed on floor	kWh/m^2	0.706	USEIA, 2006
Cost of Electricity	$/kWh	0.1	USEIA, 2011a
Cost of Diesel	$/L	0.84	`USEIA, 2011b
Cost of Propane	$/L	0.42	[1]USEIA, 2011c
Transportation Diesel Consumption	L/km-Mg	0.0272	NREL, 2006

[1]Weekly U.S. fuel prices were averaged between Jan 1, 2011 and Nov 7, 2011

MRF Structure Parameters

Indoor Floor Area Rate	m^2/tpd	1.136	surveys, Nishtala, 1994
Percent Office Floor Area	% of total m^2	4.00	surveys
Life of MRF Structure	yrs	30	Assumption
Construction Cost Rate	$\$/m^2$	1051.74	R.S. Means Company, 2010
Engineering Cost Factor		.316	Nishtala, 1994
Land Cost	$\$/m^2$	2.50	[1]
Land Requirement Factor		2.83	Nishtala, 1994
Days Operating Per Year	days/year	276	[2]
Annual Interest Rate	%	5.00	SWOLF

[1]Industrial land cost variability is so high between urban/rural/metro sites and region-specific that a value of $10,000/acre was chosen

[2] Interviews with representatives from Van Dyk Baler

Appendix B.4 Self-Reported MRF Surveys

MRF A

How many tons of recyclables do you process in a month?
6500 to 7000 tons inbound with a 2% residual

Do you receive any presorted material?
Very little commercial

Consumables?
7000 lbs bailing wire per month, sanitary supplies

Tipping Fees
No fees for incoming county material, large/hard plastics are sold (does this mean that other materials are not sold?)

What type of fuels are consumed on site?

-1250 gal diesel fuel per month in rolling stock
-facility uses a 1000 gal tank
-145733 kWh consumed per month

What is the square footage of the facility?

Total	80,000 ft^2
Offices	8,000 ft^2
Tipping Floor	11,500 ft^2
Bale Storage	5,000 ft^2

- Bale Dimensions: 3’x3’x6’
- Bales stacked 4 high
- Bales will remain in storage less than a week

Labor

- O&M cost per ton $12
- 88% uptime
- Downtime is typically associated with non recyclable junk
- Only backup equipment is rolling stock
- 9.5 hrs paid on a ten hour shift
- $28/ton for all staff and benefits

Pickers	30
Drivers	3
Admin	4
Maintenance	4

MRF B

How many tons of recyclables do you process in a month?
11,000tons/month inbound 10,400tons/month to remanufacturing

Do you receive any presorted material?
25% of inbound material is presorted. Not just commercial OCC, also sorted white ledger, mixed paper, plastic, metal, and tubes.

Consumables?
20 spools per month of baling wire

Tipping Fees
Varies by customers and by commodity

What type of Fuels do you consume her on site
Total monthly fuel cost for rolling stock $11,000
Total monthly electricity cost $15,000

What is the square footage of the facility?
Total 100,000sqft
4% office space
20% tipping floor
20% bale storage
Bales will be stacked 4 high
Bales will typically be shipped out within 5 days.
Approximately 8000 square feet will be reserved for mixed glass and bales

Labor
91% uptime
9 hours paid on a 9.5 hour shift

Pickers	22
Drivers	10
Admin	3
Maint	2
Mgmt	2

MRF C

How many tons of recyclables do you process in a month?
9000 tons

Do you receive any presorted material?
25% of inbound material is presorted. Not just commercial OCC, also sorted white ledger, mixed paper, plastic, metal, and tubes.

Consumables?
Baling wire (amount not given)

Tipping Fees
No tipping fees

What type of Fuels do you consume her on site
1000 gal fuel tank is refilled twice monthly
95757 kW - January
56824 kW - February

What is the square footage of the facility?
Total 60,000sqft
3% office space
13% tipping floor
15% bale storage
Bales will be stacked no more than 6 high
Bales will typically be shipped out within 5 days.
No bales will be stored outside

LABOR
Downtime is typically associated with non recyclable junk.
Only backup equipment is rolling stock

Pickers	18
Drivers	2
Admin	2
Maint	2
Mgmt	2

9 hours paid on a 9.5 hour shift
2 shifts

Appendix C Abbreviations

Table C.1 Definitions for Waste Fractions

AL	Aluminum
ALF	Aluminum – Foil
ALNR	Al - Non-recyclable
ALO	Aluminum – Other
EW	E-Waste
FCAN	Ferrous Cans
FNR	Ferrous Non-recyclable
FOTH	Ferrous Metal – Other
FWA	Food Waste, Animal
FWV	Food Waste, Vegetable
GBRN	Glass-Brown
GCLR	Glass-Clear
GGRN	Glass-Green
GMX	Mixed Glass
GNR	Glass Non-recyclable
HDP	HDPE – Pigmented Containers
HDT	HDPE – Translucent Containers
MP	Mixed Paper
MP	Mixed Plastic
MSCI	Miscellaneous Inorganic
MSCO	Miscellaneous Organic
OCC	Corrugated Cardboard
OFP	Office Paper
OMG	Magazines
ONP	Newsprint
PET	PET – Containers
PF	Plastic Film
PNR	Paper Non-recyclable
PNR	Plastic – Non-recyclable
PO1	Paper Other #1
PO1	Plastic – Other #1
PO2	Paper Other #2
PO2	Plastic – Other #2
RL	Rubber/Leather
TCM	3rd Class Mail
TXT	Textiles
WD	Wood

Table C.1 Definitions for Waste Fractions (continued)

WDO	Wood Other
YTB	Yard Trimmings, Branches
YTG	Yard Trimmings, Grass
YTL	Yard Trimmings, Leaves

Table C.2: Definitions for variables used in equations

$ADTNL\_SRTRS\_REQ_f$	sorter-hr/Mg	Number of sorters required for additional sorting of individual waste fractions from a mixed stream
$AIRBORNE\_POLLUTANT_i$	kg/Mg	Emission rate of airborne pollutant, i, per Mg of waste fraction, *f* processed by the MRF
BALE_HEIGHT	m	The height of a bale
$BALE\_MASS_f$	Mg/bale	Mass of a bale of waste fraction, *f*
BALE_WIDTH	m	The width of a bale
BALING_WIRE_COST	$/m	Cost of baling wire per unit length
BALING_WIRE_COST_RATE	$/Mg	Cost of baling wire per incoming Mg of material processed
BUILD_CONST_COST_RATE	$\$/m^2$	Construction costs associated with structure construction per unit floor area
CONST_COST_RATE	$/Mg	Cost of planning and construction of the MRF structure and land acquisition on a per Mg basis
CRF	$(yr^{-1})^*$	Capital recovery factor (A/P,*i*,*l*) where, *i*, is the discount rate and, *l*, is the economic lifetime of the equipment
DAYS_OP_ANN	days/yr	Number of days per year that the MRF operates
DRIVER_PAY_RATE	$/driver-hr	Hourly wage of each driver
DRIVER_REQ	driver-hr/Mg	Drivers required for rolling stock to process 1 Mg of waste

Table C.2 Definitions for variables used in equations. (continued)

$DSL\_AB\_CMB\_EMISS\_FACTOR_i$	kg/L	Diesel airborne emissions of pollutant, *i*, resulting from combustion of 1L of diesel fuel
$DSL\_AB\_PRECMB\_EMISS\_FACTOR_i$	kg/L	Diesel airborne emissions of pollutant, *i*, resulting from 1L diesel production (i.e. precombustion)
DSL_WB_PRECMB_EMISS_FACTOR	kg/L	Diesel waterborne emissions of pollutant, *i*, resulting from 1L diesel production (i.e. precombustion)
$ELC\_AB\_EMISS\_FACTOR_i$	kg/L	Emission rate of pollutant, *i*, resulting from, *1*, kWh of electricity production
ELC_CONS_RATE	kWh/Mg	Electricity associated with processing a Mg of recyclables
$ELC\_CONS_{f,t}$	kWh/Mg	Electricity consumption by technology, *t*, for waste fraction, *f*
$ELC\_WB\_EMISS\_FACTOR_i$	kg/kWh	Emission rate of waterborne pollutant, *i*, associated with 1 kWh of electricity production
ENG_COST_FACTOR		Fraction of construction cost associated with engineering and planning of structure
FIXOM	$/yr	Fixed operations and maintenance cost of the equipment
FRINGE_RATE		Fraction of labor wage paid again as employee overhead
FRXN		Set of all waste fractions
HRS_PER_SHIFT	hrs/shift	The number of working hours (paid and operational) in a shift
$INVCOST_t$	$	Installed cost of a technology, *t*
INV_t	$/Mg	Annual cost associated with purchase, installation, and O&M associated with processing a Mg of material for technology, *t*
LABORERS_REQf	laborers/Mg	Number of laborers required to pick one Mg per hour of waste fraction, *f*
LABORER_PAY_RATE	$/hr	Hourly wage of each laborer

Table C.2 Definitions for variables used in equations. (continued)

LAND_ACQ_COST_RATE	$/m^2	Cost of land per square meter
LAND_REQ_FACTOR		Multiple of indoor floor area to represent required land
$MAN\_SRTRS\_REQ_f$	sorters/Mg	Number of sorters required to pick one Mg per hour of waste fraction, *f*
MATERIAL_SALE_PRICE	$/Mg	Price per incoming Mg charged by the MRF to remanufacturing for sorted material
MGMT_RATE		Fraction of labor wage paid again for administrative and management overhead
MRF_CRF	$(yr^{-1})^*$	Capital recovery factor (A/P,*i*,*l*), where *i* is the global discount rate and *l* represents the economic lifetime of the facility
NUMBER_STRAPS		The number of bale ties used for one bale of material
OFFICE_ELC_RATE	kWh/m^2-day	Electricity consumption per unit floor area
PERCENT_OFFICE		Percent indoor floor area used as office space
POWER	kW	Nameplate power consumption of a piece of equipment
$PROPANE\_AB\_CMB\_$ $EMISS\_FACTOR_i$	kg/m^3	Propane airborne emissions of pollutant, *i*, resulting from the combustion of 1m^3 of propane
$PROPANE\_AB\_PRECMB\_$ $EMISS\_FACTOR_i$	kg/m^3	Propane airborne emissions of pollutant, *i*, resulting from 1 m^3 of propane production

Table C.2 Definitions for variables used in equations. (continued)

PROPANE_WB_PRECMB_ EMISS_FACTOR	kg/m^3	Propane waterborne emissions of pollutant, *i*, resulting from 1 m^3 propane production (i.e. precombustion)
SEP_EFF		Fractiona of target material recovered by a separation technology
SHIFTS_PER_DAY	shifts/day	Number of shifts per day that the MRF operates
SRTR_PAY_RATE	$/sorter-hr	Hourly wage of each sorter
SRTRS_REQ	sorter-hr/Mg	Total required number of manual laborers
$SRTRS\_REQ_f$	sorter-hr/Mg	The number of sorters required to process 1Mg of waste fraction, *f*
TECH		Set of all separation technologies
TECH_MAN_REQ	sorters	Manual laborers required to support a given separation technology
THROUGHPUT	Mg/hr	Hourly throughput capacity of a piece of equipment
TOT_FLOOR_AREA	m^2-day/Mg	Total floor area required to process one Mg if material
$TOTAL\_DSL\_CONS_f$:	L/Mg	Total diesel consumption required to process 1 Mg of waste fraction, *f*
$TOTAL\_ELC\_CONS_f$:	kWh/Mg	Total electricity consumption required to process 1 Mg of waste fraction, *f*
TOTAL_EQUIPMENT_COST	$/Mg	Total cost of investment, installation, and maintenance of equipment required to process 1 Mg of recyclables

Table C.2 Definitions for variables used in equations. (continued)

TOTAL_LABOR_COST	\$/Mg	Total labor cost associated with the processing of 1Mg of recyclables
$TOTAL\_PROPANE\_CONS_f$:	m^3/Mg	Total propane consumption required to process 1 Mg of waste fraction, *f*
$UTIL_t$		Binary utilization of a particular piece of equipment, *t* (0/1)
UTIL_FRXN		Fractional utilization of any piece of separation equipment
WAREHOUSE_ELC_RATE:	kWh/m^2-day	Electricity consumption per unit floor area.
$WATERBORNE\_POLLUTANT_{f,i}$	kg/Mg	Emission rate of waterborne pollutant, *i*, per Mg of waste fraction, *f*, processed by the MRF

* Units implicit to the calculation despite no formal notation are expressed in parentheses.

Appendix D   Process Flow Diagrams of Visited MRFs

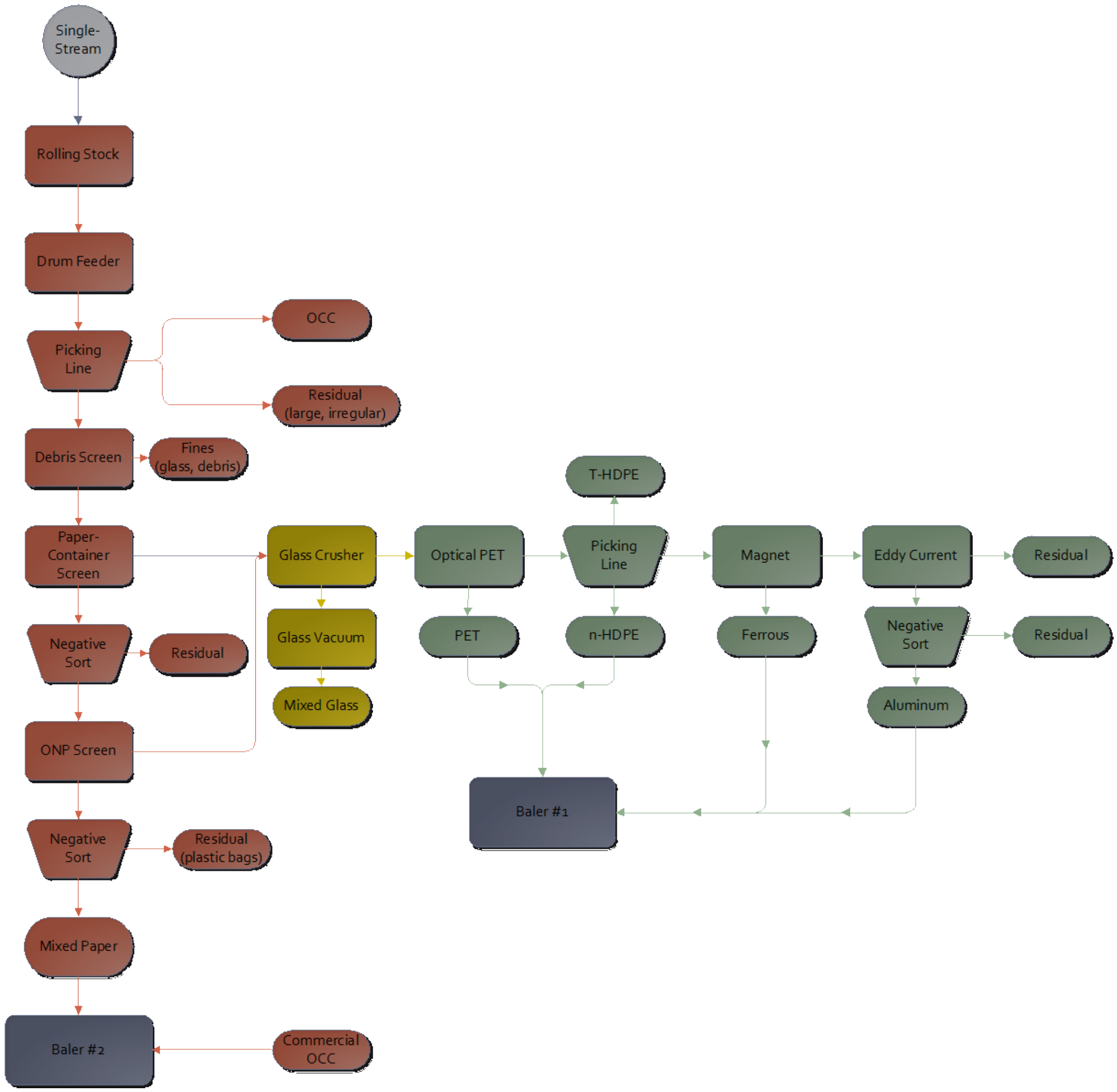

Figure D.1: Single-stream MRF A

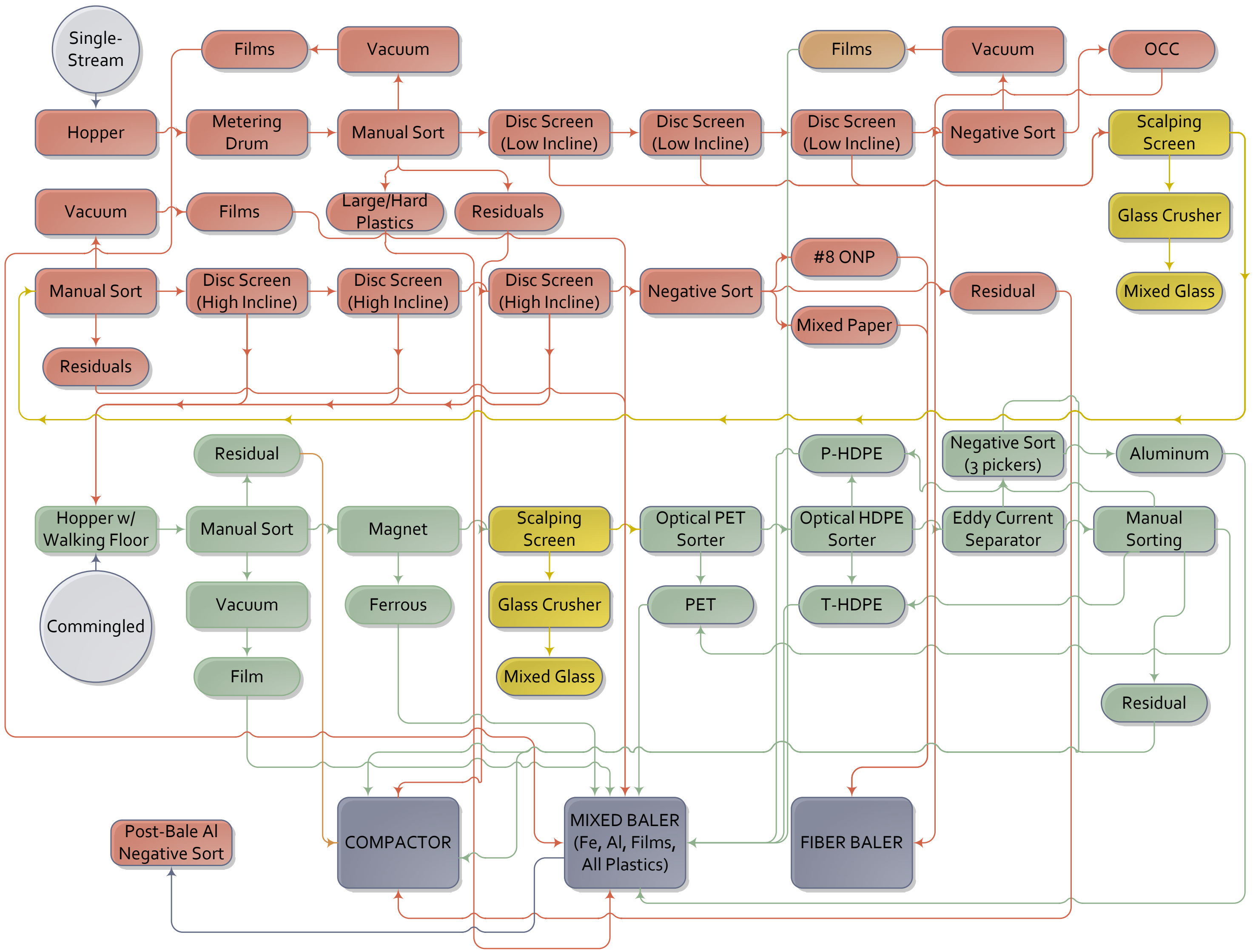

Figure D.2: Single/Dual Stream MRF

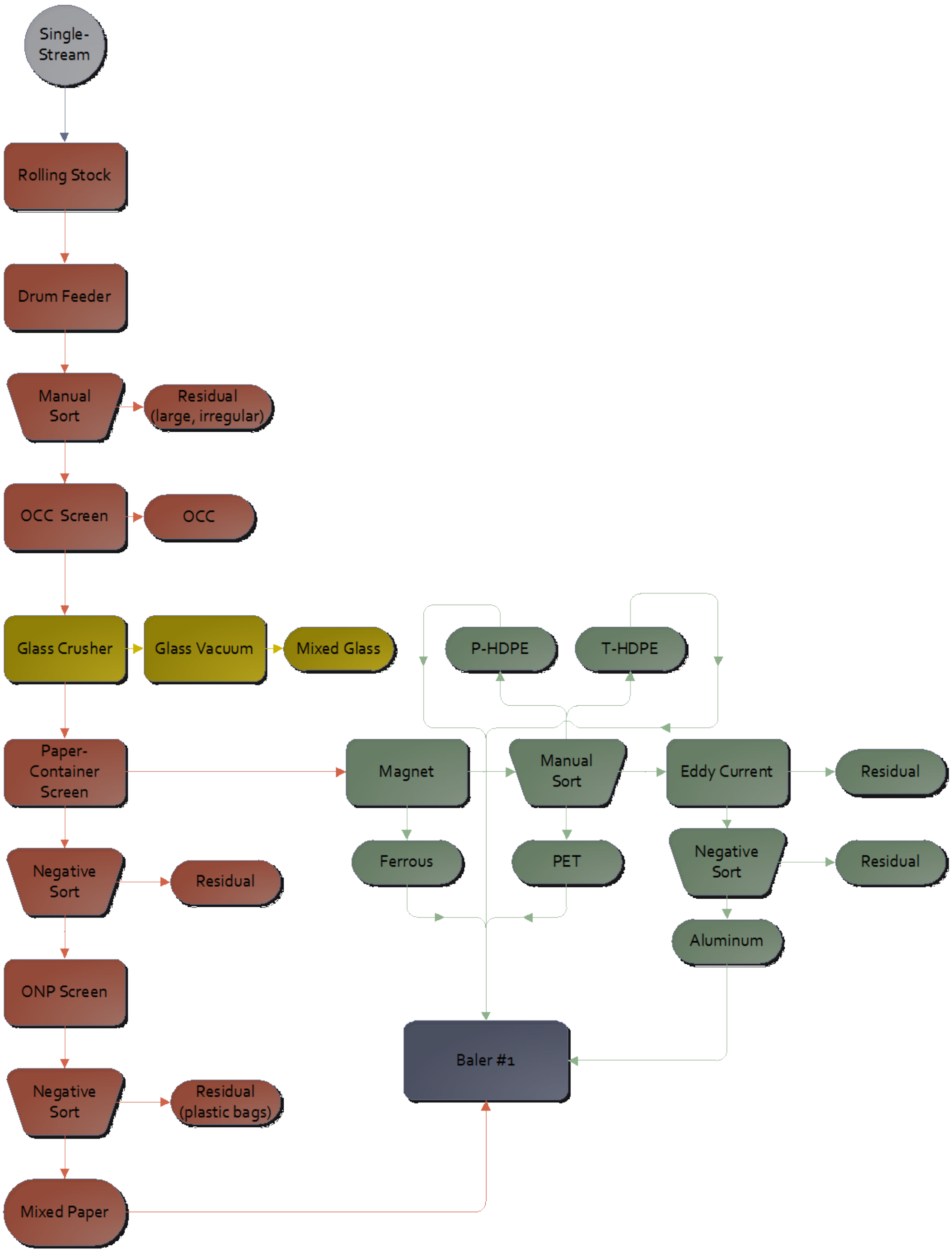

Figure D.3:Single-stream MRF B

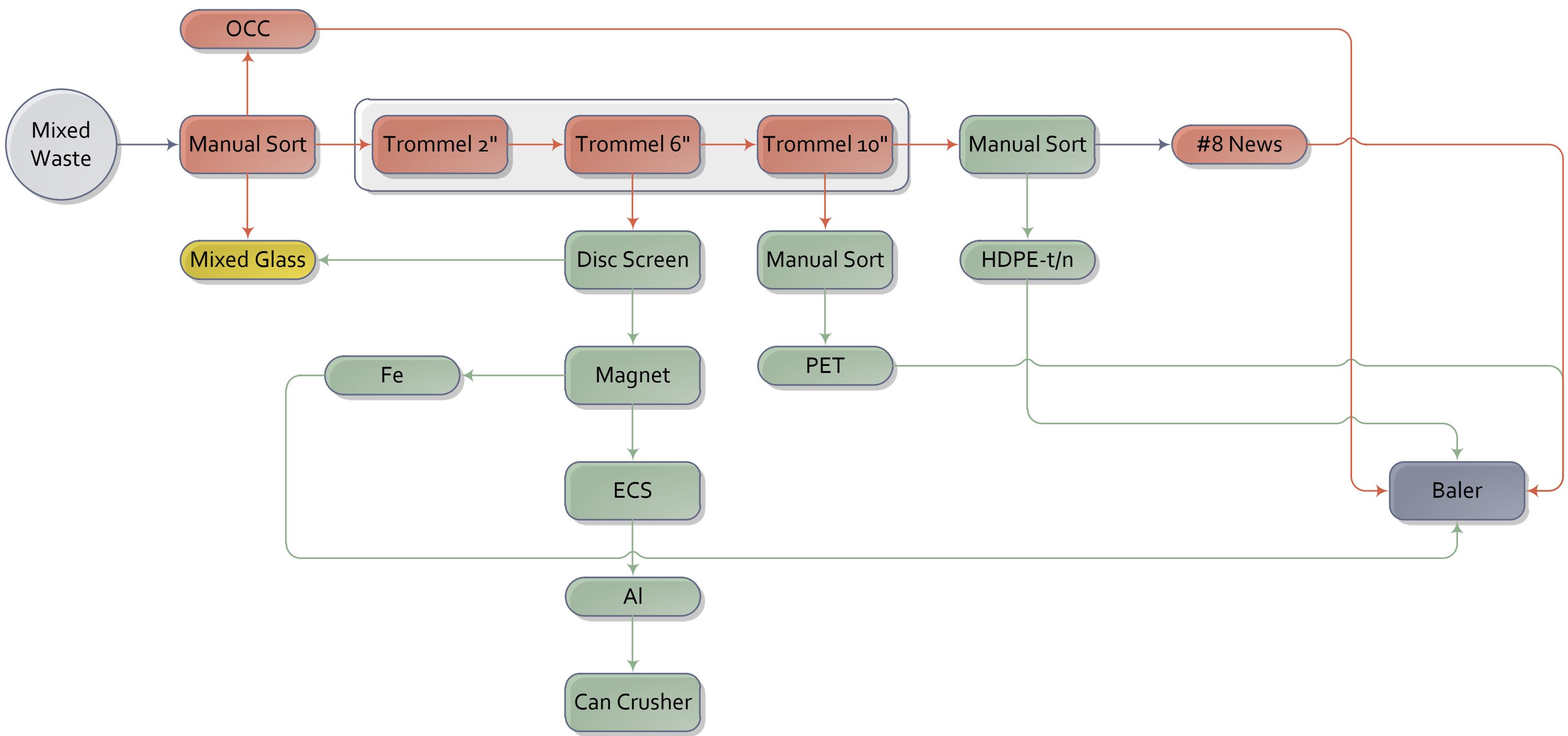

Figure D.4 Mixed Waste MRF

Appendix E Model Results

Appendix E.1 Cost Coefficients

Table E.1: Total cost per Mg of material as offset by sale of recovered material.

	Single Stream	Dual Stream	Mixed Waste	Presorted Recyclables
Yard Trimmings, Leaves	N/A	N/A	$9.98	N/A
Yard Trimmings, Grass	N/A	N/A	$9.98	N/A
Yard Trimmings, Branches	N/A	N/A	$9.98	N/A
Food Waste, Meat	N/A	N/A	$9.98	N/A
Food Waste, Vegetable	N/A	N/A	$9.98	N/A
Wood	N/A	N/A	$9.98	N/A
Wood Other	N/A	N/A	$9.98	N/A
Textiles	N/A	N/A	$9.98	N/A
Rubber/Leather	N/A	N/A	$9.98	N/A
Newsprint	-$60.68	-$63.85	-$14.18	-$73.98
Corr. Cardboard	-$44.21	-$56.07	-$15.54	-$103.28
Office Paper	-$60.68	-$63.85	-$14.18	-$73.98
Magazines	-$58.54	-$61.71	-$14.18	-$73.98
3rd Class Mail	$16.08	$16.19	$14.52	-$73.98
Paper Other #1	$9.98	$9.98	$9.98	$8.01
Paper Other # 2	$9.98	$9.98	$9.98	$8.00
Mixed Paper	N/A	N/A	$0.00	N/A
Paper - Non-recyclable	N/A	N/A	$9.98	N/A
Glass - Brown	$0.61	$0.61	$10.21	-$16.13
Glass - Green	$18.67	$18.67	$19.15	$2.80
Glass -Clear	-$7.00	-$7.00	$6.45	-$23.84
Mixed Glass	N/A	N/A	$0.00	N/A
Glass - Non-recyclable	N/A	N/A	$9.98	N/A
Ferrous Cans	-$118.56	-$118.56	-$49.08	-$135.03
Ferrous Metal - Other	-$118.56	-$118.56	-$49.09	-$135.04
Ferrous - Non-recyclable	N/A	N/A	$9.98	N/A
Aluminum	-$1,414.98	-$1,414.98	-$707.68	-$1,472.61
Aluminum - Foil	-$1,414.98	-$1,414.98	-$707.68	-$1,472.61
Aluminum - Other	-$1,414.98	-$1,414.98	-$707.68	-$1,472.61
Al - Non-recyclable	N/A	N/A	$9.98	N/A

Table E.1: Total cost per Mg of material as offset by sale of recovered material. (continued)

	Single Stream	Dual Stream	Mixed Waste	Presorted Recyclables
HDPE - Translucent Containers	$21.53	$21.53	$18.49	-$495.06
HDPE - Pigmented Containers	-$468.47	-$468.47	-$216.51	-$324.87
PET - Containers	-$302.82	-$302.82	-$137.56	-$307.15
Plastic - Other #1	-$278.02	-$278.02	-$278.02	$9.15
Plastic - Other #2	$9.98	$9.98	$9.98	$9.15
Mixed Plastic	$0.00	$0.00	$0.00	$0.00
Plastic Film	$9.98	$9.98	$9.98	$9.12
Plastic - Non-recylcable	$0.00	$0.00	$9.98	$0.00
Misc. Organic	$0.00	$0.00	$9.98	$0.00
Misc. Inorganic	$0.00	$0.00	$9.98	$0.00
E-waste	$0.00	$0.00	$0.00	$0.00

Appendix E.3 Airborne Emissions Coefficients

	CO2-Fossil	CO2-Biomass	CO2-Storage	Methane	Nitrous Oxide	PM-10	Total Particulates	Nitrogen Oxides	Hydrocarbons (non-CH4)	Sulfur Oxides	Carbon Monoxide	Ammonia	Lead
Yard Trimmings, Leaves	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Grass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Branches	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Meat	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Vegetable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood Other	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Textiles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rubber/Leather	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Newsprint	1.07E+01	3.94E+00	4.79E-06	8.96E-02	3.05E-02	6.06E-03	5.43E-03	0.00E+00	5.36E-02	2.02E-02	1.64E-01	1.30E-01	1.96E-04
Corr. Cardboard	1.06E+01	3.93E+00	4.68E-06	8.95E-02	3.05E-02	6.01E-03	5.39E-03	0.00E+00	5.34E-02	2.02E-02	1.64E-01	1.30E-01	1.96E-04
Office Paper	1.07E+01	3.94E+00	4.79E-06	8.96E-02	3.05E-02	6.06E-03	5.43E-03	0.00E+00	5.36E-02	2.02E-02	1.64E-01	1.30E-01	1.96E-04
Magazines	1.07E+01	3.94E+00	4.79E-06	8.96E-02	3.05E-02	6.06E-03	5.43E-03	0.00E+00	5.36E-02	2.02E-02	1.64E-01	1.30E-01	1.96E-04
3rd Class Mail	1.07E+01	3.94E+00	4.79E-06	8.96E-02	3.05E-02	6.06E-03	5.43E-03	0.00E+00	5.36E-02	2.02E-02	1.64E-01	1.30E-01	1.96E-04
Paper Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper Other # 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Paper	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Brown	2.29E+01	3.95E+00	2.54E-05	1.15E-01	3.25E-02	1.60E-02	1.26E-02	0.00E+00	8.30E-02	2.15E-02	2.53E-01	1.45E-01	2.10E-04
Glass - Green	2.29E+01	3.95E+00	2.54E-05	1.15E-01	3.25E-02	1.60E-02	1.26E-02	0.00E+00	8.30E-02	2.15E-02	2.53E-01	1.45E-01	2.10E-04
Glass -Clear	2.29E+01	3.95E+00	2.54E-05	1.15E-01	3.25E-02	1.60E-02	1.26E-02	0.00E+00	8.30E-02	2.15E-02	2.53E-01	1.45E-01	2.10E-04
Mixed Glass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ferrous Cans	1.29E+01	3.94E+00	8.56E-06	9.42E-02	3.09E-02	7.87E-03	6.74E-03	0.00E+00	5.89E-02	2.04E-02	1.80E-01	1.33E-01	1.99E-04
Ferrous Metal - Other	1.29E+01	3.94E+00	8.56E-06	9.42E-02	3.09E-02	7.87E-03	6.74E-03	0.00E+00	5.89E-02	2.04E-02	1.80E-01	1.33E-01	1.99E-04
Ferrous - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aluminum	1.18E+01	3.94E+00	6.76E-06	9.20E-02	3.07E-02	7.01E-03	6.11E-03	0.00E+00	5.64E-02	2.03E-02	1.73E-01	1.32E-01	1.98E-04
Aluminum - Foil	1.18E+01	3.94E+00	6.76E-06	9.20E-02	3.07E-02	7.01E-03	6.11E-03	0.00E+00	5.64E-02	2.03E-02	1.73E-01	1.32E-01	1.98E-04
Aluminum - Other	1.18E+01	3.94E+00	6.76E-06	9.20E-02	3.07E-02	7.01E-03	6.11E-03	0.00E+00	5.64E-02	2.03E-02	1.73E-01	1.32E-01	1.98E-04
Al - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HDPE - Translucent Containers	1.46E+01	3.94E+00	1.14E-05	9.77E-02	3.12E-02	9.26E-03	7.75E-03	0.00E+00	6.30E-02	2.06E-02	1.93E-01	1.35E-01	2.01E-04
HDPE - Pigmented Containers	1.46E+01	3.94E+00	1.14E-05	9.77E-02	3.12E-02	9.26E-03	7.75E-03	0.00E+00	6.30E-02	2.06E-02	1.93E-01	1.35E-01	2.01E-04
PET - Containers	1.23E+01	3.94E+00	7.55E-06	9.30E-02	3.08E-02	7.39E-03	6.39E-03	0.00E+00	5.75E-02	2.04E-02	1.76E-01	1.32E-01	1.98E-04
Plastic - Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic - Other #2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Plastic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic Film	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Plastic - Non-recylcable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Organic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Inorganic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E-waste	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Hydrochloric Acid	Mercury	Benzene	Chloroform	Carbon Tetrachloride	Ethylene Dichloride	Methylene Chloride	Trichloroethylene	Tetrachloroethene	Vinyl Chloride	Toluene	Xylenes	Ethylbenzene	Dioxins/ Furans
Yard Trimmings, Leaves	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Grass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Branches	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Meat	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Vegetable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood Other	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Textiles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rubber/Leather	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Newsprint	3.05E-04	5.95E-04	1.52E-06	9.35E-05	3.41E-08	7.31E-09	8.23E-08	4.31E-07	8.05E-09	1.75E-08	0.00E+00	8.34E-05	4.86E-05	6.48E-06
Corr. Cardboard	3.05E-04	5.89E-04	1.48E-06	9.24E-05	3.33E-08	7.29E-09	8.05E-08	4.28E-07	7.87E-09	1.71E-08	0.00E+00	8.29E-05	4.83E-05	6.44E-06
Office Paper	3.05E-04	5.95E-04	1.52E-06	9.35E-05	3.41E-08	7.31E-09	8.23E-08	4.31E-07	8.05E-09	1.75E-08	0.00E+00	8.34E-05	4.86E-05	6.48E-06
Magazines	3.05E-04	5.95E-04	1.52E-06	9.35E-05	3.41E-08	7.31E-09	8.23E-08	4.31E-07	8.05E-09	1.75E-08	0.00E+00	8.34E-05	4.86E-05	6.48E-06
3rd Class Mail	3.05E-04	5.95E-04	1.52E-06	9.35E-05	3.41E-08	7.31E-09	8.23E-08	4.31E-07	8.05E-09	1.75E-08	0.00E+00	8.34E-05	4.86E-05	6.48E-06
Paper Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper Other # 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Paper	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Brown	3.11E-04	1.86E-03	7.94E-06	3.22E-04	1.81E-07	1.11E-08	4.37E-07	1.09E-06	4.27E-08	9.30E-08	0.00E+00	1.80E-04	1.05E-04	1.41E-05
Glass - Green	3.11E-04	1.86E-03	7.94E-06	3.22E-04	1.81E-07	1.11E-08	4.37E-07	1.09E-06	4.27E-08	9.30E-08	0.00E+00	1.80E-04	1.05E-04	1.41E-05
Glass -Clear	3.11E-04	1.86E-03	7.94E-06	3.22E-04	1.81E-07	1.11E-08	4.37E-07	1.09E-06	4.27E-08	9.30E-08	0.00E+00	1.80E-04	1.05E-04	1.41E-05
Mixed Glass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ferrous Cans	3.06E-04	8.25E-04	2.69E-06	1.35E-04	6.08E-08	8.00E-09	1.47E-07	5.52E-07	1.44E-08	3.13E-08	0.00E+00	1.01E-04	5.88E-05	7.86E-06
Ferrous Metal - Other	3.06E-04	8.25E-04	2.69E-06	1.35E-04	6.08E-08	8.00E-09	1.47E-07	5.52E-07	1.44E-08	3.13E-08	0.00E+00	1.01E-04	5.88E-05	7.86E-06
Ferrous - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aluminum	3.05E-04	7.16E-04	2.13E-06	1.15E-04	4.81E-08	7.67E-09	1.16E-07	4.94E-07	1.14E-08	2.47E-08	0.00E+00	9.26E-05	5.40E-05	7.20E-06
Aluminum - Foil	3.05E-04	7.16E-04	2.13E-06	1.15E-04	4.81E-08	7.67E-09	1.16E-07	4.94E-07	1.14E-08	2.47E-08	0.00E+00	9.26E-05	5.40E-05	7.20E-06
Aluminum - Other	3.05E-04	7.16E-04	2.13E-06	1.15E-04	4.81E-08	7.67E-09	1.16E-07	4.94E-07	1.14E-08	2.47E-08	0.00E+00	9.26E-05	5.40E-05	7.20E-06
Al - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HDPE - Translucent Containers	3.07E-04	1.00E-03	3.58E-06	1.67E-04	8.13E-08	8.53E-09	1.96E-07	6.43E-07	1.92E-08	4.18E-08	0.00E+00	1.14E-04	6.66E-05	8.92E-06
HDPE - Pigmented Containers	3.07E-04	1.00E-03	3.58E-06	1.67E-04	8.13E-08	8.53E-09	1.96E-07	6.43E-07	1.92E-08	4.18E-08	0.00E+00	1.14E-04	6.66E-05	8.92E-06
PET - Containers	3.05E-04	7.64E-04	2.38E-06	1.24E-04	5.37E-08	7.82E-09	1.30E-07	5.19E-07	1.27E-08	2.76E-08	0.00E+00	9.63E-05	5.61E-05	7.49E-06
Plastic - Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic - Other #2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Plastic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic Film	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Plastic - Non-recylcable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Organic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Inorganic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E-waste	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table E.1b: Airborne Emissions resulting from material recovery using a single stream MRF (kg/Mg). Part II

	CO2-Fossil	CO2-Biomass	CO2-Storage	Methane	Nitrous Oxide	PM-10	Total Particulates	Nitrogen Oxides	Hydrocarbons (non-CH4)	Sulfur Oxides	Carbon Monoxide	Ammonia	Lead
Yard Trimmings, Leaves	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Grass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Branches	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Meat	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Vegetable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood Other	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Textiles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rubber/Leather	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Newsprint	1.07E+01	3.94E+00	4.79E-06	8.96E-02	3.05E-02	6.06E-03	5.43E-03	0.00E+00	5.36E-02	2.02E-02	1.64E-01	1.30E-01	1.96E-04
Corr. Cardboard	1.06E+01	3.93E+00	4.68E-06	8.95E-02	3.05E-02	6.01E-03	5.39E-03	0.00E+00	5.34E-02	2.02E-02	1.64E-01	1.30E-01	1.96E-04
Office Paper	1.07E+01	3.94E+00	4.79E-06	8.96E-02	3.05E-02	6.06E-03	5.43E-03	0.00E+00	5.36E-02	2.02E-02	1.64E-01	1.30E-01	1.96E-04
Magazines	1.07E+01	3.94E+00	4.79E-06	8.96E-02	3.05E-02	6.06E-03	5.43E-03	0.00E+00	5.36E-02	2.02E-02	1.64E-01	1.30E-01	1.96E-04
3rd Class Mail	1.07E+01	3.94E+00	4.79E-06	8.96E-02	3.05E-02	6.06E-03	5.43E-03	0.00E+00	5.36E-02	2.02E-02	1.64E-01	1.30E-01	1.96E-04
Paper Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper Other # 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Paper	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Brown	2.29E+01	3.95E+00	2.54E-05	1.15E-01	3.25E-02	1.60E-02	1.26E-02	0.00E+00	8.30E-02	2.15E-02	2.53E-01	1.45E-01	2.10E-04
Glass - Green	2.29E+01	3.95E+00	2.54E-05	1.15E-01	3.25E-02	1.60E-02	1.26E-02	0.00E+00	8.30E-02	2.15E-02	2.53E-01	1.45E-01	2.10E-04
Glass -Clear	2.29E+01	3.95E+00	2.54E-05	1.15E-01	3.25E-02	1.60E-02	1.26E-02	0.00E+00	8.30E-02	2.15E-02	2.53E-01	1.45E-01	2.10E-04
Mixed Glass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ferrous Cans	1.29E+01	3.94E+00	8.56E-06	9.42E-02	3.09E-02	7.87E-03	6.74E-03	0.00E+00	5.89E-02	2.04E-02	1.80E-01	1.33E-01	1.99E-04
Ferrous Metal - Other	1.29E+01	3.94E+00	8.56E-06	9.42E-02	3.09E-02	7.87E-03	6.74E-03	0.00E+00	5.89E-02	2.04E-02	1.80E-01	1.33E-01	1.99E-04
Ferrous - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aluminum	1.18E+01	3.94E+00	6.76E-06	9.20E-02	3.07E-02	7.01E-03	6.11E-03	0.00E+00	5.64E-02	2.03E-02	1.73E-01	1.32E-01	1.98E-04
Aluminum - Foil	1.18E+01	3.94E+00	6.76E-06	9.20E-02	3.07E-02	7.01E-03	6.11E-03	0.00E+00	5.64E-02	2.03E-02	1.73E-01	1.32E-01	1.98E-04
Aluminum - Other	1.18E+01	3.94E+00	6.76E-06	9.20E-02	3.07E-02	7.01E-03	6.11E-03	0.00E+00	5.64E-02	2.03E-02	1.73E-01	1.32E-01	1.98E-04
Al - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HDPE - Translucent Containers	1.46E+01	3.94E+00	1.14E-05	9.77E-02	3.12E-02	9.26E-03	7.75E-03	0.00E+00	6.30E-02	2.06E-02	1.93E-01	1.35E-01	2.01E-04
HDPE - Pigmented Containers	1.46E+01	3.94E+00	1.14E-05	9.77E-02	3.12E-02	9.26E-03	7.75E-03	0.00E+00	6.30E-02	2.06E-02	1.93E-01	1.35E-01	2.01E-04
PET - Containers	1.23E+01	3.94E+00	7.55E-06	9.30E-02	3.08E-02	7.39E-03	6.39E-03	0.00E+00	5.75E-02	2.04E-02	1.76E-01	1.32E-01	1.98E-04
Plastic - Other #1	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Plastic - Other #2	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Mixed Plastic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic Film	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Plastic - Non-recylcable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Organic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Inorganic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E-waste	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table E.2a: Airborne Emissions resulting from material recovery using a dual stream MRF (kg/Mg). Part I

	Hydrochloric Acid	Mercury	Benzene	Chloroform	Carbon Tetrachloride	Ethylene Dichloride	Methylene Chloride	Trichloroethylene	Tetrachloroethene	Vinyl Chloride	Toluene	Xylenes	Ethylbenzene	Dioxins/ Furans
Yard Trimmings, Leaves	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Grass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Branches	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Meat	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Vegetable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood Other	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Textiles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rubber/Leather	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Newsprint	3.05E-04	5.95E-04	1.52E-06	9.35E-05	3.41E-08	7.31E-09	8.23E-08	4.31E-07	8.05E-09	1.75E-08	0.00E+00	8.34E-05	4.86E-05	6.48E-06
Corr. Cardboard	3.05E-04	5.89E-04	1.48E-06	9.24E-05	3.33E-08	7.29E-09	8.05E-08	4.28E-07	7.87E-09	1.71E-08	0.00E+00	8.29E-05	4.83E-05	6.44E-06
Office Paper	3.05E-04	5.95E-04	1.52E-06	9.35E-05	3.41E-08	7.31E-09	8.23E-08	4.31E-07	8.05E-09	1.75E-08	0.00E+00	8.34E-05	4.86E-05	6.48E-06
Magazines	3.05E-04	5.95E-04	1.52E-06	9.35E-05	3.41E-08	7.31E-09	8.23E-08	4.31E-07	8.05E-09	1.75E-08	0.00E+00	8.34E-05	4.86E-05	6.48E-06
3rd Class Mail	3.05E-04	5.95E-04	1.52E-06	9.35E-05	3.41E-08	7.31E-09	8.23E-08	4.31E-07	8.05E-09	1.75E-08	0.00E+00	8.34E-05	4.86E-05	6.48E-06
Paper Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper Other # 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Paper	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Brown	3.11E-04	1.86E-03	7.94E-06	3.22E-04	1.81E-07	1.11E-08	4.37E-07	1.09E-06	4.27E-08	9.30E-08	0.00E+00	1.80E-04	1.05E-04	1.41E-05
Glass - Green	3.11E-04	1.86E-03	7.94E-06	3.22E-04	1.81E-07	1.11E-08	4.37E-07	1.09E-06	4.27E-08	9.30E-08	0.00E+00	1.80E-04	1.05E-04	1.41E-05
Glass -Clear	3.11E-04	1.86E-03	7.94E-06	3.22E-04	1.81E-07	1.11E-08	4.37E-07	1.09E-06	4.27E-08	9.30E-08	0.00E+00	1.80E-04	1.05E-04	1.41E-05
Mixed Glass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ferrous Cans	3.06E-04	8.25E-04	2.69E-06	1.35E-04	6.08E-08	8.00E-09	1.47E-07	5.52E-07	1.44E-08	3.13E-08	0.00E+00	1.01E-04	5.88E-05	7.86E-06
Ferrous Metal - Other	3.06E-04	8.25E-04	2.69E-06	1.35E-04	6.08E-08	8.00E-09	1.47E-07	5.52E-07	1.44E-08	3.13E-08	0.00E+00	1.01E-04	5.88E-05	7.86E-06
Ferrous - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aluminum	3.05E-04	7.16E-04	2.13E-06	1.15E-04	4.81E-08	7.67E-09	1.16E-07	4.94E-07	1.14E-08	2.47E-08	0.00E+00	9.26E-05	5.40E-05	7.20E-06
Aluminum - Foil	3.05E-04	7.16E-04	2.13E-06	1.15E-04	4.81E-08	7.67E-09	1.16E-07	4.94E-07	1.14E-08	2.47E-08	0.00E+00	9.26E-05	5.40E-05	7.20E-06
Aluminum - Other	3.05E-04	7.16E-04	2.13E-06	1.15E-04	4.81E-08	7.67E-09	1.16E-07	4.94E-07	1.14E-08	2.47E-08	0.00E+00	9.26E-05	5.40E-05	7.20E-06
Al - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HDPE - Translucent Containers	3.07E-04	1.00E-03	3.58E-06	1.67E-04	8.13E-08	8.53E-09	1.96E-07	6.43E-07	1.92E-08	4.18E-08	0.00E+00	1.14E-04	6.66E-05	8.92E-06
HDPE - Pigmented Containers	3.07E-04	1.00E-03	3.58E-06	1.67E-04	8.13E-08	8.53E-09	1.96E-07	6.43E-07	1.92E-08	4.18E-08	0.00E+00	1.14E-04	6.66E-05	8.92E-06
PET - Containers	3.05E-04	7.64E-04	2.38E-06	1.24E-04	5.37E-08	7.82E-09	1.30E-07	5.19E-07	1.27E-08	2.76E-08	0.00E+00	9.63E-05	5.61E-05	7.49E-06
Plastic - Other #1	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Plastic - Other #2	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Mixed Plastic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic Film	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Plastic - Non-recylcable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Organic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Inorganic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E-waste	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table E.2b: Airborne Emissions resulting from material recovery using a dual stream MRF (kg/Mg). Part II

	CO2-Fossil	CO2-Biomass	CO2-Storage	Methane	Nitrous Oxide	PM-10	Total Particulates	Nitrogen Oxides	Hydrocarbons (non-CH4)	Sulfur Oxides	Carbon Monoxide	Ammonia	Lead
Yard Trimmings, Leaves	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Yard Trimmings, Grass	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Yard Trimmings, Branches	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Food Waste, Meat	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Food Waste, Vegetable	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Wood	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Wood Other	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Textiles	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Rubber/Leather	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Newsprint	1.07E+01	3.94E+00	4.79E-06	8.96E-02	3.05E-02	6.06E-03	5.43E-03	0.00E+00	5.36E-02	2.02E-02	1.64E-01	1.30E-01	1.96E-04
Corr. Cardboard	1.06E+01	3.93E+00	4.68E-06	8.95E-02	3.05E-02	6.01E-03	5.39E-03	0.00E+00	5.34E-02	2.02E-02	1.64E-01	1.30E-01	1.96E-04
Office Paper	1.07E+01	3.94E+00	4.79E-06	8.96E-02	3.05E-02	6.06E-03	5.43E-03	0.00E+00	5.36E-02	2.02E-02	1.64E-01	1.30E-01	1.96E-04
Magazines	1.07E+01	3.94E+00	4.79E-06	8.96E-02	3.05E-02	6.06E-03	5.43E-03	0.00E+00	5.36E-02	2.02E-02	1.64E-01	1.30E-01	1.96E-04
3rd Class Mail	1.07E+01	3.94E+00	4.79E-06	8.96E-02	3.05E-02	6.06E-03	5.43E-03	0.00E+00	5.36E-02	2.02E-02	1.64E-01	1.30E-01	1.96E-04
Paper Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper Other # 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Paper	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper - Non-recyclable	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Glass - Brown	2.29E+01	3.95E+00	2.54E-05	1.15E-01	3.25E-02	1.60E-02	1.26E-02	0.00E+00	8.30E-02	2.15E-02	2.53E-01	1.45E-01	2.10E-04
Glass - Green	2.29E+01	3.95E+00	2.54E-05	1.15E-01	3.25E-02	1.60E-02	1.26E-02	0.00E+00	8.30E-02	2.15E-02	2.53E-01	1.45E-01	2.10E-04
Glass -Clear	2.29E+01	3.95E+00	2.54E-05	1.15E-01	3.25E-02	1.60E-02	1.26E-02	0.00E+00	8.30E-02	2.15E-02	2.53E-01	1.45E-01	2.10E-04
Mixed Glass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Non-recyclable	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Ferrous Cans	1.29E+01	3.94E+00	8.56E-06	9.42E-02	3.09E-02	7.87E-03	6.74E-03	0.00E+00	5.89E-02	2.04E-02	1.80E-01	1.33E-01	1.99E-04
Ferrous Metal - Other	1.29E+01	3.94E+00	8.56E-06	9.42E-02	3.09E-02	7.87E-03	6.74E-03	0.00E+00	5.89E-02	2.04E-02	1.80E-01	1.33E-01	1.99E-04
Ferrous - Non-recyclable	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Aluminum	1.18E+01	3.94E+00	6.76E-06	9.20E-02	3.07E-02	7.01E-03	6.11E-03	0.00E+00	5.64E-02	2.03E-02	1.73E-01	1.32E-01	1.98E-04
Aluminum - Foil	1.18E+01	3.94E+00	6.76E-06	9.20E-02	3.07E-02	7.01E-03	6.11E-03	0.00E+00	5.64E-02	2.03E-02	1.73E-01	1.32E-01	1.98E-04
Aluminum - Other	1.18E+01	3.94E+00	6.76E-06	9.20E-02	3.07E-02	7.01E-03	6.11E-03	0.00E+00	5.64E-02	2.03E-02	1.73E-01	1.32E-01	1.98E-04
Al - Non-recyclable	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
HDPE - Translucent Containers	1.46E+01	3.94E+00	1.14E-05	9.77E-02	3.12E-02	9.26E-03	7.75E-03	0.00E+00	6.30E-02	2.06E-02	1.93E-01	1.35E-01	2.01E-04
HDPE - Pigmented Containers	1.46E+01	3.94E+00	1.14E-05	9.77E-02	3.12E-02	9.26E-03	7.75E-03	0.00E+00	6.30E-02	2.06E-02	1.93E-01	1.35E-01	2.01E-04
PET - Containers	1.23E+01	3.94E+00	7.55E-06	9.30E-02	3.08E-02	7.39E-03	6.39E-03	0.00E+00	5.75E-02	2.04E-02	1.76E-01	1.32E-01	1.98E-04
Plastic - Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic - Other #2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Plastic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic Film	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Plastic - Non-recylcable	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Misc. Organic	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
Misc. Inorganic	8.31E+00	3.93E+00	8.51E-07	8.48E-02	3.02E-02	4.16E-03	4.05E-03	0.00E+00	4.80E-02	2.00E-02	1.47E-01	1.27E-01	1.94E-04
E-waste	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table E.3a Airborne Emissions resulting from material recovery using a mixed waste MRF (kg/Mg). Part I

	Hydrochloric Acid	Mercury	Benzene	Chloroform	Carbon Tetrachloride	Ethylene Dichloride	Methylene Chloride	Trichloroethylene	Tetrachloroethene	Vinyl Chloride	Toluene	Xylenes	Ethylbenzene	Dioxins/ Furans
Yard Trimmings, Leaves	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Yard Trimmings, Grass	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Yard Trimmings, Branches	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Food Waste, Meat	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Food Waste, Vegetable	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Wood	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Wood Other	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Textiles	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Rubber/Leather	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Newsprint	3.05E-04	5.95E-04	1.52E-06	9.35E-05	3.41E-08	7.31E-09	8.23E-08	4.31E-07	8.05E-09	1.75E-08	0.00E+00	8.34E-05	4.86E-05	6.48E-06
Corr. Cardboard	3.05E-04	5.89E-04	1.48E-06	9.24E-05	3.33E-08	7.29E-09	8.05E-08	4.28E-07	7.87E-09	1.71E-08	0.00E+00	8.29E-05	4.83E-05	6.44E-06
Office Paper	3.05E-04	5.95E-04	1.52E-06	9.35E-05	3.41E-08	7.31E-09	8.23E-08	4.31E-07	8.05E-09	1.75E-08	0.00E+00	8.34E-05	4.86E-05	6.48E-06
Magazines	3.05E-04	5.95E-04	1.52E-06	9.35E-05	3.41E-08	7.31E-09	8.23E-08	4.31E-07	8.05E-09	1.75E-08	0.00E+00	8.34E-05	4.86E-05	6.48E-06
3rd Class Mail	3.05E-04	5.95E-04	1.52E-06	9.35E-05	3.41E-08	7.31E-09	8.23E-08	4.31E-07	8.05E-09	1.75E-08	0.00E+00	8.34E-05	4.86E-05	6.48E-06
Paper Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper Other # 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Paper	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper - Non-recyclable	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Glass - Brown	3.11E-04	1.86E-03	7.94E-06	3.22E-04	1.81E-07	1.11E-08	4.37E-07	1.09E-06	4.27E-08	9.30E-08	0.00E+00	1.80E-04	1.05E-04	1.41E-05
Glass - Green	3.11E-04	1.86E-03	7.94E-06	3.22E-04	1.81E-07	1.11E-08	4.37E-07	1.09E-06	4.27E-08	9.30E-08	0.00E+00	1.80E-04	1.05E-04	1.41E-05
Glass -Clear	3.11E-04	1.86E-03	7.94E-06	3.22E-04	1.81E-07	1.11E-08	4.37E-07	1.09E-06	4.27E-08	9.30E-08	0.00E+00	1.80E-04	1.05E-04	1.41E-05
Mixed Glass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Non-recyclable	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Ferrous Cans	3.06E-04	8.25E-04	2.69E-06	1.35E-04	6.08E-08	8.00E-09	1.47E-07	5.52E-07	1.44E-08	3.13E-08	0.00E+00	1.01E-04	5.88E-05	7.86E-06
Ferrous Metal - Other	3.06E-04	8.25E-04	2.69E-06	1.35E-04	6.08E-08	8.00E-09	1.47E-07	5.52E-07	1.44E-08	3.13E-08	0.00E+00	1.01E-04	5.88E-05	7.86E-06
Ferrous - Non-recyclable	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Aluminum	3.05E-04	7.16E-04	2.13E-06	1.15E-04	4.81E-08	7.67E-09	1.16E-07	4.94E-07	1.14E-08	2.47E-08	0.00E+00	9.26E-05	5.40E-05	7.20E-06
Aluminum - Foil	3.05E-04	7.16E-04	2.13E-06	1.15E-04	4.81E-08	7.67E-09	1.16E-07	4.94E-07	1.14E-08	2.47E-08	0.00E+00	9.26E-05	5.40E-05	7.20E-06
Aluminum - Other	3.05E-04	7.16E-04	2.13E-06	1.15E-04	4.81E-08	7.67E-09	1.16E-07	4.94E-07	1.14E-08	2.47E-08	0.00E+00	9.26E-05	5.40E-05	7.20E-06
Al - Non-recyclable	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
HDPE - Translucent Containers	3.07E-04	1.00E-03	3.58E-06	1.67E-04	8.13E-08	8.53E-09	1.96E-07	6.43E-07	1.92E-08	4.18E-08	0.00E+00	1.14E-04	6.66E-05	8.92E-06
HDPE - Pigmented Containers	3.07E-04	1.00E-03	3.58E-06	1.67E-04	8.13E-08	8.53E-09	1.96E-07	6.43E-07	1.92E-08	4.18E-08	0.00E+00	1.14E-04	6.66E-05	8.92E-06
PET - Containers	3.05E-04	7.64E-04	2.38E-06	1.24E-04	5.37E-08	7.82E-09	1.30E-07	5.19E-07	1.27E-08	2.76E-08	0.00E+00	9.63E-05	5.61E-05	7.49E-06
Plastic - Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic - Other #2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Plastic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic Film	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Plastic - Non-recylcable	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Misc. Organic	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
Misc. Inorganic	3.03E-04	3.55E-04	2.91E-07	5.00E-05	6.06E-09	6.58E-09	1.46E-08	3.05E-07	1.43E-09	3.11E-09	0.00E+00	6.50E-05	3.79E-05	5.03E-06
E-waste	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table E.3b: Airborne Emissions resulting from material recovery using a mixed waste MRF (kg/Mg). Part II

	CO2-Fossil	CO2-Biomass	CO2-Storage	Methane	Nitrous Oxide	PM-10	Total Particulates	Nitrogen Oxides	Hydrocarbons (non-CH4)	Sulfur Oxides	Carbon Monoxide	Ammonia	Lead
Yard Trimmings, Leaves	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Grass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Branches	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Animal	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Vegetable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood Other	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Textiles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rubber/Leather	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Newsprint	3.24E+00	8.43E-02	4.90E-06	9.53E-03	1.07E-03	2.57E-03	1.82E-03	0.00E+00	9.25E-03	7.58E-04	2.48E-02	1.16E-02	1.57E-05
Corr. Cardboard	3.24E+00	8.43E-02	4.90E-06	9.53E-03	1.07E-03	2.57E-03	1.82E-03	0.00E+00	9.25E-03	7.58E-04	2.48E-02	1.16E-02	1.57E-05
Office Paper	3.24E+00	8.43E-02	4.90E-06	9.53E-03	1.07E-03	2.57E-03	1.82E-03	0.00E+00	9.25E-03	7.58E-04	2.48E-02	1.16E-02	1.57E-05
Magazines	3.24E+00	8.43E-02	4.90E-06	9.53E-03	1.07E-03	2.57E-03	1.82E-03	0.00E+00	9.25E-03	7.58E-04	2.48E-02	1.16E-02	1.57E-05
3rd Class Mail	3.24E+00	8.43E-02	4.90E-06	9.53E-03	1.07E-03	2.57E-03	1.82E-03	0.00E+00	9.25E-03	7.58E-04	2.48E-02	1.16E-02	1.57E-05
Paper Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper Other # 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Paper	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Brown	3.24E+00	8.43E-02	4.90E-06	9.53E-03	1.07E-03	2.57E-03	1.82E-03	0.00E+00	9.25E-03	7.58E-04	2.48E-02	1.16E-02	1.57E-05
Glass - Green	3.24E+00	8.43E-02	4.90E-06	9.53E-03	1.07E-03	2.57E-03	1.82E-03	0.00E+00	9.25E-03	7.58E-04	2.48E-02	1.16E-02	1.57E-05
Glass -Clear	3.24E+00	8.43E-02	4.90E-06	9.53E-03	1.07E-03	2.57E-03	1.82E-03	0.00E+00	9.25E-03	7.58E-04	2.48E-02	1.16E-02	1.57E-05
Mixed Glass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ferrous Cans	3.24E+00	8.43E-02	4.90E-06	9.53E-03	1.07E-03	2.57E-03	1.82E-03	0.00E+00	9.25E-03	7.58E-04	2.48E-02	1.16E-02	1.57E-05
Ferrous Metal - Other	3.24E+00	8.43E-02	4.90E-06	9.53E-03	1.07E-03	2.57E-03	1.82E-03	0.00E+00	9.25E-03	7.58E-04	2.48E-02	1.16E-02	1.57E-05
Ferrous - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aluminum	3.24E+00	8.43E-02	4.90E-06	9.53E-03	1.07E-03	2.57E-03	1.82E-03	0.00E+00	9.25E-03	7.58E-04	2.48E-02	1.16E-02	1.57E-05
Aluminum - Foil	3.24E+00	8.43E-02	4.90E-06	9.53E-03	1.07E-03	2.57E-03	1.82E-03	0.00E+00	9.25E-03	7.58E-04	2.48E-02	1.16E-02	1.57E-05
Aluminum - Other	3.24E+00	8.43E-02	4.90E-06	9.53E-03	1.07E-03	2.57E-03	1.82E-03	0.00E+00	9.25E-03	7.58E-04	2.48E-02	1.16E-02	1.57E-05
Al - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HDPE - Translucent Containers	3.17E+00	8.42E-02	4.78E-06	9.38E-03	1.05E-03	2.51E-03	1.78E-03	0.00E+00	9.07E-03	7.50E-04	2.42E-02	1.15E-02	1.56E-05
HDPE - Pigmented Containers	3.24E+00	8.43E-02	4.90E-06	9.53E-03	1.07E-03	2.57E-03	1.82E-03	0.00E+00	9.25E-03	7.58E-04	2.48E-02	1.16E-02	1.57E-05
PET - Containers	3.24E+00	8.43E-02	4.90E-06	9.53E-03	1.07E-03	2.57E-03	1.82E-03	0.00E+00	9.25E-03	7.58E-04	2.48E-02	1.16E-02	1.57E-05
Plastic - Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic - Other #2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Plastic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic Film	3.24E+00	8.43E-02	4.90E-06	9.53E-03	1.07E-03	2.57E-03	1.82E-03	0.00E+00	9.25E-03	7.58E-04	2.48E-02	1.16E-02	1.57E-05
Plastic - Non-recylcable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Organic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Inorganic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E-waste	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table E.4a: Airborne Emissions resulting from material recovery using a presorted recyclables MRF (kg/Mg). Part I

	Hydrochloric Acid	Mercury	Benzene	Chloroform	Carbon Tetrachloride	Ethylene Dichloride	Methylene Chloride	Trichloroethylene	Tetrachloroethene	Vinyl Chloride	Toluene	Xylenes	Ethylbenzene	Dioxins/ Furans
Yard Trimmings, Leaves	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Grass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Branches	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Animal	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Vegetable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood Other	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Textiles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rubber/Leather	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Newsprint	7.61E-06	3.19E-04	1.53E-06	5.68E-05	3.48E-08	1.32E-09	8.41E-08	1.74E-07	8.23E-09	1.79E-08	0.00E+00	2.68E-05	1.56E-05	2.10E-06
Corr. Cardboard	7.61E-06	3.19E-04	1.53E-06	5.68E-05	3.48E-08	1.32E-09	8.41E-08	1.74E-07	8.23E-09	1.79E-08	0.00E+00	2.68E-05	1.56E-05	2.10E-06
Office Paper	7.61E-06	3.19E-04	1.53E-06	5.68E-05	3.48E-08	1.32E-09	8.41E-08	1.74E-07	8.23E-09	1.79E-08	0.00E+00	2.68E-05	1.56E-05	2.10E-06
Magazines	7.61E-06	3.19E-04	1.53E-06	5.68E-05	3.48E-08	1.32E-09	8.41E-08	1.74E-07	8.23E-09	1.79E-08	0.00E+00	2.68E-05	1.56E-05	2.10E-06
3rd Class Mail	7.61E-06	3.19E-04	1.53E-06	5.68E-05	3.48E-08	1.32E-09	8.41E-08	1.74E-07	8.23E-09	1.79E-08	0.00E+00	2.68E-05	1.56E-05	2.10E-06
Paper Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper Other # 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Paper	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Brown	7.61E-06	3.19E-04	1.53E-06	5.68E-05	3.48E-08	1.32E-09	8.41E-08	1.74E-07	8.23E-09	1.79E-08	0.00E+00	2.68E-05	1.56E-05	2.10E-06
Glass - Green	7.61E-06	3.19E-04	1.53E-06	5.68E-05	3.48E-08	1.32E-09	8.41E-08	1.74E-07	8.23E-09	1.79E-08	0.00E+00	2.68E-05	1.56E-05	2.10E-06
Glass -Clear	7.61E-06	3.19E-04	1.53E-06	5.68E-05	3.48E-08	1.32E-09	8.41E-08	1.74E-07	8.23E-09	1.79E-08	0.00E+00	2.68E-05	1.56E-05	2.10E-06
Mixed Glass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ferrous Cans	7.61E-06	3.19E-04	1.53E-06	5.68E-05	3.48E-08	1.32E-09	8.41E-08	1.74E-07	8.23E-09	1.79E-08	0.00E+00	2.68E-05	1.56E-05	2.10E-06
Ferrous Metal - Other	7.61E-06	3.19E-04	1.53E-06	5.68E-05	3.48E-08	1.32E-09	8.41E-08	1.74E-07	8.23E-09	1.79E-08	0.00E+00	2.68E-05	1.56E-05	2.10E-06
Ferrous - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aluminum	7.61E-06	3.19E-04	1.53E-06	5.68E-05	3.48E-08	1.32E-09	8.41E-08	1.74E-07	8.23E-09	1.79E-08	0.00E+00	2.68E-05	1.56E-05	2.10E-06
Aluminum - Foil	7.61E-06	3.19E-04	1.53E-06	5.68E-05	3.48E-08	1.32E-09	8.41E-08	1.74E-07	8.23E-09	1.79E-08	0.00E+00	2.68E-05	1.56E-05	2.10E-06
Aluminum - Other	7.61E-06	3.19E-04	1.53E-06	5.68E-05	3.48E-08	1.32E-09	8.41E-08	1.74E-07	8.23E-09	1.79E-08	0.00E+00	2.68E-05	1.56E-05	2.10E-06
Al - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HDPE - Translucent Containers	7.57E-06	3.11E-04	1.49E-06	5.54E-05	3.40E-08	1.29E-09	8.20E-08	1.71E-07	8.02E-09	1.75E-08	0.00E+00	2.62E-05	1.53E-05	2.06E-06
HDPE - Pigmented Containers	7.61E-06	3.19E-04	1.53E-06	5.68E-05	3.48E-08	1.32E-09	8.41E-08	1.74E-07	8.23E-09	1.79E-08	0.00E+00	2.68E-05	1.56E-05	2.10E-06
PET - Containers	7.61E-06	3.19E-04	1.53E-06	5.68E-05	3.48E-08	1.32E-09	8.41E-08	1.74E-07	8.23E-09	1.79E-08	0.00E+00	2.68E-05	1.56E-05	2.10E-06
Plastic - Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic - Other #2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Plastic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic Film	7.61E-06	3.19E-04	1.53E-06	5.68E-05	3.48E-08	1.32E-09	8.41E-08	1.74E-07	8.23E-09	1.79E-08	0.00E+00	2.68E-05	1.56E-05	2.10E-06
Plastic - Non-recylcable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Organic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Inorganic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E-waste	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table E.4b: Airborne Emissions resulting from material recovery using a single stream MRF (kg/Mg). Part II

Appendix E.4 Waterborne Emissions Coefficients

	Dissolved Solids	Suspended Solids	BOD	COD	Oil	Sulfuric Acid	Iron	Ammonia	Copper	Cadmium	Arsenic	Mercury	Phosphate	Selenium	Chromium	Lead
Yard Trimmings, Leaves	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Grass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Branches	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Meat	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Vegetable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood Other	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Textiles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rubber/Leather	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Newsprint	1.62E+00	9.57E-02	1.50E-03	8.35E-04	0.00E+00	6.49E-03	6.62E-04	1.17E-05	1.57E-06	1.01E-05	3.61E-08	0.00E+00	2.66E-06	8.77E-05	2.10E-05	7.46E-05
Corr. Cardboard	1.62E+00	9.57E-02	1.48E-03	8.34E-04	0.00E+00	6.48E-03	6.62E-04	1.17E-05	1.56E-06	1.01E-05	3.60E-08	0.00E+00	2.61E-06	8.77E-05	2.10E-05	7.45E-05
Office Paper	1.62E+00	9.57E-02	1.50E-03	8.35E-04	0.00E+00	6.49E-03	6.62E-04	1.17E-05	1.57E-06	1.01E-05	3.61E-08	0.00E+00	2.66E-06	8.77E-05	2.10E-05	7.46E-05
Magazines	1.62E+00	9.57E-02	1.50E-03	8.35E-04	0.00E+00	6.49E-03	6.62E-04	1.17E-05	1.57E-06	1.01E-05	3.61E-08	0.00E+00	2.66E-06	8.77E-05	2.10E-05	7.46E-05
3rd Class Mail	1.62E+00	9.57E-02	1.50E-03	8.35E-04	0.00E+00	6.49E-03	6.62E-04	1.17E-05	1.57E-06	1.01E-05	3.61E-08	0.00E+00	2.66E-06	8.77E-05	2.10E-05	7.46E-05
Paper Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper Other # 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Paper	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Brown	1.78E+00	1.01E-01	4.08E-03	9.08E-04	0.00E+00	8.07E-03	7.17E-04	1.91E-05	2.11E-06	1.17E-05	4.67E-08	0.00E+00	1.23E-05	9.08E-05	2.32E-05	9.07E-05
Glass - Green	1.78E+00	1.01E-01	4.08E-03	9.08E-04	0.00E+00	8.07E-03	7.17E-04	1.91E-05	2.11E-06	1.17E-05	4.67E-08	0.00E+00	1.23E-05	9.08E-05	2.32E-05	9.07E-05
Glass -Clear	1.78E+00	1.01E-01	4.08E-03	9.08E-04	0.00E+00	8.07E-03	7.17E-04	1.91E-05	2.11E-06	1.17E-05	4.67E-08	0.00E+00	1.23E-05	9.08E-05	2.32E-05	9.07E-05
Mixed Glass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ferrous Cans	1.65E+00	9.67E-02	1.97E-03	8.48E-04	0.00E+00	6.78E-03	6.72E-04	1.31E-05	1.67E-06	1.04E-05	3.80E-08	0.00E+00	4.42E-06	8.83E-05	2.14E-05	7.75E-05
Ferrous Metal - Other	1.65E+00	9.67E-02	1.97E-03	8.48E-04	0.00E+00	6.78E-03	6.72E-04	1.31E-05	1.67E-06	1.04E-05	3.80E-08	0.00E+00	4.42E-06	8.83E-05	2.14E-05	7.75E-05
Ferrous - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aluminum	1.64E+00	9.62E-02	1.74E-03	8.42E-04	0.00E+00	6.64E-03	6.68E-04	1.24E-05	1.62E-06	1.03E-05	3.71E-08	0.00E+00	3.58E-06	8.80E-05	2.12E-05	7.61E-05
Aluminum - Foil	1.64E+00	9.62E-02	1.74E-03	8.42E-04	0.00E+00	6.64E-03	6.68E-04	1.24E-05	1.62E-06	1.03E-05	3.71E-08	0.00E+00	3.58E-06	8.80E-05	2.12E-05	7.61E-05
Aluminum - Other	1.64E+00	9.62E-02	1.74E-03	8.42E-04	0.00E+00	6.64E-03	6.68E-04	1.24E-05	1.62E-06	1.03E-05	3.71E-08	0.00E+00	3.58E-06	8.80E-05	2.12E-05	7.61E-05
Al - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HDPE - Translucent Containers	1.67E+00	9.75E-02	2.33E-03	8.58E-04	0.00E+00	7.00E-03	6.80E-04	1.41E-05	1.74E-06	1.06E-05	3.95E-08	0.00E+00	5.77E-06	8.87E-05	2.17E-05	7.98E-05
HDPE - Pigmented Containers	1.67E+00	9.75E-02	2.33E-03	8.58E-04	0.00E+00	7.00E-03	6.80E-04	1.41E-05	1.74E-06	1.06E-05	3.95E-08	0.00E+00	5.77E-06	8.87E-05	2.17E-05	7.98E-05
PET - Containers	1.64E+00	9.65E-02	1.84E-03	8.44E-04	0.00E+00	6.70E-03	6.70E-04	1.27E-05	1.64E-06	1.03E-05	3.75E-08	0.00E+00	3.95E-06	8.82E-05	2.13E-05	7.67E-05
Plastic - Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic - Other #2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Plastic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic Film	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Plastic - Non-recylcable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Organic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Inorganic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E-waste	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table E.5a: Waterborne Emissions resulting from material recovery using a single stream MRF (kg/Mg). Part I

	Zinc	Barium	Silver	Metals (unsp.)	Benzene	Chloroform	Carbon Tetrachloride	Ethylene Dichloride	Methylene Chloride	Trichloroethene	Tetrachloroethene	Vinyl Chloride	Toluene	Xylenes	Ethylbenzene	Hydrocarbons (unsp.)
Yard Trimmings, Leaves	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Grass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Branches	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Meat	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Vegetable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood Other	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Textiles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rubber/Leather	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Newsprint	4.24E-02	7.65E-05	3.83E-02	6.11E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.78E-05	3.06E-05	3.44E-06	7.27E-06	0.00E+00
Corr. Cardboard	4.24E-02	7.65E-05	3.81E-02	6.11E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.77E-05	3.06E-05	3.44E-06	7.27E-06	0.00E+00
Office Paper	4.24E-02	7.65E-05	3.83E-02	6.11E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.78E-05	3.06E-05	3.44E-06	7.27E-06	0.00E+00
Magazines	4.24E-02	7.65E-05	3.83E-02	6.11E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.78E-05	3.06E-05	3.44E-06	7.27E-06	0.00E+00
3rd Class Mail	4.24E-02	7.65E-05	3.83E-02	6.11E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.78E-05	3.06E-05	3.44E-06	7.27E-06	0.00E+00
Paper Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper Other # 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Paper	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Brown	4.40E-02	8.38E-05	8.24E-02	6.70E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.33E-05	3.36E-05	3.77E-06	7.98E-06	0.00E+00
Glass - Green	4.40E-02	8.38E-05	8.24E-02	6.70E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.33E-05	3.36E-05	3.77E-06	7.98E-06	0.00E+00
Glass -Clear	4.40E-02	8.38E-05	8.24E-02	6.70E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.33E-05	3.36E-05	3.77E-06	7.98E-06	0.00E+00
Mixed Glass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ferrous Cans	4.27E-02	7.79E-05	4.64E-02	6.22E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.88E-05	3.11E-05	3.50E-06	7.40E-06	0.00E+00
Ferrous Metal - Other	4.27E-02	7.79E-05	4.64E-02	6.22E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.88E-05	3.11E-05	3.50E-06	7.40E-06	0.00E+00
Ferrous - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aluminum	4.26E-02	7.72E-05	4.25E-02	6.17E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.83E-05	3.09E-05	3.47E-06	7.34E-06	0.00E+00
Aluminum - Foil	4.26E-02	7.72E-05	4.25E-02	6.17E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.83E-05	3.09E-05	3.47E-06	7.34E-06	0.00E+00
Aluminum - Other	4.26E-02	7.72E-05	4.25E-02	6.17E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.83E-05	3.09E-05	3.47E-06	7.34E-06	0.00E+00
Al - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HDPE - Translucent Containers	4.29E-02	7.89E-05	5.25E-02	6.30E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.95E-05	3.16E-05	3.54E-06	7.50E-06	0.00E+00
HDPE - Pigmented Containers	4.29E-02	7.89E-05	5.25E-02	6.30E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.95E-05	3.16E-05	3.54E-06	7.50E-06	0.00E+00
PET - Containers	4.26E-02	7.75E-05	4.42E-02	6.19E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.85E-05	3.10E-05	3.48E-06	7.37E-06	0.00E+00
Plastic - Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic - Other #2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Plastic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic Film	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Plastic - Non-recylcable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Organic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Inorganic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E-waste	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table E.5b: Waterborne Emissions resulting from material recovery using a single stream MRF (kg/Mg). Part II

	Dissolved Solids	Suspended Solids	BOD	COD	Oil	Sulfuric Acid	Iron	Ammonia	Copper	Cadmium	Arsenic	Mercury	Phosphate	Selenium	Chromium	Lead
Yard Trimmings, Leaves	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Grass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Branches	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Meat	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Vegetable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood Other	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Textiles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rubber/Leather	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Newsprint	1.62E+00	9.57E-02	1.50E-03	8.35E-04	0.00E+00	6.49E-03	6.62E-04	1.17E-05	1.57E-06	1.01E-05	3.61E-08	0.00E+00	2.66E-06	8.77E-05	2.10E-05	7.46E-05
Corr. Cardboard	1.62E+00	9.57E-02	1.48E-03	8.34E-04	0.00E+00	6.48E-03	6.62E-04	1.17E-05	1.56E-06	1.01E-05	3.60E-08	0.00E+00	2.61E-06	8.77E-05	2.10E-05	7.45E-05
Office Paper	1.62E+00	9.57E-02	1.50E-03	8.35E-04	0.00E+00	6.49E-03	6.62E-04	1.17E-05	1.57E-06	1.01E-05	3.61E-08	0.00E+00	2.66E-06	8.77E-05	2.10E-05	7.46E-05
Magazines	1.62E+00	9.57E-02	1.50E-03	8.35E-04	0.00E+00	6.49E-03	6.62E-04	1.17E-05	1.57E-06	1.01E-05	3.61E-08	0.00E+00	2.66E-06	8.77E-05	2.10E-05	7.46E-05
3rd Class Mail	1.62E+00	9.57E-02	1.50E-03	8.35E-04	0.00E+00	6.49E-03	6.62E-04	1.17E-05	1.57E-06	1.01E-05	3.61E-08	0.00E+00	2.66E-06	8.77E-05	2.10E-05	7.46E-05
Paper Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper Other # 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Paper	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Brown	1.78E+00	1.01E-01	4.08E-03	9.08E-04	0.00E+00	8.07E-03	7.17E-04	1.91E-05	2.11E-06	1.17E-05	4.67E-08	0.00E+00	1.23E-05	9.08E-05	2.32E-05	9.07E-05
Glass - Green	1.78E+00	1.01E-01	4.08E-03	9.08E-04	0.00E+00	8.07E-03	7.17E-04	1.91E-05	2.11E-06	1.17E-05	4.67E-08	0.00E+00	1.23E-05	9.08E-05	2.32E-05	9.07E-05
Glass -Clear	1.78E+00	1.01E-01	4.08E-03	9.08E-04	0.00E+00	8.07E-03	7.17E-04	1.91E-05	2.11E-06	1.17E-05	4.67E-08	0.00E+00	1.23E-05	9.08E-05	2.32E-05	9.07E-05
Mixed Glass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ferrous Cans	1.65E+00	9.67E-02	1.97E-03	8.48E-04	0.00E+00	6.78E-03	6.72E-04	1.31E-05	1.67E-06	1.04E-05	3.80E-08	0.00E+00	4.42E-06	8.83E-05	2.14E-05	7.75E-05
Ferrous Metal - Other	1.65E+00	9.67E-02	1.97E-03	8.48E-04	0.00E+00	6.78E-03	6.72E-04	1.31E-05	1.67E-06	1.04E-05	3.80E-08	0.00E+00	4.42E-06	8.83E-05	2.14E-05	7.75E-05
Ferrous - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aluminum	1.64E+00	9.62E-02	1.74E-03	8.42E-04	0.00E+00	6.64E-03	6.68E-04	1.24E-05	1.62E-06	1.03E-05	3.71E-08	0.00E+00	3.58E-06	8.80E-05	2.12E-05	7.61E-05
Aluminum - Foil	1.64E+00	9.62E-02	1.74E-03	8.42E-04	0.00E+00	6.64E-03	6.68E-04	1.24E-05	1.62E-06	1.03E-05	3.71E-08	0.00E+00	3.58E-06	8.80E-05	2.12E-05	7.61E-05
Aluminum - Other	1.64E+00	9.62E-02	1.74E-03	8.42E-04	0.00E+00	6.64E-03	6.68E-04	1.24E-05	1.62E-06	1.03E-05	3.71E-08	0.00E+00	3.58E-06	8.80E-05	2.12E-05	7.61E-05
Al - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HDPE - Translucent Containers	1.67E+00	9.75E-02	2.33E-03	8.58E-04	0.00E+00	7.00E-03	6.80E-04	1.41E-05	1.74E-06	1.06E-05	3.95E-08	0.00E+00	5.77E-06	8.87E-05	2.17E-05	7.98E-05
HDPE - Pigmented Containers	1.67E+00	9.75E-02	2.33E-03	8.58E-04	0.00E+00	7.00E-03	6.80E-04	1.41E-05	1.74E-06	1.06E-05	3.95E-08	0.00E+00	5.77E-06	8.87E-05	2.17E-05	7.98E-05
PET - Containers	1.64E+00	9.65E-02	1.84E-03	8.44E-04	0.00E+00	6.70E-03	6.70E-04	1.27E-05	1.64E-06	1.03E-05	3.75E-08	0.00E+00	3.95E-06	8.82E-05	2.13E-05	7.67E-05
Plastic - Other #1	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Plastic - Other #2	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Mixed Plastic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic Film	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Plastic - Non-recylcable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Organic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Inorganic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E-waste	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table E.6a: Waterborne Emissions resulting from material recovery using a dual stream MRF (kg/Mg). Part I

	Zinc	Barium	Silver	Metals (unsp.)	Benzene	Chloroform	Carbon Tetrachloride	Ethylene Dichloride	Methylene Chloride	Trichloroethene	Tetrachloroethene	Vinyl Chloride	Toluene	Xylenes	Ethylbenzene	Hydrocarbons (unsp.)
Yard Trimmings, Leaves	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Grass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Branches	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Meat	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Vegetable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood Other	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Textiles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rubber/Leather	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Newsprint	4.24E-02	7.65E-05	3.83E-02	6.11E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.78E-05	3.06E-05	3.44E-06	7.27E-06	0.00E+00
Corr. Cardboard	4.24E-02	7.65E-05	3.81E-02	6.11E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.77E-05	3.06E-05	3.44E-06	7.27E-06	0.00E+00
Office Paper	4.24E-02	7.65E-05	3.83E-02	6.11E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.78E-05	3.06E-05	3.44E-06	7.27E-06	0.00E+00
Magazines	4.24E-02	7.65E-05	3.83E-02	6.11E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.78E-05	3.06E-05	3.44E-06	7.27E-06	0.00E+00
3rd Class Mail	4.24E-02	7.65E-05	3.83E-02	6.11E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.78E-05	3.06E-05	3.44E-06	7.27E-06	0.00E+00
Paper Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper Other # 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Paper	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Brown	4.40E-02	8.38E-05	8.24E-02	6.70E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.33E-05	3.36E-05	3.77E-06	7.98E-06	0.00E+00
Glass - Green	4.40E-02	8.38E-05	8.24E-02	6.70E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.33E-05	3.36E-05	3.77E-06	7.98E-06	0.00E+00
Glass -Clear	4.40E-02	8.38E-05	8.24E-02	6.70E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.33E-05	3.36E-05	3.77E-06	7.98E-06	0.00E+00
Mixed Glass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ferrous Cans	4.27E-02	7.79E-05	4.64E-02	6.22E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.88E-05	3.11E-05	3.50E-06	7.40E-06	0.00E+00
Ferrous Metal - Other	4.27E-02	7.79E-05	4.64E-02	6.22E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.88E-05	3.11E-05	3.50E-06	7.40E-06	0.00E+00
Ferrous - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aluminum	4.26E-02	7.72E-05	4.25E-02	6.17E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.83E-05	3.09E-05	3.47E-06	7.34E-06	0.00E+00
Aluminum - Foil	4.26E-02	7.72E-05	4.25E-02	6.17E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.83E-05	3.09E-05	3.47E-06	7.34E-06	0.00E+00
Aluminum - Other	4.26E-02	7.72E-05	4.25E-02	6.17E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.83E-05	3.09E-05	3.47E-06	7.34E-06	0.00E+00
Al - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HDPE - Translucent Containers	4.29E-02	7.89E-05	5.25E-02	6.30E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.95E-05	3.16E-05	3.54E-06	7.50E-06	0.00E+00
HDPE - Pigmented Containers	4.29E-02	7.89E-05	5.25E-02	6.30E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.95E-05	3.16E-05	3.54E-06	7.50E-06	0.00E+00
PET - Containers	4.26E-02	7.75E-05	4.42E-02	6.19E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.85E-05	3.10E-05	3.48E-06	7.37E-06	0.00E+00
Plastic - Other #1	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Plastic - Other #2	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Mixed Plastic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic Film	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Plastic - Non-recylcable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Organic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Inorganic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E-waste	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table E.6b: Waterborne Emissions resulting from material recovery using a dual stream MRF (kg/Mg). Part II

	Dissolved Solids	Suspended Solids	BOD	COD	Oil	Sulfuric Acid	Iron	Ammonia	Copper	Cadmium	Arsenic	Mercury	Phosphate	Selenium	Chromium	Lead
Yard Trimmings, Leaves	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Yard Trimmings, Grass	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Yard Trimmings, Branches	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Food Waste, Meat	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Food Waste, Vegetable	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Wood	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Wood Other	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Textiles	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Rubber/Leather	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Newsprint	1.62E+00	9.57E-02	1.50E-03	8.35E-04	0.00E+00	6.49E-03	6.62E-04	1.17E-05	1.57E-06	1.01E-05	3.61E-08	0.00E+00	2.66E-06	8.77E-05	2.10E-05	7.46E-05
Corr. Cardboard	1.62E+00	9.57E-02	1.48E-03	8.34E-04	0.00E+00	6.48E-03	6.62E-04	1.17E-05	1.56E-06	1.01E-05	3.60E-08	0.00E+00	2.61E-06	8.77E-05	2.10E-05	7.45E-05
Office Paper	1.62E+00	9.57E-02	1.50E-03	8.35E-04	0.00E+00	6.49E-03	6.62E-04	1.17E-05	1.57E-06	1.01E-05	3.61E-08	0.00E+00	2.66E-06	8.77E-05	2.10E-05	7.46E-05
Magazines	1.62E+00	9.57E-02	1.50E-03	8.35E-04	0.00E+00	6.49E-03	6.62E-04	1.17E-05	1.57E-06	1.01E-05	3.61E-08	0.00E+00	2.66E-06	8.77E-05	2.10E-05	7.46E-05
3rd Class Mail	1.62E+00	9.57E-02	1.50E-03	8.35E-04	0.00E+00	6.49E-03	6.62E-04	1.17E-05	1.57E-06	1.01E-05	3.61E-08	0.00E+00	2.66E-06	8.77E-05	2.10E-05	7.46E-05
Paper Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper Other # 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Paper	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper - Non-recyclable	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Glass - Brown	1.78E+00	1.01E-01	4.08E-03	9.08E-04	0.00E+00	8.07E-03	7.17E-04	1.91E-05	2.11E-06	1.17E-05	4.67E-08	0.00E+00	1.23E-05	9.08E-05	2.32E-05	9.07E-05
Glass - Green	1.78E+00	1.01E-01	4.08E-03	9.08E-04	0.00E+00	8.07E-03	7.17E-04	1.91E-05	2.11E-06	1.17E-05	4.67E-08	0.00E+00	1.23E-05	9.08E-05	2.32E-05	9.07E-05
Glass -Clear	1.78E+00	1.01E-01	4.08E-03	9.08E-04	0.00E+00	8.07E-03	7.17E-04	1.91E-05	2.11E-06	1.17E-05	4.67E-08	0.00E+00	1.23E-05	9.08E-05	2.32E-05	9.07E-05
Mixed Glass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Non-recyclable	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Ferrous Cans	1.65E+00	9.67E-02	1.97E-03	8.48E-04	0.00E+00	6.78E-03	6.72E-04	1.31E-05	1.67E-06	1.04E-05	3.80E-08	0.00E+00	4.42E-06	8.83E-05	2.14E-05	7.75E-05
Ferrous Metal - Other	1.65E+00	9.67E-02	1.97E-03	8.48E-04	0.00E+00	6.78E-03	6.72E-04	1.31E-05	1.67E-06	1.04E-05	3.80E-08	0.00E+00	4.42E-06	8.83E-05	2.14E-05	7.75E-05
Ferrous - Non-recyclable	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Aluminum	1.64E+00	9.62E-02	1.74E-03	8.42E-04	0.00E+00	6.64E-03	6.68E-04	1.24E-05	1.62E-06	1.03E-05	3.71E-08	0.00E+00	3.58E-06	8.80E-05	2.12E-05	7.61E-05
Aluminum - Foil	1.64E+00	9.62E-02	1.74E-03	8.42E-04	0.00E+00	6.64E-03	6.68E-04	1.24E-05	1.62E-06	1.03E-05	3.71E-08	0.00E+00	3.58E-06	8.80E-05	2.12E-05	7.61E-05
Aluminum - Other	1.64E+00	9.62E-02	1.74E-03	8.42E-04	0.00E+00	6.64E-03	6.68E-04	1.24E-05	1.62E-06	1.03E-05	3.71E-08	0.00E+00	3.58E-06	8.80E-05	2.12E-05	7.61E-05
Al - Non-recyclable	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
HDPE - Translucent Containers	1.67E+00	9.75E-02	2.33E-03	8.58E-04	0.00E+00	7.00E-03	6.80E-04	1.41E-05	1.74E-06	1.06E-05	3.95E-08	0.00E+00	5.77E-06	8.87E-05	2.17E-05	7.98E-05
HDPE - Pigmented Containers	1.67E+00	9.75E-02	2.33E-03	8.58E-04	0.00E+00	7.00E-03	6.80E-04	1.41E-05	1.74E-06	1.06E-05	3.95E-08	0.00E+00	5.77E-06	8.87E-05	2.17E-05	7.98E-05
PET - Containers	1.64E+00	9.65E-02	1.84E-03	8.44E-04	0.00E+00	6.70E-03	6.70E-04	1.27E-05	1.64E-06	1.03E-05	3.75E-08	0.00E+00	3.95E-06	8.82E-05	2.13E-05	7.67E-05
Plastic - Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic - Other #2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Plastic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic Film	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Plastic - Non-recylcable	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Misc. Organic	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
Misc. Inorganic	1.59E+00	9.46E-02	1.01E-03	8.21E-04	0.00E+00	6.19E-03	6.52E-04	1.03E-05	1.46E-06	9.83E-06	3.41E-08	0.00E+00	8.22E-07	8.72E-05	2.06E-05	7.15E-05
E-waste	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table E.7a: Waterborne Emissions resulting from material recovery using a mixed waste MRF (kg/Mg). Part I

	Zinc	Barium	Silver	Metals (unsp.)	Benzene	Chloroform	Carbon Tetrachloride	Ethylene Dichloride	Methylene Chloride	Trichloroethene	Tetrachloroethene	Vinyl Chloride	Toluene	Xylenes	Ethylbenzene	Hydrocarbons (unsp.)
Yard Trimmings, Leaves	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Yard Trimmings, Grass	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Yard Trimmings, Branches	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Food Waste, Meat	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Food Waste, Vegetable	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Wood	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Wood Other	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Textiles	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Rubber/Leather	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Newsprint	4.24E-02	7.65E-05	3.83E-02	6.11E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.78E-05	3.06E-05	3.44E-06	7.27E-06	0.00E+00
Corr. Cardboard	4.24E-02	7.65E-05	3.81E-02	6.11E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.77E-05	3.06E-05	3.44E-06	7.27E-06	0.00E+00
Office Paper	4.24E-02	7.65E-05	3.83E-02	6.11E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.78E-05	3.06E-05	3.44E-06	7.27E-06	0.00E+00
Magazines	4.24E-02	7.65E-05	3.83E-02	6.11E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.78E-05	3.06E-05	3.44E-06	7.27E-06	0.00E+00
3rd Class Mail	4.24E-02	7.65E-05	3.83E-02	6.11E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.78E-05	3.06E-05	3.44E-06	7.27E-06	0.00E+00
Paper Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper Other # 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Paper	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper - Non-recyclable	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Glass - Brown	4.40E-02	8.38E-05	8.24E-02	6.70E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.33E-05	3.36E-05	3.77E-06	7.98E-06	0.00E+00
Glass - Green	4.40E-02	8.38E-05	8.24E-02	6.70E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.33E-05	3.36E-05	3.77E-06	7.98E-06	0.00E+00
Glass -Clear	4.40E-02	8.38E-05	8.24E-02	6.70E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.33E-05	3.36E-05	3.77E-06	7.98E-06	0.00E+00
Mixed Glass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Non-recyclable	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Ferrous Cans	4.27E-02	7.79E-05	4.64E-02	6.22E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.88E-05	3.11E-05	3.50E-06	7.40E-06	0.00E+00
Ferrous Metal - Other	4.27E-02	7.79E-05	4.64E-02	6.22E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.88E-05	3.11E-05	3.50E-06	7.40E-06	0.00E+00
Ferrous - Non-recyclable	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Aluminum	4.26E-02	7.72E-05	4.25E-02	6.17E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.83E-05	3.09E-05	3.47E-06	7.34E-06	0.00E+00
Aluminum - Foil	4.26E-02	7.72E-05	4.25E-02	6.17E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.83E-05	3.09E-05	3.47E-06	7.34E-06	0.00E+00
Aluminum - Other	4.26E-02	7.72E-05	4.25E-02	6.17E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.83E-05	3.09E-05	3.47E-06	7.34E-06	0.00E+00
Al - Non-recyclable	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
HDPE - Translucent Containers	4.29E-02	7.89E-05	5.25E-02	6.30E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.95E-05	3.16E-05	3.54E-06	7.50E-06	0.00E+00
HDPE - Pigmented Containers	4.29E-02	7.89E-05	5.25E-02	6.30E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.95E-05	3.16E-05	3.54E-06	7.50E-06	0.00E+00
PET - Containers	4.26E-02	7.75E-05	4.42E-02	6.19E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.85E-05	3.10E-05	3.48E-06	7.37E-06	0.00E+00
Plastic - Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic - Other #2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Plastic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic Film	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Plastic - Non-recylcable	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Misc. Organic	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
Misc. Inorganic	4.21E-02	7.51E-05	2.99E-02	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.67E-05	3.01E-05	3.38E-06	7.14E-06	0.00E+00
E-waste	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table E.7b: Waterborne Emissions resulting from material recovery using a mixed waste MRF (kg/Mg). Part II

	Dissolved Solids	Suspended Solids	BOD	COD	Oil	Sulfuric Acid	Iron	Ammonia	Copper	Cadmium	Arsenic	Mercury	Phosphate	Selenium	Chromium	Lead
Yard Trimmings, Leaves	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Grass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Branches	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Animal	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Vegetable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood Other	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Textiles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rubber/Leather	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Newsprint	1.39E-01	7.42E-03	6.69E-04	7.00E-05	0.00E+00	7.69E-04	5.48E-05	2.39E-06	2.21E-07	1.00E-06	4.69E-09	0.00E+00	2.32E-06	6.34E-06	1.85E-06	8.40E-06
Corr. Cardboard	1.39E-01	7.42E-03	6.69E-04	7.00E-05	0.00E+00	7.69E-04	5.48E-05	2.39E-06	2.21E-07	1.00E-06	4.69E-09	0.00E+00	2.32E-06	6.34E-06	1.85E-06	8.40E-06
Office Paper	1.39E-01	7.42E-03	6.69E-04	7.00E-05	0.00E+00	7.69E-04	5.48E-05	2.39E-06	2.21E-07	1.00E-06	4.69E-09	0.00E+00	2.32E-06	6.34E-06	1.85E-06	8.40E-06
Magazines	1.39E-01	7.42E-03	6.69E-04	7.00E-05	0.00E+00	7.69E-04	5.48E-05	2.39E-06	2.21E-07	1.00E-06	4.69E-09	0.00E+00	2.32E-06	6.34E-06	1.85E-06	8.40E-06
3rd Class Mail	1.39E-01	7.42E-03	6.69E-04	7.00E-05	0.00E+00	7.69E-04	5.48E-05	2.39E-06	2.21E-07	1.00E-06	4.69E-09	0.00E+00	2.32E-06	6.34E-06	1.85E-06	8.40E-06
Paper Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper Other # 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Paper	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Brown	1.39E-01	7.42E-03	6.69E-04	7.00E-05	0.00E+00	7.69E-04	5.48E-05	2.39E-06	2.21E-07	1.00E-06	4.69E-09	0.00E+00	2.32E-06	6.34E-06	1.85E-06	8.40E-06
Glass - Green	1.39E-01	7.42E-03	6.69E-04	7.00E-05	0.00E+00	7.69E-04	5.48E-05	2.39E-06	2.21E-07	1.00E-06	4.69E-09	0.00E+00	2.32E-06	6.34E-06	1.85E-06	8.40E-06
Glass -Clear	1.39E-01	7.42E-03	6.69E-04	7.00E-05	0.00E+00	7.69E-04	5.48E-05	2.39E-06	2.21E-07	1.00E-06	4.69E-09	0.00E+00	2.32E-06	6.34E-06	1.85E-06	8.40E-06
Mixed Glass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ferrous Cans	1.39E-01	7.42E-03	6.69E-04	7.00E-05	0.00E+00	7.69E-04	5.48E-05	2.39E-06	2.21E-07	1.00E-06	4.69E-09	0.00E+00	2.32E-06	6.34E-06	1.85E-06	8.40E-06
Ferrous Metal - Other	1.39E-01	7.42E-03	6.69E-04	7.00E-05	0.00E+00	7.69E-04	5.48E-05	2.39E-06	2.21E-07	1.00E-06	4.69E-09	0.00E+00	2.32E-06	6.34E-06	1.85E-06	8.40E-06
Ferrous - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aluminum	1.39E-01	7.42E-03	6.69E-04	7.00E-05	0.00E+00	7.69E-04	5.48E-05	2.39E-06	2.21E-07	1.00E-06	4.69E-09	0.00E+00	2.32E-06	6.34E-06	1.85E-06	8.40E-06
Aluminum - Foil	1.39E-01	7.42E-03	6.69E-04	7.00E-05	0.00E+00	7.69E-04	5.48E-05	2.39E-06	2.21E-07	1.00E-06	4.69E-09	0.00E+00	2.32E-06	6.34E-06	1.85E-06	8.40E-06
Aluminum - Other	1.39E-01	7.42E-03	6.69E-04	7.00E-05	0.00E+00	7.69E-04	5.48E-05	2.39E-06	2.21E-07	1.00E-06	4.69E-09	0.00E+00	2.32E-06	6.34E-06	1.85E-06	8.40E-06
Al - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HDPE - Translucent Containers	1.38E-01	7.39E-03	6.54E-04	6.96E-05	0.00E+00	7.60E-04	5.44E-05	2.34E-06	2.18E-07	9.92E-07	4.63E-09	0.00E+00	2.26E-06	6.32E-06	1.83E-06	8.30E-06
HDPE - Pigmented Containers	1.39E-01	7.42E-03	6.69E-04	7.00E-05	0.00E+00	7.69E-04	5.48E-05	2.39E-06	2.21E-07	1.00E-06	4.69E-09	0.00E+00	2.32E-06	6.34E-06	1.85E-06	8.40E-06
PET - Containers	1.39E-01	7.42E-03	6.69E-04	7.00E-05	0.00E+00	7.69E-04	5.48E-05	2.39E-06	2.21E-07	1.00E-06	4.69E-09	0.00E+00	2.32E-06	6.34E-06	1.85E-06	8.40E-06
Plastic - Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic - Other #2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Plastic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic Film	1.39E-01	7.42E-03	6.69E-04	7.00E-05	0.00E+00	7.69E-04	5.48E-05	2.39E-06	2.21E-07	1.00E-06	4.69E-09	0.00E+00	2.32E-06	6.34E-06	1.85E-06	8.40E-06
Plastic - Non-recylcable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Organic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Inorganic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E-waste	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table E.8a: Waterborne Emissions resulting from material recovery using a presorted recyclables MRF (kg/Mg). Part I

	Zinc	Barium	Silver	Metals (unsp.)	Benzene	Chloroform	Carbon Tetrachloride	Ethylene Dichloride	Methylene Chloride	Trichloroethene	Tetrachloroethene	Vinyl Chloride	Toluene	Xylenes	Ethylbenzene	Hydrocarbons (unsp.)
Yard Trimmings, Leaves	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Grass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yard Trimmings, Branches	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Animal	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Food Waste, Vegetable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood Other	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Textiles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rubber/Leather	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Newsprint	3.09E-03	6.55E-06	1.23E-02	5.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-06	2.62E-06	2.95E-07	6.25E-07	0.00E+00
Corr. Cardboard	3.09E-03	6.55E-06	1.23E-02	5.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-06	2.62E-06	2.95E-07	6.25E-07	0.00E+00
Office Paper	3.09E-03	6.55E-06	1.23E-02	5.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-06	2.62E-06	2.95E-07	6.25E-07	0.00E+00
Magazines	3.09E-03	6.55E-06	1.23E-02	5.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-06	2.62E-06	2.95E-07	6.25E-07	0.00E+00
3rd Class Mail	3.09E-03	6.55E-06	1.23E-02	5.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-06	2.62E-06	2.95E-07	6.25E-07	0.00E+00
Paper Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper Other # 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Paper	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paper - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Brown	3.09E-03	6.55E-06	1.23E-02	5.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-06	2.62E-06	2.95E-07	6.25E-07	0.00E+00
Glass - Green	3.09E-03	6.55E-06	1.23E-02	5.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-06	2.62E-06	2.95E-07	6.25E-07	0.00E+00
Glass -Clear	3.09E-03	6.55E-06	1.23E-02	5.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-06	2.62E-06	2.95E-07	6.25E-07	0.00E+00
Mixed Glass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glass - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ferrous Cans	3.09E-03	6.55E-06	1.23E-02	5.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-06	2.62E-06	2.95E-07	6.25E-07	0.00E+00
Ferrous Metal - Other	3.09E-03	6.55E-06	1.23E-02	5.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-06	2.62E-06	2.95E-07	6.25E-07	0.00E+00
Ferrous - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aluminum	3.09E-03	6.55E-06	1.23E-02	5.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-06	2.62E-06	2.95E-07	6.25E-07	0.00E+00
Aluminum - Foil	3.09E-03	6.55E-06	1.23E-02	5.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-06	2.62E-06	2.95E-07	6.25E-07	0.00E+00
Aluminum - Other	3.09E-03	6.55E-06	1.23E-02	5.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-06	2.62E-06	2.95E-07	6.25E-07	0.00E+00
Al - Non-recyclable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HDPE - Translucent Containers	3.08E-03	6.51E-06	1.20E-02	5.20E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.92E-06	2.61E-06	2.93E-07	6.20E-07	0.00E+00
HDPE - Pigmented Containers	3.09E-03	6.55E-06	1.23E-02	5.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-06	2.62E-06	2.95E-07	6.25E-07	0.00E+00
PET - Containers	3.09E-03	6.55E-06	1.23E-02	5.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-06	2.62E-06	2.95E-07	6.25E-07	0.00E+00
Plastic - Other #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic - Other #2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mixed Plastic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plastic Film	3.09E-03	6.55E-06	1.23E-02	5.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-06	2.62E-06	2.95E-07	6.25E-07	0.00E+00
Plastic - Non-recylcable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Organic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Misc. Inorganic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E-waste	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 8b: Waterborne Emissions resulting from material recovery using a presorted recyclables MRF (kg/Mg). Part II

Appendix F Summary of Analysis Inputs

Appendix F.1 Monte Carlo Analysis Inputs

Table F.1: Input distributions for automated single stream MRF analysis.

Parameter	Minimum	Mode	Maximum
Labor Management Rate	0.19	0.25	0.31
Labor Pay Rate	5.44	7.25	9.06
Driver Pay Rate	6.19	8.25	10.31
Fringe Rate	0.25	0.33	0.42
Paid Hours in Shift	6.75	9.00	11.25
Electricity Consumed in Offices	1.21	1.61	2.01
Electricity Consumed on Floor	0.53	0.71	0.88
Cost of Electricity	0.08	0.10	0.13
Cost of Diesel	0.63	0.84	1.05
Cost of Propane	0.32	0.42	0.53
Cost of Baling Wire	1.58	2.11	2.63
Days Operating Per Year	225.00	300.00	375.00
Annual Interest Rate	0.04	0.05	0.06
Indoor Floor Area Rate	0.85	1.14	1.42
Percent Office Floor Area	0.03	0.04	0.05
Life of MRF Structure	22.50	30.00	37.50
Construction Cost Rate	788.81	1051.74	1314.68
Engineering Rate	0.24	0.32	0.40
Land Cost Rate	484.43	645.90	807.38
Land Requirement Factor	2.12	2.83	3.54
Drum Feeder Investment Cost	112500.00	150000.00	187500.00
Drum Feeder FIXOM	75.00	100.00	125.00
Drum Feeder Electricity Consumption	11.25	15.00	18.75
Drum Feeder Electric Utilization	0.75	1.00	1.25
Drum Feeder Throughput	22.50	30.00	37.50
Drum Feeder Lifetime	7.50	10.00	12.50
Conveyor Investment Cost	37500.00	50000.00	62500.00
Conveyor FIXOM	7500.00	10000.00	12500.00
Conveyor Electricity Consumption	3.75	5.00	6.25
Conveyor Electric Utilization	0.64	0.85	1.06

Table F.1: Input distributions for automated single stream MRF analysis. (continued)

Parameter	**Minimum**	**Mode**	**Maximum**
Conveyor Throughput	22.50	30.00	37.50
Conveyor Lifetime	7.50	10.00	12.50
Vacuum Investment Cost	112500.00	150000.00	187500.00
Vacuum FIXOM	75.00	100.00	125.00
Vacuum Electricity Consumption	3.75	5.00	6.25
Vacuum Electric Utilization	0.64	0.85	1.06
Vacuum Separation Efficiency	0.73	0.97	1.21
Vacuum Throughput	7.50	10.00	12.50
Vacuum Sorters	1.50	2.00	2.50
Vacuum Lifetime	7.50	10.00	12.50
OCC Screen Investment Cost	131250.00	175000.00	218750.00
OCC Screen FIXOM	75000.00	100000.00	125000.00
OCC Screen Electricity Consumption	6.38	8.50	10.63
OCC Screen Electric Utilization	0.64	0.85	1.06
OCC Screen Separation Efficiency	0.53	0.70	0.88
OCC Screen Throughput	33.75	45.00	56.25
OCC Screen Sorters	1.50	2.00	2.50
OCC Screen Lifetime	7.50	10.00	12.50
Scalping Screen Investment Cost	210000.00	280000.00	350000.00
Scalping Screen FIXOM	75.00	100.00	125.00
Scalping Screen Electricity Consumption	7.50	10.00	12.50
Scalping Screen Electric Utilization	0.64	0.85	1.06
Scalping Screen Separation Efficiency	0.64	0.85	1.06
Scalping Screen Throughput	5.25	7.00	8.75
Scalping Screen Lifetime	7.50	10.00	12.50
Glass Breaker Screen Investment Cost	165000.00	220000.00	275000.00
Glass Breaker Screen FIXOM	7500.00	10000.00	12500.00
Glass Breaker Screen Electricity Consumption	22.50	30.00	37.50
Glass Breaker Screen Electric Utilization	0.64	0.85	1.06
Glass Breaker Screen Separation Efficiency	0.64	0.85	1.06
Glass Breaker Screen Throughput	6.75	9.00	11.25
Glass Breaker Screen Lifetime	7.50	10.00	12.50
Optical Glass Sorting Investment Cost	618750.00	825000.00	1031250.00
Optical Glass Sorting FIXOM	22500.00	30000.00	37500.00
Optical Glass Sorting Electricity Consumption	51.75	69.00	86.25
Optical Glass Sorting Electric Utilization	0.71	0.95	1.19
Optical Glass Sorting Separation Efficiency	0.74	0.98	1.23

Table F.1: Input distributions for automated single stream MRF analysis. (continued)

Parameter	**Minimum**	**Mode**	**Maximum**
Optical Glass Sorting Throughput	3.75	5.00	6.25
Optical Glass Sorting Sorters	2.25	3.00	3.75
Optical Glass Sorting Lifetime	7.50	10.00	12.50
Disc Screen Investment Cost	300000.00	400000.00	500000.00
Disc Screen FIXOM	97500.00	130000.00	162500.00
Disc Screen Electricity Consumption	4.13	5.50	6.88
Disc Screen Electric Utilization	0.64	0.85	1.06
Disc Screen Separation Efficiency	0.68	0.91	1.14
Disc Screen Throughput	15.75	21.00	26.25
Disc Screen Sorters	4.50	6.00	7.50
Disc Screen Lifetime	7.50	10.00	12.50
Optical PET Investment Cost	168750.00	225000.00	281250.00
Optical PET FIXOM	3750.00	5000.00	6250.00
Optical PET Electricity Consumption	9.75	13.00	16.25
Optical PET Electric Utilization	0.64	0.85	1.06
Optical PET Separation Efficiency	0.74	0.98	1.23
Optical PET Throughput	7.50	10.00	12.50
Optical PET Sorters	0.75	1.00	1.25
Optical PET Lifetime	7.50	10.00	12.50
Optical HDPE Investment Cost	337500.00	450000.00	562500.00
Optical HDPE FIXOM	7500.00	10000.00	12500.00
Optical HDPE Electricity Consumption	30.00	40.00	50.00
Optical HDPE Electric Utilization	0.64	0.85	1.06
Optical HDPE Separation Efficiency	0.74	0.98	1.23
Optical HDPE Throughput	7.50	10.00	12.50
Optical HDPE Sorters	0.75	1.00	1.25
Optical HDPE Lifetime	7.50	10.00	12.50
Magnet Investment Cost	26250.00	35000.00	43750.00
Magnet FIXOM	3750.00	5000.00	6250.00
Magnet Electricity Consumption	3.00	4.00	5.00
Magnet Electric Utilization	0.64	0.85	1.06
Magnet Separation Efficiency	0.74	0.98	1.23
Magnet Throughput	1.50	2.00	2.50
Magnet Lifetime	7.50	10.00	12.50
Eddy Current Investment Cost	96000.00	128000.00	160000.00
Eddy Current FIXOM	3750.00	5000.00	6250.00
Eddy Current Electricity Consumption	6.75	9.00	11.25

Table F.1: Input distributions for automated single stream MRF analysis. (continued)

Parameter	**Minimum**	**Mode**	**Maximum**
Eddy Current Electric Utilization	0.64	0.85	1.06
Eddy Current Separation Efficiency	0.73	0.97	1.21
Eddy Current Throughput	9.00	12.00	15.00
Eddy Current Sorters	0.75	1.00	1.25
Eddy Current Lifetime	7.50	10.00	12.50
1-Way Baler Investment Cost	412500.00	550000.00	687500.00
1-Way Baler FIXOM	3750.00	5000.00	6250.00
1-Way Baler Electricity Consumption	47.25	63.00	78.75
1-Way Baler Throughput	38.25	51.00	63.75
1-Way Baler Sorters	0.75	1.00	1.25
1-Way Baler Lifetime	7.50	10.00	12.50
2-Way Baler Investment Cost	397500.00	530000.00	662500.00
2-Way Baler FIXOM	3750.00	5000.00	6250.00
2-Way Baler Electricity Consumption	44.25	59.00	73.75
2-Way Baler Throughput	22.50	30.00	37.50
2-Way Baler Sorters	0.75	1.00	1.25
2-Way Baler Lifetime	7.50	10.00	12.50
Rolling Stock Investment Cost	262500.00	350000.00	437500.00
Rolling Stock FIXOM	3750.00	5000.00	6250.00
Rolling Stock Throughput	18.00	24.00	30.00
Rolling Stock Sorters	0.75	1.00	1.25
Rolling Stock Diesel Consumption	7.50	10.00	12.50
Rolling Stock Lifetime	7.50	10.00	12.50

Table F.2: Input distributions for manual single stream MRF analysis.

Parameter	**Minimum**	**Mode**	**Maximum**
Labor Management Rate	0.19	0.25	0.31
Labor Pay Rate	5.44	7.25	9.06
Driver Pay Rate	6.19	8.25	10.31
Fringe Rate	0.25	0.33	0.42
Paid Hours in Shift	6.75	9.00	11.25
Electricity Consumed in Offices	1.21	1.61	2.01
Electricity Consumed on Floor	0.53	0.71	0.88
Cost of Electricity	0.08	0.10	0.13
Cost of Diesel	0.63	0.84	1.05

Table F.2: Input distributions for manual single stream MRF analysis. (continued)

Parameter	Minimum	Mode	Maximum
Cost of Propane	0.32	0.42	0.53
Cost of Baling Wire	1.58	2.11	2.63
Days Operating Per Year	225.00	300.00	375.00
Annual Interest Rate	0.04	0.05	0.06
Indoor Floor Area Rate	0.85	1.14	1.42
Percent Office Floor Area	0.03	0.04	0.05
Life of MRF Structure	22.50	30.00	37.50
Construction Cost Rate	788.81	1051.74	1314.68
Engineering Rate	0.24	0.32	0.40
Land Cost Rate	484.43	645.90	807.38
Land Requirement Factor	2.12	2.83	3.54
Drum Feeder Investment Cost	112500.00	150000.00	187500.00
Drum Feeder FIXOM	75.00	100.00	125.00
Drum Feeder Electricity Consumption	11.25	15.00	18.75
Drum Feeder Electric Utilization	0.75	1.00	1.25
Drum Feeder Throughput	22.50	30.00	37.50
Drum Feeder Lifetime	7.50	10.00	12.50
Conveyor Investment Cost	37500.00	50000.00	62500.00
Conveyor FIXOM	7500.00	10000.00	12500.00
Conveyor Electricity Consumption	3.75	5.00	6.25
Conveyor Electric Utilization	0.64	0.85	1.06
Conveyor Throughput	22.50	30.00	37.50
Conveyor Lifetime	7.50	10.00	12.50
Scalping Screen Investment Cost	210000.00	280000.00	350000.00
Scalping Screen FIXOM	75.00	100.00	125.00
Scalping Screen Electricity Consumption	7.50	10.00	12.50
Scalping Screen Electric Utilization	0.64	0.85	1.06
Scalping Screen Separation Efficiency	0.64	0.85	1.06
Scalping Screen Throughput	5.25	7.00	8.75
Scalping Screen Lifetime	7.50	10.00	12.50
Glass Breaker Screen Investment Cost	165000.00	220000.00	275000.00
Glass Breaker Screen FIXOM	7500.00	10000.00	12500.00
Glass Breaker Screen Electricity Consumption	22.50	30.00	37.50
Glass Breaker Screen Electric Utilization	0.64	0.85	1.06
Glass Breaker Screen Separation Efficiency	0.73	0.97	1.21
Glass Breaker Screen Throughput	6.75	9.00	11.25
Glass Breaker Screen Lifetime	7.50	10.00	12.50

Table F.2: Input distributions for manual single stream MRF analysis. (continued)

Parameter	**Minimum**	**Mode**	**Maximum**
Optical Glass Sorting Investment Cost	618750.00	825000.00	1031250.00
Optical Glass Sorting FIXOM	22500.00	30000.00	37500.00
Optical Glass Sorting Electricity Consumption	51.75	69.00	86.25
Optical Glass Sorting Separation Efficiency	0.74	0.98	1.23
Optical Glass Sorting Throughput	3.75	5.00	6.25
Optical Glass Sorting Sorters	2.25	3.00	3.75
Optical Glass Sorting Lifetime	7.50	10.00	12.50
Magnet Investment Cost	26250.00	35000.00	43750.00
Magnet FIXOM	3750.00	5000.00	6250.00
Magnet Electricity Consumption	3.00	4.00	5.00
Magnet Electric Utilization	0.64	0.85	1.06
Magnet Separation Efficiency	0.74	0.98	1.23
Magnet Throughput	7.50	10.00	12.50
Magnet Lifetime	7.50	10.00	12.50
Eddy Current Investment Cost	96000.00	128000.00	160000.00
Eddy Current FIXOM	3750.00	5000.00	6250.00
Eddy Current Electricity Consumption	6.75	9.00	11.25
Eddy Current Electric Utilization	0.64	0.85	1.06
Eddy Current Separation Efficiency	0.73	0.97	1.21
Eddy Current Throughput	9.00	12.00	15.00
Eddy Current Sorters	0.75	1.00	1.25
Eddy Current Lifetime	7.50	10.00	12.50
1-Way Baler Investment Cost	412500.00	550000.00	687500.00
1-Way Baler FIXOM	3750.00	5000.00	6250.00
1-Way Baler Electricity Consumption	47.25	63.00	78.75
1-Way Baler Throughput	38.25	51.00	63.75
1-Way Baler Sorters	0.75	1.00	1.25
1-Way Baler Lifetime	7.50	10.00	12.50
2-Way Baler Investment Cost	397500.00	530000.00	662500.00
2-Way Baler FIXOM	3750.00	5000.00	6250.00
2-Way Baler Electricity Consumption	44.25	59.00	73.75
2-Way Baler Throughput	22.50	30.00	37.50
2-Way Baler Sorters	0.75	1.00	1.25
2-Way Baler Lifetime	7.50	10.00	12.50
Rolling Stock Investment Cost	262500.00	350000.00	437500.00
Rolling Stock FIXOM	3750.00	5000.00	6250.00
Rolling Stock Throughput	18.00	24.00	30.00

Table F.2: Input distributions for manual single stream MRF analysis. (continued)

Parameter	Minimum	Mode	Maximum
Rolling Stock Sorters	0.75	1.00	1.25
Rolling Stock Diesel Consumption	7.50	10.00	12.50
Rolling Stock Lifetime	7.50	10.00	12.50
Newsprint Separation Efficiency	0.68	0.90	1.13
Newsprint Sorting Capacity	0.51	0.68	0.85
Corr. Cardboard Separation Efficiency	0.68	0.90	1.13
Corr. Cardboard Sorting Capacity	0.51	0.68	0.85
Office Paper Separation Efficiency	0.68	0.90	1.13
Office Paper Sorting Capacity	0.51	0.68	0.85
Magazines Separation Efficiency	0.68	0.90	1.13
Magazines Sorting Capacity	0.51	0.68	0.85
3rd Class Mail Separation Efficiency	0.68	0.90	1.13
3rd Class Mail Sorting Capacity	0.51	0.68	0.85
HDPE - Translucent Containers Separation Efficiency	0.68	0.90	1.13
HDPE - Translucent Containers Sorting Capacity	0.04	0.05	0.07
HDPE - Pigmented Containers Separation Efficiency	0.68	0.90	1.13
HDPE - Pigmented Containers Sorting Capacity	0.07	0.09	0.11
PET - Containers Separation Efficiency	0.68	0.90	1.13
PET - Containers Sorting Capacity	0.04	0.05	0.07
Glass Transportation Distance	60.00	80.00	100.00

Appendix F.2 Parametric Analysis Inputs

Table F.3: Input values for cost analysis of an automated single stream MRF

Parameter	Units	-25%	-10%	0%	10%	25%
Eddy Current Separation Efficiency	%	0.73	0.87	0.97		
Optical HDPE Separation Efficiency	%	0.74	0.88	0.98		
OCC Screen Separation Efficiency	$/L	0.53	0.63	0.70	0.77	0.88
Optical PET Separation Efficiency	L/Mg	0.74	0.88	0.98		
Cost of Diesel	%	0.63	0.76	0.84	0.92	1.05

Table F.4: Input values for GWP analysis of an automated single stream MRF

Parameter	Units	-25%	-10%	0%	10%	25%
Rolling Stock Diesel Consumption	L/Mg	7.50	9.00	10.00	11.00	12.50
Scalping Screen Electricity Consumption	Mg/hr	7.50	9.00	10.00	11.00	12.50
Scalping Screen Throughput	kW	5.25	6.30	7.00	7.70	8.75
Scalping Screen Electric Utilization	kW	0.64	0.77	0.85	0.94	1.06
2-Way Baler Electricity Consumption	Mg/hr	44.25	53.10	59.00	64.90	73.75

Table F.5: Input values for cost analysis of an manually sorted single stream MRF

Parameter	Units	-25%	-10%	0%	10%	25%
Eddy Current Separation Efficiency	%	0.73	0.87	0.97		
Labor Pay Rate	$/hr	5.44	6.53	7.25	7.98	9.06
PET - Containers Sorting Capacity	%	0.04	0.05	0.05	0.06	0.07
HDPE - Translucent Containers Sorting Capacity	%	0.04	0.05	0.05	0.06	0.07
Corr. Cardboard Separation Efficiency	Mg/sorter-hr	0.68	0.81	0.90	0.99	

Table F.6: Input values for GWP analysis of a manually sorted single stream MRF

Parameter	Units	-25%	-10%	0%	10%	25%
Rolling Stock Diesel Consumption	L/Mg	7.50	9.00	10.00	11.00	12.50
Optical Glass Sorting Electricity Consumption	kW	51.75	62.10	69.00	75.90	86.25
2-Way Baler Throughput	Mg/hr	22.50	27.00	30.00	33.00	37.50
2-Way Baler Electricity Consumption	kW	44.25	53.10	59.00	64.90	73.75
1-Way Baler Throughput	Mg/hr	38.25	45.90	51.00	56.10	63.75

Appendix G Analysis Results

Appendix G.1 Monte Carlo Analysis Results

Table G.1: Spearman coefficients ranked according to magnitude when considering cost in a fully automated single-stream MRF.

Rank	Parameter	Spearman Coefficient
1	Eddy Current Separation Efficiency	-0.684
2	Optical HDPE Separation Efficiency	-0.551
3	OCC Screen Separation Efficiency	-0.305
4	Optical PET Separation Efficiency	-0.235
5	Cost of Diesel	0.107
6	Rolling Stock Diesel Consumption	0.104
7	Paid Hours in Shift	-0.049
8	Cost of Baling Wire	0.039
9	Days Operating Per Year	-0.035
10	Glass Breaker Screen Throughput	0.031
11	Cost of Electricity	0.028
12	Magnet Separation Efficiency	-0.027
13	Vacuum Lifetime	-0.025
14	1-Way Baler Lifetime	-0.024
15	Conveyor Investment Cost	0.024
16	Optical HDPE Investment Cost	-0.022
17	Vacuum Investment Cost	-0.021
18	Life of MRF Structure	0.021
19	Optical HDPE Lifetime	-0.020
20	Optical PET Investment Cost	0.020
21	Optical PET Electricity Consumption	0.019
22	Glass Breaker Screen FIXOM	0.018
23	Disc Screen Throughput	-0.017
24	Vacuum Sorters	-0.016
25	Optical Glass Sorting Investment Cost	0.016
26	Electricity Consumed in Offices	0.016
27	Land Cost Rate	0.015
28	Conveyor FIXOM	-0.015
29	Scalping Screen Throughput	-0.015
30	Optical HDPE Throughput	-0.015
31	2-Way Baler Sorters	0.015
32	Scalping Screen FIXOM	-0.014
33	Drum Feeder Lifetime	-0.014

Table G.1: Spearman coefficients ranked according to magnitude when considering cost in a fully automated single-stream MRF. (continued)

Rank	Parameter	Spearman Coefficient
34	Eddy Current Sorters	0.013
35	Labor Management Rate	-0.013
36	Conveyor Electric Utilization	0.013
37	Optical PET Electric Utilization	-0.013
38	Optical Glass Sorting Sorters	0.012
39	OCC Screen Electricity Consumption	0.012
40	Drum Feeder Electricity Consumption	0.011
41	Disc Screen Electric Utilization	-0.011
42	Optical Glass Sorting Electric Utilization	0.011
43	Eddy Current Electricity Consumption	0.011
44	Disc Screen Electricity Consumption	0.011
45	1-Way Baler Electricity Consumption	0.011
46	Scalping Screen Separation Efficiency	0.010
47	2-Way Baler Throughput	0.010
48	Fringe Rate	-0.010
49	Disc Screen Lifetime	-0.010
50	Scalping Screen Electricity Consumption	-0.009
51	Glass Breaker Screen Lifetime	0.009
52	Magnet Electric Utilization	0.009
53	Eddy Current Throughput	0.009
54	Engineering Rate	-0.009
55	Optical HDPE FIXOM	-0.009
56	Optical PET Throughput	0.009
57	Magnet FIXOM	0.008
58	Vacuum Electricity Consumption	-0.008
59	Disc Screen Sorters	-0.008
60	Conveyor Lifetime	0.008
61	2-Way Baler Electricity Consumption	-0.008
62	Rolling Stock Sorters	-0.008
63	Scalping Screen Lifetime	-0.008
64	OCC Screen FIXOM	-0.008
65	1-Way Baler Sorters	0.007
66	Magnet Throughput	0.007
67	Magnet Investment Cost	0.007
68	OCC Screen Throughput	-0.007
69	Driver Pay Rate	-0.007
70	Vacuum FIXOM	0.007
71	Optical PET Lifetime	0.007
72	Disc Screen Investment Cost	0.007

Table G.1: Spearman coefficients ranked according to magnitude when considering cost in a fully automated single-stream MRF. (continued)

Rank	Parameter	Spearman Coefficient
73	Drum Feeder Throughput	0.006
74	Eddy Current Investment Cost	-0.006
75	Magnet Lifetime	-0.006
76	1-Way Baler Investment Cost	-0.006
77	Optical HDPE Electricity Consumption	-0.006
78	Disc Screen FIXOM	-0.005
79	Optical Glass Sorting Electricity Consumption	-0.005
80	Vacuum Throughput	0.004
81	Optical PET Sorters	0.004
82	Rolling Stock Investment Cost	0.004
83	Scalping Screen Investment Cost	-0.004
84	1-Way Baler Throughput	-0.004
85	1-Way Baler FIXOM	-0.004
86	Annual Interest Rate	0.004
87	Glass Breaker Screen Investment Cost	0.004
88	Optical Glass Sorting Separation Efficiency	0.004
89	Scalping Screen Electric Utilization	-0.004
90	Eddy Current Electric Utilization	-0.004
91	OCC Screen Investment Cost	-0.004
92	Glass Breaker Screen Electric Utilization	0.004
93	Glass Breaker Screen Separation Efficiency	0.004
94	2-Way Baler Lifetime	-0.004
95	OCC Screen Electric Utilization	0.004
96	Construction Cost Rate	-0.004
97	Indoor Floor Area Rate	0.003
98	Rolling Stock FIXOM	0.003
99	Optical HDPE Electric Utilization	-0.003
100	Rolling Stock Lifetime	-0.003
101	Optical PET FIXOM	-0.003
102	Optical HDPE Sorters	0.002
103	Eddy Current Lifetime	0.002
104	Conveyor Electricity Consumption	0.002
105	Optical Glass Sorting Throughput	0.002
106	Cost of Propane	-0.002
107	Conveyor Throughput	0.002
108	OCC Screen Sorters	-0.002
109	2-Way Baler FIXOM	-0.001
110	Percent Office Floor Area	-0.001
111	Optical Glass Sorting FIXOM	0.001

Table G.1: Spearman coefficients ranked according to magnitude when considering cost in a fully automated single-stream MRF. (continued)

Rank	Parameter	Spearman Coefficient
112	Optical Glass Sorting Lifetime	-0.001
113	Rolling Stock Throughput	0.001
114	Land Requirement Factor	0.001
115	Labor Pay Rate	-0.001
116	Magnet Electricity Consumption	-0.001
117	Drum Feeder Electric Utilization	0.001
118	2-Way Baler Investment Cost	-0.001
119	Drum Feeder Investment Cost	0.001
120	Drum Feeder FIXOM	0.000
121	Vacuum Separation Efficiency	0.000
122	Vacuum Electric Utilization	0.000
123	Disc Screen Separation Efficiency	0.000
124	Eddy Current FIXOM	0.000
125	OCC Screen Lifetime	0.000
126	Glass Breaker Screen Electricity Consumption	0.000
127	Electricity Consumed on Floor	0.000

Table G.2: Spearman coefficients ranked according to magnitude when considering GWP in a fully automated single-stream MRF.

Rank	Parameter	Spearman Coefficient
1	Rolling Stock Diesel Consumption	0.984
2	Scalping Screen Electricity Consumption	0.076
3	Scalping Screen Throughput	-0.067
4	Scalping Screen Electric Utilization	-0.064
5	2-Way Baler Electricity Consumption	0.045
6	Optical HDPE Electric Utilization	-0.042
7	Drum Feeder Electric Utilization	-0.035
8	1-Way Baler Electricity Consumption	0.035
9	Disc Screen Throughput	-0.033
10	Optical Glass Sorting Electricity Consumption	0.033
11	Disc Screen Sorters	-0.031
12	Eddy Current Electricity Consumption	0.030
13	1-Way Baler Throughput	-0.029
14	2-Way Baler Throughput	-0.029
15	Disc Screen Electricity Consumption	0.028
16	Optical HDPE Electricity Consumption	0.028
17	Optical Glass Sorting Throughput	-0.026
18	Optical Glass Sorting Investment Cost	0.025
19	1-Way Baler Lifetime	-0.025

Table G.2: Spearman coefficients ranked according to magnitude when considering GWP in a fully automated single-stream MRF. (continued)

Rank	Parameter	Spearman Coefficient
20	Optical Glass Sorting Separation Efficiency	0.023
21	Drum Feeder Throughput	-0.023
22	Drum Feeder Investment Cost	-0.022
23	Optical PET Investment Cost	0.020
24	Land Cost Rate	-0.020
25	Vacuum Throughput	-0.020
26	Life of MRF Structure	0.019
27	Glass Breaker Screen Electricity Consumption	0.019
28	Magnet Electricity Consumption	0.018
29	Drum Feeder Electricity Consumption	0.018
30	Eddy Current Throughput	-0.017
31	Optical HDPE Throughput	-0.017
32	Driver Pay Rate	0.016
33	Magnet FIXOM	-0.015
34	OCC Screen Electric Utilization	0.015
35	Disc Screen Lifetime	0.014
36	OCC Screen Separation Efficiency	-0.014
37	Rolling Stock FIXOM	0.013
38	OCC Screen Throughput	-0.013
39	Optical PET Electric Utilization	-0.013
40	Glass Breaker Screen Investment Cost	-0.012
41	Vacuum Sorters	0.012
42	Scalping Screen Separation Efficiency	-0.012
43	Optical PET Separation Efficiency	-0.012
44	Eddy Current Investment Cost	0.011
45	Rolling Stock Sorters	-0.011
46	Optical PET Throughput	-0.011
47	Vacuum Separation Efficiency	-0.011
48	OCC Screen Sorters	0.010
49	Labor Management Rate	-0.010
50	Optical PET Sorters	0.010
51	Electricity Consumed in Offices	0.009
52	Cost of Baling Wire	-0.009
53	OCC Screen FIXOM	-0.009
54	Scalping Screen Lifetime	0.009
55	Vacuum FIXOM	0.009
56	Optical Glass Sorting Electric Utilization	-0.009
57	Optical HDPE FIXOM	-0.009
58	Percent Office Floor Area	0.009

Table G.2: Spearman coefficients ranked according to magnitude when considering GWP in a fully automated single-stream MRF. (continued)

Rank	Parameter	Spearman Coefficient
59	Magnet Electric Utilization	0.009
60	Glass Breaker Screen Electric Utilization	-0.009
61	Glass Breaker Screen Separation Efficiency	-0.009
62	Optical PET Lifetime	0.008
63	Glass Breaker Screen FIXOM	0.008
64	Optical Glass Sorting Sorters	-0.008
65	Days Operating Per Year	-0.007
66	Vacuum Electricity Consumption	0.007
67	Conveyor Lifetime	-0.007
68	Eddy Current Electric Utilization	-0.007
69	OCC Screen Investment Cost	-0.007
70	Conveyor Electric Utilization	-0.007
71	Vacuum Lifetime	0.007
72	2-Way Baler Sorters	-0.006
73	Conveyor Throughput	-0.006
74	Magnet Throughput	-0.006
75	2-Way Baler Investment Cost	-0.006
76	2-Way Baler Lifetime	0.006
77	Engineering Rate	0.006
78	Disc Screen FIXOM	0.006
79	Paid Hours in Shift	0.006
80	Rolling Stock Lifetime	-0.006
81	Optical Glass Sorting FIXOM	0.005
82	Rolling Stock Investment Cost	-0.005
83	OCC Screen Lifetime	-0.005
84	Optical HDPE Separation Efficiency	0.005
85	1-Way Baler FIXOM	-0.005
86	Disc Screen Separation Efficiency	-0.004
87	Drum Feeder FIXOM	0.004
88	Glass Breaker Screen Throughput	0.004
89	Optical HDPE Sorters	-0.004
90	Conveyor Electricity Consumption	-0.004
91	Vacuum Investment Cost	-0.004
92	Land Requirement Factor	0.004
93	Optical PET FIXOM	-0.004
94	Optical HDPE Investment Cost	-0.003
95	Scalping Screen FIXOM	-0.003
96	1-Way Baler Investment Cost	0.003
97	Cost of Electricity	-0.003

Table G.2: Spearman coefficients ranked according to magnitude when considering GWP in a fully automated single-stream MRF. (continued)

Rank	Parameter	Spearman Coefficient
98	Conveyor Investment Cost	0.003
99	Glass Breaker Screen Lifetime	0.003
100	Vacuum Electric Utilization	-0.003
101	Indoor Floor Area Rate	-0.003
102	Conveyor FIXOM	0.002
103	Optical Glass Sorting Lifetime	-0.002
104	Cost of Propane	-0.002
105	Cost of Diesel	-0.002
106	Drum Feeder Lifetime	0.002
107	Disc Screen Electric Utilization	-0.002
108	Eddy Current Lifetime	0.002
109	Magnet Investment Cost	0.002
110	OCC Screen Electricity Consumption	0.002
111	Fringe Rate	-0.002
112	Eddy Current Sorters	-0.002
113	Rolling Stock Throughput	-0.002
114	2-Way Baler FIXOM	0.001
115	Scalping Screen Investment Cost	-0.001
116	Magnet Separation Efficiency	-0.001
117	Annual Interest Rate	0.001
118	Labor Pay Rate	-0.001
119	Electricity Consumed on Floor	-0.001
120	Eddy Current Separation Efficiency	0.001
121	Construction Cost Rate	0.001
122	1-Way Baler Sorters	0.000
123	Eddy Current FIXOM	0.000
124	Optical PET Electricity Consumption	0.000
125	Magnet Lifetime	0.000
126	Disc Screen Investment Cost	0.000
127	Optical HDPE Lifetime	0.000

Table G.3: Spearman coefficients ranked according to magnitude when considering cost in a single-stream MRF employing manual sorting

Rank	Parameter	Spearman Coefficient
1	Eddy Current Separation Efficiency	-0.662
2	Labor Pay Rate	0.477
3	PET - Containers Sorting Capacity	-0.243
4	HDPE - Translucent Containers Sorting Capacity	-0.242
5	Corr. Cardboard Separation Efficiency	-0.232

Table G.3: Spearman coefficients ranked according to magnitude when considering cost in a single-stream MRF employing manual sorting. (continued)

Rank	Parameter	Spearman Coefficient
6	HDPE - Translucent Containers Separation Efficiency	-0.182
7	Rolling Stock Diesel Consumption	0.122
8	Fringe Rate	0.115
9	HDPE - Pigmented Containers Sorting Capacity	-0.107
10	Cost of Diesel	0.098
11	HDPE - Pigmented Containers Separation Efficiency	-0.089
12	Labor Management Rate	0.087
13	Newsprint Separation Efficiency	-0.072
14	PET - Containers Separation Efficiency	-0.069
15	Corr. Cardboard Sorting Capacity	-0.062
16	Cost of Baling Wire	0.038
17	Days Operating Per Year	-0.025
18	Magnet Separation Efficiency	-0.025
19	Newsprint Sorting Capacity	-0.024
20	Magnet FIXOM	0.023
21	2-Way Baler Investment Cost	0.023
22	Office Paper Separation Efficiency	0.021
23	Office Paper Sorting Capacity	-0.021
24	Rolling Stock Lifetime	0.021
25	Cost of Propane	0.021
26	Conveyor Electric Utilization	-0.020
27	2-Way Baler Lifetime	0.020
28	3rd Class Mail Sorting Capacity	-0.019
29	Indoor Floor Area Rate	0.019
30	Magazines Separation Efficiency	0.017
31	Magazines Sorting Capacity	-0.017
32	Optical Glass Sorting Lifetime	-0.016
33	Eddy Current Electricity Consumption	0.015
34	Optical Glass Sorting Throughput	0.015
35	Paid Hours in Shift	-0.015
36	Optical Glass Sorting Separation Efficiency	-0.014
37	Eddy Current FIXOM	0.013
38	3rd Class Mail Separation Efficiency	-0.013
39	1-Way Baler Electricity Consumption	0.013
40	Rolling Stock Throughput	-0.012
41	Drum Feeder Electricity Consumption	-0.012
42	Magnet Throughput	0.012
43	Magnet Lifetime	0.012
44	Optical Glass Sorting Electricity Consumption	-0.011

Table G.3: Spearman coefficients ranked according to magnitude when considering cost in a single-stream MRF employing manual sorting. (continued)

Rank	Parameter	Spearman Coefficient
45	Glass Breaker Screen Throughput	-0.011
46	Glass Breaker Screen Separation Efficiency	-0.010
47	Drum Feeder FIXOM	0.010
48	Optical Glass Sorting FIXOM	-0.010
49	Optical Glass Sorting Sorters	-0.010
50	Driver Pay Rate	0.009
51	Land Cost Rate	0.009
52	Electricity Consumed on Floor	-0.009
53	Eddy Current Throughput	-0.009
54	1-Way Baler FIXOM	0.008
55	Magnet Electric Utilization	-0.008
56	Percent Office Floor Area	0.008
57	Drum Feeder Electric Utilization	-0.007
58	Drum Feeder Lifetime	0.007
59	Cost of Electricity	0.007
60	Engineering Rate	0.007
61	Scalping Screen Lifetime	-0.007
62	Glass Breaker Screen Investment Cost	-0.007
63	Electricity Consumed in Offices	0.006
64	Life of MRF Structure	-0.006
65	Optical Glass Sorting Investment Cost	-0.006
66	2-Way Baler Sorters	0.006
67	Eddy Current Lifetime	0.006
68	Construction Cost Rate	0.005
69	Conveyor Investment Cost	-0.005
70	Rolling Stock FIXOM	-0.005
71	Glass Breaker Screen Lifetime	-0.005
72	Land Requirement Factor	-0.005
73	Drum Feeder Investment Cost	0.005
74	Conveyor Throughput	0.005
75	Scalping Screen Electricity Consumption	-0.005
76	Eddy Current Investment Cost	-0.005
77	Glass Breaker Screen FIXOM	0.005
78	Rolling Stock Investment Cost	-0.003
79	1-Way Baler Investment Cost	0.003
80	1-Way Baler Lifetime	-0.003
81	Scalping Screen Separation Efficiency	0.003
82	Magnet Electricity Consumption	0.003
83	Scalping Screen Electric Utilization	0.003

Table G.3: Spearman coefficients ranked according to magnitude when considering cost in a single-stream MRF employing manual sorting. (continued)

Rank	Parameter	Spearman Coefficient
84	2-Way Baler FIXOM	0.003
85	Annual Interest Rate	0.003
86	2-Way Baler Electricity Consumption	0.003
87	Conveyor FIXOM	0.003
88	2-Way Baler Throughput	-0.002
89	Rolling Stock Sorters	0.002
90	Conveyor Lifetime	0.002
91	Glass Breaker Screen Electric Utilization	-0.002
92	Magnet Investment Cost	-0.002
93	Eddy Current Electric Utilization	-0.001
94	1-Way Baler Throughput	-0.001
95	1-Way Baler Sorters	0.001
96	Glass Transportation Distance	0.001
97	Drum Feeder Throughput	0.001
98	Conveyor Electricity Consumption	-0.001
99	Scalping Screen Throughput	-0.001
100	Glass Breaker Screen Electricity Consumption	0.001
101	Eddy Current Sorters	0.000
102	Scalping Screen Investment Cost	0.000
103	Scalping Screen FIXOM	0.000

Table G.4: Spearman coefficients ranked according to magnitude when considering GWP in a single-stream MRF employing manual sorting.

Rank	Parameter	Spearman Coefficient
1	Rolling Stock Diesel Consumption	0.995
2	Optical Glass Sorting Electricity Consumption	0.042
3	2-Way Baler Throughput	-0.033
4	2-Way Baler Electricity Consumption	0.033
5	1-Way Baler Throughput	-0.032
6	Labor Pay Rate	0.030
7	Optical Glass Sorting Throughput	-0.029
8	Drum Feeder Electric Utilization	-0.026
9	Glass Breaker Screen Electricity Consumption	0.025
10	Eddy Current Sorters	0.024
11	Drum Feeder Throughput	-0.024
12	Drum Feeder Electricity Consumption	0.024
13	1-Way Baler Electricity Consumption	0.023
14	Optical Glass Sorting Investment Cost	-0.022
15	Eddy Current Lifetime	-0.022

Table G.4: Spearman coefficients ranked according to magnitude when considering GWP in a single-stream MRF employing manual sorting. (continued)

Rank	Parameter	Spearman Coefficient
16	Eddy Current Electric Utilization	-0.021
17	Optical Glass Sorting Lifetime	-0.020
18	Glass Breaker Screen Throughput	-0.020
19	Optical Glass Sorting Sorters	-0.019
20	Glass Transportation Distance	0.019
21	Drum Feeder Investment Cost	-0.018
22	HDPE - Pigmented Containers Separation Efficiency	0.017
23	Cost of Baling Wire	-0.016
24	Newsprint Separation Efficiency	0.016
25	Magnet Investment Cost	-0.015
26	Cost of Diesel	0.015
27	Drum Feeder FIXOM	-0.015
28	Glass Breaker Screen Electric Utilization	-0.014
29	Newsprint Sorting Capacity	-0.014
30	Scalping Screen FIXOM	0.013
31	Cost of Propane	0.013
32	Electricity Consumed in Offices	0.013
33	Eddy Current Separation Efficiency	-0.013
34	Magnet Electric Utilization	-0.013
35	Paid Hours in Shift	-0.012
36	Corr. Cardboard Sorting Capacity	0.012
37	Magnet Electricity Consumption	0.012
38	1-Way Baler Sorters	-0.012
39	1-Way Baler FIXOM	-0.012
40	Office Paper Separation Efficiency	-0.012
41	Construction Cost Rate	-0.012
42	Rolling Stock Lifetime	-0.012
43	Percent Office Floor Area	0.012
44	Life of MRF Structure	0.011
45	Glass Breaker Screen Lifetime	-0.011
46	Rolling Stock Investment Cost	0.011
47	2-Way Baler FIXOM	0.010
48	PET - Containers Sorting Capacity	0.010
49	Magnet Throughput	-0.010
50	Magnet Lifetime	-0.010
51	Indoor Floor Area Rate	0.010
52	2-Way Baler Sorters	-0.010
53	Annual Interest Rate	0.010
54	Conveyor Electricity Consumption	0.010

Table G.4: Spearman coefficients ranked according to magnitude when considering GWP in a single-stream MRF employing manual sorting. (continued)

Rank	Parameter	Spearman Coefficient
55	3rd Class Mail Separation Efficiency	-0.009
56	1-Way Baler Lifetime	-0.009
57	Scalping Screen Investment Cost	0.009
58	Glass Breaker Screen Separation Efficiency	0.009
59	Optical Glass Sorting Separation Efficiency	-0.008
60	Scalping Screen Lifetime	0.008
61	Magazines Separation Efficiency	-0.007
62	Conveyor Throughput	-0.007
63	1-Way Baler Investment Cost	0.007
64	Cost of Electricity	0.006
65	Scalping Screen Electricity Consumption	0.006
66	Scalping Screen Electric Utilization	-0.006
67	HDPE - Pigmented Containers Sorting Capacity	-0.006
68	Corr. Cardboard Separation Efficiency	-0.006
69	Conveyor Electric Utilization	-0.006
70	Conveyor Lifetime	-0.006
71	Labor Management Rate	0.006
72	PET - Containers Separation Efficiency	-0.006
73	Land Requirement Factor	0.006
74	Rolling Stock Sorters	0.005
75	Glass Breaker Screen FIXOM	0.005
76	Eddy Current Electricity Consumption	0.005
77	2-Way Baler Lifetime	-0.005
78	Rolling Stock FIXOM	0.004
79	Office Paper Sorting Capacity	0.004
80	Rolling Stock Throughput	0.004
81	2-Way Baler Investment Cost	0.004
82	Drum Feeder Lifetime	0.004
83	Conveyor Investment Cost	-0.003
84	Electricity Consumed on Floor	0.003
85	Optical Glass Sorting FIXOM	0.003
86	Engineering Rate	0.003
87	Eddy Current Investment Cost	-0.003
88	Scalping Screen Throughput	0.003
89	Magnet FIXOM	-0.003
90	Magazines Sorting Capacity	-0.003
91	Conveyor FIXOM	-0.002
92	Eddy Current FIXOM	0.002
93	Driver Pay Rate	0.001

Table G.4: Spearman coefficients ranked according to magnitude when considering GWP in a single-stream MRF employing manual sorting. (continued)

Rank	Parameter	Spearman Coefficient
94	Glass Breaker Screen Investment Cost	0.001
95	Magnet Separation Efficiency	0.001
96	Land Cost Rate	0.001
97	HDPE - Translucent Containers Sorting Capacity	0.001
98	Fringe Rate	-0.001
99	HDPE - Translucent Containers Separation Efficiency	0.001
100	3rd Class Mail Sorting Capacity	0.000
101	Eddy Current Throughput	0.000
102	Scalping Screen Separation Efficiency	0.000
103	Days Operating Per Year	0.000

Appendix G.2 Parametric Analysis Results

Table G.5: Output values for automated single stream MRF cost when imposing independent variation of input parameters by -25%, -10%, no change, +10%, +25%. Hashed cells indicate those parameters rendered infeasible after being scaled by the specified percentage.

Input Parameter	Units	-25%	-10%	0%	+10%	+25%
Eddy Current Separation Efficiency	%	-118.46	-126.44	-131.77		
Optical HDPE Separation Efficiency	%	-120.73	-127.35	-131.77		
OCC Screen Separation Efficiency	$/L	-125.60	-129.30	-131.77	-134.24	-137.94
Optical PET Separation Efficiency	L/Mg	-126.84	-129.80	-131.77		
Cost of Diesel	%	-133.81	-132.59	-131.77	-130.95	-129.73

Table G.6: Output values for automated single stream MRF GWP when imposing independent variation of input parameters by -25%, -10%, no change, +10%, +25%. Hashed cells indicate those parameters rendered infeasible after being scaled by the specified percentage.

Input Parameter	Units	-25%	-10%	0%	+10%	+25%
Rolling Stock Diesel Consumption	L/Mg	18.66	21.38	23.20	25.02	27.74
1-Way Baler Throughput	Mg/hr	22.86	23.07	23.20	23.33	23.54
1-Way Baler Electricity Consumption	kW	23.65	23.35	23.20	23.08	22.93
2-Way Baler Electricity Consumption	kW	23.65	23.35	23.20	23.08	22.93
2-Way Baler Throughput	Mg/hr	23.06	23.14	23.20	23.26	23.34

Table G.7: Output values for manually separated single stream MRF cost when imposing independent variation of input parameters by -25%, -10%, no change, +10%, +25%. Hashed cells indicate those parameters rendered infeasible after being scaled by the specified percentage.

Input Parameter	Units	-25%	-10%	0%	+10%	+25%
Eddy Current Separation Efficiency	%	-81.88	-90.09	-95.57		
Labor Pay Rate	$/hr	-106.44	-99.92	-95.57	-91.22	-84.70
Corr. Cardboard Separation Efficiency	%	-91.18	-94.11	-95.57	-96.77	-98.20
HDPE - Translucent Containers Separation Efficiency	%	-91.32	-94.15	-95.57	-96.73	-98.12
HDPE - Translucent Containers Sorting Capacity	Mg/sorter-hr	-90.41	-93.50	-95.57	-97.64	

Table G.8: Output values for manually separated single stream MRF GWP when imposing independent variation of input parameters by -25%, -10%, no change, +10%, +25%. Hashed cells indicate those parameters rendered infeasible after being scaled by the specified percentage.

Input Parameter	**Units**	**-25%**	**-10%**	**0%**	**+10%**	**+25%**
Rolling Stock Diesel Consumption	L/Mg	18.78	21.61	23.50	25.39	28.22
1-Way Baler Electricity Consumption	kW	23.33	23.43	23.50	23.57	23.67
1-Way Baler Throughput	Mg/hr	23.69	23.56	23.50	23.45	23.38
2-Way Baler Electricity Consumption	kW	23.36	23.44	23.50	23.56	23.64
2-Way Baler Throughput	Mg/hr	23.70	23.57	23.50	23.44	23.38