TRANSFER STATION PROCESS MODEL

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1. INTRODUCTION

The objective of the transfer station process model is to calculate the cost and life-cycle inventory (LCI) for municipal solid waste (MSW) transfer stations. Costs and LCI coefficients are calculated on the basis of user-input and default design information that is described in this document. These coefficients take into account both the quantity and composition of the waste entering triangle stations. They are used in the solid waste management model to calculate the total system cost and LCI for solid waste management alternatives that involve transfer stations. Five roadway vehicle transfer station types (TR1 to TR5) and three rail transfer station types (RT1 to RT3) are modeled.

The design basis for each of the eight transfer station types is described in Section 2 of this document. Section 3 presents the governing equations for economic and LCI parameters. Default values for input parameters are given in Appendices 1 and 2.

2. CONCEPTUAL DESIGN

2.1 GENERAL

The following general description applies to all types of transfer stations modeled. Transfer stations require a covered structure that houses collection vehicle unloading areas, trailer loading bays, refuse tipping floor space, and office space. Collection vehicles enter a transfer station via a scale house, then proceed to unloading areas. Therefore, the site is partially paved to accommodate maneuvering of both collection and transport vehicles and container storage. Facility staff operate waste handling equipment to load and distribute refuse in hauling containers and to move refuse on the tipping floor. Office space includes an employee rest area and locker rooms and an administrative work area. The loading bay area includes a trailer footprint and trailer maneuvering space. The cost of refuse drop-off areas open to the general public is included in the construction cost for each design.

The five roadway vehicle transfer stations (TR1 to TR5) are categorized by the type of material processed. Rail transfer station nodes (RT1 to RT3) consist of a transfer station for unloading mixed refuse from collection vehicles onto rail cars and receiving transfer stations located at a traditional landfill (D1) and an enhanced bioreactor landfill (D3). Table 1 identifies all transfer station types, and the remainder of this section presents the design for each type.

Table 1: Transfer Station Types

Transfer Station	Material Processed
TR1	mixed MSW
TR2	commingled recyclables
TR3	separately bagged MSW and commingled recyclables in a single compartment, fiber in separate compartment
TR4	separately bagged MSW and commingled recyclables in separate compartments, fiber in separate compartment
TR5	pre-sorted recyclables
RT1	rail transfer of MSW from collection vehicles
RT2	rail transfer of MSW from trains to landfill
RT3	rail transfer of MSW from trains to enhanced bioreactor landfill

2.2 TR1 -- MIXED WASTE

For mixed waste transfer stations, the user selects from five design options summarized in Table 2. The major differences between these design options are single or multi-level design, the presence or absence of a compactor, and the type of rolling stock required. In listing rolling stock, excavator refers to a clam shell crane. With a two-level loading bay, open-top trailers are at a level below the tipping floor and may be loaded either by allowing vehicles to directly tip refuse into trailers or by rolling stock pushing refuse from the tipping floor into trailers. One-level loading bays require that refuse be lifted from a tipping floor into hauling trailers. Designs with tipping floors have reduced trailer loading time because more collection vehicles are able to unload simultaneously relative to a direct tip arrangement. Note that when a compactor option is selected a stationary compactor is used. The haul vehicle density will increase compared to densities achieved for options in which waste is compacted with an excavator.

Table 2: Five TR1 Transfer Station Designs

Design	Tipping floor/ direct tip	Loading Bay Type	Compaction	Loading Equipment
1	tipping floor	1 level	no	excavator front-end loader loading bay scale
2	tipping floor	2 level	no	front-end loader excavator loading bay scale
3	direct tip	2 level	no	backhoe loading bay scale
4	tipping floor	1 level	yes	front-end loader
5	direct tip	2 level	yes	backhoe

2.2.1 Design 1 -- One-Level Loading Bay with Tipping Floor

Collection vehicles unload onto a tipping floor that is sized for peak incoming traffic. The unloading area is also sized for peak traffic. An excavator (clam shell crane) is situated at an elevation approximately 5 feet above the tipping floor level to increase the operator visibility of the tipping floor while minimizing site preparation. This design incorporates the use of a loading bay scale to minimize trailer loading time. Loading bay scales ensure that regulated wheel loads are achieved during loading to avoid later time-consuming load adjustments. This design is typically used for larger capacity facilities (over approximately 500 TPD).

2.2.2 Design 2 -- Two-Level Loading Bay with Tipping Floor

As in design 1, refuse is unloaded onto a tipping floor that is sized for peak storage and loading area requirements. Unlike design 1, two-level trailer loading bays allow front-end loaders to push refuse from the tipping floor into open-top trailers on the level below. Excavators compact and redistribute refuse in trailers. Similar to Design 1, a loading bay scale is used to ensure that regulated axle loadings are met for tractor trailers.

2.2.3 Design 3 -- Two-Level Loading Bay with Direct Tip

In this option, collection vehicles unload directly into open-top trailers. Direct tip loading requires more trailer loading time than other options because loading time includes time to maneuver and unload collection vehicles. Each bay includes area requirements for collection vehicle unloading and maneuvering and for refuse storage during operational problems. A backhoe is used to compact and redistribute refuse inside the trailer and to keep the unloading area debris-free. Trailer loading bay scales are used to ensure that regulated axle loadings are met.

2.2.4 Design 4 -- One-Level Loading Bay with Tipping Floor And Compactor

For this design option, refuse is unloaded onto a tipping floor and lifted by a front-end loader into a hopper. The hopper feeds a compactor that pushes refuse into a trailer. Each loading bay has adequate space for a compactor, a trailer, and vehicle maneuvering.

2.2.5 Design 5 -- One-Level Loading Bay with Direct Tip And Compactor

Incoming collection vehicles unload directly into a hopper that feeds a compactor. The loading bay area accommodates a trailer, hopper, compactor, and space for vehicle maneuvering. Loading bays also allow for waste storage during equipment failure. Backhoes assist in loading the hopper.

2.3 TR2 – COMMINGLED RECYCLABLES

At a commingled recyclables transfer station, collection vehicles arrive with fibrous content material in a separate compartment. Fibrous content material includes all paper items that are recovered. Commingled recyclables are loaded from collection vehicles into tractor trailers. The user can select from the same five transfer station designs described for TR1 to process commingled recyclables. The percentage of broken glass is a user-input model parameter to account for unrecoverable glass at the downstream material recovery facilities. However, for all TR2 designs, fibrous content material is processed in the same manner. Commingled transfer stations have a separate unloading area where fibrous content material is tipped onto a tipping floor and loaded into hauling trailers.

2.4 TR3 -- SINGLE COMPARTMENT CO-COLLECTION, FIBROUS CONTENT MATERIAL SEPARATE

Single compartment co-collection vehicles have commingled recyclables (typically in blue bags), mixed refuse (typically in black bags), and fibrous content material (typically in blue bags) in one compartment. A single design option is provided for this facility. Co-collected blue and black bags are tipped onto a tipping floor, then pushed by front-end loaders onto a conveyer. Blue bags are manually sorted from the conveyer stream into separate piles for commingled recyclables and fibrous content material, while black bags remaining on the conveyer feed into a compactor. Each mixed refuse trailer loading bay has a compactor that is fed by a separate in-floor conveyer. Manually separated blue bags are stored until loaded into compactor hoppers with front-end loaders and backhoes. If the user does not want to include compactors for commingled recyclables, then the input values for cost and energy usage by compactors processing commingled recyclables can be set to zero. Separated blue bags containing fibrous content material are stored until loaded into hauling trailers with front-end loaders and backhoes. In summary, the facility area for TR3 consists of a tipping floor for mixed black and blue bags, separate storage areas for separated blue bags containing commingled recyclables and for blue bags containing fibrous content material, and separate tractor trailer loading areas for all three types of material processes.

2.5 TR4 – CO-COLLECTION IN THREE SEPARATE COMPARTMENTS

Three compartment collection vehicles deliver source-separated black bags (mixed refuse), blue bags containing commingled recyclables, and blue bags containing fibrous content material to TR4. Recyclables and fibrous content materials are unloaded onto separate tipping floors and then loaded into trailers with front-end loaders. Mixed refuse is directly tipped into a compactor via a hopper. Rolling stock includes front-end loaders and backhoes.

2.6 TR5 – PRE-SORTED RECYCLABLES

A presorted recyclable transfer station is expected to operate at low capacities relative to other transfer stations. Thus, the facility is of a simpler design and includes a roof but no walls. Recyclables are unloaded into separate roll-on/roll-off containers with adequate collection vehicle maneuvering. A small backhoe is used for material handling. Full containers are removed from loading areas and stored on site until transported.

2.7 RT1 -- MSW RAIL TRANSFER FROM COLLECTION VEHICLES

Mixed refuse is transferred from collection vehicles to a rail car at RT1. The user selects from two design options for RT1 transfer stations. Both options have tipping floor storage space; however, the first is a one-level design and the second is a two-level design. For the one-level design, excavators are used to load containers. For the two-level design, refuse is pushed from the tipping floor into a preload compactor. Equipment for both designs includes front-end-loaders to push refuse on the tipping floor and container handling units (CHU) to mobilize rail containers. For either design option, transport containers are loaded, then lifted with CHUs and moved with tractors to a loading location for rail car chassis. Thus, the rail haul transfer station is not required to have onsite rail spurs.

2.8 RT2 -- MSW RAIL TRANSFER FROM TRAINS TO LANDFILL (D1)

At the landfill rail haul transfer station, a container handling unit unloads incoming containers of MSW into a storage area. Storage space accommodates the transfer station's entire capacity because the daily MSW capacity may arrive in a single shipment. Stored containers are loaded onto tractors, then hauled to the landfill working face. Tippers unload containers by inclining them greater than 60 degrees from horizontal. (The cost of the tipper is included in the transfer station cost.) The area requirements include container storage, rail car unloading space, and tractor loading space.

2.9 RT3 -- MSW RAIL TRANSFER TROM TRAINS TO ENHANCED BIOREACTOR (D3)

The design of rail transfer stations receiving containers at an enhanced bioreactor is the same as the design for RT2.

3. GOVERNING EQUATIONS

The process model equations for a specific transfer station are based on typical operating practices for that transfer station. The economic parameters include annualized construction and equipment capital costs and operating costs per ton processed at the facility. LCI parameters include energy consumption and emissions such as waterborne releases, atmospheric emissions, and solid waste production associated with energy consumption and wash water at the transfer station. The cost and LCI factors associated with transport to and from a transfer station are determined in the collection and transport process models, respectively.

This section presents equations required to calculate the cost and LCI factors for MSW and recyclables in each of the eight transfer stations modeled. Default values for each of the user-input parameters utilized in the equations below are listed in Appendix 1 along with their respective units and description. The set of input values varies slightly depending on the type of transfer station. Values referenced from other models (electric energy, collection, common) developed for this modeling effort are listed by their respective model in Tables 3 and 4. Default values for these parameters are given in Appendix 2.

Table 3: Electric Energy Process Model References

Description	Variable Name	Units
Btu conversion factor	region_btu_per_elec_kwh	Btu/ kWh
Electricity Precombustion Emission Factor	*emission*_r_tot*	lb/kWh

**Emission* refers to atmospheric, solid waste, and water pollutants. For example, lb CO/kWh would be expressed as co_r_tot.

Table 4: Common Process Model References

Description	Variable Name*,†	Units
Density of Mixed Refuse in Collection Vehicle	D_cv	lb/cu. yd.
Loose Density of Recyclable Items	*item*_D_rcv*	lb/cu. yd.
Weight Fraction of Items in MSW	*item*_RES_WT_FRAC*	lb of item/lb total
Electricity cost	elec_c	$/ kWh
Diesel Precombustion Energy Usage	dsl_pc_enrg	Btu/gallon
Diesel Combustion Energy Usage	dsl_enrg	Btu/gallon
Diesel Fuel Cost	dies_c	$/gallon
Diesel Production (Precombustion) Emission	*emission* _d_em**	lb/1,000 gallon produced
Tipper Operating Emissions	*emission* _tip_em**	lb/hour
Tractor Operating Emissions	*emission* _tr_em**	lb/hour
Crane Operating Emissions	*emission* _cr_em**	lb/hour
Front-end Loader Operating Emissions	*emission* _fel_em**	lb/hour
Excavator Operating Emissions	*emission* _exc_em**	lb/hour
Backhoe Operating Emissions	*emission* _bh_em**	lb/hour
20-Year Global Warming Potential	GWP_*emission***	greenhouse gas equivalent / lb emission

**Item* designates MSW categories listed in Appendix 3. For example, the density of fibrous content material prior to compaction is fcm_d_rcv.
†*Emission* refers to atmospheric, solid waste, and water pollutants. See example in Table 3.

Table 5 lists output value names for TR1. The variable description and name pattern also apply to transfer stations TR2 to TR5 and RT1 to RT3. In the case of transfer stations handling recyclables, TR2 to TR5, certain factors are calculated per ton of specific recyclable to reflect density differences among recyclables. In this case, the output variable names listed in Table 5 have an additional prefix. For example, particulate emissions associated with fibrous content material at TR2 would be designated as fcm_tr2_pm_factor.

The solid waste management model uses these parameters to evaluate whether to incorporate each transfer station in a waste management strategy. This evaluation is made in consideration of the site-specific collection, treatment, and disposal alternatives available. Parameter equations required to calculate output values for each transfer station type are presented in the sections below. Each section of transfer station equations is further divided into two subsections of calculations for cost and LCI factors. Values of variables referenced in the equations presented below that are not included in Tables 3 through 5 are presented in the input values section of Appendix 1.

Table 5: Process model Output Values

Cost Factor

Cost Coefficient	$/ton	TR1_COST_COEF

LCI FACTORS

Energy Usage Factors

Electricity Usage	Btu/ton	TR1_ELEC_COEF
Diesel Usage	Btu/ton	TR1_DIES_COEF
Total Energy Usage	Btu/ton	TR1_ENG_TL

Water Usage Factor

Facility Wash Down	gallon/ton	TR1_WR USE_FACTOR

Atmospheric Emissions

Total Particulates	lb/ton	TR1_pm_FACTOR
Particulates (PM10)	lb/ton	TR1_pm10_FACTOR
Nitrogen Oxides	lb/ton	TR1_no_FACTOR
Hydrocarbons (non CH_4)	lb/ton	TR1_hc_FACTOR
Sulfur Oxides	lb/ton	TR1_so_FACTOR
Carbon Monoxide	lb/ton	TR1_co_FACTOR
CO_2 (biomass)	lb/ton	TR1_co2_bm_FACTOR
CO_2 (non biomass)	lb/ton	TR1_co2_FACTOR
Ammonia	lb/ton	TR1_a_nh3_FACTOR
Lead	lb/ton	TR1_a_pb_ FACTOR
Methane	lb/ton	TR1_ch4_FACTOR
Hydrochloric acid	lb/ton	TR1_hcl_FACTOR
Greenhouse Gas Equivalent	greenhouse equivalents/ton	TR1_gwp_FACTOR

Solid Waste

Solid Waste #1	lb/ton	TR1_SW1_FACTOR
Solid Waste #2	lb/ton	TR1_SW1_FACTOR
Solid Waste #3	lb/ton	TR1_SW1_FACTOR
Solid Waste #4	lb/ton	TR1_SW1_FACTOR
Solid Waste #5	lb/ton	TR1_SW1_FACTOR

Waterborne Emissions

Dissolved Solids	lb/ton	TR1_ds_FACTOR
Suspended Solids	lb/ton	TR1_ss_FACTOR
BOD	lb/ton	TR1_bad_FACTOR
COD	lb/ton	TR1_cad_FACTOR
Oil	lb/ton	TR1_oil_FACTOR
Sulfuric Acid	lb/ton	TR1_h2so4_FACTOR
Iron	lb/ton	TR1_fe_FACTOR
Ammonia	lb/ton	TR1_w_nh3_FACTOR
Copper	lb/ton	TR1_cu_FACTOR
Cadmium	lb/ton	TR1_cd_FACTOR
Arsenic	lb/ton	TR1_as_FACTOR
Mercury	lb/ton	TR1_hg_FACTOR
Phosphate	lb/ton	TR1_p_x_FACTOR
Selenium	lb/ton	TR1_se_FACTOR
Chromium	lb/ton	TR1_cr_FACTOR
Lead	lb/ton	TR1_w_pb_FACTOR
Zinc	lb/ton	TR1_zn_FACTOR

3.1 EQUATIONS: TR1 -- MIXED WASTE

The following sections give equations for TR1 cost and LCI factors. To simplify the presentation, the prefix (TR1_) for variables referenced in this section have been omitted from the variable names given below.

3.1.1 Cost Factors

The following cost factor equations apply to all five TR1 design options. Total transfer station cost is obtained by summing operating costs and annualized capital costs for the facility and equipment:

EQ 3.1.1

$$TR1\_COST\_FACTOR = \frac{(FAC\_AC + EQ\_COST + OP\_AC)}{ywd}$$

$$\begin{aligned} \text{where } TR1\_COST\_FACTOR &= \text{cost per ton processed at transfer station, \$/ton} \\ FAC\_AC &= \text{annual capital cost for facility (EQ. 3.1.2), \$/TPD - year} \\ EQ\_AC &= \text{annual equipment capital costs (EQ. 3.1.12), \$/TPD - year} \\ OP\_COST &= \text{annual operating costs (EQ. 3.1.14), \$/TPD - year} \\ ywd &= \text{working days in a year, days/year} \end{aligned}$$

An explanation of calculations for each component of EQ 3.1.1 follows. The explanation is divided into three parts: facility capital costs, equipment capital costs, and operating costs. In the remainder of this report, similar sectioning of cost components will occur whenever it is applicable.

3.1.1.1 Facility Capital Costs

Annualized facility capital cost per ton MSW processed (FAC_AC) is determined from the sum of facility capital costs:

EQ 3.1.2

Facility Capital Cost (FAC_AC) = (Construction + Paving and Site work + Land + Engineering) X CRF

Since components of facility capital cost are dependent on the transfer station building area requirement per ton MSW processed, calculations begin by determining building area as the sum of various area requirements:

EQ 3.1.3

Facility Area per Ton MSW = Refuse storage + Vehicle unloading + Trailer loading bays + Office space

Required storage area for refuse on the tipping floor is calculated by:

EQ 3.1.4

$$STR\_A = \frac{1.25 * stor * 2000 * 27}{ht * D\_cv}$$

where STR_A = refuse tipping floor storage area, sq. ft./TPD
$stor$ = storage time on the tipping floor, days
ht = height of refuse stored on the tipping floor, ft.
D_cv = density of refuse on tipping floor, lb/cu. yd.
1.25 factor to account for tipping floor expansion and vehicle manueverin g ,
2,000 lb/ton and 27 cu. ft./cu. yd conversion factors.

When a direct tip design option is chosen, the default value for storage time on the tipping floor is zero. For direct tip designs, refuse storage space required during equipment malfunction is included in vehicle unloading areas.

Collection vehicle unloading area per ton processed is determined by:

EQ 3.1.5

$$CV\_UL\_A = \frac{single\_cv\_ul\_a * cv\_ul\_hr * 2000 * peak\_fct}{EWh\_d * cv\_load}$$

where CV_UL_A = area required for collection vehicle unloading, sq. ft./TPD
$single\_cv\_ul\_a$ = area required for a single collection vehicle to unload, sq. ft.
cv_ul_hr = time to unload a collection vehicle, hours
$peak\_fct$ = peak collection vehicle arrival factor, no units
EWh_d = effective work day length, workday less breaks and stoppages, hour/day
cv_load = average weight of MSW in single collection vehicle, lb
2,000 lb/ton conversion factor

The peak collection vehicle arrival factor is a factor that when multiplied by the average hourly arrival rate gives the peak arrival rate during the day.

Loading bay area per ton of MSW processed is determined by:

EQ 3.1.6

$$LD\_A = \frac{ld\_bay\_a * (load\_hr + tr\_rep\_hr) * 2000}{Ewh\_d * tr\_vol\_cap * tr\_d}$$

where LD_A = area required for trailer loading, sq. ft./TPD
ld_bay_a = trailer loading area requirement, sq. ft.
$load\_hr$ = time to load a trailer, hours
tr_rep_hr = time to replace a full trailer, hours
Ewh_d = effective working day length, hours/day
tr_vol_cap = transfer trailer capacity, cu. yd.
tr_d = density of MSW in transfer vehicle, lb/cu. yd.
2,000 lb/ton conversion factor

Trailer loading time (load_hr) is a function of the transfer station design option selected. For designs with a tipping floor, trailer loading time designates the time for continual loading from the tipping floor. For designs with direct tip, trailer loading time designates time with peak collection vehicle traffic. The office area rate is applied to the sum of the area requirements calculated above to obtain the total facility area:

EQ 3.1.7

$$FAC\_A = (STR\_A + LD\_A + CV\_UL\_A) * (1 + off\_area\_r)$$

where FAC_A = total facility area, sq. ft./TPD
STR_A = refuse storage area, sq. ft./TPD
LD_A = trailer loading area, sq. ft./TPD
CV_UL_A = collection vehicle unloading area, sq. ft./TPD
off_area_r = fraction of facility attributed to office space, no units

Once area is calculated, then components of facility capital cost (EQ 3.1.2) can be determined. The first component, construction cost, is calculated as:

EQ 3.1.8

$$const\_C = FAC\_A * const\_c$$

$$\begin{aligned} \text{where} \quad const\_C &= \text{facility construction cost, \$/TPD} \\ FAC\_A &= \text{facility area (EQ 3.1.7), sq.ft./TPD} \\ const\_c &= \text{construction cost rate, \$/sq.ft.} \end{aligned}$$

Paving and site work costs are calculated as:

EQ 3.1.9

$$sitew\_C = FAC\_A * land\_area\_r * sitew\_c$$

$$\begin{aligned} \text{where} \quad sitew\_C &= \text{paving and sitework cost, \$/TPD} \\ FAC\_A &= \text{facility area per daily capacity (EQ 3.1.7), sq.ft./TPD} \\ land\_area\_r &= \text{land to building area ratio, sq.ft./sq.ft.} \\ sitew\_c &= \text{paving and sitework cost rate, \$/sq.ft.} \end{aligned}$$

The basis for default values for construction cost rates and the paving and site work rates are provided in Appendix 4. The paving and site work rate accounts for earthwork, paving, drainage, and fencing for the entire site (including vehicle maneuvering space and roadways throughout the facility). The site area requirement is based on a land-to-building area ratio. The basis for the default value of land-to-building area ratio is also given in Appendix 4.

The contribution of engineering, permitting, and contingency to capital cost of the facility is calculated by:

EQ 3.1.10

$$eng\_C = (const\_C + sitew\_C) * eng\_r$$

$$\begin{aligned} \text{where} \quad eng\_C &= \text{capital cost for engineering, permitting and contigency of facility construction, \$/TPD} \\ const\_C &= \text{capital cost of facility construction, \$/TPD} \\ sitew\_C &= \text{capital cost of paving and sitework, \$/TPD} \\ eng\_r &= \text{engineering, permitting and contingency cost as a fraction of construction and sitework costs} \end{aligned}$$

The land acquisition rate multiplied by land requirement gives the capital cost for land:

EQ 3.1.11

$$land\_C = \frac{FAC\_A * land\_area\_r * land\_c}{43,561}$$

where $land\_C$ = capital cost of land, \$/TPD
FAC_A = facility area per daily capacity (EQ 3.1.7), sq. ft./TPD
$area\_r$ = building to land ratio, sq. ft./sq. ft.
$land\_c$ = land acquisistion rate, \$/acre
and 43,560 sq. ft/acre

The capital costs determined by EQ 3.1.8 to EQ 3.1.11 are summed and annualized over the facility life to give annual cost (FAC_AC).

3.1.1.2 Equipment Capital Costs

Equipment capital costs (EQ_AC) that include purchase and installation costs depend on the rolling stock and compactors required for a given transfer station design:

EQ 3.1.12

$$EQ\_AC = RS\_TC + COMP\_TC$$

where EQ_AC = annual equipment capital cost per facility daily capacity, \$/TPD - year
RS_TC = rolling stock capital cost (EQ 3.1.13), \$/TPD - year
$COMP\_TC$ = compactor capital cost (as in EQ 3.1.13), \$/TPD - year

Rolling stock capital cost is determined by:

EQ 3.1.13

$$RS\_TC = (RS\_cost * (1 + eq\_inst\_r)) * CRF$$

where RS_TC = rolling stock purchase and installation costs, \$/TPD - year
RS_cost = cost of transfer station rolling stock, \$/TPD
eq_inst_r = installation cost as a fraction of purchase price (same rate for all equipment)

The basis for default rolling stock cost (RS_cost) is given in Appendix 5. Default values are determined from a linear regression of rolling stock costs for a range of facility capacities for each transfer station design modeled. The cost for compactors is determined in a similar manner based on the capital cost per ton for compactors (COMP_cost). The basis for default values for compactor cost are also given in Appendix 5.

3.1.1.3 Operating Costs

Facility operation costs include annual costs for labor, energy usage, and maintenance for building and equipment. The components of operating costs are determined on an annual basis in terms of tons processed per day.

EQ 3.1.14

$$OP\_AC = WG\_AC + \sum_{i}^{Equipment\ and\ Facility} E\_AC + \sum_{i}^{Equipment\ and\ Facility} M\_AC$$

where OP_AC = total annual cost per ton processed per day, $/TPD - year
WG_AC = labor and management annual costs, $/TPD - year
E_AC = rolling stock, compactor and facility annual energy costs, $/TPD - year
M_AC = rolling stock, compactor and facility annual maintenance costs, $/TPD - year

Calculation of labor costs is determined by:

EQ 3.1.15

$$WG\_AC = op\_wage * ywd * op\_req * (1 + mang\_r)$$

where WG_AC = labor annual wage cost, $/TPD - year
op_wage = equipment operator wages, $/hour
op_req = operator labor hours required per ton, hour/day/TPD
ywd = working days in a year, day/year
$mang\_r$ = management rate as a fraction of labor cost, no units

The basis for default values of equipment operator requirement (op_req) is a regression analysis of the equipment operator requirement as a function of transfer station capacity. The regression analysis is presented in Appendix 5 for each transfer station design modeled.

Energy costs for diesel-powered rolling stock are calculated by:

EQ 3.1.16

$$RS\_E\_AC = dies\_c * rs\_e * ywd$$

where

$$\begin{aligned} RS\_E\_AC &= \text{rolling stock annual energy cost, \$/TPD - year} \\ dies\_c &= \text{cost of diesel fuel from common model, \$/gallon} \\ rs\_e &= \text{diesel fuel requirement, gallon/ton MSW processed} \\ ywd &= \text{work days in a year, day/year} \end{aligned}$$

The fuel requirement for rolling stock (rs_e) is determined from a regression analysis of fuel requirements for transfer stations of varying capacities. The basis for default values is presented in Appendix 5 for each transfer station design.

For electric-powered compactors, the energy cost is:

EQ 3.1.17

$$COMP\_E\_AC = elec\_c * comp\_e * ywd$$

where

$$\begin{aligned} COMP\_E\_AC &= \text{compactor annual energy cost, \$/TPD - year} \\ ywd &= \text{work days per year, days/year} \\ comp\_e &= \text{compactor energy usage, kWh/ton} \\ elec\_c &= \text{electricity cost from common model, \$/kWh} \end{aligned}$$

Facility energy cost is calculated by:

EQ 3.1.18

$$FAC\_E\_AC = fac\_e * FAC\_A * elec\_c * ywd$$

where

$$\begin{aligned} FAC\_E\_AC &= \text{facility energy cost, \$/TPD - year} \\ fac\_e &= \text{facility electricity usage, kWh/sq.ft} - \text{day} \\ FAC\_A &= \text{area required for transfer station (EQ.3.1.7), sq.ft./TPD} \\ elec\_c &= \text{electricity cost from common model, \$/kWh} \\ ywd &= \text{yearly working days, day/year} \end{aligned}$$

The annual cost per ton per day for facility maintenance is a user-entered or a default value; therefore, calculations are not required. Rolling stock maintenance costs are calculated by:

EQ 3.1.19

$$EQ\_M\_AC = eq\_mc * (RS\_TC + COMP\_TC)$$

where
$$EQ\_M\_AC = \text{annual equipment maintanace cost, \$/TPD - year}$$
$$eq\_mc = \text{annual equipment maintenance cost as percent of equipment cost, fraction/year}$$
$$RS\_cost = \text{capital cost of rolling stock, \$/TPD}$$
$$COMP\_cost = \text{capital cost of compactor, \$/TPD}$$

3.1.2 Life Cycle Inventory Factors

There are three types of LCI factor equations presented in the following sections: energy usage, water usage, and emissions (including atmospheric releases, solid waste production, and waterborne releases). In the remainder of this document, similar sectioning of LCI factor equations occurs whenever it is applicable.

3.1.2.1 Energy Usage

Total energy usage is the sum of electricity and diesel required:

EQ 3.1.20

$$TR1\_TL\_ENG\_FACTOR = TR1\_ELEC\_FACTOR + TR1\_DIES\_FACTOR$$

where
$$TR1\_TL\_ENG\_FACTOR = \text{total energy per ton of refuse processed by the facility, Btu/ton}$$
$$TR1\_ELEC\_FACTOR = \text{total electric energy per ton processsed (EQ. 3.1.21), Btu/ton}$$
$$TR1\_DIES\_FACTOR = \text{total diesel energy per ton processsed (EQ. 3.1.22), Btu/ton}$$

Electric energy usage is determined by the following summation:

EQ 3.1.21

$$TR1\_ELEC\_FACTOR = (fac\_e * FAC\_A + comp\_e) * region\_btu\_per\_elec\_kwh$$

where
$$TR1\_ELEC\_FACTOR = \text{electric energy use per ton processed, Btu/ton}$$
$$fac\_e = \text{building electric energy requirement, kWh/sq. ft./day}$$
$$FAC\_A = \text{building area requirement (EQ. 3.1.7), sq. ft./TPD}$$
$$comp\_e = \text{compactor electric energy requirement, kWh/ton}$$
$$region\_btu\_per\_elec\_kwh = \text{energy usage per kWh produced (electric energy module), Btu/kWh}$$

Diesel fuel usage includes energy from precombustion (generation) and combustion of diesel required for rolling stock operation:

EQ 3.1.22

$$TR1\_DIES\_FACTOR = DIES\_COMB + DIES\_PREC$$

$$\begin{aligned} \textit{where} \quad TR1\_DIES\_FACTOR &= \textit{total energy used by diesel powered equipment per ton processed, Btu/ton} \\ DIES\_COMB &= \textit{energy usage in combustion of diesel per ton refuse processed, Btu/ton} \\ DIES\_PREC &= \textit{energy usage in generation of diesel per ton refuse processed, Btu/ton} \end{aligned}$$

Precombustion energy usage is found from total gallons per ton utilized:

EQ 3.1.23

$$DIES\_PREC = rs\_e * dsl\_pc\_enrg$$

$$\begin{aligned} \textit{where} \quad DIES\_PREC &= \textit{energy use in diesel fuel generation, Btu/ton} \\ rs\_e &= \textit{rolling stock diesel use, gallon/ton} \\ dsl\_pc\_enrg &= \textit{energy required to produce fuel, Btu/gallon fuel} \end{aligned}$$

Default values for energy usage requirements (rs_e) are obtained from linear regressions of fuel requirement versus facility capacity. The fuel requirement is calculated based on the quantity and types of rolling stock required for each transfer station design. Appendix 5 presents the basis for default values of fuel usage. Energy consumed by rolling stock combustion of diesel also depends on the energy usage factor:

EQ 3.1.24

$$DIES\_COMB = rs\_e * dsl\_enrg$$

$$\begin{aligned} \textit{where} \quad DIES\_COMB &= \textit{diesel energy used by rolling stock, Btu/ton} \\ rs\_e &= \textit{rolling stock diesel use, gallon/ton} \\ dsl\_enrg &= \textit{energy of the fuel, Btu/gallon fuel} \end{aligned}$$

3.1.2.2 Water Usage

Water usage for transfer station washdown is found by:

EQ 3.1.25

$$TR1\_WRUSE\_FACTOR = \frac{wash\_r * fac\_wr * FAC\_A * 12}{ywd}$$

where $TR1\_WRUSE\_FACTOR$ = transfer station wash water use, gallon/ton of refuse processed
$wash\_r$ = washdown frequency, wash/month
fac_wr = washwater required, gallon/sq.ft.
FAC_A = building area per facility capacity (EQ 3.1.7), sq.ft./TPD
ywd = yearly work days, day/year
and 12 months/year conversion factor

3.1.2.3 Emissions

3.1.2.3.1 Atmospheric Releases

Atmospheric releases for each of the twelve pollutants listed in Table 5 are found by summing sources in facility operation. The emission sources are the same for each atmospheric pollutant. For particulate matter the summation is:

EQ 3.1.26

$$TR1\_pm\_FACTOR = pm\_elec + pm\_rs\_pc + pm\_rs\_c$$

$TR1\_pm\_FACTOR$ = total particulate emissions, lb/ton MSW processed
pm_elec = total particulate matter released in electricity consumption, lb/ton MSW processed
pm_rs_pc = total particulate matter released in production of diesel used by rolling stock, lb/ton MSW processed
pm_rs_c = total particulate matter released in combustion of diesel by rolling stock, lb/ton MSW processed

Electricity generation particulate matter emissions are found by:

EQ 3.1.27

$$pm\_elec = (comp\_e + fac\_e * FAC\_A) * PM\_r\_tot$$

where pm_elec = electricity generation particulate matter emission, lb/ton of refuse
$comp\_e$ = compactor energy usage, kWh/ton MSW processed
FAC_A = building area requirement (EQ.3.1.7), sq.ft/TPD
fac_e = building energy usage, kWh/sq.ft/day
PM_r_tot = particulate matter factor (electric energy model), lb/kWh

The emission factor (PM_r_tot) accounts for the emission of particulate matter resulting from the production of electricity. For diesel generation or precombustion emissions, the calculation is:

EQ 3.1.28

$$pm\_rs\_pc = \frac{rs\_e * pm\_dies\_pc\_em}{1,000}$$

$$\begin{aligned} \text{where} \quad pm\_rs\_pc &= \text{particulate matter emitted in diesel generatation, lb/ton refuse processed} \\ rs\_e &= \text{rolling stock diesel usage, gallon/ton refuse processed} \\ pm\_dies\_pc\_lb\_gal &= \text{diesel precombustion pm emissions (common model), lb/1,000 gallon} \end{aligned}$$

The atmospheric emissions from rolling stock operation [*emission* _rs_c for (example, pm_rs_c)] are user-input or default values determined from a regression analysis of the equipment emissions for a range of transfer station capacities. (Appendix 5).

Greenhouse gas equivalents are calculated with factors for the 20-year global warming potential for relevant pollutants:

EQ 3.1.29

$$\begin{aligned} TR1\_gwp\_FACTOR = \; & TR1\_co2biomass\_FACTOR * GWP\_CO2biomass \\ & + TR1\_co2fossil\_FACTOR * GWP\_CO2fossil \\ & + TR1\_ch4\_FACTOR * GWP\_CH4 \\ & + TR1\_nox\_FACTOR * GWP\_NOX \\ & + TR1\_hc\_FACTOR * GWP\_HC \end{aligned}$$

$$\begin{aligned} \text{where} \quad TR1\_gwp\_FACTOR &= \text{greenhouse gas equivalents/ton MSW processed} \\ TR1\_emission\_FACTOR &= \text{emissions of carbon dioxide (biomass and non - biomass),} \\ & \quad \text{nitrous oxides, methane or hydrocarbons (EQ 3.1.26), lb pollutant/ton MSW} \\ GWP\_emission &= \text{20 year global warming potential factor for emissions of carbon dioxide} \\ & \quad \text{(biomass and non - biomass), nitrous oxides, methane or hydrocarbons,} \\ & \quad \text{(common model), greeenhouse gas equivalent/lb pollutant} \end{aligned}$$

3.1.2.3.2 Solid Waste Production

The transfer station process model also accounts for solid waste production associated with MSW processing at TR1. For a given solid waste (SW1), the total production is:

EQ 3.1.30

$$TR1\_sw1\_FACTOR = sw1\_elec + sw1\_rs\_pc$$

$TR1\_sw1\_FACTOR$ = total SW1 production, lb/ton refuse processed
$sw1\_elec$ = solid waste produced by electricity generation (EQ. 3.1.31), lb/ton MSW processed
$sw1\_rs\_pc$ = solid waste produced in production of diesel used by rolling stock (EQ. 3.1.32) lb/ton MSW processed

Solid waste produced in electricity generation is:

EQ 3.1.31

$$sw1\_elec = (comp\_e + fac\_e * FAC\_A) * SW1\_r\_tot$$

where $sw1\_elec$ = solid waste (SW1) produced in electricity generation, lb/ton of refuse
$comp\_e$ = compactor energy usage, kWh/ton MSW processed
fac_e = building energy usage, kWh/sq. ft/day
FAC_A = building area requirement, sq. ft./TPD
$SW1\_r\_tot$ = solid waste (SW1) factor (electric energy module), lb/kWh

For diesel generation or precombustion emissions, the calculation is:

EQ 3.1.32

$$sw1\_rs\_pc = \frac{rs\_e * sw1\_dies\_pc\_em}{1{,}000}$$

where $sw1\_rs\_pc$ = solid waste (SW1) produced in diesel generation, lb/ton refuse processed
rs_e = rolling stock diesel usage, gallon/ton refuse processed
$sw1\_dies\_pc\_em$ = diesel precombustion solid waste (SW1) production (common module), lb/1000 gallon

3.1.2.3.3 Waterborne Releases

Equations for dissolved solids waterborne releases are given to exemplify waterborne release equations. Total waterborne releases are the sum of releases from facility washdown and energy generation:

EQ 3.1.33

$$TR1\_ds\_FACTOR = ds\_wwr + ds\_elec + ds\_rs$$

where $TR1\_ds\_FACTOR$ = waterborne dissolved solids per ton of refuse processed, lb/ton
ds_wwr = dissolved solids in facility washwater (EQ. 3.1.34), lb/ton refuse processed
ds_elec = dissolved solids released in production of electricity used, (EQ. 3.1.35), lb/ton refuse processed
ds_rs = dissolved solids released in production of diesel used by rolling stock, (EQ. 3.1.36), lb/ton refuse processed

For facility wash water, dissolved solids are calculated as:

EQ 3.1.34

$$ds\_wwr = TR1\_WR\ USE\_FACTOR * DS\_wwr\_r$$

where ds_wwr = dissolved solids from wash water, lb/ton of refuse processed
$TR1\_WR\ USE\_FACTOR$ = wash water use, gallon/ton
DS_wwr_r = wash water dissolved solids, lb/gallon

For electricity generation, dissolved solids are calculated with a factor that accounts for the releases associated with electricity production:

EQ 3.1.35

$$ds\_elec = (fac\_e * FAC\_A + comp\_e) * DS\_elec\_lb\_KWH$$

where ds_elec = waterborne dissolved solids due to electricity generation, lb/ton refuse processed
fac_e = facility energy usage, kWh/sq.ft./day
FAC_A = building area requirement (EQ 3.1.7), sq.ft./TPD
$comp\_e$ = compactor energy usage, KWh/ton
$DS\_elec\_lb\_KWH$ = dissolved solids emissions from electricity generation (from electricity model), lb/kWh

For diesel precombustion, dissolved solids are:

EQ 3.1.36

$$ds\_rs = \frac{rs\_e * ds\_dies\_pc\_em}{1000}$$

where ds_rs = *dissolved solids released in generation of diesel used by rolling stock, lb/ton MSW*

ds_dies = *dissolved solids emissions due to diesel generation, lb/ton MSW processed*

rs_e = *rolling stock diesel usage, gallon/ton refuse processed*

$ds\_dies\_pc\_em$ = *diesel precombustion dissolved solids release factor (from common), lb/1, 000 gallon diesel*

3.2 EQUATIONS: TR2 -- COMMINGLED RECYCLABLES

Equations to derive cost and LCI factors for TR2 are presented in this section. To simplify the presentation, the prefix (TR2_) has been omitted from variable names given in this section.

3.2.1 Cost Factors

The following facility parameter equations to calculate cost factors apply to all five TR2 design options. Separate cost factors are calculated for each of the recyclable items listed in Appendix 3. The costs for all recyclable components except fibrous content material are calculated in Section 3.2.1.1 (Equations 3.2.1 to 3.3.20). Fibrous content material is delivered in a separate compartment and is loaded directly into roll-on/roll-off containers. Equations for fibrous content material cost determination are presented in Section 3.2.1.2.

3.2.1.1 Commingled Recyclables (Excluding Fibrous Content Material)

For all recyclables except fibrous content material, volume-specific cost factors along with item-specific densities are utilized to calculate weight-based cost factors:

EQ 3.2.1

$$item\_TR2\_COST\_FACTOR = \frac{r\_TR2\_COST\_CY * 2000}{item\_D\_rcv * item\_CF}$$

$$\begin{aligned}
\text{where} \quad item_TR2_COST_FACTOR &= \text{cost per ton of individual recyclable item processed, \$/ton} \\
r_TR2_COST_CY &= \text{cost per volume processed calculated below, \$/cubic yard} \\
item_D_rcv &= \text{item specific loose density from common model, lb/cubic yard} \\
item_CF &= \text{compaction factor for item, compacted density/loose density} \\
& \text{2,000 lb/ton conversion factor.}
\end{aligned}$$

Total transfer station cost per cubic yard of material is obtained by summing operating costs and annualized capital costs for the facility and equipment:

EQ 3.2.2

$$r\_TR2\_COST\_CY = (r\_FAC\_AC + r\_EQ\_COST + r\_OP\_AC)/ywd$$

$$\begin{aligned}
\text{where} \quad r_TR2_COST_CY &= \text{cost per cubic yard processed at transfer station, \$/cubic yard} \\
r_FAC_AC &= \text{annual capital cost for facility (EQ. 3.2.3), \$/CYPD - year} \\
r_EQ_AC &= \text{annual equipment capital costs (EQ. 3.2.13), \$/CYPD - year} \\
r_OP_COST &= \text{annual operating costs (EQ. 3.2.15), \$/CYPD - year} \\
ywd &= \text{working days in a year, days/year}
\end{aligned}$$

An explanation of calculations for each component of EQ 3.2.2 follows.

3.2.1.1.1 Facility Capital Costs for Commingled Recyclables

Annualized facility capital cost per cubic yard of material processed (r_FAC_AC) is determined from the sum of facility capital costs:

EQ 3.2.3

Facility Capital Cost(r_FAC_AC) = (Construction + Paving and Site work + Land + Engineering) X CRF

Since components of facility capital cost are obtained by multiplying unit costs such as land acquisition and construction rates by facility area per ton of recyclables processed, the facility area as the sum of various area requirements is calculated:

EQ 3.2.4

Recyclables Facility Area per Ton = Recyclable storage + Vehicle unloading + Trailer loading bays + Office space

Required storage area for commingled recyclables on the tipping floor is calculated by:

EQ 3.2.5

$$r\_STR\_A = \frac{1.25 * r\_stor * 27}{r\_ht}$$

where r_STR_A = recyclable tipping floor storage area, sq. ft./CYPD
r_stor = storage time on the tipping floor, days
r_ht = height of refuse stored on the tipping floor, ft.
1.25 factor to account for tipping floor expansion and vehicle manuevering and 27 cu. ft./cu. yd conversion factors.

When a direct tip design option is chosen, the default value for storage time on the tipping floor is zero. For direct tip designs, refuse storage space required during equipment malfunction is included in vehicle unloading areas.

Collection vehicle unloading area per cubic yard processed is determined by:

EQ 3.2.6

$$r\_CV\_UL\_A = \frac{r\_single\_cv\_ul\_a * r\_cv\_ul\_hr * peak\_fct}{EWh\_d * r\_cv\_vol}$$

where $r\_CV\_UL\_A$ = area required for collection vehicle unloading, sq. ft./CYPD
$r\_single\_cv\_ul\_a$ = area required for a single collection vehicle to unload, sq. ft.
$r\_cv\_ul\_hr$ = time to unload a collection vehicle, hours
$peak\_fct$ = peak collection vehicle arrival rate, no units
EWh_D = effective work day length, workday less breaks and stoppages, hour/day
r_cv_vol = average volume of commingled recyclables compartment in single collection vehicle, cubic yards

Loading bay area per cubic yard of recyclable processed is determined by:

EQ 3.2.7

$$r\_LD\_A = \frac{r\_ld\_bay\_a * (r\_load\_hr + r\_tr\_rep\_hr)}{Ewh\_d * r\_tr\_vol\_cap}$$

where r_LD_A = area required for trailer loading, sq. ft./CYPD
$r\_ld\_bay\_a$ = trailer loading area requirement, sq. ft.
r_load_hr = time to load a trailer, hours
$r\_tr\_rep\_hr$ = time to replace a full trailer, hours
Ewh_d = effective working day length, hours/day
$r\_tr\_vol\_cap$ = transfer trailer capacity, cu. yd.

The time to load trailers is a function of the design option chosen. For designs with a tipping floor, trailer loading time is the trailer loading time for continual loading from the tipping floor. For designs with direct tip, trailer loading time is the loading time with peak collection vehicle traffic.

The office area rate is applied to the sum of the area requirements calculated above to obtain the total facility area:

EQ 3.2.8

$$r\_FAC\_A = (r\_STR\_A + r\_LD\_A + r\_CV\_UL\_A) * (1 + off\_area\_r)$$

$$\begin{aligned} \text{where} \quad r\_FAC\_A &= \text{total facility area, sq.ft./CYPD} \\ r\_STR\_A &= \text{refuse storage area, sq.ft./CYPD} \\ r\_LD\_A &= \text{trailer loading area, sq.ft./CYPD} \\ r\_CV\_UL\_A &= \text{collection vehicle unloading area, sq.ft./CYPD} \\ off\_area\_r &= \text{fraction of facility attributed to office space, no units} \end{aligned}$$

Once area is calculated, then components of facility capital cost (EQ 3.2.3) can be determined. The first component, construction cost, is calculated as:

EQ 3.2.9

$$r\_const\_C = r\_FAC\_A * const\_c$$

$$\begin{aligned} \text{where} \quad r\_const\_C &= \text{facility construction cost, \$/CYPD} \\ r\_FAC\_A &= \text{facility area (EQ 3.2.8), sq.ft./CYPD} \\ const\_c &= \text{construction cost rate, \$/sq.ft.} \end{aligned}$$

Paving and site work costs are calculated as:

EQ 3.2.10

$$r\_sitew\_C = r\_FAC\_A * land\_area\_r * sitew\_c$$

$$\begin{aligned} \text{where} \quad r\_sitew\_C &= \text{paving and sitework cost,\$/CYPD} \\ r\_FAC\_A &= \text{facility area per daily capacity (EQ 3.2.8),sq.ft./CYPD} \\ land\_area\_r &= \text{land to building area ratio,sq.ft.land/sq.ft.building} \\ sitew\_c &= \text{paving and sitework cost rate,\$/sq.ft.} \end{aligned}$$

The basis for default values for construction rates, paving, and site work and land-to-building area ratio are provided in Appendix 4. The paving and site work rate accounts for earthwork, paving, drainage, and fencing for the entire site including vehicle maneuvering space and roadways throughout the facility. The site area requirement is based on a land-to-building area ratio. The basis for the default value of land-to-building area ratio is also given in Appendix 4.

The contribution of engineering, permitting, and contingency to capital costs for the facility is determined by:

EQ 3.2.11

$$r\_eng\_C = (r\_const\_C + r\_sitew\_C) * eng\_r$$

$$\begin{aligned} \text{where} \quad r\_eng\_C &= \text{capital cost for engineering, permitting and contingency, \$/CYPD} \\ r\_const\_C &= \text{capital cost of facility construction, \$/CYPD} \\ r\_sitew\_C &= \text{capital cost of paving and sitework, \$/CYPD} \\ eng\_r &= \text{engineering, permitting and contingecy cost as a fraction of construction and sitework costs} \end{aligned}$$

The land acquisition rate multiplied by land requirement gives the capital cost for land:

EQ 3.2.12

$$r\_land\_C = \frac{r\_FAC\_A * land\_area\_r * land\_c}{43{,}561}$$

$$\begin{aligned} \text{where} \quad r\_land\_C &= \text{capital cost of land, \$/CYPD} \\ r\_FAC\_A &= \text{facility area per daily volume capacity (EQ 3.2.8), sq. ft./CYPD} \\ area\_r &= \text{building to land ratio, sq. ft./sq. ft.} \\ land\_c &= \text{land acquisistion rate, \$/acre} \\ &\text{and 43,560 sq. ft/acre} \end{aligned}$$

The capital costs determined by EQ 3.2.9 to EQ 3.2.12 are summed and annualized over the facility life to give annual cost (r_FAC_AC).

3.2.1.1.2 Equipment Capital Costs for Commingled Recyclables

Equipment capital cost (r_EQ_AC) that includes purchase and installation costs depends on the rolling stock and compactors required for a given transfer station design:

EQ 3.2.13

$$r\_EQ\_AC = r\_RS\_TC + r\_COMP\_TC$$

$$\begin{aligned} \text{where} \quad r\_EQ\_AC &= \text{annual equipment capital cost per facility daily capacity, \$/CYPD - year} \\ r\_RS\_TC &= \text{rolling stock capital cost (EQ 3.2.14), \$/CYPD - year} \\ r\_COMP\_TC &= \text{compactor capital cost (as in EQ 3.2.14), \$/CYPD - year} \end{aligned}$$

Rolling stock capital cost is determined by:

EQ 3.2.14

$$r\_RS\_TC = (r\_RS\_cost * (1 + eq\_inst\_r)) * CRF$$

$$\begin{aligned} \text{where} \quad r\_RS\_TC &= \text{rolling stock purchase and installation costs, \$/CYPD - year} \\ r\_RS\_cost &= \text{cost purchasing transfer station rolling stock, \$/CYPD} \\ eq\_inst\_r &= \text{installation cost as a fraction of purchase price (same rate for all equipment)} \end{aligned}$$

The basis for default rolling stock cost (r_RS_cost) is given in Appendix 5. Default values are determined from a linear regression of rolling stock costs as a function of facility capacity for each transfer station design modeled. The cost for compactors and hoppers are determined in a similar manner based on the capital cost per cubic yard of material processed for compactors (r_COMP_cost). The basis for default values for compactor cost are also given in Appendix 5.

3.2.1.1.3 Operating Costs for Commingled Recyclables

Facility operation costs include annual costs for labor, energy usage, and maintenance for building and equipment.

EQ 3.2.15

$$r\_OP\_AC = r\_WG\_AC + \sum_{i}^{\text{Equipment and Facility}} r\_E\_AC + \sum_{i}^{\text{Equipment and Facility}} r\_M\_AC$$

$$\begin{aligned} \text{where} \quad r\_OP\_AC &= \text{total annual cost per cubic yard processed per day, \$/CYPD - year} \\ r\_WG\_AC &= \text{labor and management annual costs, \$/CYPD - year} \\ r\_E\_AC &= \text{rolling stock, compactor and facility annual energy costs, \$/CYPD - year} \\ r\_M\_AC &= \text{rolling stock, compactor and facility annual maintenance costs, \$/CYPD - year} \end{aligned}$$

Calculation of labor costs is determined by:

EQ 3.2.16

$$r\_WG\_AC = op\_wage * ywd * r\_op\_req * (1 + mang\_r)$$

$$\begin{aligned} \text{where} \quad r\_WG\_AC &= \text{labor annual wage cost, \$/CYPD - year} \\ op\_wage &= \text{equipment operator wages, \$/hour} \\ r\_op\_req &= \text{operator labor hours required per cubic yard, hour/day/CYPD} \\ ywd &= \text{working days in a year, day/year} \\ mang\_r &= \text{management rate as a fraction of labor cost, no units} \end{aligned}$$

The basis for default values of equipment operator requirement (r_op_req) is a regression analysis of the equipment operator requirement for various sizes of transfer stations. The regression analysis is presented in Appendix 5 for each transfer station design modeled.

Energy costs for diesel-powered rolling stock are calculated by:

EQ 3.2.17

$$r\_RS\_E\_AC = dies\_c * r\_s\_e * ywd$$

$$\begin{aligned} \text{where} \quad r\_RS\_E\_AC &= \text{rolling stock annual energy cost, \$/CYPD - year} \\ dies\_c &= \text{cost of diesel fuel from common module, \$/gallon} \\ r\_rs\_e &= \text{diesel fuel requirement, gallon/CY material processed} \\ ywd &= \text{work days in a year, day/year} \end{aligned}$$

The fuel requirement for rolling stock (r_rs_e) is determined from a regression analysis of fuel requirements for various sizes of transfer stations. The basis for default values is presented in Appendix 5 for each transfer station design.

For electric powered compactors, the energy cost is:

EQ 3.2.18

$$r\_COMP\_E\_AC = elec\_c * r\_comp\_e * ywd$$

$$\begin{aligned} \text{where} \quad r\_COMP\_E\_AC &= \text{compactor annual energy cost, \$/CYPD - year} \\ ywd &= \text{work days per year, days/year} \\ r\_comp\_e &= \text{compactor energy usage, kWh/cubic yard} \\ elec\_c &= \text{electricity cost from common model, \$/kWh} \end{aligned}$$

Facility energy cost is calculated by:

EQ 3.2.19

$$r\_FAC\_E\_AC = fac\_e * r\_FAC\_A * elec\_c * ywd$$

$$\begin{aligned} \text{where } r\_FAC\_E\_AC &= \text{facility energy cost, } \$/CYPD\text{ - year} \\ fac\_e &= \text{facility electricity usage, } kWh/sq.ft - day \\ r\_FAC\_A &= \text{area required for transfer station (EQ.3.2.8), } sq.ft./CYPD \\ elec\_c &= \text{electricity cost from common model, } \$/kWh \\ ywd &= \text{yearly working days, } day/year \end{aligned}$$

The annual cost per ton per day for facility maintenance is a user-entered or a default value; therefore, calculations are not required. Rolling stock maintenance costs are calculated by:

EQ 3.2.20

$$r\_EQ\_M\_AC = eq\_mc * (r\_RS\_cost + r\_COMP\_cost)$$

$$\begin{aligned} \text{where } r\_EQ\_M\_AC &= \text{annual equipment maintanace cost, } \$/CYPD\text{ - year} \\ eq\_mc &= \text{annual equipment maintenance cost as fraction of equipment cost, } 1/year \\ r\_RS\_cost &= \text{capital cost of rolling stock, } \$/CYPD \\ r\_COMP\_cost &= \text{capital cost of compactor, } \$/CYPD \end{aligned}$$

3.2.1.2 Cost Factor for Fibrous Content Material

In TR2, fibrous content material is delivered in a separate compartment of the commingled-recyclable vehicle. Fibrous content material has a separate tipping floor as described in Section 2.3. Fibrous content material cost factors include costs given below:

EQ 3.2.21

$$fcm\_TR2\_COST\_FACTOR = \frac{(fcm\_FAC\_AC + fcm\_EQ\_COST + fcm\_OP\_AC)}{ywd}$$

$$\begin{aligned} \text{where } fcm\_TR2\_COST\_FACTOR &= \text{cost per ton processed at transfer station, } \$/ton \\ fcm\_FAC\_AC &= \text{annual capital cost for facility (EQ.3.2.22), } \$/TPD\text{ - year} \\ fcm\_EQ\_AC &= \text{annual equipment capital costs (EQ.3.1.12), } \$/TPD\text{ - year} \\ fcm\_OP\_COST &= \text{annual operating costs (EQ.3.1.14), } \$/TPD\text{ - year} \\ ywd &= \text{working days in a year, } days/year \end{aligned}$$

An explanation of calculations for each component of EQ 3.2.21 follows.

3.2.1.2.1 Facility Capital Costs for Fibrous Content Material

Annualized facility capital cost per ton fibrous content material processed (FCN_FAC_AC) is determined from the sum of facility capital costs:

EQ 3.2.22

Fibrous Content Material Facility Annual Cost(FCM_FAC_AC) = (Construction + Paving and Site work + Land + Engineering) X CRF

To calculate facility capital costs, the area required for fibrous content material processing is determined. Facility area attributed to fibrous content material processing includes the fibrous content material tipping floor, collection vehicle unloading area, trailer loading bay area, and office space:

EQ 3.2.23

Recyclables Facility Area per Ton = Tipping floor + Vehicle unloading + Trailer loading bays + Office space

Required storage area for fibrous content material on the tipping floor is calculated by:

EQ 3.2.24

$$fcm\_STR\_A = \frac{1.25 * fcm\_stor * 27}{fcm\_ht}$$

where
fcm_STR_A = recyclable tipping floor storage area, sq. ft./CYPD
fcm_stor = storage time on the tipping floor, days
fcm_ht = height of refuse stored on the tipping floor, ft.
1.25 factor to account for tipping floor expansion and vehicle manuevering and 27 cu. ft./cu. yd conversion factors.

Collection vehicle unloading area per cubic yard processed is determined by:

EQ 3.2.25

$$fcm\_CV\_UL\_A = \frac{fcm\_single\_cv\_ul\_a * fcm\_cv\_ul\_hr * peak\_fct}{EWh\_d * fcm\_cv\_vol}$$

where
$fcm\_CV\_UL\_A$ = area required for collection vehicle unloading, sq. ft./CYPD
$fcm\_single\_cv\_ul\_a$ = area required for a single collection vehicle to unload, sq. ft.
$fcm\_cv\_ul\_hr$ = time to unload a collection vehicle, hours
$peak\_fct$ = peak collection vehicle arrival rate, no units
EWh_D = effective work day length, workday less breaks and stoppages, hour/day
fcm_cv_vol = average volume of commingled recyclables compartmen in single collection vehicle, cubic yards

Loading bay area per cubic yard of fibrous content material processed is determined by:

EQ 3.2.26

$$fcm\_LD\_A = \frac{fcm\_ld\_bay\_a * (fcm\_load\_hr + fcm\_tr\_rep\_hr)}{Ewh\_d * fcm\_tr\_vol\_cap}$$

where
fcm_LD_A = area required for trailer loading, sq. ft./CYPD
$fcm\_ld\_bay\_a$ = trailer loading area requirement, sq. ft.
fcm_load_hr = time to load a trailer, hours
$fcm\_tr\_rep\_hr$ = time to replace a full trailer, hours
Ewh_d = effective working day length, hours/day
$fcm\_tr\_vol\_cap$ = transfer trailer capacity, cu. yd.

The office area rate is applied to the sum of the area requirements calculated above to obtain the total facility area:

EQ 3.2.27

$$fcm\_FAC\_A = (fcm\_STR\_A + fcm\_LD\_A + fcm\_CV\_UL\_A) * (1 + off\_area\_r)$$

where
fcm_FAC_A = total facility area, sq. ft./CYPD
fcm_STR_A = refuse storage area, sq. ft./CYPD
f_LD_A = trailer loading area, sq. ft./CYPD
$fcm\_CV\_UL\_A$ = collection vehicle unloading area, sq. ft./CYPD
off_area_r = fraction of facility attributed to office space, no units

Once the fibrous content material facility area is known, construction, paving and site work, land acquisition, and engineering costs are determined as for TR1 (EQ 3.1.8 through EQ 3.1.11).

3.2.1.2.2 Equipment Capital Costs for Fibrous Content Material

Capital costs for rolling stock required to process fibrous content material (fcm_EQ_AC) are determined as in TR1 with EQ 3.1.13.

3.2.1.2.3 Operating Costs for fibrous Content Material

Operating costs (fcm_OP_AC) include the cost of labor, energy, and maintenance as determined by the equations for commingled recyclables (EQ 3.1.15 through EQ 3.1.19).

3.2.2 Life Cycle Inventory Factors

Similar to TR2 cost equations, LCI factors are determined for each item listed in Appendix 3 based on the recyclable item density and a volume-based LCI factor. The prefix “item” implies that the equation is utilized to calculate factors for each of the recyclable items listed in Appendix 3. Fibrous content material factors are calculated separately in equations presented below because fibrous content material is collected in a separate compartment of collection vehicles.

3.2.2.1 Commingled Recyclables LCI Factors

3.2.2.1.1 Energy Usage for Commingled Recyclables

Total energy usage is calculated for each recyclable item:

EQ 3.2.28

$$item\_TR2\_TL\_ENG\_FACTOR = \frac{(r\_TR2\_ELEC\_VOL\_FACTOR + r\_TR2\_DIES\_VOL\_FACTOR) * 2{,}000}{item\_D\_rcv * item\_CF}$$

where *item_TR2_TL_ENG_FACTOR* = *total energy per cubic yard of recyclable processed, Btu/ton*
r_TR2_ELEC_VOL_FACTOR = *total electric energy (EQ 3.2.29), Btu/CY*
r_TR2_DIES_VOL_FACTOR = *total diesel energy (EQ 3.2.30), Btu/CY*
item_D_rcv = *loose density of item in recycling vehicle, lb/CY*
item_CF = *compaction factor for item, compacted density/loose density*
2,000 lb/ton conversion factor

Electric energy usage is determined by:

EQ 3.2.29

$$r\_TR2\_ELEC\_VOL\_FACTOR = (fac\_e * r\_FAC\_A + r\_comp\_e) * region\_btu\_per\_elec\_kwh$$

where *r_TR2_ELEC_VOL_FACTOR* = *electric energy use per cubic yard processed, Btu/CY*
fac_e = *building electric energy requirement, kWh/sq.ft./day*
r_FAC_A = *building area requirement (EQ.3.2.8), sq.ft./CYPD*
r_comp_e = *compactor electric energy requirement, kWh/CY*
region_btu_per_elec_kwh = *energy usage per kWh produced (electric energy model), Btu/kWh*

Diesel fuel usage includes energy from precombustion (generation) and combustion of diesel required for rolling stock operation:

EQ 3.2.30

$$r\_TR2\_DIES\_VOL\_FACTOR = r\_DIES\_PREC + r\_DIES\_COMB$$

where $r\_TR2\_DIES\_VOL\_FACTOR$ = total energy used by diesel powered equipment, Btu/CY recyclables
r_DIES_PREC = energy usage in generation of diesel, Btu/CY recyclables
r_DIES_COMB = energy usage by diesel powered rolling stock, Btu/CY recyclables

Precombustion energy usage is calculated from total gallons fuel utilized per cubic yard of recyclables processed:

EQ 3.2.31

$$r\_DIES\_PREC = r\_rs\_e * dsl\_pc\_enrg$$

where r_DIES_PREC = energy use in diesel fuel generation, Btu/CY recyclables
r_rs_e = rolling stock diesel use, gallon/CY recyclables
dsl_pc_enrg = energy required to produce fuel, Btu/gallon fuel

Diesel energy usage by rolling stock is calculated in EQ 3.2.32 with factor (dsl_enrg) representing the energy content of diesel.

EQ 3.2.32

$$r\_DIES\_COMB = r\_rs\_e * dsl\_enrg$$

where r_DIES_COMB = diesel energy used by rolling stock, Btu/CY recyclables
r_rs_e = rolling stock diesel use, gallon/CY recyclables
dsl_enrg = energy used by rolling stock combustion of diesel, Btu/gallon fuel

3.2.2.1.2 Water usage for Commingled Recyclables

For each recyclable item, water usage for transfer station washdown is found by:

EQ 3.2.33

$$item\_TR2\_WRUSE\_FACTOR = \frac{r\_TR2\_WRUSE\_VOL\_FACTOR * 2{,}000}{item\_D\_rcv * item\_CF}$$

where $item\_TR2\_WRUSE\_FACTOR$ = water used in facility washdown for recyclable item, gallon/ton item
$item\_D\_rcv$ = density of recylable item, lb/CY recyclables
$r\_TR2\_WRUSE\_VOL\_FACTOR$ = volume based water use defined below, gallon water/CY recyclables
$item\_CF$ = compaction factor for item, compacted density/loose density
2,000 lb/ton conversion factor

EQ 3.2.34

$$r\_TR2\_WRUSE\_VOL\_FACTOR = \frac{wash\_r * fac\_wr * r\_FAC\_A * 12}{ywd}$$

where $r\_TR1\_WRUSE\_VOL\_FACTOR$ = transfer station wash water use, gallon/CY recyclables
$wash\_r$ = washdown frequency, wash/month
fac_wr = washwater required, gallon/sq.ft.
r_FAC_A = building area per facility capacity (EQ 3.2.8), sq.ft./CYPD
ywd = yearly work days, day/year
and 12 months/year conversion factor

3.2.2.1.3 Emissions for Commingled Recyclables

Atmospheric releases

Atmospheric releases of pollutants are found by summing emissions from sources in facility operation. The emission sources and therefore equations required are the same for each pollutant listed in Table 5. Equations for particulate matter emissions are given to exemplify emissions calculations:

EQ 3.2.35

$$item\_TR2\_pm\_FACTOR = \frac{(r\_pm\_elec + r\_pm\_rs\_pc + r\_pm\_rs\_c) * 2{,}000}{item\_D\_rcv * item\_CF}$$

where $TR2\_pm\_FACTOR$ = *total particulate emissions, lb/CY recyclables processed*
r_pm_elec = *total particulate matter released in electricity consumption, lb/CY recyclables*
$r\_pm\_rs\_pc$ = *total particulate matter released in production of diesel used by rolling stock, lb/CY recyclables processed*
$r\_pm\_rs\_c$ = *total particulate matter released in combustion of diesel by rolling stock, lb/CY recyclables processed*
$item\_D\_rcv$ = *density of item in recycling vehicle, lb/CY*
$item\_CF$ = *compaction factor for item, compacted density/loose density*
and 2,000 lb/ton conversion factor

Electricity generation particulate matter emissions are found by:

EQ 3.2.36

$$r\_pm\_elec = (r\_comp\_e + fac\_e * r\_FAC\_A) * PM\_r\_tot$$

where r_pm_elec = *electricity generation particulate matter emission, lb/CY recyclables*
r_comp_e = *compactor energy usage, kWh/CY recyclables*
r_FAC_A = *building area requirement (EQ.3.2.8), sq.ft/CYPD*
fac_e = *building energy usage, kWh/sq.ft./day*
PM_r_tot = *particulate matter factor (electric energy model), lb/kWh*

The emission factor (PM_r_tot) accounts for the emission of particulate matter resulting from the production of electricity. For diesel generation or precombustion emissions the calculation is:

EQ 3.2.37

$$r\_pm\_rs\_pc = \frac{r\_rs\_e * pm\_dies\_pc\_em}{1{,}000}$$

where $r\_pm\_rs\_pc$ = *particulate matter emitted in diesel generatation, lb/CY recyclables*
r_rs_e = *rolling stock diesel usage, gallon/CY recyclables*
$pm\_dies\_pc\_lb\_gal$ = *diesel precombustion pm emissions (common model), lb/1,000 gallon*

The atmospheric emissions from rolling stock operation (*emission* _rs_c for example, pm_rs_c) are user-input or default values determined from a regression analysis of the equipment emissions for a range of sizes of transfer stations (Appendix 5).

Greenhouse gas equivalents are calculated with factors for the 20-year global warming potential for relevant pollutants:

EQ 3.2.38

$$\begin{aligned} item\_TR2\_gwp\_FACTOR = \; & item\_TR2\_co2biomass\_FACTOR * GWP\_CO2biomass \\ & + item\_TR2\_co2fossil\_FACTOR * GWP\_CO2fossil \\ & + item\_TR2\_ch4\_FACTOR * GWP\_CH4 \\ & + item\_TR2\_nox\_FACTOR * GWP\_NOX \\ & + item\_TR2\_hc\_FACTOR * GWP\_HC \end{aligned}$$

where $item\_TR2\_gwp\_FACTOR$ = greenhouse gas equivalents/ton recyclables processed

$item\_TR2\_emission\_FACTOR$ = emissions of carbon dioxide (biomass and non - biomass), nitrous oxides, methane and hydrocarbons (EQ 3.2.35), lb/ton recyclables

$GWP\_emission$ = 20 year global warming potential factor for emissions of carbon dioxide (biomass and non - biomass), nitrous oxides, methane and hydrocarbons, (common model), greeen house gas equivalent/lb pollutant

Solid waste production

The transfer station process model also accounts for solid waste production associated with MSW processing at TR2. For a given solid waste (SW1), the total production is:

EQ 3.2.39

$$item\_TR2\_sw1\_FACTOR = \frac{(r\_sw1\_elec + r\_sw1\_rs\_pc) * 2{,}000}{item\_D\_rcv * item\_CF}$$

$item\_TR1\_sw1\_FACTOR$ = total SW1 production, lb/ton recyclables processed

r_sw1_elec = solid waste produced in generation of electricity used, lb/CY recyclables processed

$r\_sw1\_rs\_pc$ = solid waste produced in generation of diesel used, lb/CY recyclables processed

$item\_D\_rcv$ = density of recycled item, lb/CY

$item\_CF$ = compaction factor for item, compacted density/loose density

2,000 lb/ton conversion factor

Solid waste produced in electricity generation is:

EQ 3.2.40

$$r\_sw1\_elec = (comp\_e + fac\_e * r\_FAC\_A) * SW1\_r\_tot$$

$$\begin{aligned} where \quad r\_sw1\_elec &= \text{solid waste (SW1) produced in electricity generation, lb/CY recyclables} \\ r\_comp\_e &= \text{compactor energy usage, kWh/CY recyclables} \\ fac\_e &= \text{building energy usage, kWh/sq.ft/day} \\ r\_FAC\_A &= \text{building area requirement, sq.ft./CYPD} \\ SW1\_r\_tot &= \text{solid waste (SW1) factor (electric energy model), lb/kWh} \end{aligned}$$

For diesel generation or precombustion emissions the calculation is:

EQ 3.2.41

$$r\_sw1\_rs\_pc = \frac{r\_rs\_e * sw1\_dies\_pc\_em}{1{,}000}$$

$$\begin{aligned} where \quad r\_sw1\_rs\_pc &= \text{solid waste (SW1) produced in diesel generatation, lb/CY recyclables} \\ r\_rs\_e &= \text{rolling stock diesel usage, gallon/CY recyclables} \\ sw1\_dies\_pc\_em &= \text{diesel precombustion solid waste (SW1) production (common model), lb/1000 gallon} \end{aligned}$$

<u>Waterborne releases</u>

Equations for dissolved solids waterborne releases are given to exemplify waterborne release equations. For a complete list of waterborne pollutants tracked, refer to Table 5. Total waterborne releases are the sum of releases from facility washdown and energy generation:

EQ 3.2.42

$$item\_TR2\_ds\_FACTOR = \frac{(r\_ds\_wwr + r\_ds\_elec + r\_ds\_rs) * 2{,}000}{item\_D\_rcv * item\_CF}$$

$$\begin{aligned} where \quad item\_TR2\_ds\_FACTOR &= \text{waterborne dissolved solids per ton of refuse processed, lb/ton} \\ r\_ds\_wwr &= \text{dissolved solids released in facility washwater, lb/CY recyclables} \\ r\_ds\_elec &= \text{dissolved solids released in generation of electricity used, lb/CY recyclables} \\ r\_ds\_rs &= \text{dissolved solids released in generation of diesel used, lb/CY recyclables} \\ item\_D\_rcv &= \text{density of recyclable item, lb/CY} \\ item\_CF &= \text{compaction factor for item, compacted density/loose density} \\ & \text{2,000 lb/ton conversion factor} \\ & \text{and other variables as defined below.} \end{aligned}$$

For facility wash water, dissolved solids are calculated as:

EQ 3.2.43

$$r\_ds\_wwr = r\_TR2\_WR\ USE\_VOL\_\ FACTOR * DS\_wwr\_r$$

where r_ds_wwr = dissolved solids from wash water, lb/CY recyclables
$r\_TR2\_WR\ USE\_VOL\_\ FACTOR$ = wash water use, gallon/CY recyclables
DS_wwr_r = wash water dissolved solids, lb/gallon

For electricity generation, dissolved solids are calculated with a factor that accounts for the releases associated with electricity production:

EQ 3.2.44

$$r\_ds\_elec = (fac\_e * r\_FAC\_A + r\_comp\_e) * DS\_elec\_lb\_KWH$$

where r_ds_elec = waterborne dissolved solids due to electricity generation, lb/CY recyclables
fac_e = facility energy usage, kWh/sq.ft./day
r_FAC_A = building area requirement (EQ 3.2.8), sq.ft./CYPD
r_comp_e = compactor energy usage, KWh/CY
$DS\_elec\_lb\_KWH$ = dissolved solids emissions from electricity generation, lb/kWh

For diesel precombustion, dissolved solids are:

EQ 3.2.45

$$r\_ds\_rs = \frac{r\_rs\_e * ds\_dies\_pc\_em}{1000}$$

where r_ds_dies = dissolved solids emissions due to diesel generation, lb/CY recyclables
r_rs_e = rolling stock diesel usage, gal/CY recyclables
$ds\_dies\_pc\_em$ = precombustion dissolved solids release factor (common model), lb/1000 gallon

3.2.2.2 Fibrous Content Material LCI Factors

Similar to LCI factors for commingled recyclables, a weight-based LCI factor is determined for each type of fibrous content material. Weight-based factors for each item are determined from a volume-based factor that applies to all types of fibrous content material. The following subsections of Section 3.2.2.2 give the methodology for determining energy usage, water usage, and emissions associated with fibrous content materials processed at a commingled recyclables MRF.

3.2.2.2.1 Energy Usage for Fibrous Content Material

Total energy usage is calculated for each fibrous content item:

EQ 3.2.46

$$item\_TR2\_TL\_ENG\_FACTOR = \frac{(fcm\_TR2\_ELEC\_VOL\_FACTOR + fcm\_TR2\_DIES\_VOL\_FACTOR) * 2{,}000}{item\_D\_rcv * item\_CF}$$

where $item\_TR2\_TL\_ENG\_FACTOR$ = total energy per cubic yard of recyclable processed, Btu/ton
$fcm\_TR2\_ELEC\_VOL\_FACTOR$ = total electric energy (EQ 3.2.47), Btu/CY
$fcm\_TR2\_DIES\_VOL\_FACTOR$ = total diesel energy (EQ 3.2.48), Btu/CY
$item\_D\_rcv$ = loose density of item in recycling vehicle, lb/CY
$item\_CF$ = compaction factor for item, compacted density/loose density
2,000 lb/ton conversion factor

Electric energy usage is determined by:

EQ 3.2.47

$$fcm\_TR2\_ELEC\_VOL\_FACTOR = (fac\_e * fcm\_FAC\_A) * region\_btu\_per\_elec\_kwh$$

where $fcm\_TR2\_ELEC\_VOL\_FACTOR$ = electric energy use per cubic yard processed, Btu/CY
fac_e = building electric energy requirement, kWh/sq.ft./day
fcm_FAC_A = building area requirement (EQ.3.2.27), sq.ft./CYPD
$region\_btu\_per\_elec\_kwh$ = energy usage per kWh produced (electric energy model), Btu/kWh

Diesel fuel usage includes energy from precombustion (generation) and combustion of diesel required for rolling stock operation:

3.2.48

$$fcm\_TR2\_DIES\_VOL\_FACTOR = fcm\_DIES\_PREC + fcm\_DIES\_COMB$$

where $fcm\_TR2\_DIES\_VOL\_FACTOR$ = total energy used by diesel powered equipment, Btu/CY recyclables
fcm_DIES_PREC = energy usage in generation of diesel, Btu/CY recyclables
fcm_DIES_COMB = energy usage by diesel powered rolling stock, Btu/CY recyclables

Precombustion energy usage is calculated from total gallons fuel utilized per cubic yard of fibrous content material processed:

EQ 3.2.49

$$fcm\_DIES\_PREC = fcm\_rs\_e * dsl\_pc\_enrg$$

where fcm_DIES_PREC = energy use in diesel fuel generation, Btu/CY recyclables
fcm_rs_e = rolling stock diesel use, gallon/CY recyclables
dsl_pc_enrg = energy required to produce fuel, Btu/gallon fuel

Diesel energy usage by rolling stock is calculated in Equation 3.2.50 with factor (dsl_enrg) representing the energy content of diesel.

EQ 3.2.50

$$fcm\_DIES\_COMB = fcm\_rs\_e * dsl\_enrg$$

where

$$\begin{aligned} fcm\_DIES\_COMB &= \text{diesel energy used by rolling stock, Btu/CY recyclables} \\ fcm\_rs\_e &= \text{rolling stock diesel use, gallon/CY recyclables} \\ dsl\_enrg &= \text{energy used by rolling stock combustion of diesel, Btu/gallon fuel} \end{aligned}$$

3.2.2.2.2 Water usage for Fibrous Content Material

For each recyclable item, water usage for transfer station washdown is found by:

EQ 3.2.51

$$item\_TR2\_WRUSE\_FACTOR = \frac{fcm\_TR2\_WRUSE\_VOL\_FACTOR * 2{,}000}{item\_D\_rcv * item\_CF}$$

where

$$\begin{aligned} item\_TR2\_WRUSE\_FACTOR &= \text{water used in facility washdown for recyclable item, gallon/ton item} \\ item\_D\_rcv &= \text{density of recylable item, lb/CY recyclables} \\ fcm\_TR2\_WRUSE\_VOL\_FACTOR &= \text{volume based water use defined below, gallon water/CY recyclables} \\ item\_CF &= \text{compaction factor for item, compacted density/loose density} \\ & \quad 2{,}000 \text{ lb/ton conversion factor} \end{aligned}$$

EQ 3.2.52

$$fcm\_TR2\_WRUSE\_VOL\_FACTOR = \frac{wash\_r * fac\_wr * fcm\_FAC\_A * 12}{ywd}$$

where

$$\begin{aligned} fcm\_TR1\_WRUSE\_VOL\_FACTOR &= \text{transfer station wash water use, gallon/CY recyclables} \\ wash\_r &= \text{washdown frequency, wash/month} \\ fac\_wr &= \text{washwater required, gallon/sq. ft.} \\ fcm\_FAC\_A &= \text{building area per facility capacity (EQ 3.2.27), sq. ft./CYPD} \\ ywd &= \text{yearly work days, day/year} \\ & \quad \text{and 12 months/year conversion factor} \end{aligned}$$

3.2.2.2.3 Emissions for Fibrous Content Material

Atmospheric releases

Atmospheric releases of pollutants are found by summing emissions from sources in facility operation. The emission sources and, therefore, equations required are the same for each pollutant listed in Table 5. Equations for particulate matter emissions are given to illustrate emissions calculations:

EQ 3.2.53

$$item\_TR2\_pm\_FACTOR = \frac{(fcm\_pm\_elec + fcm\_pm\_rs\_pc + fcm\_pm\_rs\_c) * 2{,}000}{item\_D\_rcv * item\_CF}$$

where $item\_TR2\_pm\_FACTOR$ = total particulate emissions, lb/CY recyclables processed
fcm_pm_elec = total particulate matter released in electricity consumption, lb/CY recyclables
$fcm\_pm\_rs\_pc$ = total particulate matter released in production of diesel used by rolling stock, lb/CY recyclables processed
$fcm\_pm\_rs\_c$ = total particulate matter released in combustion of diesel by rolling stock, lb/CY recyclables processed
$item\_D\_rcv$ = density of item in recycling vehicle, lb/CY
$item\_CF$ = compaction factor for item, compacted density/loose density
and 2,000 lb/ton conversion factor

Electricity generation particulate matter emissions are found by:

EQ 3.2.54

$$fcm\_pm\_elec = (fcm\_comp\_e + fac\_e * fcm\_FAC\_A) * PM\_r\_tot$$

where fcm_pm_elec = electricity generation particulate matter emission, lb/CY recyclables
fcm_comp_e = compactor energy usage, kWh/CY recyclables
fcm_FAC_A = building area requirement (EQ.3.2.27), sq.ft/CYPD
fac_e = building energy usage, kWh/sq.ft./day
PM_r_tot = particulate matter factor (electric energy model), lb/kWh

The emission factor (PM_r_tot) accounts for the emission of particulate matter resulting from the production of electricity. For diesel generation or precombustion emissions, the calculation is:

EQ 3.2.55

$$fcm\_pm\_rs\_pc = \frac{fcm\_rs\_e * pm\_dies\_pc\_em}{1{,}000}$$

$$\begin{aligned} \text{where} \quad fcm\_pm\_rs\_pc &= \text{particulate matter emitted in diesel generatation, lb/CY recyclables} \\ fcm\_rs\_e &= \text{rolling stock diesel usage, gallon/CY recyclables} \\ pm\_dies\_pc\_lb\_gal &= \text{diesel precombustion pm emissions (common model), lb/1,000 gallon} \end{aligned}$$

The atmospheric emissions from rolling stock operation (*emission* _rs_c for example, pm_rs_c) are user-input or default values determined from a regression analysis of the equipment emissions for a range of transfer station sizes (Appendix 5).

Greenhouse gas equivalents are calculated with factors for the 20-year global warming potential for relevant pollutants:

EQ 3.2.56

$$\begin{aligned} item\_TR2\_gwp\_FACTOR = \; & item\_TR2\_co2biomass\_FACTOR * GWP\_CO2biomass \\ & + item\_TR2\_co2fossil\_FACTOR * GWP\_CO2fossil \\ & + item\_TR2\_ch4\_FACTOR * GWP\_CH4 \\ & + item\_TR2\_nox\_FACTOR * GWP\_NOX \\ & + item\_TR2\_hc\_FACTOR * GWP\_HC \end{aligned}$$

$$\begin{aligned} \text{where} \quad item\_TR2\_gwp\_FACTOR &= \text{greenhouse gas equivalents/ton recyclables processed} \\ item\_TR2\_emission\_FACTOR &= \text{emissions of carbon dioxide (biomass and non - biomass),} \\ & \quad \text{nitrous oxides, methane and hydrocarbons (EQ 3.2.53), lb/ton recyclables} \\ GWP\_emission &= \text{20 - year global warming potential factor for emissions of carbon dioxide} \\ & \quad \text{(biomass and non - biomass), nitrous oxides, methane and hydrocarbons,} \\ & \quad \text{(common model), greeen house gas equivalent/lb pollutant} \end{aligned}$$

Solid waste production

The transfer station process model also accounts for solid waste production associated with fibrous content material processing at TR2. For a given solid waste (SW1), the total production is:

EQ 3.2.57

$$item\_TR2\_sw1\_FACTOR = \frac{(fcm\_sw1\_elec + fcm\_sw1\_rs\_pc) * 2{,}000}{item\_D\_rcv * item\_CF}$$

$item\_TR1\_sw1\_FACTOR$ = total SW1 production, lb/ton recyclables processed
fcm_sw1_elec = solid waste produced in generation of electricity used, lb/CY recyclables processed
$fcm\_sw1\_rs\_pc$ = solid waste produced in generation of diesel used, lb/CY recyclables processed
$item\_D\_rcv$ = density of recycled item, lb/CY
$item\_CF$ = compaction factor for item, compacted density/loose density
2,000 lb/ton conversion factor

Solid waste produced in electricity generation is:

EQ 3.2.58

$$fcm\_sw1\_elec = (comp\_e + fac\_e * fcm\_FAC\_A) * SW1\_r\_tot$$

where fcm_sw1_elec = solid waste (SW1) produced in electricity generation, lb/CY recyclables
fcm_comp_e = compactor energy usage, kWh/CY recyclables
fac_e = building energy usage, kWh/sq. ft/day
fcm_FAC_A = building area requirement (EQ 3.2.27), sq. ft./CYPD
$SW1\_r\_tot$ = solid waste (SW1) factor (electric energy model), lb/kWh

For diesel generation or precombustion emissions the calculation is:

EQ 3.2.59

$$fcm\_sw1\_rs\_pc = \frac{fcm\_rs\_e * sw1\_dies\_pc\_em}{1{,}000}$$

where $fcm\_sw1\_rs\_pc$ = solid waste (SW1) produced in diesel generatation, lb/CY recyclables
fcm_rs_e = rolling stock diesel usage, gallon/CY recyclables
$sw1\_dies\_pc\_em$ = diesel precombustion solid waste (SW1) production (common model), lb/1000 gallon

Waterborne releases

Equations for dissolved solids waterborne releases are given to illustrate waterborne release equations. For a complete list of waterborne pollutants tracked, refer to Table 5. Total waterborne releases are the sum of releases from facility washdown and energy generation:

EQ 3.2.60

$$item\_TR2\_ds\_FACTOR = \frac{(fcm\_ds\_wwr + fcm\_ds\_elec + fcm\_ds\_rs) * 2{,}000}{item\_D\_rcv * item\_CF}$$

where $item\_TR2\_ds\_FACTOR$ = waterborne dissolved solids per ton of refuse processed, lb/ton
fcm_ds_wwr = dissolved solids released in facility washwater, lb/CY recyclables
fcm_ds_elec = dissolved solids released in generation of electricity used, lb/CY recyclables
fcm_ds_rs = dissolved solids released in generation of diesel used, lb/CY recyclables
$item\_D\_rcv$ = density of recyclable item, lb/CY
$item\_CF$ = compaction factor for item, compacted density/loose density
2,000 lb/ton conversion factor
and other variables as defined below.

For facility wash water, dissolved solids are calculated as:

EQ 3.2.61

$$fcm\_ds\_wwr = fcm\_TR2\_WRUSE\_VOL\_FACTOR * DS\_wwr\_r$$

where fcm_ds_wwr = dissolved solids from wash water, lb/CY recyclables
$fcm\_TR2\_WRUSE\_VOL\_FACTOR$ = wash water use, gallon/CY recyclables
DS_wwr_r = wash water dissolved solids, lb/gallon

For electricity generation, dissolved solids are calculated with a factor that accounts for the releases associated with electricity production:

EQ 3.2.62

$$fcm\_ds\_elec = (fac\_e * fcm\_FAC\_A + fcm\_comp\_e) * DS\_elec\_lb\_KWH$$

where fcm_ds_elec = waterborne dissolved solids due to electricity generation, lb/CY recyclables
fac_e = facility energy usage, kWh/sq.ft./day
fcm_FAC_A = building area requirement (EQ 3.2.27), sq.ft./CYPD
fcm_comp_e = compactor energy usage, KWh/CY
$DS\_elec\_lb\_KWH$ = dissolved solids emissions from electricity generation, lb/kWh

For diesel precombustion, dissolved solids are:

EQ 3.2.63

$$fcm\_ds\_rs = \frac{fcm\_rs\_e * ds\_dies\_pc\_em}{1000}$$

where fcm_ds_dies = dissolved solids emissions due to diesel generation, lb/CY recyclables
fcm_rs_e = rolling stock diesel usage, gal/CY recyclables
$ds\_dies\_pc\_em$ = precombustion dissolved solids release factor (common model), lb/1000 gallon

3.3 EQUATIONS: TR3 – ONE-COMPARTMENT CO-COLLECTION VEHICLE

TR3 cost and LCI factors are calculated for the three types of material streams entering this transfer station: mixed refuse, recyclables, and fibrous content materials. The equations are presented in separate sections for each of the three material streams. Factors obtained for fibrous content material and mixed refuse are weight based. Item-specific weight-based factors for recyclables are calculated from volume-based factors for recyclables divided by the item-specific loose density. To simplify the presentation of equations, the prefix (TR3_) for variables referred to in this section has been omitted from variable names given below.

3.3.1 Cost Factors

3.3.1.1 Mixed Refuse Cost Factor

The costs for handling mixed refuse at TR3 are determined by summing applicable capital and operating cost components:

EQ 3.3.1

$$m\_TR3\_COST\_FACTOR = \frac{(m\_FAC\_AC + m\_EQ\_COST + m\_OP\_AC)}{ywd}$$

where $m\_TR3\_COST\_FACTOR$ = cost per ton mixed refuse processed at transfer station, \$/ton
m_FAC_AC = annual capital cost for facility (EQ. 3.3.2), \$/TPD - year
m_EQ_AC = annual equipment capital costs (EQ. 3.1.12), \$/TPD - year
m_OP_COST = annual operating costs (EQ. 3.3.8), \$/TPD - year
ywd = working days in a year, days/year

An explanation of calculations for each component of EQ 3.3.1 follows.

3.3.1.1.1 Facility Capital Cost for Mixed Refuse

Annualized facility capital cost per ton mixed refuse processed is determined from the sum of facility capital costs.

EQ 3.3.2

Facility Capital Cost (m_FAC_AC) = (Construction + Paving and Site work + Land + Engineering) X CRF

Facility capital costs depend on building area required for processing of mixed refuse as determined by the summation:

EQ 3.3.3

Mixed Refuse Facility Area = Mixed refuse fraction of black and blue bag tipping floor + Office space + Collection vehicle unloading area + Mixed refuse trailer loading bays

Black and blue bag tipping floor area is:

EQ 3.3.4

$$m\_mixed\_STR\_A = \frac{1.25 * rm\_stor * 2,000 * 27}{rm\_ht * D\_cv}$$

where

$m\_mixed\_STR\_A$ = co – collected bags tipping floor storage area, sq. ft./TPD
rm_stor = black and blue bag storage time on the tipping floor, days
rm_ht = height of black and blue bags stored on the tipping floor, ft.
D_cv = density of black and blue bags in collection vehicle, lb/cu. ft.
2,000 lb/ton, 27 CF/CY
and a 1.25 maneuverability and tipping floor expansion factor

Collection vehicle unloading area is:

EQ 3.3.5

$$m\_CV\_UL\_A = \frac{single\_cv\_ul\_a * cv\_ul\_hr * peak\_fct * 2000}{EWh\_d * cv\_load}$$

where

$m\_CV\_UL\_A$ = collection vehicle unloading area, sq. ft./TPD
$single\_cv\_ul\_a$ = area required for single collection vehicle to unload, sq. ft.
cv_ul_hr = time to unload a collection vehicle, hours
$peak\_fct$ = peak collection vehicle arrival rate, no units
EWh_d = effective work day length, workday less breaks and stoppages, hour/day
cv_load = average weight of collection vehicle, lb

Loading bay area for mixed refuse is determined by:

EQ 3.3.6

$$m\_LD\_A = \frac{m\_ld\_bay\_a * (m\_load\_hr + m\_tr\_rep\_hr) * 2000}{Ewh\_d * tr\_vol\_cap * tr\_d}$$

where
m_LD_A = mixed refuse trailer loading bay area, sq.ft./TPD
ld_bay_no = area required for single loading bay, sq.ft.
m_load_hr = time to load a trailer, hours
$m\_tr\_rep\_hr$ = time to replace a full trailer, hours
Ewh_d = effective working day length, hours/day
tr_vol_cap = transfer trailer capacity, cu.yd.
m_tr_d = density in of MSW in transfer vehicle, lb/cu.yd.

The office area rate is applied to the sum of the area requirements calculated above to obtain the total facility area:

EQ 3.3.7

$$M\_FAC\_A = (m\_mixed\_STR\_A + m\_LD\_A + m\_CV\_UL\_A) * (1 + off\_area\_r)$$

where
M_FAC_A = total facility area attributed to mixed refuse processing, sq.ft./TPD
$m\_mixed\_STR\_A$ = mixed refuse storage area, sq.ft./TPD
m_LD_A = mixed refuse trailer loading area, sq.ft./TPD
$m\_CV\_UL\_A$ = mixed refuse collection vehicle unloading area, sq.ft./TPD
off_area_r = percent of facility attributed to office space, no units

Once facility area is known, construction, paving and site work, land acquisition, and engineering costs are determined from EQ 3.1.8 through EQ 3.1.11.

3.3.1.1.2 Equipment Capital Costs for Mixed Refuse

Capital costs for equipment (m_EQ_AC) are determined as in TR1 with EQ 3.1.12 through EQ 3.1.13.

3.3.1.1.3 Operating Costs for Mixed Refuse

Operating costs include cost of labor, energy, and maintenance:

EQ 3.3.8

$$m\_OP\_AC = m\_WG\_AC + \sum_{i}^{\text{Equipment and Facility}} m\_E\_AC + \sum_{i}^{\text{Equipment and Facility}} m\_M\_AC$$

where m_OP_AC = *total annual cost per ton processed per day, $/TPD - year*
m_WG_AC = *labor and management annual costs, $/TPD - year*
m_E_AC = *rolling stock, compactor and facility annual energy costs, $/TPD - year*
m_M_AC = *rolling stock, compactor and facility annual maintenance costs, $/TPD - year*

Energy cost (m_E_AC) is calculated with TR1 equations EQ 3.1.16 through EQ 3.1.18 and maintenance costs (m_M_AC) are calculated with EQ 3.1.19. Operating costs associated with labor are calculated by:

EQ 3.3.9

$$m\_WG\_AC = ((1/m\_pick) + m\_op\_req) * op\_wage * ywd * (1 + mang\_r)$$

where m_WG_AC = *labor annual wage cost, $/TPD - year*
m_pick_ac = *manual sorting rate, ton/hour*
op_wage = *equipment operator wages, $/hour*
m_op_req = *operator labor hours required per ton, hour/day/TPD*
ywd = *working days in a year, day/year*
$mang\_r$ = *management rate as a fraction of labor cost, no units*

The default value for equipment operator requirement (op_req) is determined with a linear regression with operator hours required per day as a function of facility capacity (Appendix 5).

3.3.1.2 Recyclables Cost Factor

Weight-based cost factors for recyclable items are calculated from volume-based cost factors and the item density:

EQ 3.3.10

$$item\_TR3\_COST\_FACTOR = \frac{r\_TR3\_COST\_CY * 2{,}000}{item\_D\_rcv * item\_CF}$$

where $item\_TR3\_COST\_FACTOR$ = *cost factor for specific recyclable item, $/ton*
$r\_TR3\_COST\_CY$ = *volume based cost factor for recyclables defined below, $/CY*
$item\_D\_rcv$ = *density of specific recyclable item, lb/CY*
$item\_CF$ = *compaction factor for item, compacted density/loose density*
and 2,000 lb/ton conversion factor

EQ 3.3.11

$$r\_TR3\_COST\_CY = (r\_FAC\_AC + r\_EQ\_COST + r\_OP\_AC)/ywd$$

where
$r\_TR3\_COST\_CY$ = cost per cubic yard processed at transfer station, \$/cubic yard
r_FAC_AC = annual capital cost for facility(EQ. 3.3.12), \$/CYPD - year
r_EQ_AC = annual equipment capital costs (EQ. 3.3.19), \$/CYPD - year
r_OP_COST = annual operating costs (EQ. 3.3.20), \$/CYPD - year
ywd = working days in a year, days/year

The equations for components of EQ 3.3.11 are given below.

3.3.1.2.1 Facility Capital Costs for Recyclables

Facility capital costs are calculated by:

EQ 3.3.12

Facility Capital Cost(r_FAC_AC) = (Construction + Paving and Site work + Land + Engineering) X CRF

Facility capital costs for recyclables depend on area requirement to process recyclables, which is:

EQ 3.3.13

Recyclable Facility Area = Black and blue bag tipping floor + Separated blue bags storage area + Collection vehicle unloading area + Trailer loading bays + Office space

The mixed black and blue bag tipping floor area is:

EQ 3.3.14

$$r\_mixed\_STR\_A = \frac{1.25 * rm\_stor * 27}{rm\_ht}$$

where
$r\_mixed\_STR\_A$ = co – collected bags tipping floor storage area, sq. ft./CY PD
rm_stor = co – collected bags storage time after separation, days
rm_ht = height of co - collected bags piled in storage area, ft.
27 CF/CY and a 1.25 maneuverability and tipping floor expansion factor.

Collection vehicle unloading area for black and blue bag compartment is:

EQ 3.3.15

$$r\_CV\_UL\_A = \frac{single\_cv\_ul\_a * cv\_ul\_hr * peak\_fct}{EWh\_d * cv\_vol}$$

$$\begin{aligned}
\text{where} \quad r_CV_UL_A &= \text{collection vehicle unloading area, sq. ft./CYPD} \\
single_cv_ul_a &= \text{area required for single collection vehicle to unload, sq. ft.} \\
cv_ul_hr &= \text{time to unload a collection vehicle, hours} \\
peak_fct &= \text{peak collection vehicle arrival rate, no units} \\
EWh_d &= \text{effective work day length, workday less breaks and stoppages, hour/day} \\
cv_vol &= \text{utilized volume of collection vehicle, CY}
\end{aligned}$$

For commingled recyclables separated from mixed refuse, the storage area calculation is:

EQ 3.3.16

$$r\_STR\_A = \frac{1.25 * r\_stor * 27}{r\_ht}$$

$$\begin{aligned}
\text{where} \quad r_STR_A &= \text{recyclables storage area after manual separation, sq. ft./CYPD} \\
r_stor &= \text{recyclables storage time after separation, days.} \\
r_ht &= \text{height of recyclables piled in storage area, ft.} \\
& \text{27 CF/CY and a 1.25 maneuverability factor.}
\end{aligned}$$

The loading bay area is determined by:

EQ 3.3.17

$$r\_LD\_A = \frac{(r\_load\_hr + r\_tr\_rep\_hr) * r\_ld\_bay\_a}{Ewh\_d * tr\_vol\_cap}$$

$$\begin{aligned}
\text{where} \quad r_LD_A &= \text{area required for recyclable trailer loading, sq. ft./CYPD} \\
r_ld_bay_a &= \text{area required for single loading bay, sq. ft.} \\
r_load_hr &= \text{time to load a trailer, hours} \\
r_tr_rep_hr &= \text{time to replace a full trailer, hours} \\
Ewh_d &= \text{effective working day length, hours/day} \\
tr_vol_cap &= \text{transfer trailer capacity, cu. yd.}
\end{aligned}$$

The office area rate is applied to the sum of the area requirements calculated above to obtain the total recyclables processing facility area:

EQ 3.3.18

$$r\_FAC\_A = (r\_mixed\_STR\_A + r\_LD\_A + r\_CV\_UL\_A + r\_STR\_A) * (1 + off\_area\_r)$$

where
r_FAC_A = total facility area attributed to mixed refuse processing, sq. ft./CYPD
$r\_mixed\_STR\_A$ = mixed black and blue bag storage area attributed to recyclables, sq. ft./CYPD
r_STR_A = separated blue bag storage area, sq. ft./CYPD
r_LD_A = commingled recyclables trailer loading area, sq. ft./CYPD
$r\_CV\_UL\_A$ = commingled recyclables collection vehicle unloading area, sq. ft./CYPD
off_area_r = percent of facility attributed to office space, no units

Once recyclables area is known, construction, paving and site work, land acquisition, permitting, engineering, and contingency costs for recyclables are determined with equations used for TR2 (EQ 3.2.9 through EQ 3.2.12).

3.3.1.2.2 Equipment Capital Costs for Recyclables

Equipment capital costs (r_EQ_AC) include purchase and installation costs for rolling stock, compactors, and hoppers:

EQ 3.3.19

$$r\_EQ\_AC = (r\_RS\_cost + r\_COMP\_cost) * (1 + eq\_inst\_r)) * CRF$$

where
r_EQ_AC = rolling stock purchase and installation costs, \$/CYPD - year
r_RS_cost = cost purchasing transfer station rolling stock, \$/CYPD
r_COMP_cost = cost purchasing compactor and hopper for commingled recyclables, \$/CYPD
eq_inst_r = installation cost as a percentage of purchase price (same rate for all equipment)

The basis for default rolling stock cost (r_RS_cost) and compactor and hopper cost (r_COMP_cost) are given in Appendix 5. Default values are determined from a linear regression of rolling stock costs for a range of facility capacities and from a linear regression of compactor and hopper costs for a range of facility capacities.

3.3.1.2.3 Operating Costs for Recyclables

Facility operation costs include annual costs for labor, energy usage, and maintenance for building and equipment. The components of operating costs are determined on an annual basis in terms of cubic yards processed per day.

EQ 3.3.20

$$r\_OP\_AC = r\_WG\_AC + \sum_{i}^{\text{Equipment and Facility}} r\_E\_AC + \sum_{i}^{\text{Equipment and Facility}} r\_M\_AC$$

where r_OP_AC = *total annual cost per cubic yard processed per day, $/CYPD - year*
r_WG_AC = *labor and management annual costs, $/CYPD - year*
r_E_AC = *rolling stock and facility annual energy costs, $/CYPD - year*
r_M_AC = *rolling stock and facility annual maintenance costs, $/CYPD - year*

Labor costs include both costs for equipment operators and manual sorters:

EQ 3.3.21

$$r\_WG\_AC = (r\_op\_req + \frac{1}{r\_pick\_r}) * op\_wage * ywd * (1 + mang\_r)$$

where r_WG_AC = *loader annual wage cost, $/CYPD - year*
op_wage = *equipment operator wages, $/hour*
r_op_req = *operator labor hours required per cubic yard, hour/day/CYPD*
r_pick_r = *picking rate, CY/person/hr*
ywd = *working days in a year, day/year*
$mang\_r$ = *management rate as a percent of labor cost, no units*

The default value for equipment operator requirement (r_op_req) is determined with a regression analysis of the labor requirements as a function of transfer station capacity (Appendix 5).

Energy costs for diesel-powered rolling stock are calculated by:

EQ 3.3.22

$$r\_RS\_E\_AC = dies\_c * r\_rs\_e * ywd$$

where $r\_RS\_E\_AC$ = *rolling stock annual energy cost, $/CYPD - year*
$dies\_c$ = *cost of diesel fuel from common module, $/gallon*
r_rs_e = *diesel fuel requirement, gallon/cubic yard*
ywd = *work days in a year, day/year*

The fuel requirement for rolling stock is determined from a regression analysis of fuel as a function of facility capacity (Appendix 5).

Facility energy cost is:

EQ 3.3.23

$$r\_FAC\_E\_AC = (fac\_e * r\_FAC\_A + comp\_e) * elec\_c * ywd$$

$$\begin{aligned} \text{where } r\_FAC\_E\_AC &= \text{facility energy cost, \$/CYPD - year} \\ fac\_e &= \text{facility electricity usage, kWh/sq. ft} - \text{day} \\ r\_FAC\_A &= \text{area required for transfer station (EQ. 3.3.18), sq. ft./CYPD} \\ elec\_c &= \text{electricity cost from common model, \$/kWh} \\ comp\_e &= \text{compactor energy requirement, kWh/CY} \\ ywd &= \text{yearly working days, day/year} \end{aligned}$$

The annual cost per ton per day for facility maintenance is a user-entered or a default value; therefore, calculations are not required. Rolling stock maintenance costs are calculated by:

EQ 3.3.24

$$r\_EQ\_M\_AC = eq\_mc * (r\_RS\_cost + r\_COMP\_cost)$$

$$\begin{aligned} \text{where } r\_EQ\_M\_AC &= \text{annual equipment maintanace cost, \$/CYPD - year} \\ eq\_mc &= \text{annual equipment maintenance cost as a fraction of equipment cost, 1/year} \\ r\_EQ\_cost &= \text{capital cost of rolling stock, \$/CYPD} \\ r\_COMP\_cost &= \text{capital cost of compactor and hopper, \$/CYPD} \end{aligned}$$

The default value for rolling stock cost (r_RS_cost) and compactor and hopper (r_COMP_cost) is determined from a linear regression of equipment costs for a range of facility capacities (Appendix 5).

3.3.1.3 Fibrous Content Material Cost Factor

3.3.1.3.1 FACILITY CAPITAL COSTS FOR FIBROUS CONTENT MATERIAL

The determination of facility capital costs associated with processing fibrous content materials are the same as equations presented in Section 3.3.1.2.1. Input parameters for recyclables (designated with an "*r_*") are replaced with input parameters pertaining to fibrous content material (designated with "*fcm_*").

3.3.1.3.2 EQUIPMENT CAPITAL COSTS FOR FIBROUS CONTENT MATERIAL

Equipment capital costs (r_EQ_AC) include purchase and installation costs for rolling stock:

EQ 3.3.25

$$fcm\_EQ\_AC = fcm\_RS\_cost * (1 + eq\_inst\_r) * CRF$$

$$\begin{aligned} \text{where} \quad fcm\_EQ\_AC &= \text{rolling stock purchase and installation costs,} \quad \$/CYPD\text{ - year} \\ fcm\_RS\_cost &= \text{cost of purchasing transfer station rolling stock,} \quad \$/CYPD \\ eq\_inst\_r &= \text{installation cost as a percentage of purchase price} \\ &\quad \text{(same rate for all equipment)} \end{aligned}$$

The basis for default rolling stock cost (fcm_RS_cost) is given in Appendix 5. Default values are determined from a linear regression of rolling stock costs for a range of facility capacities and of compactor and hopper costs for a range of facility capacities.

3.3.1.3.3 OPERATING COSTS FOR FIBROUS CONTENT MATERIAL

Operating costs for fibrous content material include the cost of labor, energy, and maintenance. Operating Cost equations are similar to TR2 equations for commingled recyclables (EQ 3.2.20 through 3.2.24) except that EQ 3.3.23 is revised because compactors are not used for fibrous content materials. The new equation is 3.3.26:

EQ 3.3.26

$$fcm\_FAC\_E\_AC = (fac\_e * fcm\_FAC\_A) * elec\_c * ywd$$

$$\begin{aligned} \text{where} \quad fcm\_FAC\_E\_AC &= \text{facility energy cost,} \$/CYPD\text{ - year} \\ fac\_e &= \text{facility electricity usage,} \quad kWh/sq.ft - day \\ fcm\_FAC\_A &= \text{area required for transfer station,} \quad sq.ft./CYPD \\ elec\_c &= \text{electricity cost from common model,} \quad \$/kWh \\ ywd &= \text{yearly working days,} \quad day/year \end{aligned}$$

3.3.2 Life Cycle Inventory Factors

Different sets of equations are used for calculation of LCI factors for mixed refuse, commingled recyclables, and fibrous content material. For mixed refuse, emissions, water usage, and energy usage, factors are calculated in the same manner as described for TR1 in Section 3.1.2. Item-specific recyclables LCI factors, including factors for fibrous content materials, are determined from volume-based factors and the item-specific density. Equations for the LCI section of TR2 (3.2.2) also apply to the recyclables processed at TR3.

3.4 EQUATIONS: TR4 – THREE COMPARTMENT CO-COLLECTION

In TR4, mixed refuse, commingled recyclables, and fibrous content materials are all delivered in separate compartments of the same truck. Cost and LCI equations are developed separately for each compartment in Sections 3.4.1 and 3.4.2, respectively. Factors obtained for mixed refuse are weight-based. Item-specific weight-based factors for commingled recyclables and fibrous content materials are calculated from volume-based factors for recyclables divided by the item-specific loose density. To simplify the presentation of equations, the prefix (TR4_) for variables referred to in this section has been omitted from variable names given below.

3.4.1 Cost Factors

TR4 costs are determined separately for mixed refuse, fibrous content materials, and commingled recyclables by summing applicable capital and operating cost components attributable to each.

3.4.1.1 Mixed Refuse Cost Factor

The cost factor for mixed refuse includes facility and equipment capital costs and operating costs:

EQ 3.4.1

$$m\_TR4\_COST\_FACTOR = \frac{(m\_FAC\_AC + m\_EQ\_COST + m\_OP\_AC)}{ywd}$$

$$\begin{aligned} \text{where } m\_TR4\_COST\_FACTOR &= \text{cost per ton mixed refuse processed at transfer station, \$/ton} \\ m\_FAC\_AC &= \text{annual capital cost for facility, \$/TPD - year} \\ m\_EQ\_AC &= \text{annual equipment capital costs, \$/TPD - year} \\ m\_OP\_COST &= \text{annual operating costs, \$/TPD - year} \\ ywd &= \text{working days in a year, days/year} \end{aligned}$$

An explanation of calculations for each component of EQ 3.4.1 for mixed refuse follows.

3.4.1.1.1 FACILITY CAPITAL COSTS FOR MIXED REFUSE

Annualized facility capital cost per ton MSW processed is determined from the sum of facility capital costs.

EQ 3.4.2

Facility Capital Cost (m_FAC_AC) = (Construction + Paving and Site work + Land + Engineering) X CRF

Facility capital costs depend on building area attributed to processing of mixed refuse as determined by the summation:

EQ 3.4.3

Mixed Refuse Facility Area = Mixed refuse tipping floor storage + Collection vehicle unloading + Trailer loading bays + Office space

All area calculations for TR4 are obtained from TR3 equations EQ 3.3.5 through EQ 3.3.8, and facility capital cost equations for TR4 are the same as those for TR1 equations EQ 3.1.8 through EQ 3.1.11.

3.4.1.1.2 Equipment Capital Costs for Mixed Refuse

TR4 equipment costs are calculated with equations used for TR1 equipment costs (EQ 3.1.12 through EQ 3.1.13).

3.4.1.1.3 Operating Cost for Mixed Refuse

TR4 operating costs are calculated with equations used for TR1 operating costs (EQ 3.1.14 through EQ 3.1.19).

3.4.1.2 Recyclables Cost Factor

The cost factor for recyclables processed at TR4 is determined as for TR3 with EQ 3.3.10 through EQ 3.3.11. Weight-based factors are calculated for each item from a volume-based factor for processing recyclables at the facility and the item-specific density. The volume-based cost factor for recyclables includes the facility and equipment capital costs and facility operating costs.

3.4.1.2.1 Facility Capital Cost for Recyclables

Facility capital costs for recyclables are determined as for TR3 (EQ 3.3.12**)** and depend on facility area attributable to recyclables:

EQ 3.4.4

Recyclables Facility Area = Recyclables tipping floor + Trailer loading bays + Collection vehicle unloading + Office space

Areas listed above are calculated as in TR2 equations EQ 3.3.15 through EQ 3.3.18. Facility capital costs are then determined from TR2 equations EQ 3.2.9 through EQ 3.2.12.

3.4.1.2.2 Equipment Capital Costs for Recyclables

TR4 equipment costs for recyclables are calculated with the equation used for TR3 equipment costs for recyclables (EQ 3.3.19).

3.4.1.2.3 Operating Costs for Recyclables

TR4 operating costs are calculated with equations used for TR3 operating costs (EQ 3.3.20 through EQ 3.3.24). However, the picker wage rate in EQ 3.3.21 is zero since blue and black bags are already separated.

3.4.1.3 Fibrous Content Material Cost factor

The fibrous content material cost factor is determined with the same equations presented for commingled recyclables for TR4.

3.4.2 Life Cycle Inventory Factors

Different sets of equations are used for calculation of LCI factors for mixed refuse, commingled recyclables, and fibrous content materials. For mixed refuse, emissions, water usage, and energy usage, factors are calculated in the same manner as described for TR1 in Section 3.1.2. Item-specific recyclable LCI factors for commingled recyclables and fibrous content material are determined from volume-based factors and the item-specific density. Equations for the LCI section of TR2 (3.2.2) also apply to the recyclables processed at TR4.

3.5 EQUATIONS: TR5 -- PRESORTED RECYCLABLES

3.5.1 Cost Factors

TR5 receives presorted recyclables. For each recyclable item, a volume-specific cost factor and item-specific densities are utilized to calculate weight-based cost factors:

EQ 3.5.1

$$item\_TR5\_COST\_FACTOR = \frac{TR5\_COST\_CY * 2000}{item\_D\_rcv * item\_CF}$$

$$\begin{aligned} where \quad item\_TR5\_COST\_FACTOR &= cost\ per\ ton\ of\ recyclable\ item\ processed, \quad \$/ton \\ TR5\_COST\_CY &= cost\ per\ volume\ processed\ calculated\ below, \quad \$/cubic\ yard \\ item\_D\_rcv &= item\ specific\ density\ from\ common\ model, \quad lb/cubic\ yard \\ item\_CF &= compaction\ factor\ for\ item, \quad compacted\ density/loose\ density \\ & \quad 2{,}000\ lb/ton\ conversion\ factor. \end{aligned}$$

Total transfer station cost per cubic yard of recyclables is obtained by summing operating costs and annualized capital costs for the facility and equipment:

EQ 3.5.2

$$TR5\_COST\_CY = (FAC\_AC + EQ\_COST + OP\_AC)/ywd$$

$$\begin{aligned} where \quad TR5\_COST\_CY &= cost\ per\ cubic\ yard\ processed\ at\ transfer\ station, \$/cubic\ yard \\ FAC\_AC &= annual\ capital\ cost\ for\ facility (EQ. 3.5.3), \$/CYPD - year \\ EQ\_AC &= annual\ equipment\ capital\ costs\ (EQ. 3.3.19), \$/CYPD - year \\ OP\_COST &= annual\ operating\ costs\ (EQ. 3.3.20), \$/CYPD - year \\ ywd &= working\ days\ in\ a\ year, days/year \end{aligned}$$

An explanation of calculations for each component of EQ 3.5.2 follows.

3.5.1.1 Facility Capital Cost

Annualized facility capital cost per cubic yard recyclables processed (FAC_AC) is determined from the sum of facility capital costs:

EQ 3.5.3

Facility Capital Cost(FAC_AC) = (Construction + Paving and Site work + Land + Engineering) X CRF

Since components of facility capital cost are obtained by multiplying unit costs such as land acquisition and construction rates by facility area per cubic yard MSW processed, the facility area is calculated:

EQ 3.5.4

$$FAC\_A = CTM\_A * (1 + off\_area\_r)$$

where FAC_A = total facility area, sq. ft./CYPD
CTM_A = container and vehicle manuevering area (EQ 3.5.5), sq. ft./CYPD
off_area_r = office area as a percentage of facility area

EQ 3.5.5

$$CTM\_A = \frac{fac\_vol\_cap * (load\_hr + ct\_rep\_hr) * ct\_a}{EWh\_d * ct\_vol\_cap}$$

where CTM_A = area required for containers and vehicle maneuvering, sq. ft./CYPD
fac_vol_cap = facility volume capacity, cu. yd./day
$load\_hr$ = container loading time, hour
ct_rep_hr = container replacement time, hour
ct_a = area required for single container and vehicle maneuvering, sq. ft.
ct_vol_cap = capacity of container, cu. yd.
EWh_d = effective workday, hours/day

Typically containers fill at varying rates; however, an average container loading rate is used to determine the number of containers. Once total facility area is known, facility costs are calculated with TR2 equations EQ 3.2.9 through EQ 3.2.12.

3.5.1.2 Equipment Capital Costs

Capital costs for equipment are determined as for recyclables in TR3 with EQ 3.3.19.

3.5.1.3 Operating Costs

Operating costs are calculated as in TR3 equations EQ 3.3.20 through EQ 3.3.24.

3.5.2 Life Cycle Inventory Factors

Item-specific recyclables LCI factors are determined from a volume-based factor and the item-specific densities. Equations for the LCI section of commingled recyclables for TR2 apply to the recyclables processed at TR5 (EQ 3.2.28 through 3.2.45).

3.6 EQUATIONS: RT1 -- MSW RAIL TRANSFER FROM COLLECTION VEHICLES

3.6.1 Cost Factors

RT1 is designed to transfer mixed refuse to rail cars. The RT1 cost factor includes the same components as TR1 (EQ 3.1.1); the governing facility design equations are equivalent to those presented in section 3.1.1. The paving and site work rate calculated in EQ 3.1.9 is assumed to include the cost of rail spurs that connect the facility to local rail lines. The local rail line between this facility and a landfill or anaerobic digester is assumed to be included in transportation costs that are determined by the transportation process model.

3.6.2 Life Cycle Inventory Factors

Governing design equations and LCI factor calculations for RT1 are determined by using EQ 3.1.20 to EQ 3.1.36.

3.7 EQUATIONS: RT2 -- MSW RAIL TRANSFER FROM RAIL TO LANDFILL D1

3.7.1 Cost Factors

RT2 is designed to receive loaded rail cars of MSW and transfer the MSW to a landfill. The cost equations for RT2 are the same equations as given for TR1 in Section 3.1.1.1 except total facility area is determined differently. Building area includes loading and unloading areas, as well as a container storage area. Storage space is required for one day because an entire train load of containers arrives at once. The loading and unloading areas are assumed to be included in the maneuverability factor of the facility area equation. Building area is calculated by:

EQ 3.7.1

$$FAC\_A = \frac{1.25 * stor * 2000 * 27}{ct\_ht * stk\_no * trans\_d} * (1 + off\_area\_r)$$

$$\begin{aligned}
\text{where} \quad FAC_A &= \text{area per daily ton processed, sq.ft./TPD} \\
stor &= \text{container storage time, days} \\
trans_d &= \text{refuse density in transfer container, lb./cu. yd.} \\
stk_no &= \text{storage stack hieght, number of containers stacked} \\
ct_ht &= \text{container height, ft.} \\
off_area_r &= \text{office area as a fraction of building area, unitless} \\
&\quad \text{and a 1.25 manueverability factor.}
\end{aligned}$$

Once facility area per daily tonnage is determined in EQ 3.7.1, the remaining cost calculations utilize TR1 equations EQ 3.1.8 through EQ 3.1.11. The paving and site work rate used for the facility capital cost calculation is assumed to include the cost of rail spurs that connect the facility to local rail lines. The local rail line between this facility and a landfill or anaerobic digester is assumed to be included in transportation costs that are determined by the transportation process model.

Equipment and operating costs are calculated with equations presented for TR1 (EQ 3.1.14 through EQ 3.1.19).

3.7.2 Life Cycle Inventory Factors

LCI factors are calculated in a similar manner to that for TR1 in Section 3.1.2 but based on the area and equipment requirements for RT2.

3.8 EQUATIONS: RT3 -- MSW RAIL TRANSFER FROM RAIL TO LANDFILL D3

RT3 factors are determined with the same equations as RT2, because RT3 operates similarly to RT2.

APPENDICES

APPENDIX 1 – TRANSFER STATION MODEL TABLES

This appendix presents default input values for each of the eight transfer station types. References for general input are given at the end of this section. The source of input values that are generally site-specific is designated with "*". The source of input values that are derived from the regression analysis presented in Appendix 5 is designated with "**". If default data are unavailable for an input parameter, then the table cell for that parameter is blank.

TR1 - INPUT VALUES

Design Selection

1

	units	variable name	Design 1	Design 2	Design 3	Design 4	Design 5	Source
Economic								
Life of Transfer Station Structure	years	fac_l	20	20	20	20	20	*
Operating Hours								
Working Day Length	hours	wh_d	8	8	8	8	8	*
Effective Working Day Length	hours	EWh_d	7	7	7	7	7	*
Number of workdays per year	days	ywd	260	260	260	260	260	*
Facility Construction Data								
Construction rate	$/sq. ft	const_c	55	55	55	55	55	[1]
Engineering, Permitting & Contingency Rate(% Bldg & Site Cost)	fraction	eng_r	0.30	0.30	0.30	0.30	0.30	[2]
Land acquisition rate	$/acre	land_c	1000	1000	1000	1000	1000	*
Paving and Sitework	$/sq ft	sitew_c	1.44	1.44	1.44	1.44	1.44	[1]
Equipment Installation rate(% of equip. cost)	fraction	eq_inst_r	0.05	0.05	0.05	0.15	0.15	[2]
Data for Area Calculation								
Height of Refuse on Tipping Floor	ft	ht	10	10	10	10	10	*
Storage Time on Tipping Floor	day	stor	1	1	0.25	1	0.25	*
Trailer Load Time for Continuous Loading from Tipping Floor	hours	tr_ld_hr	0.15	0.25	n/a	0.25	n/a	[7]
Trailer Load Time for Peak Direct Tip Collection Vehicle Traffic	hours	tr_ld_hr	n/a	n/a	0.4	n/a	0.5	[7]
Trailer Replace Time	hours	tr_rep_hr	0.2	0.2	0.2	0.2	0.2	[7]
Haul Trailer Volume	cu yd	tr_vol_cap	100	100	100	100	100	[3]
Transfer Veh. Density	lb./cu yd	tr_d	450	450	450	550	550	[7]
Area Required for one Trailer/Loading Bay	sq ft	ld_bay_a	1800	1200	1200	1500	1500	[10]
Collection Veh. Unload Time	hours	cv_ul_hr	0.15	0.15	0.15	0.20	0.20	[7]
Peak Collection Vehicle Arrival Factor	unitless	peak_fct	1.5	1.5	1.5	1.5	1.5	*
Collection Vehicle Weight of Load	cv_load	lb	14000	14000	14000	14000	14000	[6]
Single Collection Vehicle Unloading Area	sq ft	single_cv_ul_a	525	525	525	525	525	[10]
Office Area (% of Tipping Floor)	fraction	off_area_r	0.10	0.10	0.10	0.10	0.10	[10]
Land Requirement(multiple of building area)	unitless	land_area_r	10	10	10	10	10	[1]
Equipment Cost Data								
Rolling Stock Cost Rate	$/TPD		816	1308	837	497	244	**
Compactor and Hopper Cost Rate	$/TPD		0	0	0	156	190	**
Rolling Stock Life	years		10	10	10	10	10	[9]
Compactor Life	years		10	10	10	10	10	[7]
Operating and Maintenance								
Labor								
Equipment Operator Requirement	hr/day-TPD	op_req	0.047	0.070	0.097	0.051	0.051	**
Equipment Operator and Labor Wage Rate	$/hr	op_wage	10	10	10	10	10	*
Management Rate	Fraction of labor	mang_r	0.3	0.3	0.3	0.3	0.3	*
Maintenance								
Equipment	Fraction of Cost	eq_mc	0.05	0.05	0.05	0.05	0.05	[4]
Building	$/TPD-yr	fac_mc	3.25	3.25	3.25	3.25	3.25	[5]
Fuel and Energy								
Building Electric Energy Usage	kWh/sf/day	fac_e	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	[6]
Compactor Electric Energy Usage	kWh/ton	comp_e	n/a	n/a	n/a	0.53	0.53	[7]
Rolling Stock Fuel Usage	gal/ton MSW	rs_e	8.45E-02	1.41E-01	7.13E-02	7.92E-02	3.76E-02	**
LCI Input Values								
Rolling Stock Emissions								
Particulates (PM10)	lb/ton	pm10_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
Total Particulates	lb/ton	pm_rs_c	5.65E-03	9.31E-03	1.05E-02	6.63E-03	5.52E-03	**
Nitrogen Oxides	lb/ton	no_rs_c	7.59E-02	1.27E-01	9.15E-02	9.90E-02	4.83E-02	**
Hydrocarbons (non CH4)	lb/ton	hc_rs_c	5.32E-03	9.23E-03	1.03E-02	8.65E-03	5.42E-03	**
Sulfur Oxides	lb/ton	so_rs_c	6.68E-03	1.11E-02	6.08E-03	8.17E-03	3.21E-03	**
Carbon Monoxide	lb/ton	co_rs_c	1.87E-02	3.10E-02	3.97E-02	2.31E-02	2.10E-02	**
CO2 (biomass)	lb/ton	co2_bm_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
CO2 (non biomass)	lb/ton	co2_rs_c	1.94E+00	3.25E+00	1.64E+00	1.82E+00	8.66E-01	**
Ammonia	lb/ton	a_nh3_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
Lead	lb/ton	a_pb_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
Methane	lb/ton	ch4_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
Hydrochloric acid	lb/ton	hlc_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
WASHWATER								
Facility Washdown Water Volume	gallon/sf-wash	fac_wr_sf	0.2	0.2	0.2	0.2	0.2	[6]
Washdown Rate	wash/month	wash_r	1	1	1	1	1	[8]

TR1 - INPUT VALUES

Design Selection

	units	variable name	Design 1	Design 2	Design 3	Design 4	Design 5	Source
			1					
Waterborne Release Rates								
Dissolved solids	lb./gallon	DS_wwr_r						
Suspended solids	lb./gallon	SS_wwr_r						
BOD of washdown water	lb./gallon	BOD_wwr_r						
COD of washdown water	lb./gallon	COD_wwr_r						
Oil	lb./gallon	OIL_wwr_r						
Sulfuric acid	lb./gallon	H2S04_wwr_r						
Iron	lb./gallon	FE_wwr_r						
Ammonia	lb./gallon	W_NH3_wwr_r						
Copper	lb./gallon	Cu_wwr_r						
Cadmium	lb./gallon	Cd_wwr_r						
Arsenic	lb./gallon	As_wwr_r						
Mercury	lb./gallon	Hg_wwr_r						
Phosphate	lb./gallon	P_x_wwr_r						
Selenium	lb./gallon	Se_wwr_r						
Chromium	lb./gallon	CR_wwr_r						
Lead	lb./gallon	W_PB_wwr_r						
Zinc	lb./gallon	ZN_wwr_r						

TR2 - INPUT VALUES

Design Selection

	units	variable name	Design 1	Design 2	Design 3	Design 4	Design 5	Source
	1							
Economic								
Life of Transfer Station Structure	years	fac_l	20	20	20	20	20	*
Glass Breakage Factor for Model	fraction	gl_break	0.3	0.3	0.3	0.3	0.3	[10]
Operating Hours								
Working Day Length	hours	wh_d	8	8	8	8	8	*
Effective Working Day Length	hours	EWh_d	7	7	7	7	7	*
Number of workdays per year	days	ywd	260	260	260	260	260	*
Facility Construction Data								
Construction rate	$/sq. ft	const_c	55	55	5	55	55	[1]
Engineering, Permitting & Contingency Rate	%	eng_r	0.3	0.3	0.3	0.3	0.3	[2]
Land acquisition rate	$/acre	land_c	1000	1000	1000	1000	1000	*
Paving and Sitework	$/sq ft	sitew_c	1.44	1.44	1.44	1.44	1.44	[1]
Equipment Installation rate(% of equip. cost)	%	eq_inst_r	5%	5%	5%	15%	15%	[2]
Recyclables Processing Area								
Height of Refuse on Tipping Floor	ft	ht	10	10	10	10	10	*
Storage Time on Tipping Floor	day	stor	1	1	0.25	1	0.25	*
Trailer Load Time for Continuous Loading	hours	tr_ld_hr	0.15	0.25	n/a	0.25	n/a	[7]
Trailer Load Time for Peak Direct Tip Vehicle Traffic	hours	tr_ld_hr	n/a	n/a	0.4	n/a	0.5	[7]
Trailer Replace Time	hours	tr_rep_hr	0.2	0.2	0.2	0.2	0.2	[7]
Haul Trailer Volume	cu yd	tr_vol_cap	100	100	100	100	100	[3]
Area Required for one Trailer/Loading Bay	sq ft	ld_bay_a	1800	1200	1200	1500	1500	[10]
Collection Veh. Unload Time	hours	cv_ul_hr	0.15	0.15	0.15	0.2	0.2	[7]
Peak Collection Vehicle Arrival Factor	unitless	peak_fct	1.5	1.5	1.5	1.5	1.5	*
Collection Vehicle Volume	cubic yard	cv_vol	22	22	22	22	22	[6]
Single Collection Vehicle Unloading Area	sq ft	single_cv_ul_a	525	525	525	525	525	[7]
Fibrous Content Material Processing Area								
Height of Refuse on Tipping Floor	ft	ht	10	10	10	10	10	*
Storage Time on Tipping Floor	day	stor	1	1	1	1	1	*
Trailer Load Time for Continuous Loading	hours	tr_ld_hr	0.4	0.4	0.4	0.4	0.4	[7]
Trailer Replace Time	hours	tr_rep_hr	0.2	0.2	0.2	0.2	0.2	[7]
Haul Trailer Volume	cu yd	tr_vol_cap	100	100	100	100	100	[7]
Area Required for one Trailer/Loading Bay	sq ft	ld_bay_a	1200	1200	1200	1200	1200	[10]
Collection Veh. Unload Time	hours	cv_ul_hr	0.15	0.15	0.15	0.15	0.15	[7]
Peak Collection Vehicle Arrival Factor	unitless	peak_fct	1.5	1.5	1.5	1.5	1.5	[7]
Collection Vehicle Volume	cubic yard	cv_vol	6	6	6	6	6	[7]
Single Collection Vehicle Unloading Area	sq ft	single_cv_ul_a	525	525	525	525	525	[10]
General Area								
Office Area (% of Tipping Floor)	%	off_area_r	10%	10%	10%	10%	10%	[10]
Land Requirement(multiple of building area)	unitless	land_area_r	10	10	10	10	10	[10
Equipment Cost Data								
Recyclables Rolling Stock Cost Rate	$/CYPD	r_RS_cost	193	220	106	119	58	**
Compactor and Hopper Cost Rate	$/CYPD	r_COMP_cost	0.00	0.00	0.00	37.16	35.10	**
Fibrous Content Material Rolling Stock Cost Rate	$/TPD	fcm_RS_cost	99	99	99	99	99	**
Rolling Stock Life	years	r_l	10.00	10.00	10.00	10.00	10.00	[9]
Compactor Life	years	comp_l	10.00	10.00	10.00	10.00	10.00	[7]
Operating and Maintenance								
Labor								
Rec. Equipment Operator Requirement	hr/day-CYPD	r_op_req	1.64E-02	9.69E-03	8.29E-03	1.23E-02	1.23E-02	**
Fibrous Content Material Equipment Operator Requirement	hr/day-CYPD	fcm_op_req	1.42E-03	1.42E-03	1.42E-03	1.42E-03	1.42E-03	**
Equipment Operator and Labor Wage Rate	$/hr	op_wage	10	10	10	10	10	*
Management Rate	% of labor	mang_r	0.3	0.3	0.3	0.3	0.3	*
Maintenance								
Equipment	% Cost	eq_mc	0.05	0.05	0.05	0.05	0.05	[4]
Building	$/CYPD-yr	fac_mc	3.25	3.25	3.25	3.25	3.25	[5]
Fuel and Energy								
Building Electric Energy Usage	kWh/sf/day	fac_e	0.001	0.001	0.001	0.001	0.001	[6]
Compactor Electric Energy Usage	kWh/CY	r_comp_e	n/a	n/a	n/a	0.53	0.53	[7]
Recyclables Rolling Stock Fuel Usage	gal/CY MSW	r_rs_e	1.95E-02	2.27E-02	8.99E-03	2.60E-02	8.99E-03	**
Fibrous Content Material Rolling Stock Fuel Usage	gal/ton ONP	fcm_rs_e	1.41E-02	1.41E-02	1.41E-02	1.41E-02	1.41E-02	**
LCI Input Values								

TR2 - INPUT VALUES

Design Selection

	units	variable name	Design 1	Design 2	Design 3	Design 4	Design 5	Source
		1						
Recyclables Rolling Stock Emissions								
Particulates (PM10)	lb/CY	r_pm10_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
Total Particulates	lb/CY	r_pm_rs_c	1.29E-03	1.52E-03	1.32E-03	1.58E-03	1.32E-03	**
Nitrogen Oxides	lb/CY	r_nfcm_rs_c	1.75E-02	2.10E-02	1.15E-02	2.36E-02	1.15E-02	**
Hydrocarbons (non CH4)	lb/CY	r_hc_rs_c	1.27E-03	1.58E-03	1.29E-03	2.06E-03	1.29E-03	**
Sulfur Oxides	lb/CY	r_sfcm_rs_c	1.53E-03	1.82E-03	7.66E-04	1.95E-03	7.66E-04	**
Carbon Monoxide	lb/CY	r_cfcm_rs_c	4.28E-03	5.10E-03	5.01E-03	5.50E-03	5.01E-03	**
CO2 (biomass)	lb/CY	r_co2_bm_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
CO2 (non biomass)	lb/CY	r_co2_rs_c	4.48E-01	5.21E-01	2.07E-01	5.98E-01	2.07E-01	**
Ammonia	lb/CY	r_a_nh3_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
Lead	lb/CY	r_a_pb_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
Methane	lb/CY	r_ch4_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
Hydrochloric acid	lb/CY	r_hlc_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
Fibrous Content Material Rolling Stock Emissions								
Particulates (PM10)	lb/CY	fcm_pm10_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
Total Particulates	lb/CY	fcm_pm_rs_c	8.58E-04	8.58E-04	8.58E-04	8.58E-04	8.58E-04	**
Nitrogen Oxides	lb/CY	fcm_nfcm_rs_c	1.28E-02	1.28E-02	1.28E-02	1.28E-02	1.28E-02	**
Hydrocarbons (non CH4)	lb/CY	fcm_hc_rs_c	1.12E-03	1.12E-03	1.12E-03	1.12E-03	1.12E-03	**
Sulfur Oxides	lb/CY	fcm_sfcm_rs_c	1.06E-03	1.06E-03	1.06E-03	1.06E-03	1.06E-03	**
Carbon Monoxide	lb/CY	fcm_cfcm_rs_c	2.98E-03	2.98E-03	2.98E-03	2.98E-03	2.98E-03	**
CO2 (biomass)	lb/CY	fcm_co2_bm_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
CO2 (non biomass)	lb/CY	fcm_co2_rs_c	3.24E-01	3.24E-01	3.24E-01	3.24E-01	3.24E-01	**
Ammonia	lb/CY	fcm_a_nh3_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
Lead	lb/CY	fcm_a_pb_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
Methane	lb/CY	fcm_ch4_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
Hydrochloric acid	lb/CY	fcm_hlc_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
WASHWATER								
Facility Washdown Water Volume	gallon/sf	fac_wr_sf	0.2	0.2	0.2	0.2	0.2	[6]
Washdown Rate	wash/month	wash_r	1	1	1	1	1	[8]
Waterborne Release Rates								
Dissolved solids	lb./gallon	DS_wwr_r						
Suspended solids	lb./gallon	SS_wwr_r						
BOD of washdown water	lb./gallon	BOD_wwr_r						
COD of washdown water	lb./gallon	COD_wwr_r						
Oil	lb./gallon	OIL_wwr_r						
Sulfuric acid	lb./gallon	H2S04_wwr_r						
Iron	lb./gallon	FE_wwr_r						
Ammonia	lb./gallon	W_NH3_wwr_r						
Copper	lb./gallon	Cu_wwr_r						
Cadmium	lb./gallon	Cd_wwr_r						
Arsenic	lb./gallon	As_wwr_r						
Mercury	lb./gallon	Hg_wwr_r						
Phosphate	lb./gallon	P_x_wwr_r						
Selenium	lb./gallon	Se_wwr_r						
Chromium	lb./gallon	CR_wwr_r						
Lead	lb./gallon	W_PB_wwr_r						
Zinc	lb./gallon	ZN_wwr_r						

TR3 and TR4 - INPUT VALUES

	units	variable name	TR3	TR4	Source
Economic					
Life of Transfer Station Structure	years	fac_l	20	20	*
Operating Hours					
Working Day Length	hours	wh_d	8	8	*
Effective Working Day Length	hours	EWh_d	7	7	*
Number of workdays per year	days	ywd	260	260	*
Facility Construction Data					
Construction rate	$/sq. ft	const_c	55	55	[1]
Engineering, Permitting & Contingency Rate(% Bldg & Site C	%	eng_r	0.30	0.30	[2]
Land acquisition rate	$/acre	land_c	1000	1000	*
Paving and Sitework	$/sq ft	sitew_c	1.44	1.44	[1]
Equipment Installation rate(% of equip. cost)	fraction	eq_inst_r	0.15	0.15	[2]
Data for Area Calculation					
Collection Vehicle Unloading Area					
Collection Veh. Unload Time	hours	cv_ul_hr	0.15	0.15	[7]
Collection Vehicle Weight of Load	lb	cv_load	500	500	[6]
Cocollection Compartment UsableVolume	cubic yards	cv_vol	16	16	[6]
Peak Collection Vehicle Arrival Factor	unitless	peak_fct	1.5	1.5	*
Single Collection Vehicle Unloading Area	sq ft	single_cv_ul_a	525	525	[7]
Mixed Refuse Tipping Floor Area					
Height of Refuse on Tipping Floor	ft	rm_ht	10	10	*
Storage Time on Tipping Floor	day	rm_stor	1	1	*
Mixed Refuse Trailer Loading Area					
Trailer Load Time for Continuous Loading	hours	m_tr_ld_hr	0.25	0.25	[7]
Trailer Replace Time	hours	m_tr_rep_hr	0.2	0.2	[7]
Haul Trailer Volume	cu yd	m_tr_vol_cap	100	100	[3]
Transfer Veh. Density	lb./cu yd	m_tr_d	500	500	[7]
Area Required for one Trailer/Loading Bay	sq ft	ld_bay_a	1500	1500	[10]
Recyclable Storage Area					
Height of Blue Bags	ft	r_ht	10	10	*
Loose Aggregate Blue Bag Density	lb/cu yd	r_tf_d	133	133	[6]
Storage Time on Tipping Floor	day	r_stor	0.25	0.25	*
Recyclable Trailer Loading Area					
Rec. Haul Veh. Load Time	hours	r_load_hr	1.5	1.5	[7]
Trailer Replace Time	hours	r_rep_hr	0.25	0.25	[7]
Haul Trailer Volume	cu yd	r_cap_vol	100	100	[3]
Transfer Veh. Density	lb/cu yd	r_trans_d	162	162	[10]
FCM Processing Area					
Collection Vehicle Unloading Area					
Fibrous Material Collection Veh. Unload Time	hours	cv_ul_hr	0.15	0.15	[7]
Fibrous Material Compartment UsableVolume	cubic yards	cv_vol	16	16	[3]
Peak Collection Vehicle Arrival Factor	unitless	peak_fct	1.5	1.5	*
Single Collection Vehicle Unloading Area	sq ft	single_cv_ul_a	525	525	[10]
FCM Tipping Floor Area					
Height of Refuse on Tipping Floor	ft	rm_ht	10	10	*
Storage Time on Tipping Floor	day	rm_stor	1	1	*
FCM Trailer Loading Area					
Trailer Load Time for Continuous Loading	hours	m_tr_ld_hr	0.25	0.25	[7]
Trailer Replace Time	hours	m_tr_rep_hr	0.2	0.2	[7]
Haul Trailer Volume	cu yd	m_tr_vol_cap	100	100	[3]
Transfer Veh. Density	lb./cu yd	m_tr_d	500	500	[7]
Area Required for one Trailer/Loading Bay	sq ft	ld_bay_a	1500	1500	[7]
General Area Input Values					
Office Area (% of Tipping Floor)	fraction	off_area_r	0.10	0.10	[5]
Land Requirement(multiple of building area)	unitless	land_area_r	10	10	[1]
Equipment Cost Data					
Mixed Refuse Rolling Stock Cost Rate	$/TPD		769	769	**
Mixed Refuse Compactor and Hopper Cost Rate	$/TPD		178	178	**
Recyclables Rolling Stock Cost Rate	$/CYPD		219	219	**
Mixed Refuse Compactor and Hopper Cost Rate	$/CYPD		51	51	**
FCM Rolling Stock Cost Rate	$/CYPD		99	99	**
Rolling Stock Life	years		10	10	[9]

TR3 and TR4 - INPUT VALUES

	units	variable name	TR3	TR4	Source
Economic					
Compactor Life	years		10	10	[7]
Operating and Maintenance					
Labor					
Manual Separation Rate	ton/hr	m_pick	4	n/a	
Mixed Refuse Equipment Operator Requirement	hr/day-TPD	m_op_req	0.069	0.069	**
Recyclables Equipment Operator Requirement	hr/day-CYPD	r_op_req	0.020	0.020	**
FCM Equipment Operator Requirement	hr/day-CYPD	f_op_req	0.003	0.003	**
Equipment Operator and Labor Wage Rate	$/hr	op_wage	10	10	*
Management Rate	fraction	mang_r	0.30	0.30	*
Maintenance					
Equipment	fraction	eq_mc	5%	5%	[4]
Building	$/TPD-yr	fac_mc	3.25	3.25	[5]
Building	$/CYPD-yr	fac_mc	48.9	48.9	[5]
Fuel and Energy					
Building Electric Energy Usage	kWh/sf/day	fac_e	0.001	0.001	[6]
Mixed Refuse Compactor Electric Energy Usage	kWh/ton	m_comp_e	0.002	0.002	[7]
Recyclables Compactor Electric Energy Usage	kWh/ton	m_comp_e	0.002	0.002	**
Mixed Refuse Rolling Stock Fuel Usage	gal/ton MSW	m_rs_e	0.112	0.112	**
Recyclables Rolling Stock Fuel Usage	gal/CY MSW	r_rs_e	0.032	0.032	**
FCM Rolling Stock Fuel Usage	gal/ton MSW	f_rs_e	0.002	0.002	**
LCI Input Values					
Mixed Refuse Rolling Stock Emissions					
Particulates (PM10)	lb/ton	r_pm10_rs_c	0.00E+00	0.00E+00	**
Total Particulates	lb/ton	r_pm_rs_c	9.25E-03	9.25E-03	**
Nitrogen Oxides	lb/ton	r_nr_rs_c	1.12E-01	1.12E-01	**
Hydrocarbons (non CH4)	lb/ton	r_hc_rs_c	1.07E-02	1.07E-02	**
Sulfur Oxides	lb/ton	r_sr_rs_c	8.66E-03	8.66E-03	**
Carbon Monoxide	lb/ton	r_cr_rs_c	3.35E-02	3.35E-02	**
CO2 (biomass)	lb/ton	r_co2_bm_rs_c	0.00E+00	0.00E+00	**
CO2 (non biomass)	lb/ton	r_co2_rs_c	2.57E+00	2.57E+00	**
Ammonia	lb/ton	r_a_nh3_rs_c	0.00E+00	0.00E+00	**
Lead	lb/ton	r_a_pb_rs_c	0.00E+00	0.00E+00	**
Methane	lb/ton	r_ch4_rs_c	0.00E+00	0.00E+00	**
Hydrochloric acid	lb/ton	r_hlc_rs_c	0.00E+00	0.00E+00	**
Recyclables Rolling Stock Emissions					
Particulates (PM10)	lb/CY	m_pm10_rs_c	0.00E+00	0.00E+00	**
Total Particulates	lb/CY	m_pm_rs_c	2.63E-03	2.63E-03	**
Nitrogen Oxides	lb/CY	m_nm_rs_c	3.19E-02	3.19E-02	**
Hydrocarbons (non CH4)	lb/CY	m_hc_rs_c	3.05E-03	3.05E-03	**
Sulfur Oxides	lb/CY	m_sm_rs_c	2.46E-03	2.46E-03	**
Carbon Monoxide	lb/CY	m_cm_rs_c	9.54E-03	9.54E-03	**
CO2 (biomass)	lb/CY	m_co2_bm_rs_c	0.00E+00	0.00E+00	**
CO2 (non biomass)	lb/CY	m_co2_rs_c	7.31E-01	7.31E-01	**
Ammonia	lb/CY	m_a_nh3_rs_c	0.00E+00	0.00E+00	**
Lead	lb/CY	m_a_pb_rs_c	0.00E+00	0.00E+00	**
Methane	lb/CY	m_ch4_rs_c	0.00E+00	0.00E+00	**
Hydrochloric acid	lb/CY	m_hlc_rs_c	0.00E+00	0.00E+00	**
FCM Rolling Stock Emissions					
Particulates (PM10)	lb/ton	f_pm10_rs_c	0.00E+00	0.00E+00	**
Total Particulates	lb/ton	f_pm_rs_c	8.58E-04	8.58E-04	**
Nitrogen Oxides	lb/ton	f_nf_rs_c	1.28E-02	1.28E-02	**
Hydrocarbons (non CH4)	lb/ton	f_hc_rs_c	1.12E-03	1.12E-03	**
Sulfur Oxides	lb/ton	f_sf_rs_c	1.06E-03	1.06E-03	**
Carbon Monoxide	lb/ton	f_cf_rs_c	2.98E-03	2.98E-03	**
CO2 (biomass)	lb/ton	f_co2_bm_rs_c	0.00E+00	0.00E+00	**
CO2 (non biomass)	lb/ton	f_co2_rs_c	4.63E-02	4.63E-02	**
Ammonia	lb/ton	f_a_nh3_rs_c	0.00E+00	0.00E+00	**
Lead	lb/ton	f_a_pb_rs_c	0.00E+00	0.00E+00	**
Methane	lb/ton	f_ch4_rs_c	0.00E+00	0.00E+00	**
Hydrochloric acid	lb/ton	f_hlc_rs_c	0.00E+00	0.00E+00	**
WASHWATER					
Facility Washdown Water Volume	gallon/sf-wash	fac_wr_sf	0.2	0.2	[6]
Washdown Rate	wash/month	wash_r	1	1	[8]
Waterborne Release Rates					

TR3 and TR4 - INPUT VALUES

	units	variable name	TR3	TR4	Source
Economic					
Dissolved solids	lb./gallon	DS_wwr_r			
Suspended solids	lb./gallon	SS_wwr_r			
BOD of washdown water	lb./gallon	BOD_wwr_r			
COD of washdown water	lb./gallon	COD_wwr_r			
Oil	lb./gallon	OIL_wwr_r			
Sulfuric acid	lb./gallon	H2S04_wwr_r			
Iron	lb./gallon	FE_wwr_r			
Ammonia	lb./gallon	W_NH3_wwr_r			
Copper	lb./gallon	Cu_wwr_r			
Cadmium	lb./gallon	Cd_wwr_r			
Arsenic	lb./gallon	As_wwr_r			
Mercury	lb./gallon	Hg_wwr_r			
Phosphate	lb./gallon	P_x_wwr_r			
Selenium	lb./gallon	Se_wwr_r			
Chromium	lb./gallon	CR_wwr_r			
Lead	lb./gallon	W_PB_wwr_r			
Zinc	lb./gallon	ZN_wwr_r			

TR5 - INPUT VALUES

	units	variable name		Source
Economic				
Life of Transfer Station Structure	years	fac_l	20	*
Operating Hours				
Working Day Length	hours	wh_d	8	*
Effective Working Day Length	hours	EWh_d	7	*
Number of workdays per year	days	ywd	260	*
Facility Construction Data				
Construction rate	$/sq. ft	const_c	55	[1]
Engineering, Permitting & Contingency Rate	%	eng_r	30%	[2]
Land acquisition rate	$/acre	land_c	1000	*
Paving and Sitework	$/sq ft	sitew_c	1.44	[1]
Equipment Installation rate(% of equip. cost)	%	eq_inst_r	5%	[2]
Data for Area Calculation				
Single Maneuvering Space and Trailer Area	sq. ft.	ct_a	160	[7]
Haul Veh. Load Time	hours	load_hr	0.25	*
Trailer Replace Time	hours	ct_rep_hr	0.2	[7]
Haul Trailer Volume	cu yd	cap_vol	35	[3]
General Area Input Values				
Office Area (% of Tipping Floor)	%	off_area_r	10%	[5]
Land Requirement(multiple of building area)	unitless	land_area_r	10	[1]
Equipment Cost Data				
Rolling Stock Cost Rate	$/CYPD		28	**
Rolling Stock Life	years		10	[9]
Operating and Maintenance				
Labor				
Equipment Operator Requirement	hr/day-CYPD	op_req	0.003	**
Equipment Operator and Labor Wage Rate	$/hr	op_wage	10	*
Management Rate	% of labor	mang_r	30%	*
Maintenance				
Equipment	% Cost	eq_mc	5%	[4]
Building	$/CYPD-yr	fac_mc	48.9	[5]
Fuel and Energy				
Building Electric Energy Usage	kWh/sf/day	fac_e	0.001	[6]
Rolling Stock Fuel Usage	gal/CY MSW	r_rs_e	0.004	**
LCI Input Values				
Rolling Stock Emissions				
Particulates (PM10)	lb/CY	pm10_rs_c	0.00E+00	**
Total Particulates	lb/CY	pm_rs_c	6.40E-04	**
Nitrogen Oxides	lb/CY	no_rs_c	5.60E-03	**
Hydrocarbons (non CH4)	lb/CY	hc_rs_c	6.28E-04	**
Sulfur Oxides	lb/CY	so_rs_c	3.72E-04	**
Carbon Monoxide	lb/CY	co_rs_c	2.43E-03	**
CO2 (biomass)	lb/CY	co2_bm_rs_c	0.00E+00	**
CO2 (non biomass)	lb/CY	co2_rs_c	1.00E-01	**
Ammonia	lb/CY	a_nh3_rs_c	0.00E+00	**
Lead	lb/CY	a_pb_rs_c	0.00E+00	**
Methane	lb/CY	ch4_rs_c	0.00E+00	**
Hydrochloric acid	lb/CY	hlc_rs_c	0.00E+00	**
WASHWATER				
Facility Washdown Water Volume	gallon/sf-wash	fac_wr_sf	0.2	[6]
Washdown Rate	wash/month	wash_r	1	[6]
Waterborne Release Rates				
Dissolved solids	lb./gallon	DS_wwr_r		
Suspended solids	lb./gallon	SS_wwr_r		
BOD of washdown water	lb./gallon	BOD_wwr_r		
COD of washdown water	lb./gallon	COD_wwr_r		
Oil	lb./gallon	OIL_wwr_r		
Sulfuric acid	lb./gallon	H2S04_wwr_r		
Iron	lb./gallon	FE_wwr_r		
Ammonia	lb./gallon	W_NH3_wwr_r		
Copper	lb./gallon	Cu_wwr_r		
Cadmium	lb./gallon	Cd_wwr_r		
Arsenic	lb./gallon	As_wwr_r		

TR5 - INPUT VALUES

	units	variable name		Source
Economic				
Life of Transfer Station Structure	years	fac_l	20	*
Mercury	lb./gallon	Hg_wwr_r		
Phosphate	lb./gallon	P_x_wwr_r		
Selenium	lb./gallon	Se_wwr_r		
Chromium	lb./gallon	CR_wwr_r		
Lead	lb./gallon	W_PB_wwr_r		
Zinc	lb./gallon	ZN_wwr_r		
Methane	lb/ton	ch4_rs_c		

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Rail Transfer Input Values

Design type for RT1

	units	variable name	RT1 Design 1	RT1 Design 2	RT2 - at Landfill	RT3 - at Enhanced Bioreactor	Source
Economic							
Life of Transfer Station Structure	years	fac_l	20	20	20	20	*
Operating Hours							
Working Day Length	hours	wh_d	8	8	8	8	*
Effective Working Day Length	hours	EWh_d	7	7	7	7	*
Number of workdays per year	days	ywd	260	260	260	260	*
Facility Construction Data							
Construction rate	$/sq. ft	const_c	55	55	55	55	[1]
Engineering, Permitting & Contingency Rate(% Bldg & Site Cost)	%	eng_r	30%	30%	30%	30%	[2]
Land acquisition rate	$/acre	land_c	1000	1000	1000	1000	*
Paving and Sitework	$/sq ft	sitew_c	1.44	1.44	1.44	1.44	[1]
Equipment Installation rate(% of equip. cost)	%	eq_inst_r	5%	5%	5%	5%	[2]
Data for Area Calculation							
Height of Refuse on Tipping Floor	ft	ht	10	10	10	10	*
Storage Time on Tipping Floor	day	stor	1	1	1	1	*
Trailer Load Time for Continuous Loading from Tipping Floor	hours	tr_ld_hr	0.25	0.4	0.25	0.25	[7]
Trailer Replace Time	hours	tr_rep_hr	0.3	0.3	0.3	0.3	[7]
Haul Trailer Volume	cu yd	tr_vol_cap	100	100	100	100	[3]
Transfer Veh. Density	lb./cu yd	tr_d	500	500	500	500	[7]
Area Required for one Trailer/Loading Bay	sq ft	ld_bay_a	2000	2000	2000	2000	[7]
Collection Veh. Unload Time	hours	cv_ul_hr	0.15	0.15	0.15	0.15	[7]
Peak Collection Vehicle Arrival Factor	unitless	peak_fct	1.5	1.5	1.5	1.5	*
Collection Vehicle Weight of Load	cv_load	lb	14000	14000	14000	14000	[6]
Single Collection Vehicle Unloading Area	sq ft	single_cv_ul_a	525	525	525	525	[7]
Office Area (% of Tipping Floor)	%	off_area_r	10%	10%	10%	10%	[5]
Land Requirement(multiple of building area)	unitless	land_area_r	10	10	10	10	[1]
Equipment Cost Data							
Rolling Stock Cost Rate	$/TPD		640	395	1329	1329	**
Compactor and Hopper Cost Rate	$/TPD		n/a	935	n/a	n/a	**
Rolling Stock Life	years		10	10	10	10	[9]
Compactor Life	years		n/a	10	n/a	n/a	[7]
Operating and Maintenance							
Labor							
Equipment Operator Requirement	hr/day-TPD	op_req	0.034	0.025	0.044	0.044	**
Equipment Operator and Labor Wage Rate	$/hr	op_wage	10	10	10	10	*
Management Rate	% of labor	mang_r	30%	30%	30%	30%	*
Maintenance							
Equipment	% Cost	eq_mc	0.05	0.05	0.05	0.05	[4]
Building	$/TPD-yr	fac_mc	3.25	3.25	3.25	3.25	[5]
Fuel and Energy							
Building Electric Energy Usage	kWh/sf/day	fac_e	0.001	0.001	0.001	0.001	[6]
Compactor Electric Energy Usage	kWh/ton	comp_e	n/a	1.5	n/a	n/a	[7]
Rolling Stock Fuel Usage	gal/ton MSW	rs_e	0.127	0.081	0.186	0.186	**
LCI Input Values							
Rolling Stock Emissions							
Particulates (PM10)	lb/ton	pm10_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
Total Particulates	lb/ton	pm_rs_c	7.80E-03	5.32E-03	8.10E-03	8.10E-03	**
Nitrogen Oxides	lb/ton	no_rs_c	1.03E-01	7.25E-02	9.85E-02	9.85E-02	**
Hydrocarbons (non CH4)	lb/ton	hc_rs_c	6.85E-03	5.27E-03	5.13E-03	5.13E-03	**
Sulfur Oxides	lb/ton	so_rs_c	9.15E-03	6.33E-03	9.23E-03	9.23E-03	**
Carbon Monoxide	lb/ton	co_rs_c	2.56E-02	1.77E-02	2.56E-02	2.56E-02	**
CO2 (biomass)	lb/ton	co2_bm_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
CO2 (non biomass)	lb/ton	co2_rs_c	2.93E+00	1.85E+00	4.27E+00	4.27E+00	**
Ammonia	lb/ton	a_nh3_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
Lead	lb/ton	a_pb_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
Methane	lb/ton	ch4_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
Hydrochloric acid	lb/ton	hlc_rs_c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**
WASHWATER							
Facility Washdown Water Volume	gallon/sf-wash	fac_wr_sf	0.2	0.2	0.2	0.2	[6]

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Rail Transfer Input Values

Design type for RT1

			RT1		RT2 - at	RT3 - at	Source
Washdown Rate	wash/month	wash_r	1	1	1	1	[8]
Waterborne Release Rates							
Dissolved solids	lb./gallon	DS_wwr_r					
Suspended solids	lb./gallon	SS_wwr_r					
BOD of washdown water	lb./gallon	BOD_wwr_r					
COD of washdown water	lb./gallon	COD_wwr_r					
Oil	lb./gallon	OIL_wwr_r					
Sulfuric acid	lb./gallon	H2S04_wwr_r					
Iron	lb./gallon	FE_wwr_r					
Ammonia	lb./gallon	W_NH3_wwr_r					
Copper	lb./gallon	Cu_wwr_r					
Cadmium	lb./gallon	Cd_wwr_r					
Arsenic	lb./gallon	As_wwr_r					
Mercury	lb./gallon	Hg_wwr_r					
Phosphate	lb./gallon	P_x_wwr_r					
Selenium	lb./gallon	Se_wwr_r					
Chromium	lb./gallon	CR_wwr_r					
Lead	lb./gallon	W_PB_wwr_r					
Zinc	lb./gallon	ZN_wwr_r					

References

[1] Construction Cost Appendix 4.

[2] Dempsey, John, "Dollars and Sense: taking a close look at Cost of Transfer Station Options," notes from short course titled Successful Planning and Design of Transfer Stations," University of Wisconsin in Madison,1995.

[3] Tchobanoglous, G. , H. Theisen and S. Vigil, Integrated Solid Waste Management, McGraw-Hill, Inc., New York, 1993, p. 346.

[4] Peluso, Rich, EMCON, notes from short course titled Successful Planning and Design of Transfer Stations," University of Wisconsin in Madison, 1995.

[5] U.S. Environmental Protection Agency, "EPA Handbook: Material Recovery Facilities for Municipal Solid Waste," EPA/625/6-91/031, September 1991.

[6] Curtis, Ed, "A Spreadsheet Framework for Analysis of Cost and LCI Parameters Associated with Collection of Municipal Solid Waste," Independent study report submitted for partial fulfillment of requirements for MCE degree at North Carolina State University, August 13, 1996.

[7] Felker, M, Selecting Transfer Loading Equipment, WMX Technologies, notes from short course titled "Successful Planning and Design of Transfer Stations," University of Wisconsin in Madison, 1995. (0.05-0.03 $/ton) at $0.075/KWH.

[8] Etheridge, Michael, Solid Waste Director, Pasquotank County, personal conversation, Spring 1996.

[9] Caterpillar Performance Handbook, Ed. 26, Caterpillar Inc., Peoria, Illinois, October 1995.

[10] Felker, Marty, Memo to Dr. Barlaz, Review of Transfer Station Document, June 1997.

APPENDIX 2 – REFERENCED MODELS

Portions of the common, electric energy, and collection models that contain referenced input values are presented below. The values referenced are also listed in the introduction to Section 3 of this document.

Misc. Costs		
DESCRIPTION	**VARIABLE NAME**	VALUE
Diesel Fuel ($/gal)	dies_cost	1.40
Electricity ($/kWh)	elec_cost	0.075
Waste as Fuel ($/MBtu)	Waste_fuel_cost	0.960
Scrap Iron Price ($/ton)	scrap_fe_price	0.00

TRANSPORTATION FUELS PRECOMBUSTION EMISSIONS TABLE		
DESCRIPTION	**VARIABLE NAME**	**DIESEL** pre comb. (lbs emission per 1000 gal. combusted)
	Trans_fuel_pre_comb_table	d_pc_em
Atmospheric Emissions		
Particulates (PM10)	T_F_PC_A_PART_10	
Particulates (Total)	T_F_PC_A_PART	1.82
Nitrogen Oxides	T_F_PC_A_NO	7.19
Hydrocarbons (non CH_4)	T_F_PC_A_HC	67.49014
Sulfur Oxides	T_F_PC_A_SO	8.8
Carbon Monoxide	T_F_PC_A_CO	5.01
CO_2 (biomass)	T_F_PC_A_CO2_BM	
CO_2 (non biomass)	T_F_PC_A_CO2	3594
Ammonia	T_F_PC_A_NH3	0.039
Lead	T_F_PC_A_PB	1.10E-05
Methane	T_F_PC_A_CH4	0.05
Hydrochloric acid	T_F_PC_A_HCL	0.0012
Solid Waste		
Solid Waste #1	T_F_PC_SW_1	82.4
Solid Waste #2	T_F_PC_SW_2	
Solid Waste #3	T_F_PC_SW_3	
Solid Waste #4	T_F_PC_SW_4	
Solid Waste #5	T_F_PC_SW_5	
Waterborne Emissions		
Dissolved Solids	T_F_PC_W_DS	102
Suspended Solids	T_F_PC_W_SS	0.095
BOD	T_F_PC_W_BOD	0.1
COD	T_F_PC_W_COD	0.49058
Oil	T_F_PC_W_OIL	1.23
Sulfuric Acid	T_F_PC_W_H2SO4	0.31
Iron	T_F_PC_W_FE	0.081
Ammonia	T_F_PC_W_NH3	0.014
Copper	T_F_PC_W_Cu	
Cadmium	T_F_PC_W_Cd	
Arsenic	T_F_PC_W_As	
Mercury	T_F_PC_W_Hg	
Phosphate	T_F_PC_W_P_x	
Selenium	T_F_PC_W_Se	
Chromium	T_F_PC_W_CR	3.40E-05
Lead	T_F_PC_W_PB	1.50E-05
Zinc	T_F_PC_W_ZN	2.20E-04

TRANSPORTATION FUELS PRECOMBUSTION ENERGY TABLE		
DESCRIPTION	VARIABLE NAME	pre comb. energy (btu/gal.)
Diesel - mobil source	dsl_pc_enrg	2.59E+04

TRANSPORTATION FUELS COMBUSTION ENERGY TABLE		
DESCRIPTION	VARIABLE NAME	comb. energy (btu/gal.)
Diesel - mobil source	dsl_enrg	1.37E+05

GREENHOUSE GAS	variable name	20 Year Global Warming Potential
Carbon dioxide (fossil fuel)	CO2_f_GWP	1
Carbon dioxide (biomass)	CO2_bm_GWP	0
Methane	CH4_GWP	63
Nitrous Oxide	NO_GWP	270
Other hydrocarbons	HC_GWP	

MSW PHYSICAL PROPERTIES TABLE

DESCRIPTION	VARIABLE NAME	Density in Recycling Collection Vehicle (lb/yd3)
	MSW_COMP_TABLE	D_rcv
Yard Trimmings, Leaves	YTL	350
Yard Trimmings, Grass	YTG	350
Yard Trimmings, Branches	YTB	350
Old News Print	ONP	500
Old Corr. Cardboard	OCC	150
Office Paper	OFF	500
Phone Books	PBK	500
Books	BOOK	500
Old Magazines	OMG	500
3rd Class Mail	MAIL	500
Pallets	PALLETS	185
Paper Other #1	PAOT1	500
Paper Other #2	PAOT2	500
Paper Other #3	PAOT3	500
Paper Other #4	PAOT4	500
Paper Other #5	PAOT5	500
CCCR Other	CCR_O	500
Mixed Paper	PMIX	500
HDPE - Translucent	HDT	24
HDPE - Pigmented	HDP	24
PET	PPET	40
Plastic - Other #1	PLOT1	50
Plastic - Other #2	PLOT2	50
Plastic - Other #3	PLOT3	50
Plastic - Other #4	PLOT4	50
Plastic - Other #5	PLOT5	50
Mixed Plastic	PLMIX	50
CCNR Other	CNR_O	50
Ferrous Cans	FCAN	150
Ferrous Metal - Other	FMOT	750
Aluminum Cans	ACAN	75
Aluminum - Other #1	ALOT1	400
Aluminum - Other #2	ALOT2	400
Glass - Clear	GCLR	400
Glass - Brown	GBRN	400
Glass - Green	GGRN	400
Mixed Glass	GMIX	400
CNNR Other	NNR_O	150
Paper - Non-recyclable	PANR	500
Food Waste	FW	800
CCCN Other	CCN_O	700
Plastic - Non-Recyclable	PLNR	50
Misc.	MIS_CNN	110
CCNN Other	CNN_O	110
Ferrous - Non-recyclable	FNR	750
Al - Non-recyclable	ANR	400
Glass - Non-recyclable	GNR	400
Misc.	MIS_NNN	300
CNNN Other	NNN_O	400

DESCRIPTION	VARIABLE NAME	Residential Composition	Multi-family Composition	Commercial Composition
		Default Residential Composition (wt. fraction)	Default Mult. Family Composition (wt. fraction)	Default Commercial Composition (wt. fraction)
	MSW_COMP_TABLE			
Yard Trimmings, Leaves	YTL	0.056	0.056	
Yard Trimmings, Grass	YTG	0.093	0.093	
Yard Trimmings, Branches	YTB	0.037	0.037	
Old News Print	ONP	0.067	0.067	0.022
Old Corr. Cardboard	OCC	0.021	0.021	0.360
Office Paper	OFF	0.013	0.013	0.072
Phone Books	PBK	0.002	0.002	0.003
Books	BOOK	0.009	0.009	
Old Magazines	OMG	0.017	0.017	
3rd Class Mail	MAIL	0.022	0.022	0.023
Pallets	PALLETS			
Paper Other #1	PAOT1	0.000	0.000	0.000
Paper Other #2	PAOT2	0.000	0.000	0.000
Paper Other #3	PAOT3	0.000	0.000	0.000
Paper Other #4	PAOT4	0.000	0.000	
Paper Other #5	PAOT5	0.000	0.000	
CCCR Other	CCR_O			0.019
Mixed Paper	PMIX	0.000	0.000	
HDPE - Translucent	HDT	0.004	0.004	
HDPE - Pigmented	HDP	0.005	0.005	
PET	PPET	0.004	0.004	0.002
Plastic - Other #1	PLOT1	0.000	0.000	
Plastic - Other #2	PLOT2	0.000	0.000	
Plastic - Other #3	PLOT3	0.000	0.000	
Plastic - Other #4	PLOT4	0.000	0.000	
Plastic - Other #5	PLOT5	0.000	0.000	
Mixed Plastic	PLMIX	0.000	0.000	
CCNR Other	CNR_O			0.041
Ferrous Cans	FCAN	0.015	0.015	0.007
Ferrous Metal - Other	FMOT	0.000	0.000	
Aluminum Cans	ACAN	0.009	0.009	0.004
Aluminum - Other #1	ALOT1	0.000	0.000	
Aluminum - Other #2	ALOT2	0.000	0.000	
Glass - Clear	GCLR	0.039	0.039	0.019
Glass - Brown	GBRN	0.016	0.016	0.008
Glass - Green	GGRN	0.010	0.010	0.005
Mixed Glass	GMIX	0.000	0.000	
CNNR Other	NNR_O			0.024
Paper - Non-recyclable	PANR	0.171	0.171	
Food Waste	FW	0.049	0.049	
CCCN Other	CCN_O			0.171
Plastic - Non-Recyclable	PLNR	0.099	0.099	
Misc.	MIS_CNN	0.075	0.075	
CCNN Other	CNN_O			0.113
Ferrous - Non-recyclable	FNR	0.032	0.032	
Al - Non-recyclable	ANR	0.005	0.005	
Glass - Non-recyclable	GNR	0.007	0.007	
Misc.	MIS_NNN	0.123	0.123	
CNNN Other	NNN_O			0.107
		1.000	1.000	1.000

		variable name	Regional Grid
Electricity Emissions		emissions table (lb/k/\Wh)	r_tot
Atmospheric Emissions			
	Particulates (PM10)	PART_10	
	Total Particulates	PART	2.19E-03
	Nitrogen Oxides	NO	5.93E-03
	Hydrocarbons (non CH4)	HC	2.32E-03
	Sulfur Oxides	SO	1.12E-02
	Carbon Monoxide	CO	1.97E-03
	CO2 (biomass)	CO2_bm	1.77E-02
	CO2 (non biomass)	CO2	1.33E+00
	Ammonia	A_NH3	4.08E-08
	Lead	A_PB	1.13E-11
	Methane	CH4	8.04E-06
	Hydrochloric acid	HCL	1.22E-09
	Solid Waste #1	SW_1	1.45E-01
	Solid Waste #2	SW_2	1.66E-02
	Solid Waste #3	SW_3	0.00E+00
	Solid Waste #4	SW_4	0.00E+00
	Solid Waste #5	SW_5	0.00E+00
Waterborne Emissions			
	Dissolved Solids	DS	1.16E-04
	Suspended Solids	SS	9.59E-08
	BOD	BOD	1.05E-07
	COD	COD	5.57E-07
	Oil	OIL	3.92E-06
	Sulfuric Acid	H2SO4	9.41E-04
	Iron	FE	2.34E-04
	Ammonia	W_NH3	1.42E-08
	Copper	Cu	0.00E+00
	Cadmium	Cd	0.00E+00
	Arsenic	As	0.00E+00
	Mercury	Hg	0.00E+00
	Phosphate	P_x	0.00E+00
	Selenium	Se	0.00E+00
	Chromium	CR	3.50E-11
	Lead	W_PB	1.53E-11
	Zinc	ZN	2.27E-10

APPENDIX 3 – LIST OF ITEMS RECOVERED IN SEPARATION FACILITIES

Abbreviation	Item
ONP	Old News Print
OCC	Old Corrugated. Cardboard
OFF	Office Paper
PBK	Phone Books
BOOK	Books
OMG	Old Magazines
MAIL	3rd Class Mail
PAOT1	Paper Other #1
PAOT2	Paper Other #2
PAOT3	Paper Other #3
PAOT4	Paper Other #4
PAOT5	Paper Other #5
PMIX	Mixed Paper
FCAN	Ferrous Cans
FMOT	Ferrous Metal – Other
ACAN	Aluminum Cans
ALOT1	Aluminum – Other #1
ALOT2	Aluminum – Other #2
GCLR	Glass – Clear
GBRN	Glass – Brown
GGRN	Glass – Green
GMIX	Mixed Glass
HDT	HDPE – Translucent
HDP	HDPE – Pigmented
PPET	PET
PLOT1	Plastic – Other #1
PLOT2	Plastic – Other #2
PLOT3	Plastic – Other #3
PLOT4	Plastic – Other #4
PLOT5	Plastic – Other #5
PLMIX	Mixed Plastic
CCRO	Combustible/ Compostable /Recyclable Other
CNRO	Combustible /Non-Compostable /Recyclable Other
CCNO	Combustible / Compostable /Non-Recyclable Other
NNRO	Non-Combustible /Non-Compostable /Recyclable Other

APPENDIX 4 – DEFAULT CONSTRUCTION COST BASIS

Facility capital costs are based on rates for construction and paving and site work determined from the following cost estimate for a 500 TPD transfer station. Land to building area ratio is also determined in order to calculate land requirements.

Table 1 Cost Estimate for Transfer Station

Transfer Station Cost Estimate*

I. Construction

Item	Quantity	Units	Unit Price	Item Cost	
Maneuvering Area	1200	sq. yd.	$40	$48,000	
Metal Building	13500	sq. ft.	$20	$270,000	
Concrete Slabwork	400	cu. yd.	$120	$48,000	
Concrete Footings	60	cu. yd.	$250	$15,000	
Concrete Push Walls	250	cu. yd.	$300	$75,000	
Mechanical	13500	sq. ft.	$6	$81,000	
Electrical	13500	sq. ft.	$10	$135,000	
Scalehouse Cost					
Metal Building	400	sq. ft.	$40	$16,000	
Concrete Slabwork	15	cu. yd.	$120	$1,800	
Concrete Footings	10	cu. yd.	$250	$2,500	
Interior Treatment	400	sq. ft.	$50	$20,000	
Motor Truck Scales	2	LS	$50,000	$100,000	
Mechanical	400	sq. ft.	$12	$4,800	
Electrical	400	sq. ft.	$13	$5,200	
TOTAL				$822,300	
TOTAL AREA				13500	sq. ft.
Construction Cost per unit area				**60.91**	**$/sq. ft.**

II. Paving and Site work

Item	Quantity	Units	Unit Price	Item Cost
Earthwork				
Excavation & Backfill-trench	1000	cu. yd.	$8	$8,000
General Earthwork	30000	cu. yd.	$3	$90,000
Finishing Grassing and Grading	15000	sq. yd.	$0	$5,550
Roadways Concrete	500	sq yd	$40	$20,000
Asphalt Pavement, Parking	5000	sq. yd.	$30	$150,000
Retaining Walls	3800	sq. ft.	$25	$95,000
Site Utilities				$0
Fire Protection	2000	linear feet	$25	$50,000
Water Supply	1000	linear feet	$25	$25,000
Sewer System	1000	linear feet	$25	$25,000
Electrical	1	L.S.	$50,000	$50,000

Site Drainage	1	L.S.	$20,000	$20,000	
Fencing	5000	linear feet	$7	$35,000	
Landscaping	1	L.S.	$10,000	$10,000	
TOTAL				$583,550	
AREA TOTAL				15000	sq. yd.
Paving and Site work Cost per unit area				**1.44**	**$/sq. ft.**

III. Land to Building Ratio

Building Area	sq. ft.	13500	
Land Area	sq. yd.	15000	
Land to Building Ratio		**10**	**sq. ft./sq. ft.**

**Source*: Dempsey, John, "Dollars and Sense: taking a close look at Cost of Transfer Station Options," notes from short course titled "Successful Planning and Design of Transfer Stations," University of Wisconsin in Madison,1995.

APPENDIX 5 – LINEAR REGRESSION TECHNIQUE BASIS

Default data for several parameters were derived by plotting the value of a parameter (for example, rolling stock diesel consumption) as a function of transfer station capacity. The slope of the resulting plot represents the default value. This appendix presents the general equations used in the regression analysis followed by sections containing default values for transfer stations TR1 to TR5 and RT1 to RT3. The values used as a basis for calculating default values are also presented for each transfer station. A series of four tables is presented for each transfer station, displaying a summary of the default data derivation:

Table 1: Default Values Resulting from Linear Regressions
Table 2: r-squared Values for Linear Regressions
Table 3: General Input Values Utilized in Linear Regressions
Table 4: Capacity Dependent Values Utilized in Linear Regressions

Regression Analysis for Weight-Based Factors

Regression analysis is utilized to calculate input values for the parameters listed in Table A:

Table A: Inputs with Default Values Based on Linear Regressions

Item	Variable Name	Units
Rolling Stock Cost Rate	RS_cost	$/TPD
Compactor Cost	COMP_cost	$/TPD
Equipment Operator Requirement	op_req	hr/TPD/day
Rolling Stock Fuel Use	rs_e	gallon fuel/TPD/day
Rolling Stock Emissions	emission_rs_c_	lb pollutant/TPD/day

Rolling Stock and Compactor Cost Rates

The rolling stock cost rate ($/TPD) is determined with a linear regression of rolling stock cost ($) as a function of transfer station capacity (TPD). Rolling stock cost is found by summing the product of quantity and cost for each type of rolling stock:

$$\textit{Rolling stock cost} = \sum^{\textit{rolling stock utilized at a transfer station}} (\textit{quantity of rolling stock} * \textit{cost of single rolling stock unit})$$

The compactor cost rate ($/TPD) is determined with a linear regression of compactor and hopper cost as a function of facility capacity (TPD).   The compactor and hopper cost is determined by:

$$\begin{aligned}\textit{Compactor and hopper cost} = \; & \textit{quantity of compactors} * \textit{cost of single compactor} \\ & + \textit{quantity of hoppers} * \textit{cost of single hopper}\end{aligned}$$

Equipment Operator Requirement

The equipment operator requirement (hr/TPD/day) is determined with a linear regression of total operator hours per day as a function of facility capacity (TPD). The total daily operator requirement is calculated by:

$$\textit{Total daily operator hours} = \sum^{\textit{equipment operators}} \textit{quantity of equipment operators} * \textit{daily hours of operation}$$

Rolling Stock Fuel Use

The fuel used by rolling stock (gallon/TPD/day) is determined with a linear regression of daily rolling stock fuel use (gallon/day) as a function of facility capacity (TPD). Daily rolling stock fuel use is determined by the sum:

$$\textit{Daily rolling stock fuel use} = \sum^{\textit{types of rolling stock utilized}} (\textit{quantity of rolling stock} * \textit{gallon fuel/hour for single unit}) * \textit{hours worked per day}$$

Rolling Stock Emissions, Except C0$_2$ (non-biomass)

Rolling stock emissions (lb/ton) are determined from a linear regression with total daily emissions (lb/day) as a function of facility capacity (TPD). The regression analysis is repeated for each atmospheric pollutant type accounted for in the transfer station model, except CO_2 (non-biomass). Rolling stock emissions per day are determined by the sum of daily emissions for each type of rolling stock:

$$\textit{Daily rolling stock emissions} = \sum^{\textit{types of rolling stock utilized}} (\textit{quantity of rolling stock} * \textit{emissions per hour for single unit}) * \textit{hours worked per day}$$

Emissions per hour are determined from emissions standards for various types of rolling stock (grams/hp-hour)[1] and the horsepower values taken from the Caterpillar handbook [2].

$$\textit{hourly emissions} = \textit{grams per horse power per hour} * \textit{horsepower}$$

The emission rates for various rolling stock are given in Table B.

Table B:

Emission Factors for Diesel Equipment used in Solid Waste Management Operations (EPA, 1991a) [3]

(grams/hp-hr)

Type of vehicle	Equipment Use	HC[a,b]	CO[a]	NOx[a]	PM[a]	SOx[a]	Aldehyde
Tracked Tractors[c]	Used to spread and compact material	0.9	2.4	10.3	0.69	0.85	0.17
Tracked Loader[c]	Used to handle waste and compact	0.6	2.4	10	0.66	0.85	0.1
Scraper[c]	Used to excavate material	0.5	2.5	9.6	0.79	0.9	0.28
Forklift[d]	Used to lift bales and bins	1.57	6.08	14	1.6	0.93	0.21
Roller & Compactor[c]	Used to compact refuse	0.8	3.1	9.3	0.78	1.0	0.2
Skid Steer Loader (wheeled)[e]	Used to handle waste in MRF	2.1	9	9.6	1.44	0.93	0.2
Sprayer[e]	Used to spray water on landfill	2.23	3.78	7.78	1.51	0.92	0.3

[a]HC = Hydrocarbons; CO = Carbon Monoxide; NOx = Nitrogen Oxides; PM = Particulate Matter; SOx = Sulfur dioxides.

[b]Hydrocarbons estimates in Table B are total exhaust and crankcase emissions.

[c]Emission factors (EFs) for State Implementation Plans (SIPs).

[d]EFs for Inventory A, Exhaust HC, CO, & PM adjusted for transient speed and/or transient load operation.

[e]EFs for Inventory A.

Rolling Stock Emissions for $C0_2$ (non-biomass)

$C0_2$ (non-biomass) emissions are determined for each transfer station type and design by multiplying fuel usage (gallon/ton material processed) by an emission factor for C02 (lb $C0_2$ (non-biomass)/gallon diesel utilized by rolling stock). The fuel usage factor is calculated with the linear regression approach described above. The default emission factor[4] is assumed to be appropriate for all transfer stations.

Regression Analysis for Volume-Based Factors

Regression analysis is utilized to calculate input values for parameters listed in Table C:

Table C: Inputs with Default Values Based on Linear Regressions

Item	Variable Name	Units
Rolling Stock Cost Rate	RS_cost	$/CYPD
Compactor Cost	COMP_cost	$/CYPD
Equipment Operator Requirement	op_req	hr/CYPD/day
Rolling Stock Fuel Use	rs_e	gallon fuel/CYPD/day
Rolling Stock Emissions	emission_rs_c_	lb pollutant/CYPD/day

Rolling Stock and Compactor Cost Rates

The rolling stock cost rate ($/CYPD) is determined with a linear regression of rolling stock cost ($) as a function of transfer station capacity (CYPD). Rolling stock cost is found by summing the product of quantity and cost for each type of rolling stock:

$$\textit{Rolling stock cost} = \sum^{\textit{rolling stock utilized at a transfer station}} (\textit{quantity of rolling stock} * \textit{cost of single rolling stock unit})$$

The compactor cost rate ($/CYPD) is determined with a linear regression of compactor and hopper cost as a function of facility capacity (CYPD). The compactor and hopper cost is determined by:

$$\textit{Compactor and hopper cost} = \textit{quantity of compactors} * \textit{cost of single compactor} + \textit{quantity of hoppers} * \textit{cost of single hopper}$$

Equipment Operator Requirement

The equipment operator requirement (hr/CYPD/day) is determined with a linear regression of total operator hours per day as a function of facility capacity (CYPD). The total daily operator requirements are calculated by:

$$\textit{Total daily operator hours} = \sum^{\textit{equipment operators}} \textit{quantity of equipment operators} * \textit{daily hours of operation}$$

Rolling Stock Fuel Use

The fuel used by rolling stock (gallon/CYPD/day) is determined with a linear regression of daily rolling stock fuel use (gallon/day) as a function of facility capacity (CYPD). Daily rolling stock fuel use is determined by the sum:

$$\textit{Daily rolling stock fuel use} = \sum^{\textit{types of rolling stock utilized}} (\textit{quantity of rolling stock} * \textit{gallon fuel/hour for single unit}) * \textit{hours worked per day}$$

Rolling Stock Emissions, Except $C0_2$ (non-biomass)

Rolling stock emissions (lb/cubic yard material processed) are determined from a linear regression with total daily emissions (lb/day) as a function of facility capacity (CYPD). The regression analysis is repeated for each atmospheric pollutant type except CO_2 (non-biomass) accounted for in the transfer station model. Rolling stock emissions per day are determined by the sum of daily emissions for each type of rolling stock:

$$\text{Daily rolling stock emissions} = \sum^{\text{types of rolling stock utilized}} (\text{quantity of rolling stock} * \text{emissions per hour for single unit}) * \text{hours worked per day}$$

Emissions per hour are determined from emissions standards for various types of rolling stock (grams/hp-hour)[1] presented in Table B and the horsepower values taken from the Caterpillar handbook [2].

$$\text{hourly emissions} = \text{grams per horse power per hour} * \text{horsepower}$$

Rolling Stock Emissions for $C0_2$ (non-biomass)

$C0_2$ (non-biomass) emissions are determined for each transfer station type and design by multiplying fuel usage (gallon/ton material processed) by an emission factor for C02 (lb $C0_2$ (non-biomass)/gallon diesel utilized by rolling stock). The fuel usage factor is calculated with the linear regression approach described above. The default emission factor[4] is assumed to be appropriate for all transfer stations.

Appendix 5 References

[1]Nishtala, Subba, "Memo: Suggested Emission Factors for Nonroad and Mobile Sources, Draft," 1995.

[2]Caterpiller Performance Handbook, Ed. 26, Caterpiller Inc., October 1995.

[3]United States Environmental Protection Agency. 1991a, Nonroad Engine and Vehicle Emission Study - Appendixes, (ANR-443), 21A-2001, Office of Air and Radiation.

[4]Franklin Associates, LTD. Energy Requirements and Environmental Emissions for Fuel Consumption, 1991.

TR1-Mixed Refuse

Table 1: TR1 Default Values Resulting from Linear Regressions

Cost			Design 1	Design 2	Design 3	Design 4	Design 5
Rolling Stock Cost	RS_cost	$/TPD	816	1308	837	497	244
Compactor and Hopper Cost	COMP_cost	$/TPD				156	190
Operator Labor Requirement	op_req	hour/day/TI	0.047	0.070	0.097	0.051	0.051
Energy							
Rolling Stock Fuel Use	rs_e	gallon/ton	0.084	0.141	0.071	0.079	0.038
Emissions							
Particulates (PM10)	pm10_rs_c	lb/ton	0.000	0.000	0.000	0.000	0.000
Total Particulates	pm_rs_c	lb/ton	0.006	0.009	0.010	0.007	0.006
Nitrogen Oxides	no_rs_c	lb/ton	0.076	0.127	0.091	0.099	0.048
Hydrocarbons (non CH4)	hc_rs_c	lb/ton	0.005	0.009	0.010	0.009	0.005
Sulfur Oxides	so_rs_c	lb/ton	0.007	0.011	0.006	0.008	0.003
Carbon Monoxide	co_rs_c	lb/ton	0.019	0.031	0.040	0.023	0.021
CO2 (biomass)	co2_bm_rs_c	lb/ton	0.000	0.000	0.000	0.000	0.000
CO2 (non biomass)	co2_rs_c	lb/ton	1.943	3.245	1.639	1.823	0.866
Ammonia	a_nh3_rs_c	lb/ton	0.000	0.000	0.000	0.000	0.000
Lead	a_pb_rs_c	lb/ton	0.000	0.000	0.000	0.000	0.000
Methane	ch4_rs_c	lb/ton	0.000	0.000	0.000	0.000	0.000
Hydrochloric acid	hlc_rs_c	lb/ton	0.000	0.000	0.000	0.000	0.000

Table 2: TR1 r-squared Values for Linear Regressions

Cost		Design 1	Design 2	Design 3	Design 4	Design 5
Rolling Stock Cost	$/TPD	0.87	0.92	0.91	0.95	0.95
Compactor and Hopper Cost	$/TPD				0.95	0.97
Operator Labor Requirement	hour/day/TPD	0.82	0.94	0.77	0.85	0.85
Energy						
Rolling Stock Fuel Use	gallon/ton	0.73	0.84	0.91	0.95	0.95
Emissions						
Particulates (PM10)	lb/ton	1.00	1.00	1.00	1.00	1.00
Total Particulates	lb/ton	0.76	0.84	0.91	0.95	0.95
Nitrogen Oxides	lb/ton	0.73	0.84	0.91	0.95	0.95
Hydrocarbons (non CH4)	lb/ton	0.66	0.84	0.91	0.95	0.95
Sulfur Oxides	lb/ton	0.75	0.84	0.91	0.95	0.95
Carbon Monoxide	lb/ton	0.75	0.84	0.91	0.95	0.95
CO2 (biomass)	lb/ton	1.00	1.00	1.00	1.00	1.00
CO2 (non biomass)	lb/ton	1.00	1.00	1.00	1.00	1.00
Ammonia	lb/ton	1.00	1.00	1.00	1.00	1.00
Lead	lb/ton	1.00	1.00	1.00	1.00	1.00
Methane	lb/ton	1.00	1.00	1.00	1.00	1.00
Hydrochloric acid	lb/ton	1.00	1.00	1.00	1.00	1.00

Table 3: General Input Values Utilized in Linear Regressions

	units	variable name				
Operating Hours		**Design 1**	**Design 2**	**Design 3**	**Design 4**	**Design 5**
Working Day Length	hours/day	8	8	8	8	8
Effective Work Day Length	hours/day	7	7	7	7	7
Workdays per Year	days/year	260	260	260	260	260
CO2 Rolling Stock Emission Factor	lbs/gallon	23.005	23.005	23.005	23.005	23.005

TR1-Mixed Refuse

Tables 4a-e: Capacity Dependent Values Utilized in Linear Regressions*

		Table 4a: Design 1 Capacity Dependent Values				
Facility Capacity	TPD	250	500	1000	1500	2000
Loader Operator	persons	3	4	6	8	10
Compactor Operator	persons	0	0	0	0	0
Laborer	persons	1	1	1	1	1
Compactor	$					
Hopper	$					
Front-end Loader	$	271000	271000	271000	271000	271000
Clam-shell Crane	$	202000	202000	202000	234000	234000
Scale(for tractor trailer)	$	70000	70000	70000	70000	70000
Backhoe	$					
Compactors Required	#					
Hoppers Required	#					
Front-end Loaders Required	#	1	1	1	2	2
Clam-shell Crane Required	#	1	1	2	2	3
Tr.Tr. Scales Required	#	1	2	3	4	5
Backhoes Required	#					
Energy Usage						
Front-end Loader	gal/hour	5.5	5.5	5.5	5.5	5.5
Clam-shell Crane	gal/hour	4	4	4	4	4
Backhoe	gal/hour					

		Table 4b: Design 2 Capacity Dependent Values				
Facility Capacity	TPD	250	500	750	1000	1500
Loader Operator	persons	1	4	7	8	11
Compactor Operator	persons	0	0	0	0	0
Laborer	persons	1	1	1	1	1
Compactor	$					
Hopper	$					
Front-end Loader	$	271000	271000	271000	271000	271000
Clam-shell Crane	$	202000	202000	202000	234000	234000
Scale(for tractor trailer)	$	70000	70000	70000	70000	70000
Backhoe	$					
Compactors Required	#					
Hoppers Required	#					
Front-end Loaders Required	#	1	1	2	2	3
Clam-shell Crane Required	#	1	1	2	2	3
Tr.Tr. Scales Required	#	1	2	3	4	5
Backhoes Required	#					
Energy Usage						
Front-end Loader	gal/hour	5.5	5.5	5.5	5.5	5.5
Clam-shell Crane	gal/hour	4	4	4	4	4
Backhoe	gal/hour					

*default fuel requirement values for equipment from CAT Handbook [9]

Tables 4a-e: Capacity Dependent Values Utilized i

		Table 4c: Design 3 Capacity Dependent Values				
Facility Capacity	TPD	100	250	500	750	1000
Loader Operator	persons	2	4	6	8	10
Compactor Operator	persons	0	0	0	0	0
Laborer	persons	1	1	1	1	1
Compactor	$					
Hopper	$					
Front-end Loader	$					
Clam-shell Crane	$					
Scale(for tractor trailer)	$	70000	70000	70000	70000	70000
Backhoe	$	86300	86300	86300	86300	86300
Compactors Required	#					
Hoppers Required	#					
Front-end Loaders Required	#					
Clam-shell Crane Required	#					
Tr.Tr. Scales Required	#	1	2	3	4	5
Backhoes Required	#	1	2	3	4	5
Energy Usage						
Front-end Loader	gal/hour					
Clam-shell Crane	gal/hour					
Backhoe	gal/hour	1.9	1.9	1.9	1.9	1.9

		Table 4d: Design 4 Capacity Dependent Values				
Facility Capacity	TPD	250	500	1000	1500	1800
Loader Operator	persons	1	2	3	4	5
Compactor Operator	persons	1	2	3	4	5
Laborer	persons	1	1	1	1	1
Compactor	$	35000	35000	35000	35000	35000
Hopper	$	20000	20000	20000	20000	20000
Front-end Loader	$	175700	175700	175700	175700	175700
Clam-shell Crane	$					
Scale(for tractor trailer)	$					
Backhoe	$					
Compactors Required	#	1	2	3	4	5
Hoppers Required	#	1	2	3	4	5
Front-end Loaders Required	#	1	2	3	4	5
Clam-shell Crane Required	#					
Tr.Tr. Scales Required	#					
Backhoes Required	#					
Energy Usage						
Front-end Loader	gal/hour	4	4	4	4	4
Clam-shell Crane	gal/hour					
Backhoe	gal/hour					

*default fuel requirement values for equipment from CAT Han

TR1-Mixed Refuse

Tables 4a-e: Capacity Dependent Values Utilized i

		Table 4e: Design 5 Capacity Dependent Values				
Facility Capacity	TPD	250	500	1000	1500	1800
Loader Operator	persons	1	2	3	4	5
Compactor Operator	persons	1	2	3	4	5
Laborer	persons	1	1	1	1	1
Compactor	$	35000	35000	35000	35000	35000
Hopper	$	20000	20000	20000	20000	20000
Front-end Loader	$					
Clam-shell Crane	$					
Scale(for tractor trailer)	$					
Backhoe	$	86300	86300	86300	86300	86300
Compactors Required	#	1	2	4	5	6
Hoppers Required	#	1	2	4	5	6
Front-end Loaders Required	#					
Clam-shell Crane Required	#					
Tr.Tr. Scales Required	#					
Backhoes Required	#	1	2	3	4	5
Energy Usage						
Front-end Loader	gal/hour					
Clam-shell Crane	gal/hour					
Backhoe	gal/hour	1.9	1.9	1.9	1.9	1.9

Table 1: TR2 Default Values Resulting from Linear Regressions

Recyclables Costs			Design 1	Design 2	Design 3	Design 4	Design 5
Rolling Stock Cost	$/CYPD	RS_cost	193	220	106	119	58
Compactor and HopperCost	$/CYPD	COMP_cost				37	35
Operator Labor Requirement	hour/day-	op_req	0.016	0.010	0.008	0.012	0.012
Fibrous Content Material Costs							
Rolling Stock Cost	$/CYPD	RS_cost	99	99	99	99	99
Operator Labor Requirement	hour/day-	op_req	0.001	0.001	0.001	0.001	0.001
Energy							
Recyclables Rolling Stock Fuel Use	gallon/CY	rs_e	0.02	0.02	0.01	0.03	0.01
Fibrous Content Material Rolling Stock Fuel Use	gallon/ton		0.014	0.014	0.014	0.014	0.014
Recyclables Emissions							
Particulates (PM10)	lb/CY	pm10_rs_c	0.000	0.000	0.000	0.000	0.000
Total Particulates	lb/CY	pm_rs_c	0.001	0.002	0.001	0.002	0.001
Nitrogen Oxides	lb/CY	no_rs_c	0.018	0.021	0.012	0.024	0.012
Hydrocarbons (non CH4)	lb/CY	hc_rs_c	0.001	0.002	0.001	0.002	0.001
Sulfur Oxides	lb/CY	so_rs_c	0.002	0.002	0.001	0.002	0.001
Carbon Monoxide	lb/CY	co_rs_c	0.004	0.005	0.005	0.006	0.005
CO2 (biomass)	lb/CY	co2_bm_rs_c	0.000	0.000	0.000	0.000	0.000
CO2 (non biomass)	lb/CY	co2_rs_c	0.448	0.521	0.207	0.598	0.207
Ammonia	lb/CY	a_nh3_rs_c	0.000	0.000	0.000	0.000	0.000
Lead	lb/CY	a_pb_rs_c	0.000	0.000	0.000	0.000	0.000
Methane	lb/CY	ch4_rs_c	0.000	0.000	0.000	0.000	0.000
Hydrochloric acid	lb/CY	hlc_rs_c	0.000	0.000	0.000	0.000	0.000
Fibrous Content Material Emissions							
Particulates (PM10)	lb/CY	pm10_rs_c	0.000	0.000	0.000	0.000	0.000
Total Particulates	lb/CY	pm_rs_c	0.001	0.001	0.001	0.001	0.001
Nitrogen Oxides	lb/CY	no_rs_c	0.013	0.013	0.013	0.013	0.013
Hydrocarbons (non CH4)	lb/CY	hc_rs_c	0.001	0.001	0.001	0.001	0.001
Sulfur Oxides	lb/CY	so_rs_c	0.001	0.001	0.001	0.001	0.001
Carbon Monoxide	lb/CY	co_rs_c	0.003	0.003	0.003	0.003	0.003
CO2 (biomass)	lb/CY	co2_bm_rs_c	0.000	0.000	0.000	0.000	0.000
CO2 (non biomass)	lb/CY	co2_rs_c	0.324	0.324	0.324	0.324	0.324
Ammonia	lb/CY	a_nh3_rs_c	0.000	0.000	0.000	0.000	0.000
Lead	lb/CY	a_pb_rs_c	0.000	0.000	0.000	0.000	0.000
Methane	lb/CY	ch4_rs_c	0.000	0.000	0.000	0.000	0.000
Hydrochloric acid	lb/CY	hlc_rs_c	0.000	0.000	0.000	0.000	0.000

Table 2: TR2 r-squared Values for Linear Regressions

Rolling Stock Cost	$/CYPD	RS_cost	0.72	0.90	0.99	0.99	0.99
Compactor and HopperCost	$/CYPD	COMP_cost				0.99	0.90
Operator Labor Requirement	hour/day-	op_req	0.939	0.844	0.417	0.925	0.925
Fibrous Content Material Costs							
Rolling Stock Cost	$/CYPD	RS_cost	0.440	0.440	0.440	0.440	0.440
Energy							
Recyclables Rolling Stock Fuel Use	gallon/CY	rs_e	0.42	0.95	0.99	0.99	0.99
Fibrous Content Material Rolling Stock Fuel Use	gallon/ton		0.440	0.440	0.440	0.440	0.440
Recyclables Emissions							
Particulates (PM10)	lb/CY	pm10_rs_c	1.000	1.000	1.000	1.000	1.000
Total Particulates	lb/CY	pm_rs_c	0.424	0.789	0.986	0.986	0.986
Nitrogen Oxides	lb/CY	no_rs_c	0.424	0.803	0.986	0.986	0.986
Hydrocarbons (non CH4)	lb/CY	hc_rs_c	0.424	0.824	0.986	0.986	0.986
Sulfur Oxides	lb/CY	so_rs_c	0.424	0.795	0.986	0.986	0.986
Carbon Monoxide	lb/CY	co_rs_c	0.424	0.796	0.986	0.986	0.986
CO2 (biomass)	lb/CY	co2_bm_rs_c	1.000	1.000	1.000	1.000	1.000
CO2 (non biomass)	lb/CY	co2_rs_c	1.000	1.000	1.000	1.000	1.000
Ammonia	lb/CY	a_nh3_rs_c	1.000	1.000	1.000	1.000	1.000
Lead	lb/CY	a_pb_rs_c	1.000	1.000	1.000	1.000	1.000
Methane	lb/CY	ch4_rs_c	1.000	1.000	1.000	1.000	1.000
Hydrochloric acid	lb/CY	hlc_rs_c	1.000	1.000	1.000	1.000	1.000
Fibrous Content Material Emissions							
Particulates (PM10)	lb/CY	pm10_rs_c	1.000	1.000	1.000	1.000	1.000
Total Particulates	lb/CY	pm_rs_c	0.440	0.440	0.440	0.440	0.440
Nitrogen Oxides	lb/CY	no_rs_c	0.440	0.440	0.440	0.440	0.440
Hydrocarbons (non CH4)	lb/CY	hc_rs_c	0.440	0.440	0.440	0.440	0.440
Sulfur Oxides	lb/CY	so_rs_c	0.440	0.440	0.440	0.440	0.440
Carbon Monoxide	lb/CY	co_rs_c	0.440	0.440	0.440	0.440	0.440
CO2 (biomass)	lb/CY	co2_bm_rs_c	1.000	1.000	1.000	1.000	1.000
CO2 (non biomass)	lb/CY	co2_rs_c	1.000	1.000	1.000	1.000	1.000
Ammonia	lb/CY	a_nh3_rs_c	1.000	1.000	1.000	1.000	1.000
Lead	lb/CY	a_pb_rs_c	1.000	1.000	1.000	1.000	1.000
Methane	lb/CY	ch4_rs_c	1.000	1.000	1.000	1.000	1.000
Hydrochloric acid	lb/CY	hlc_rs_c	1.000	1.000	1.000	1.000	1.000

Table 3: General Input Values Utilized in Linear Regressions

Operating Hours		Design 1	Design 2	Design 3	Design 4	Design 5
Working Day Length	hours/day	8	8	8	8	8
Effective Working Day Length	hours/day	7	7	7	7	7
Number of workdays per year	days	260	260	260	260	260
CO2 Emissions	lbs/gallon	23.005	23.005	23.005	23.005	23.005

Tables 4a-e: Capacity Dependent Values Utilized in Linear Regressions*

Recyclables		Table 4a: Design 1 Capacity Dependent Values				
Commingled Recyclables Capacity	CYPD	1200	2500	4500	6000	7500
Loader Operator	persons	3	5	7	12	14
Compactor Operator	persons	0	0	0	0	0
Laborer	persons	1	1	1	1	1
Compactor	$					
Hopper	$					
Front-end Loader	$	271000	271000	271000	271000	271000
Clam-shell Crane	$	202000	202000	202000	234000	234000
Scale(for tractor trailer)	$	70000	70000	70000	70000	70000
Backhoe	$					
Compactors Required	#					
Hoppers Required	#					
Front-end Loaders Required	#	1	1	1	2	2
Clam-shell Crane Required	#	1	1	1	2	2
Tr.Tr. Scales Required	#	1	2	3	4	5
Backhoes Required	#					
Fibrous Content Material						
Fibrous Content Material Capacity	CYPD	250	500	900	1200	1500
Loader Operator	persons	0.1	0.1	0.25	0.25	0.25
Front-end Loader	$	271000	271000	271000	271000	271000
Front-end Loader Required	#	0.25	0.25	0.25	0.5	0.5
Energy Usage						
Front-end Loader	gal/hour	5.5	5.5	5.5	5.5	5.5
Clam-shell Crane	gal/hour	4	4	4	4	4
Backhoe	gal/hour	1.9	1.9	1.9	1.9	1.9

Recyclables		Table 4b: Design 2 Capacity Dependent Values				
Facility Capacity	CYPD	1200	2500	4500	6000	7500
Loader Operator	persons	2	3	4	6	8
Compactor Operator	persons	0	0	0	0	0
Laborer	persons	1	1	1	1	1
Compactor	$					
Hopper	$					
Front-end Loader	$	271000	271000	271000	271000	271000
Clam-shell Crane	$	202000	202000	202000	234000	234000
Scale(for tractor trailer)	$	70000	70000	70000	70000	70000
Backhoe	$					
Compactors Required	#					
Hoppers Required	#					
Front-end Loaders Required	#	1	1	2	2	3
Clam-shell Crane Required	#	1	1	1	2	2
Tr.Tr. Scales Required	#	1	2	3	4	5
Backhoes Required	#					
Fibrous Content Material						
Fibrous Content Material Capacity	CYPD	250	500	900	1200	1500
Loader Operator	persons	0.1	0.1	0.25	0.25	0.25
Front-end Loader	$	271000	271000	271000	271000	271000
Front-end Loaders Required	#	0.25	0.25	0.25	0.5	0.5
Energy Usage						
Front-end Loader	gal/hour	5.5	5.5	5.5	5.5	5.5
Clam-shell Crane	gal/hour	4	4	4	4	4
Backhoe	gal/hour	1.9	1.9	1.9	1.9	1.9

*default values for equipment from CAT Handbook [9]

Tables 4a-e: Capacity Dependent Values Utilize

Recyclables

		Table 4c: Design 3 Capacity Dependent Values				
Commingled Recyclables Capacity	CYPD	1200	2500	4500	6000	7500
Loader Operator	persons	2	3	4	5	6
Compactor Operator	persons	0	0	0	0	0
Laborer	persons	1	1	1	1	1
Compactor	$					
Hopper	$					
Front-end Loader	$					
Clam-shell Crane	$					
Scale(for tractor trailer)	$	70000	70000	70000	70000	70000
Backhoe	$	86300	86300	86300	86300	86300
Compactors Required	#					
Hoppers Required	#					
Front-end Loaders Required	#					
Clam-shell Crane Required	#					
Tr.Tr. Scales Required	#	1	2	3	4	5
Backhoes Required	#	1	2	3	4	5

Fibrous Content Material

Fibrous Content Material Capacity	CYPD	250	500	900	1200	1500
Loader Operator	persons	0.1	0.1	0.25	0.25	0.25
Front-end Loader	$	271000	271000	271000	271000	271000
Front-end Loader Required	#	0.25	0.25	0.25	0.5	0.5

Energy Usage

Front-end Loader	gal/hour	5.5	5.5	5.5	5.5	5.5
Clam-shell Crane	gal/hour	4	4	5.75	5.75	5.75
Backhoe	gal/hour	1.9	1.9	1.9	1.9	1.9

Recyclables

		Table 4d: Design 4 Capacity Dependent Values				
Facility Capacity	CYPD	1200	2500	4500	6000	7500
Loader Operator	persons	1	2	3	4	5
Compactor Operator	persons	1	2	3	4	5
Laborer	persons	1	1	1	1	1
Compactor	$	35000	35000	35000	35000	35000
Hopper	$	20000	20000	20000	20000	20000
Front-end Loader	$	175700	175700	175700	175700	175700
Clam-shell Crane	$					
Scale(for tractor trailer)	$					
Backhoe	$					
Compactors Required	#	1	2	3	4	5
Hoppers Required	#	1	2	3	4	5
Front-end Loaders Required	#	1	2	3	4	5
Clam-shell Crane Required	#					
Tr.Tr. Scales Required	#					
Backhoes Required	#					

Fibrous Content Material

Fibrous Content Material Capacity	CYPD	250	500	900	1200	1500
Loader Operator	persons	0.1	0.1	0.25	0.25	0.25
Front-end Loader	$	271000	271000	271000	271000	271000
Front-end Loaders Required	#	0.25	0.25	0.25	0.5	0.5

Energy Usage

Front-end Loader	gal/hour	5.5	5.5	5.5	5.5	5.5
Clam-shell Crane	gal/hour					
Backhoe	gal/hour	1.9	1.9	1.9	1.9	1.9

*default values for equipment from CAT Handbook [9]

Tables 4a-e: Capacity Dependent Values Utilize

Recyclables

		Table 4e: Design 5 Capacity Dependent Values				
Commingled Recyclables Capacity	CYPD	1200	2500	4500	6000	7500
Loader Operator	persons	1	2	3	4	5
Compactor Operator	persons	1	2	3	4	5
Laborer	persons	1	1	1	1	1
Compactor	$	35000	35000	35000	35000	35000
Hopper	$	20000	20000	20000	20000	20000
Front-end Loader	$					
Clam-shell Crane	$					
Scale(for tractor trailer)	$					
Backhoe	$	86300	86300	86300	86300	86300
Compactors Required	#	1	2	2	4	5
Hoppers Required	#	1	2	2	4	5
Front-end Loaders Required	#					
Clam-shell Crane Required	#					
Tr.Tr. Scales Required	#					
Backhoes Required	#	1	2	3	4	5

Fibrous Content Material

Fibrous Content Material Capacity	CYPD	250	500	900	1200	1500
Loader Operator	persons	0.1	0.1	0.25	0.25	0.25
Front-end Loader	$	271000	271000	271000	271000	271000
Front-end Loader Required	#	0.25	0.25	0.25	0.5	0.5

Energy Usage

Front-end Loader	gal/hour	5.5	5.5	5.5	5.5	5.5
Clam-shell Crane	gal/hour					
Backhoe	gal/hour	1.9	1.9	1.9	1.9	1.9

Table 1: TR3 Default Values Resulting from Linear Regressions

Cost		Mixed Refuse	Recyclables	FCM
		$/TPD	$/CYPD	$/CYPD
Rolling Stock Cost	RS_cost	769	219	99
Compactor and HopperCost	COMP_cost	178	51	

Equipment Operator		hour/day-TPD	hour/day-CYPD	hour/day-CYPD
Equipment Operator Requirement	op_req	0.069	0.020	0.003

Energy		gallon/ton	gallon/cubic yard	gallon/cubic yard
Rolling Stock Fuel Use	rs_e	0.112	0.032	0.002

Emissions		lb/ton	lb/cubic yard	lb/cubic yard
Particulates (PM10)	pm10_rs_c	0.00	0.00	0.000
Total Particulates	pm_rs_c	0.009	0.003	0.001
Nitrogen Oxides	no_rs_c	0.112	0.032	0.013
Hydrocarbons (non CH4)	hc_rs_c	0.011	0.003	0.001
Sulfur Oxides	so_rs_c	0.009	0.002	0.001
Carbon Monoxide	co_rs_c	0.034	0.010	0.003
CO2 (biomass)	co2_bm_rs_c	0.000	0.000	0.000
CO2 (non biomass)	co2_rs_c	2.566	0.731	0.046
Ammonia	a_nh3_rs_c	0.000	0.000	0.000
Lead	a_pb_rs_c	0.000	0.000	0.000
Methane	ch4_rs_c	0.000	0.000	0.000
Hydrochloric acid	hlc_rs_c	0.000	0.000	0.000

Table 2: TR3 r-squared Values for Linear Regressions

	Mixed Refuse	Recyclables	FCM
Cost			
Rolling Stock Cost	0.90	0.88	0.44
Compactor and HopperCost	0.98	0.99	
Operator Labor Requirement	0.90	0.88	0.53
Energy			
Rolling Stock Fuel Use	0.90	0.88	0.44
Emissions			
Particulates (PM10)	1.00	1.00	1.00
Total Particulates	0.90	0.88	0.44
Nitrogen Oxides	0.90	0.88	0.44
Hydrocarbons (non CH4)	0.90	0.88	0.44
Sulfur Oxides	0.90	0.88	0.44
Carbon Monoxide	0.90	0.88	0.44
CO2 (biomass)	1.00	1.00	1.00
CO2 (non biomass)	1.00	1.00	1.00
Ammonia	1.00	1.00	1.00
Lead	1.00	1.00	1.00
Methane	1.00	1.00	1.00
Hydrochloric acid	1.00	1.00	1.00

Table 3: General Input Values Utilized in Linear Regressions

		Mixed Refuse	Recyclables	FCM
Operating Hours				
Working Day Length	hours/day	8	8	8
Effective Working Day Length	hours/day	7	7	7
Number of workdays per year	days	260	260	260
CO2 Emissions	lbs/gallon	23.005	23.005	23.005

Table 4: Capacity Dependent Values Utilized in Linear Regressions*

MR and Rec. Facility Capacity	TPD	350	750	1200	1800	2100
MR and Rec. Facility Capacity	CYPD	1400	3000	4800	7200	8400
FCM Facility Capacity	CYPD	250	500	900	1200	1500
MR and Rec. Equipment Operator	persons	3	6	9	12	12
Compactor Operator	persons	1	2	3	4	4
FCM Equipment Operator	persons	0.25	0.25	0.25	0.5	0.5
Compactor Unit Cost	$	35000	35000	35000	35000	35000
Hopper Unit Cost	$	40000	40000	40000	40000	40000
Front-end Loader Unit Cost	$	271000	271000	271000	271000	271000
Backhoe Unit Cost	$	86300	86300	86300	86300	86300
Compactors Required	#	1	2	3	4	5
Hoppers Required	#	1	2	3	4	5
MR and Rec. Front-end Loaders Required	#	1	2	3	4	4
MR and Rec. Backhoes Required	#	1	2	3	4	4
FCM Front-end Loader Required	#	0.25	0.25	0.25	0.5	0.5

Energy Usage

Front-end Loader	gal/hour	5.5	5.5	5.5	5.5	5.5
Backhoe	gal/hour	1.9	1.9	1.9	1.9	1.9

*default values for equipment from CAT Handbook [9]

Table 1: TR4 Default Values Resulting from Linear Regressions

Cost		Mixed Refuse	Recyclables	FCM
		$/TPD	$/CYPD	$/CYPD
Rolling Stock Cost	RS_cost	769	219	99
Compactor and HopperCost	COMP_cost	178	51	

Equipment Operator		hour/day-TPD	hour/day-CYPD	hour/day-CYPD
Equipment Operator Requirement	op_req	0.069	0.020	0.003

Energy		gallon/ton	gallon/cubic yard	gallon/cubic yard
Rolling Stock Fuel Use	rs_e	0.112	0.032	0.002

Emissions		lb/ton	lb/cubic yard	lb/cubic yard
Particulates (PM10)	pm10_rs_c	0.00	0.00	0.000
Total Particulates	pm_rs_c	0.009	0.003	0.001
Nitrogen Oxides	no_rs_c	0.112	0.032	0.013
Hydrocarbons (non CH4)	hc_rs_c	0.011	0.003	0.001
Sulfur Oxides	so_rs_c	0.009	0.002	0.001
Carbon Monoxide	co_rs_c	0.034	0.010	0.003
CO2 (biomass)	co2_bm_rs_c	0.000	0.000	0.000
CO2 (non biomass)	co2_rs_c	2.566	0.731	0.046
Ammonia	a_nh3_rs_c	0.000	0.000	0.000
Lead	a_pb_rs_c	0.000	0.000	0.000
Methane	ch4_rs_c	0.000	0.000	0.000
Hydrochloric acid	hlc_rs_c	0.000	0.000	0.000

Table 2: TR4 r-squared Values for Linear Regressions

	Mixed Refuse	Recyclables	FCM
Cost			
Rolling Stock Cost	0.90	0.88	0.44
Compactor and HopperCost	0.98	0.99	
Operator Labor Requirement	0.90	0.88	0.53
Energy			
Rolling Stock Fuel Use	0.90	0.88	0.44
Emissions			
Particulates (PM10)	1.00	1.00	1.00
Total Particulates	0.90	0.88	0.44
Nitrogen Oxides	0.90	0.88	0.44
Hydrocarbons (non CH4)	0.90	0.88	0.44
Sulfur Oxides	0.90	0.88	0.44
Carbon Monoxide	0.90	0.88	0.44
CO2 (biomass)	1.00	1.00	1.00
CO2 (non biomass)	1.00	1.00	1.00
Ammonia	1.00	1.00	1.00
Lead	1.00	1.00	1.00
Methane	1.00	1.00	1.00
Hydrochloric acid	1.00	1.00	1.00

Table 3: General Input Values Utilized in Linear Regressions

		Mixed Refuse	Recyclables	FCM
Operating Hours				
Working Day Length	hours/day	8	8	8
Effective Working Day Length	hours/day	7	7	7
Number of workdays per year	days	260	260	260
CO2 Emissions	lbs/gallon	23.005	23.005	23.005

Table 4: Capacity Dependent Values Utilized in Linear Regressions*

MR and Rec. Facility Capacity	TPD	350	750	1200	1800	2100
MR and Rec. Facility Capacity	CYPD	1400	3000	4800	7200	8400
FCM Facility Capacity	TPD	250	500	900	1200	1500
MR and Rec. Equipment Operator	persons	3	6	9	12	12
Compactor Operator	persons	1	2	3	4	4
FCM Equipment Operator	persons	0.25	0.25	0.25	0.5	0.5
Compactor Unit Cost	$	35000	35000	35000	35000	35000
Hopper Unit Cost	$	40000	40000	40000	40000	40000
Front-end Loader Unit Cost	$	271000	271000	271000	271000	271000
Backhoe Unit Cost	$	86300	86300	86300	86300	86300
Compactors Required	#	1	2	3	4	5
Hoppers Required	#	1	2	3	4	5
MR and Rec. Front-end Loaders Required	#	1	2	3	4	4
MR and Rec. Backhoes Required	#	1	2	3	4	4
FCM Font-end Loaders Required	#	0.25	0.25	0.25	0.5	0.5

Energy Usage

Front-end Loader	gal/hour	5.5	5.5	5.5	5.5	5.5
Backhoe	gal/hour	1.9	1.9	1.9	1.9	1.9

*default values for equipment from CAT Handbook [9]

Table 1: TR5 Default Values Resulting from Linear Regressio

Cost — **Design 1**

Rolling Stock Cost	RS_cost	$/CYPD	28
Equipment Operator Requiremen	COMP_cost	hour/day-CYPD	0.0026

Energy

Rolling Stock Fuel Use	rs_e	gallon/CY	0.0044

Emissions

Particulates (PM10)	pm10_rs_c	lb/CY	0.000
Total Particulates	pm_rs_c	lb/CY	0.001
Nitrogen Oxides	no_rs_c	lb/CY	0.006
Hydrocarbons (non CH4)	hc_rs_c	lb/CY	0.001
Sulfur Oxides	so_rs_c	lb/CY	0.000
Carbon Monoxide	co_rs_c	lb/CY	0.002
CO2 (biomass)	co2_bm_rs_c	lb/CY	0.000
CO2 (non biomass)	co2_rs_c	lb/CY	0.100
Ammonia	a_nh3_rs_c	lb/CY	0.000
Lead	a_pb_rs_c	lb/CY	0.000
Methane	ch4_rs_c	lb/CY	0.000
Hydrochloric acid	hlc_rs_c	lb/CY	0.000

Table 2: TR5 r-squared Values for Linear Regressions

Cost — **Design 1**

Rolling Stock Cost	$/CYPD	0.73
Equipment Operator Requiremen	hour/day-CYPD	0.73

Energy

Rolling Stock Fuel Use	gallon/CY	0.73

Emissions

Particulates (PM10)	lb/CY	1.00
Total Particulates	lb/CY	0.73
Nitrogen Oxides	lb/CY	0.73
Hydrocarbons (non CH4)	lb/CY	0.73
Sulfur Oxides	lb/CY	0.73
Carbon Monoxide	lb/CY	0.73
CO2 (biomass)	lb/CY	1.00
CO2 (non biomass)	lb/CY	1.00
Ammonia	lb/CY	1.00
Lead	lb/CY	1.00
Methane	lb/CY	1.00
Hydrochloric acid	lb/CY	1.00

Table 3: General Input Values Utilized in Linear Regressions

Operating Hours

Working Day Length	hours/day	8
Effective Working Day Length	hours/day	7
Number of workdays per year	days	260
CO2 Emissions	lbs/gallon	23.005

Table 4: Capacity Dependent Values Utilized in Linear Regressions*

			Design 1				
Facility Capacity	CYPD	fac_cap	1504	3008	4511	7519	9023
Loader Operator	persons	load_op	1	1	2	2	3
Backhoe	$	bh_c	86300	86300	86300	86300	86300
Backhoes Required	#	bh_q	1	1	2	2	3
Backhoe	gal/hour	bh_e	1.9	1.9	1.9	1.9	1.9

*default values for equipment from CAT Handbook [9]

Table 1: RT1 Default Values Resulting from Linear Regressions

Cost

			Design 1	Design 2
Rolling Stock Cost	RS_cost	$/TPD	640	395
Compactor and HopperCost	COMP_cost	$/TPD		935
Operator Labor Requirement	op_req	hour/day-TP	0.034	0.025

Energy

			Design 1	Design 2
Rolling Stock Fuel Use	rs_e	gallon/ton	0.127	0.08

Emissions

			Design 1	Design 2
Particulates (PM10)	pm10_rs_c	lb/ton	0.000	0.000
Total Particulates	pm_rs_c	lb/ton	0.008	0.005
Nitrogen Oxides	no_rs_c	lb/ton	0.103	0.073
Hydrocarbons (non CH4)	hc_rs_c	lb/ton	0.007	0.005
Sulfur Oxides	so_rs_c	lb/ton	0.009	0.006
Carbon Monoxide	co_rs_c	lb/ton	0.026	0.018
CO2 (biomass)	co2_bm_rs_c	lb/ton	0.000	0.000
CO2 (non biomass)	co2_rs_c	lb/ton	2.928	1.854
Ammonia	a_nh3_rs_c	lb/ton	0.000	0.000
Lead	a_pb_rs_c	lb/ton	0.000	0.000
Methane	ch4_rs_c	lb/ton	0.000	0.000
Hydrochloric acid	hlc_rs_c	lb/ton	0.000	0.000

Table 2: RT1 r-squared Values for Linear Regressions

Cost

		Design 1	Design 2
Rolling Stock Cost	$/TPD	0.77	0.77
Compactor and HopperCost	$/TPD		0.93
Operator Labor Requirement	hour/day-TPD	0.88	0.84

Energy

		Design 1	Design 2
Rolling Stock Fuel Use	gallon/ton	0.87	0.77

Emissions

		Design 1	Design 2
Particulates (PM10)	lb/ton	1.00	1.00
Total Particulates	lb/ton	0.77	0.77
Nitrogen Oxides	lb/ton	0.77	0.77
Hydrocarbons (non CH4)	lb/ton	0.77	0.77
Sulfur Oxides	lb/ton	0.77	0.77
Carbon Monoxide	lb/ton	0.77	0.77
CO2 (biomass)	lb/ton	1.00	1.00
CO2 (non biomass)	lb/ton	1.00	1.00
Ammonia	lb/ton	1.00	1.00
Lead	lb/ton	1.00	1.00
Methane	lb/ton	1.00	1.00
Hydrochloric acid	lb/ton	1.00	1.00

Table 3: General Input Values Utilized in Linear Regressions

Operating Hours

			Design 1	Design 2
Working Day Length	hours/day	wh_d	8	8
Effective Working Day Lengtl	hours/day	EWh_d	7	7
Number of workdays per year	days	ywd	260	260
CO2 Emissions	lbs/gallon		23.005	23.005

Table 4: Capacity Dependent Values Utilized in Linear Regressions

			Design 1				
Facility Capacity	TPD	fac_cap	500	750	1000	1500	1800
Loader Operator	persons	load_op	1	3	4	5	6
Compactor Operator	persons	comp_op	0	0	0	0	0
Laborer	persons	lab_op	1	1	1	1	1
Compactor	$	comp_c					
Hopper	$	hop_c					
Front-end Loader	$	fel_c	271000	271000	271000	271000	271000
Excavator	$	crn_c	202000	202000	202000	202000	202000
Container Handling Unit	$	tr_c	55000	55000	55000	55000	55000
Compactors Required	#	comp_q					
Hoppers Required	#	hop_q					
Front-end Loaders Required	#	fel_q	1	1	1	2	2
Excavators Required	#	crn_q	1	1	1	2	2
Container Handling Units Req	#	tr_q	1	1	1	2	2
Energy Usage							
Front-end Loader	gal/hour	fel_e	5.5	5.5	5.5	5.5	5.5
Excavator	gal/hour	crn_e	4	4	5.75	5.75	5.75
Container Handling Unit	gal/hour	tr_e	4	4	4	4	4

			Design 2				
Facility Capacity	TPD	fac_cap	500	750	1000	1500	1800
Loader Operator	persons	load_op	1	2	2	4	4
Compactor Operator	persons	comp_op	0	0	0	0	0
Laborer	persons	lab_op	1	1	1	1	1
Compactor	$	comp_c	261000	261000	261000	261000	261000
Hopper	$	hop_c	20000	20000	20000	20000	20000
Front-end Loader	$	fel_c	271000	271000	271000	271000	271000
Excavator	$	crn_c					
Container Handling Unit	$	tr_c	55000	55000	55000	55000	55000
Compactors Required	#	comp_q	1	2	4	5	6
Hoppers Required	#	hop_q	1	2	4	5	6
Front-end Loaders Required	#	fel_q	1	1	1	2	2
Excavators Required	#	crn_q					
Container Handling Units Req	#	tr_q	1	1	1	2	2
Energy Usage							
Front-end Loader	gal/hour	fel_e	5.5	5.5	5.5	5.5	5.5
Excavator	gal/hour	crn_e					
Container Handling Unit	gal/hour	tr_e	4	4	4	4	4

Table 1: RT2 & RT3 Default Values Resulting from Linear Regressions

Cost

			RT2	RT3
Rolling Stock Cost	RS_cost	$/TPD	1329	1329
Operator Labor Requirement	COMP_cost	hour/day-TPD	0.044	0.044

Energy

			RT2	RT3
Rolling Stock Fuel Use	rs_e	gallon/ton	0.186	0.186

Emissions

			RT2	RT3
Particulates (PM10)	pm10_rs_c	lb/ton	0.000	0.000
Total Particulates	pm_rs_c	lb/ton	0.008	0.008
Nitrogen Oxides	no_rs_c	lb/ton	0.098	0.098
Hydrocarbons (non CH4)	hc_rs_c	lb/ton	0.005	0.005
Sulfur Oxides	so_rs_c	lb/ton	0.009	0.009
Carbon Monoxide	co_rs_c	lb/ton	0.026	0.026
CO2 (biomass)	co2_bm_rs_c	lb/ton	0.000	0.000
CO2 (non biomass)	co2_rs_c	lb/ton	4.275	4.275
Ammonia	a_nh3_rs_c	lb/ton	0.000	0.000
Lead	a_pb_rs_c	lb/ton	0.000	0.000
Methane	ch4_rs_c	lb/ton	0.000	0.000
Hydrochloric acid	hlc_rs_c	lb/ton	0.000	0.000

Table 2: RT2 & RT3 r-squared Values for Linear Regressions

Cost

		RT2	RT3
Rolling Stock Cost	$/TPD	0.82	0.82
Operator Labor Requirement	hour/day-TPD	0.72	0.90

Energy

		RT2	RT3
Rolling Stock Fuel Use	gallon/ton	0.84	0.84

Emissions

		RT2	RT3
Particulates (PM10)	lb/ton	1.00	1.00
Total Particulates	lb/ton	0.82	0.82
Nitrogen Oxides	lb/ton	0.82	0.82
Hydrocarbons (non CH4)	lb/ton	0.82	0.82
Sulfur Oxides	lb/ton	0.82	0.82
Carbon Monoxide	lb/ton	0.82	0.82
CO2 (biomass)	lb/ton	1.00	1.00
CO2 (non biomass)	lb/ton	1.00	1.00
Ammonia	lb/ton	1.00	1.00
Lead	lb/ton	1.00	1.00
Methane	lb/ton	1.00	1.00
Hydrochloric acid	lb/ton	1.00	1.00

Table 3: General Input Values Utilized in Linear Regressions

Operating Hours

			RT2	RT3
Working Day Length	hours/day	wh_d	8	8
Effective Working Day Length	hours/day	EWh_d	7	7
Number of workdays per year	days	ywd	260	260
CO2 Emissions	lbs/gallon		23.005	23.005

Table 4: Capacity Dependent Values Utilized in Linear Regressions*

		RT2				
Facility Capacity	TPD	400	750	1000	1500	1800
Loader Operator	persons	3	3	6	6	9
Laborer	persons	1	1	1	1	1
Tippers	$	250000	250000	250000	250000	250000
Container handling units	$	500000	500000	500000	500000	500000
Tractors	$	80000	80000	80000	80000	80000
Tippers Required	#	1	1	2	2	3
Container handling units Required	#	1	1	2	2	3
Tractors Required	#	1	1	2	2	3
Energy Usage						
Tippers	gal/hour	5.5	5.5	5.5	5.5	5.5
Container handling units	gal/hour	4	4	5.75	5.75	5.75
Tractors	gal/hour	5.5	5.5	5.5	5.5	5.5

		RT3				
Facility Capacity	TPD	400	750	1000	1500	1800
Loader Operator	persons	1	3	6	6	9
Laborer	persons	1	1	1	1	1
Tippers	$	250000	250000	250000	250000	250000
Container handling units	$	500000	500000	500000	500000	500000
Tractors	$	80000	80000	80000	80000	80000
Tippers Required	#	1	1	2	2	3
Container handling units Required	#	1	1	2	2	3
Tractors Required	#	1	1	2	2	3
Energy Usage						
Tippers	gal/hour	5.5	5.5	5.5	5.5	5.5
Container handling units	gal/hour	4	4	5.75	5.75	5.75
Tractors	gal/hour	5.5	5.5	5.5	5.5	5.5

*default values for equipment from CAT Handbook [9]