Volume 3: Cost Modelling

A Study of the Optimization of the Blue Box Material Processing System in Ontario

Final Report

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Prepared for Waste Diversion Ontario by:

Resource Recycling Systems
Sustainable Systems for a Waste-Free Future

STEWARDEDGE

Volume 3: Cost Modelling

Table of Contents

List of Tables

List of Figures

Volume 3: Cost Modelling

1. Introduction

The purpose of this study is to provide Waste Diversion Ontario (WDO), including the Continuous Improvement Fund (CIF), individual municipal owners, the Association of Municipalities of Ontario (AMO) and Stewardship Ontario (SO) with comprehensive independent information on a theoretical optimized MRF and transfer facility network for the province of Ontario.

The Project Team has developed a geographic information system (GIS) model that will:

- Theoretically reflect a cost-effective, efficient and successful recovery system for packaging & printed paper in Ontario, and
- Inform decision-making toward an optimized provincial system for the transfer, hauling and sorting of Blue Box recyclables for market

Volume 3 presents how system costs have been estimated. It addresses the cost data and estimates for the existing province-wide system as well as projections for the system if it were operating in 2025 as a comparison to the optimized system.

Volume 3 presents the assumptions for greenfield facilities and operations, MRFs and transfer stations, and the justification, applicability and tailoring of those assumptions to the Ontario Blue Box system. Lastly, the method of estimating the cost of alternative optimized systems which use existing facilities is described.

The analyses of the sensitivity of the cost estimates to key variables and to changing the assumptions are presented.

2. Existing System Cost

2.1. Approach to Estimating 2010 Existing System Cost

An estimate of the cost of the Existing System is required to compare to the estimated cost of the optimized system options.

The cost data for 2010 reported by municipalities, verified by WDO and stored in the WDO Database, has been used as the basis of our cost estimates for the Existing System. These represent the most current and complete data on the actual cost of the Blue Box system.

However, noting that the analysis covers processing and transfer alone, there are many limitations to these data because of the structure of many of the contracts, i.e. the processing cost may not be reported separately from collection and revenue sharing may not be clear. For this study it is important to work with cost data that covers processing only and from which revenue can be isolated. These are considered reliable data for this study. Therefore, the most reliable data were extracted and used and estimates were developed to represent the cost of programs for which data were not reliable. The estimated cost for the Existing System in 2010 was developed as follows and summarized in Table 1.

Processing

- Processing cost data[1] were extracted for 27 of the largest 30 programs, for which reliable data were available for processing alone.
- An additional five of the larger programs with good data were added.
- Cost data were extracted for 11 small programs for which processing cost data and revenue have been reported separately.
- Costs were estimated for 3 of the largest 30 programs (Simcoe County, Barrie, and Chatham-Kent), for which data for processing were not isolated by multiplying a greenfield MRF per-tonne cost to the tonnes managed by these programs.
- The cost for the remaining 177 smaller programs was estimated by multiplying the tonnes managed by the average cost per tonne for the 11 smaller programs with good cost data.
- Therefore, the actual processing cost is used for programs covering 87% of tonnes, while the cost for the remaining 13% of the tonnes are extrapolated based on actual reported costs.

Transfer

Since municipalities report transfer cost data on the same form and combined with depot costs, it is not possible to extract a reliable transfer cost directly from the WDO database. Therefore, a modelled transfer cost is used, together with information about the quantity of the material recovered within each applicable program and the distance transferred according to the identified MRF destination.

The transfer cost covers loading, hauling and unloading of material and the assumed unit cost is described in section 8 below.

Since 32% of the material in the province is currently transferred, that portion of the system cost is modelled. However, as with the processing cost, the modelled unit transfer costs are based on capital and labour costs provided by municipalities. These costs include building costs, rolling stock, compactors, labour costs, operating & maintenance and taxes together with data on the quantities transferred. Further details can be found in Section 8. These costs are considered to be representative of the actual costs within the current system.

Combined Processing and Processing Cost 2010

Table 1 summarizes the gross cost of the Blue Box transfer and processing system in Ontario for 2010 as described above.

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[1] Only the gross processing costs are being considered. For programs with revenue sharing agreements, the revenue kept by the contractors was added to the gross processing cost under the assumption that the cost had been discounted by the service provider to account for revenue.

Table 1: Estimated Existing System Cost in 2010

	Tonnes	Annual Capital and Operating Cost ($)
Cost data from 27 of the largest 30 programs + 5 smaller programs for which processing and revenue are reported separately	767,914	$93,633,000
Theoretical costs for the remaining 3 of the 30 largest programs	38,689	$4,596,000
11 smaller programs with cost data for which processing and revenue are reported separately	7,915	$1,508,000
Estimate of costs for the 177 small programs based on the 11 representative smaller programs	72,725	$13,860,000
Total Processing	**887,242**	**$113,596,000**
Theoretical transfer cost for known transfer operations	284,363	$9,505,000
Transfer cost for programs with unknown material flows based on costs from known transfer operations	3,487	$117,000
Total Transfer	**287,849**	**$9,622,000**
TOTALS[2]	887,242	$123,218,000

2.2. Approach to Projecting 2025 Natural Growth Existing System Cost

The greenfield baseline and optimized system options are estimated for 2025. Therefore, in order to compare to the Existing System, an estimate of the cost of the Existing System in 2025 is required.

Two key changes will affect the processing and transfer cost:

1. Change in the tonnes recovered: Under the Natural Growth Scenario (see Volume 2), material recovery rates remain approximately the same or are slightly higher given recent trends. Also, the population will have increased. Therefore, overall an increase in tonnages is projected.

2. Change in composition: The change in composition toward lighter weight, more complex and in some cases lower value material will tend to result in a higher management cost.

It is possible that any underutilized capacity in the system that could allow the increase in tonnes to be managed at a lower unit cost would be entirely offset by the higher cost to manage the remaining and incremental tonnes.

Therefore, the projected cost of the Existing System in 2025 was calculated as a range +/- 5% as follows:

- The projected tonnes in 2025 in the largest 32 programs and the 11 smaller programs with reliable processing cost will be multiplied by the per-tonne cost in those programs +/-5%.
- The projected tonnes in 2025 in the 3 large programs with limited processing cost data will be multiplied by the average per-tonne cost for a similar sized greenfield MRF +/-5%.

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[2] Tonnes transferred are included in the tonnes processed.

- The projected tonnes in 2025 in the 177 smaller programs with limited processing cost data will be multiplied by the average per-tonne cost for the smaller programs +/-5%.
- The projected tonnes in 2025 for all programs that transfer material will be multiplied by the average cost per tonne per km for transfer +/-5%, assuming the same distances and relative tonnes hauled as for the 2010 system.

The projected cost of the Existing System transfer and processing operations in 2025 will be expressed as a range as summarized in Table 2.

Table 2: Projected Existing System Cost in 2025

	Tonnes	Annual Capital and Operating Cost ($)
Cost data from 27 of the largest 30 programs + 5 smaller programs for which processing and revenue are reported separately	901,067	$104,328,000 - $115,310,000
Theoretical costs for the remaining 3 of the 30 largest programs	45,955	$5,122,000 - $5,122,000
11 smaller programs with cost data for which processing and revenue are reported separately	11,366	$2,131,000 - $2,355,000
Estimate of costs for the 177 small programs based on the 11 representative smaller programs	88,066	$15,944,000 - $17,623,000
Total Processing	1,046,453	$127,524,000 - $140,409,000
Theoretical transfer cost for known transfer operations	351,235	$10,662,000 - $11,410,000
Transfer cost for programs with unknown material flows based on costs from known transfer operations	4,207	$125,000 - $132,000
Total Transfer	355,441	$10,787,000 - $11,542,000
TOTALS[3]	**1,046,453**	**$138,311,000 - $151,951,000**

In summary, the Existing System processing and transfer cost is estimated to be $123,218,000 in 2010 and between $138,311,000 and $151,951,000 in 2025. For 2010, approximately 77% of the cost is the actual reported cost while the remaining 23% is modelled either on the actual cost in representative programs or a theoretical unit cost.

[3] Tonnes transferred are included in the tonnes processed.

3. Approach to MRF costing

3.1. Collection Design Assumption

3.1.1. Single-Stream Modelling

This study is not intended to optimize the collection system. It is not intended to determine collection routing or to recommend single- or dual-stream collection. However, in order to complete the modelling, the Project Team made an assumption regarding the collection system. Single-stream recycling was assumed throughout for two key reasons:

1. The cost estimates within this study are considered to be more conservative since the study deals only with processing and transfer and generally the benefits and savings associated with a single-stream collection system are realized on the collection operations, while processing operations are typically more costly than dual-stream, and
2. Overall system benefits continue to be realized across North America as single-stream collection systems are implemented, and the trend to implementing single-stream collection continues
    - The benefits of implementing single-stream collection are presented in detail in Appendix 1 of this Volume.

3.2. MRF Design

3.2.1. Single-Stream Scale of Operation

Historically the optimal throughput for single-stream facilities has been 14 tonnes per hour (tph) or 27,000 tonnes per year (tpy) or greater. This was based on the early screens that separated fibre from containers performing well at 14 tph. The screens could be run at lower rates, but manual sorting staff requirements did not decrease much because of the sort locations that must be staffed, making smaller facilities proportionately more costly to operate. Some facilities were built in the 8 tph-size range, using smaller or less advanced screen designs, mostly to serve isolated populations, large rural areas or where recycling rates were low. These lower throughput facilities could not compete economically with larger facilities where sufficient volume of recyclables is available.

Recent designs with a single sort line appear to perform well in the 14-32 tph-size range. At throughputs below 32 tph, increased capacity is obtained through an increase in the size of separation equipment and an increase in the number of separation stages rather than through parallel equipment. The primary advantage of this approach is that few additional staff is required to increase throughput. The additional separation stages also have the potential of providing better separation or even production of additional fibre grades.

Most equipment designers choose to split the material stream after the OCC screen into two lines when processing 32 tph or more rather than build huge components to handle it all as one stream. This allows for a loading/metering station, a single large presort and a single OCC screen. These split systems have been designed to operate at more than 60 tph.

Facilities sized to process 50,000 tonnes or more per year can usually justify optical sorters for PET and NHDPE. Some facilities in this size range are also adding optical sorters for #3-7 plastics and cartons. As facilities get still larger, additional optical and mechanical sorting becomes cost effective.

A number of facilities have been built to process more than 200,000 tpy. Most recent large facilities use optical sorters for most plastics. A few MRFs use optical sorters to post sort mixed fibre. The larger facilities are usually set up to receive transfer trailers and to serve a large geographical area. In the Chicago area, several large MRFs compete, drawing materials from five states.

3.2.2. General Assumptions: Sequence of Operation

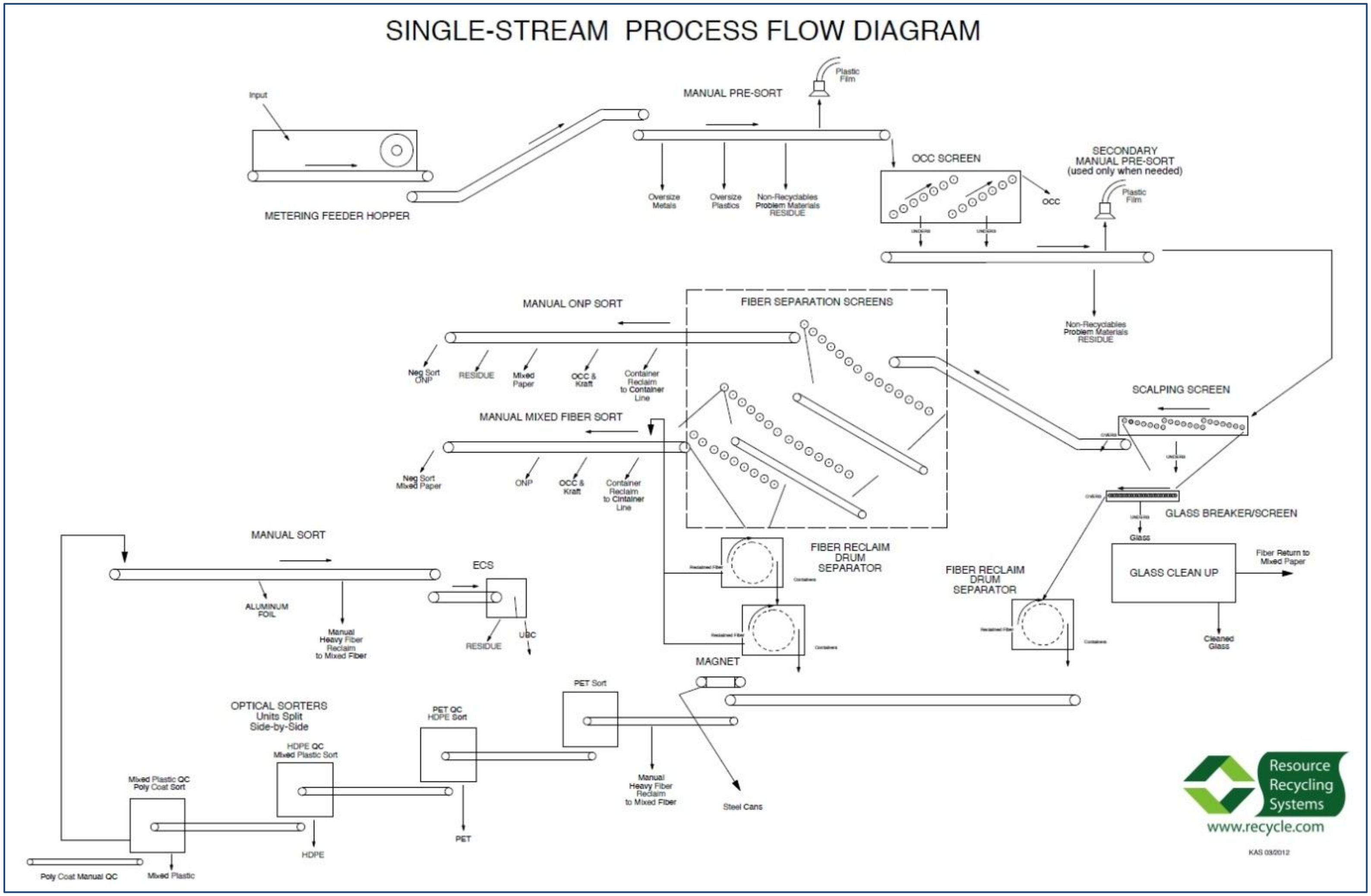
The separation technologies vary somewhat from one manufacturer to another, but with a few exceptions there is general agreement on the process sequence. The two areas where design sequences vary significantly are the place and method of glass removal and the place and method of small fibre recovery. Figure 1 and the text that precedes it describe a typical single-stream equipment sequence.

Process Flow Description:

- Metering Feeder Hopper
  - Hopper is usually loaded from the tipping floor by a large wheel loader.
  - Metering is either from the hopper or metering drum following the hopper with optical control.
- Manual Presort
  - Large horizontal conveyor with picking stations for materials such as trash, large rigid plastic, junk metal, and any materials that might wrap screen shafts. If no OCC screen follows, large OCC is picked here. If plastic film is collected, overhead suction tubes may be provided for film sorting.
- OCC screen
  - Large OCC is removed (not needed in facilities where little OCC shows up in single-stream)
  - Most facilities provide an OCC post-sort station that may or may not be staffed.
  - Secondary Manual Presort: Needed where lots of large OCC is delivered in single-stream materials.
- Scalping Screen
  - Glass Breaker/Screen: This can be done under OCC screen (BHS) or under a scalping screen following OCC screen (CP). This is often accomplished with a multi-stage all-metal roll-screen designed to break and screen glass.
  - Fibre Reclaim Drum Separator: The materials that passed through the OCC screen but not the glass breaker are fed to a news screen that separates newspaper from bottles and cans with smaller fibre. The ONP goes to a post-sort station where brows, contaminants and out-throw are sorted to the needed market specification.
- Fibre Separation Screens
  - Manual ONP Sort: The unders from the news screen pass to the next screen which separates mixed paper from the mixed bottles and cans. The mixed paper goes to a post-sort station where bottles and cans, contaminants and newspaper that was not captured by the news screen are manually sorted to appropriate bins or conveyors.
  - Manual Mixed Fibre Sort: The small paper that comes out with the bottles and cans from the mixed paper screen is recaptured either as part of the mixed paper screen operation or as a secondary process (CP uses air drum separators – ADS). Small paper is fed to the mixed paper post sort.
- Magnet Sorter: The bottles and cans are conveyed to the container sort section. Steel cans are pulled off with an overhead magnet.
- Optical Sorters
  - Optical sorters remove PET, NHDPE and possibly other materials (CHDPE, #3-7, cartons). Post sort manual inspection stations allow sorting materials missed by optical sorters. If PETG must be kept separate from PETE, this is usually accomplished manually at the PET post-sort station.
- Final Sort
  - Materials not sorted by optical sorters are manually sorted into appropriate bins.
  - If aluminum is left on the line, an eddy current separator (ECS) captures the aluminum.
  - Post sort stations can be staffed to capture missed aluminum and pick recyclables from residue.

All sorted materials are stored in bunkers and bins and fed to one or more balers as bins fill.

Figure 1: Process Flow Diagram



3.3. Development of MRF Cost Curve

The following assumptions were made in developing the MRF cost model to reflect what should be possible in Ontario MRFs with the listed target products. Six model MRF facilities were designed and priced out to develop capital and operating costs for each one. Annual operating costs are estimated for both single and two-shift operations for each facility. The six facilities are:

- Dual-stream Small – 6 tonnes per hour (tph)
- Dual-stream Medium – 14 tph
- Single-stream Small – 14 tph
- Single-stream Intermediate – 20 tph
- Single-stream Medium – 32 tph
- Single-stream Large – 64 tph

The base model does not address difficult materials such as EPS, plastic film and plastic laminates (juice pouch type materials). The additional costs to sort these materials are addressed in the sensitivity analysis.

Table 3: Cost Model Assumptions

Assumed average operating % of rated capacity	85%
Assumed Productive hours per 8-hour shift	7.5
Approximate output material split	Fibre 68%; Containers 25%, Residue 7% with nearly all recyclables captured
Assumed Products	• OCC • ONP • Mixed fibre • Mixed broken glass • Steel cans (includes aerosol & paint cans) • PET (w or w/o thermoform) • HDPEn • HDPEc • Mixed Plastics (includes plastic paint cans (3-7 plus non-bottle 1&2) • Polycoat fibre materials • Aluminum (may be split UBC & other Al)
MRF level of mechanization increases with throughput rating	• Dual-stream models assume mechanical glass separation and manual sort for other materials • Single-stream Small – OCC, ONP, Mixed paper screen, glass breaker and glass cleanup, mechanical fibre reclaim from container split; optical sorting for PET • Single-stream Intermediate – has above plus optical HDPE • Single-stream Medium – has above plus optical quality control (QC)- on PET, optical sort for Mixed plastic & cartons • Single-stream Large – has above plus polishing screen; fibre recovery from glass; optical sorter cascading sequence to optically QC all optical sort products

Sorting tph/sorter	Based on level of mechanization. • Dual-stream Small Facility: 0.50 tph/sorter • Dual-stream Medium Facility: 0.60 tph/sorter • Single-stream Small Facility: 0.75 tph/sorter • Single-stream Intermediate Facility: 1.00 tph/sorter • Single-stream Medium Facility: 1.35 tph/sorter • Single-stream Large Facility: 1.35 tph/sorter
Staff Roles	• Sorters manually sort recyclables either positively or negatively along sort lines. Some sorters are doing manual QC for products sorted mechanically. • Equipment operators operate loaders, forklifts and balers. In larger facilities, balers are able to operate automatically for many materials, allowing baler operator to also operate a forklift. Also in large single-stream MRFs, second loader and/or second skid-steer is idle much of the time, allowing all functions to be completed with fewer operators than total pieces of equipment. • Maintenance staff maintains equipment and completes minor equipment repairs. Larger repair needs are contracted using maintenance funds. • Scale/clerical staff operates scale, answers phone and does clerical work. In smaller facilities, this work overlaps with management staff functions. This staff only works first shift. • Management staff includes line supervisors and plant managers. Plant manager only works first shift or shift is split to overlap two shifts.
Tax Rate	Based on taxes listed in WDO Datacall for existing programs, the project team determined that 40% of annual building cost provided a similar cost number.

The estimated capital cost for each facility is listed in Table 4. These estimates are based on the assumed mechanization for each facility described in the previous table. The building size assumed for each facility is listed in the following table as well. When these costs are amortized in the capital and operating budgets in the subsequent tables, the building is amortized over 20 years, the equipment over 10 years and the rolling stock over 8 years.

Land costs have not been included in the capital costs for the following reasons:

- In some cases, property already owned by the municipality or private company could be used for a new facility.
- Property costs are highly variable even within a municipality and specific sites of MRFs or transfer stations within a City are not being selected as part of this study.
- Land costs will need to be determined on a case-by-case basis as facilities are being considered.
- Land costs are not included in the cost data reported in the WDO Datacall for the public facilities in the Existing system.

The labour assumed for each facility is listed in Table 5 based on the work descriptions and assumptions listed previously in Table 3. Detailed labour rates and benefit assumptions can be found in Table 12 in Appendix 2.

In addition to the annual capital and labour costs, operating costs are estimated based on a series of assumptions listed in Table 13 in Appendix 2. The annual operating budget for each facility is summarized below in Table 6.

Table 4: Capital Cost

	DS Small MRF	DS Medium MRF	SS Small MRF	SS Intermediate MRF	SS Medium MRF	SS Large MRF
Building Size (m^2)	2,200	4,000	4,000	5,000	6,200	10,500
Building Cost	$2,842,400	$5,168,000	$5,168,000	$6,460,000	$8,010,400	$13,566,000
Site Cost	$ -	$ -	$ -	$ -	$ -	$ -
Equipment	$2,400,000	$3,250,000	$4,050,000	$6,750,000	$ 9,300,000	$17,600,000
Rolling Stock	$170,000	$265,000	$170,000	$265,000	$300,000	$565,000
Total Capital	$5,412,400	$8,683,000	$9,388,000	$13,475,000	$17,610,400	$31,731,000

Table 5: Labour Assumptions

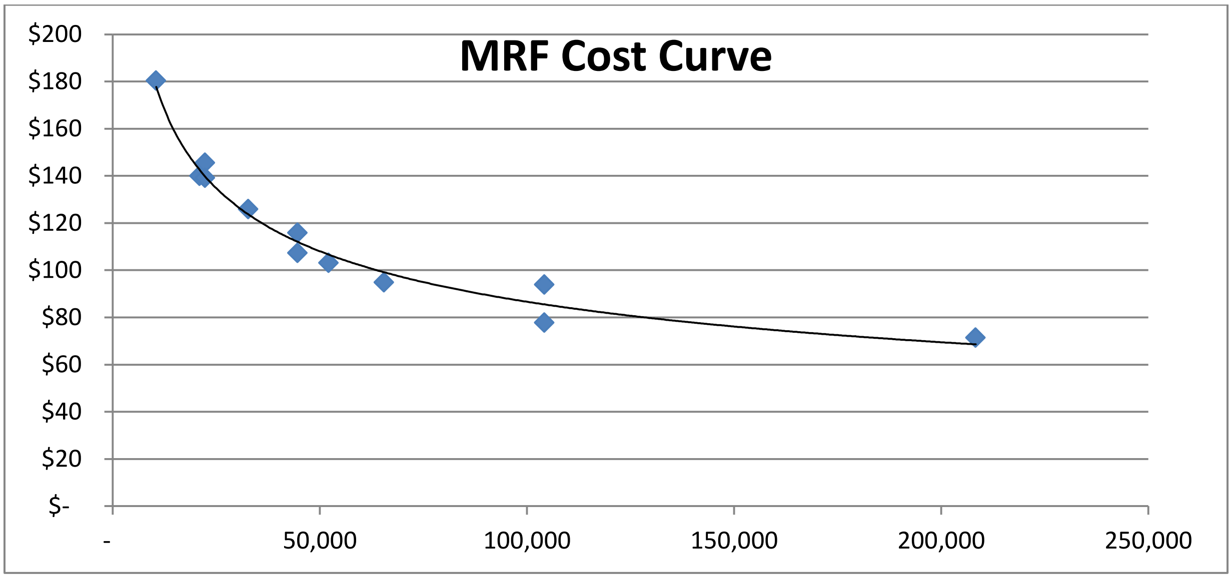
	DS Small MRF	DS Small MRF 2-Shift	DS Medium MRF	DS Medium MRF 2-Shift	SS Small MRF	SS Small MRF 2-Shift	SS Intermediate MRF	SS Inter-mediate MRF 2-Shift	SS Medium MRF	SS Medium MRF 2-Shift	SS Large MRF	SS Large MRF 2-Shift
Sorter Productivity (T/hr/sorter)	0.50	0.50	0.60	0.60	0.75	0.75	1.00	1.00	1.35	1.35	1.35	1.35
Sorter	13	26	23	46	18	36	20	40	24	48	47	94
Driver	0	0	0	0	0	0	0	0	0	0	0	0
Equipment Operator	1	2	3	6	3	6	4	8	5	10	7	14
Maintenance	1	2	1	2	1	2	1	2	1	2	2	4
Scale/Clerical	1	1	1	1	1	1	1	1	1	1	1	2
Management, Clerical & Scale	1	2	2	3	2	3	2	4	2	4	2	4
Total FTE	17	33	30	58	25	48	28	55	33	65	59	118

Table 6: Operating Budget Summary

	DS Small MRF	DS Small MRF 2-Shift	DS Medium MRF	DS Medium MRF 2-Shift	SS Small MRF	SS Small MRF 2-Shift	SS Inter-mediate MRF	SS Inter-mediate MRF 2-Shift	SS Medium MRF	SS Medium MRF 2-Shift	SS Large MRF	SS Large MRF 2-Shift
Annual Incoming Tonnes	10,492	20,984	22,324	44,647	22,324	44,647	32,741	65,482	52,088	104,177	104,177	208,353
Annual Capital ($)	530,297	530,297	820,326	820,326	904,849	904,849	1,346,912	1,346,912	1,780,583	1,780,583	3,252,049	3,252,049
Annual Labour Cost (includes Fringe Benefits) ($)	735,488	1,430,416	1,272,232	2,503,904	1,069,432	2,098,304	1,234,376	2,428,192	1,443,936	2,847,312	2,518,776	5,037,552
Residual Disposal Costs ($)	58,756	117,511	125,012	250,024	125,012	250,024	183,351	366,701	291,694	583,389	583,389	1,166,777
Annual Building O&M Costs ($)	43,809	43,809	79,653	79,653	79,653	79,653	99,566	99,566	123,462	123,462	209,089	209,089
Building Insurance Costs ($)	8,000	8,000	10,000	10,000	10,000	10,000	15,000	15,000	20,000	20,000	30,000	30,000
Taxes ($)	83,660	83,660	152,108	152,108	152,108	152,108	190,135	190,135	235,768	235,768	399,284	399,284
Annual Processing O&M Costs ($)	116,400	232,799	247,659	495,318	247,659	495,318	363,233	726,466	577,871	1,155,742	1,155,742	2,311,484
Management and Profit Allowance (20% of Operating Total) ($)	315,282	489,298	541,398	862,267	517,743	798,051	686,515	1,034,595	894,663	1,349,251	1,629,666	2,481,247
Total Capital and Operating Cost ($)	1,891,690	2,935,790	3,248,388	5,173,599	3,106,455	4,788,306	4,119,088	6,207,568	5,367,977	8,095,507	9,777,994	14,887,482
Cost per Tonne ($)	180	140	146	116	139	107	126	95	103	78	94	71

Using the 12 operating budgets developed for the six facilities, an equation was developed to relate processing cost per tonne to the annual throughput shown in Figure 2. The equation can then be used to estimate the cost per tonne for any size facility. This was done to compensate for the overlapping tonnage ranges for the different facilities and the potential to design other facilities that fit in between our modelled sizes. This equation is not meant to take into account the actual fixed and variable costs of a real facility.

Figure 2: MRF Cost Curve



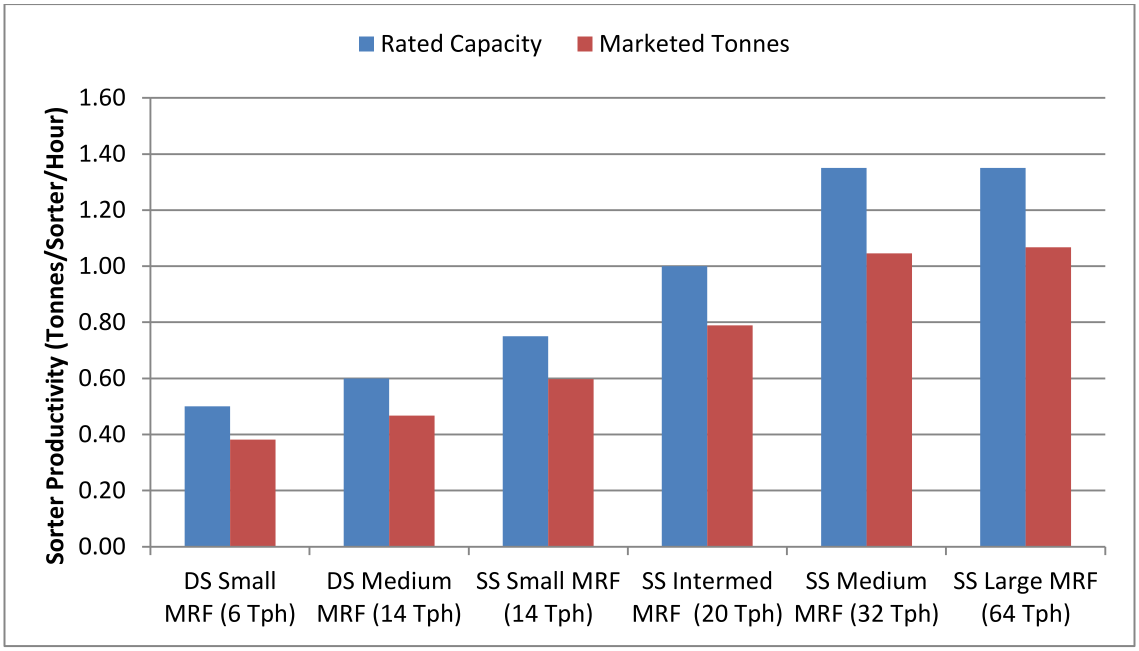
The efficiency calculation that we used to estimate the number of sorters in each of the modelled facilities is based on rated tonnes of facility capacity. In contrast Figure 3 also shows the same calculation based on marketed tonnes per year and our estimates of operating time per year. This brings our medium and large facilities down to about 1.05 tonnes per hour per sorter.

The analysis of cost for the hub MRFs in the greenfield analysis and options is based on:

- the capital cost of the smallest of the specific model MRFs with sufficient capacity for the throughput required, and
- the operating cost from the cost curve for the specific throughput required.

That means that the MRFs are typically oversized and the operating cost used is based on the appropriately sized MRF rather than the larger more efficient MRF. The result is that the cost estimates for the Baseline and greenfield options include excess capacity. For example, in the Baseline scenario for all four regions, there is 19% excess capacity in the MRFs that are modelled. This excess capacity is not spread evenly throughout the province with 33% of the excess capacity in the Eastern Region and 48% in the Central region. This would allow material from outside of one region to be temporarily transferred to another region in the event of an emergency shutdown. As well it provides for additional material recovery in the system.

Figure 3: Sorter Productivity



4. Reference Facilities

4.1. Reference Facilities

To demonstrate that the assumptions that are incorporated in each of the single-stream model facilities are achievable in Ontario, the Project Team identified three reference facilities. These facilities were chosen because they all exhibit the qualities that we are modelling.

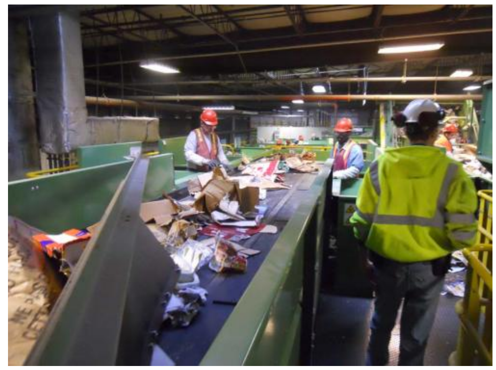
- High throughput to sorter ratio (Tonnes/Sorter/Hr)
- Low residue rate (5-7%)
- Use of optical sorters
- Diverse products
- New design and equipment

Each of the facilities utilizes optical sorting. The large facility in particular exhibits the setup that eliminates manual quality control (QC) on both the PET and natural HDPE streams, reducing the labour requirements for these facilities. None of these facilities processes the full range of materials that many in Ontario accept including EPS and plastic film; however, the large facility is marketing large mixed rigid plastics and scrap metal which are less common in Ontario.

4.1.1. Large MRF: Rhode Island Resource Recovery Corporation

The Rhode Island Resource Recovery Corporation is responsible for handling Rhode Island's solid waste and recyclables. They operated a dual-stream MRF that handled 99,000 tons per year prior to upgrading this facility. With the conversion to single-stream, they estimate they will be processing 120,000 tons per year.

This facility demonstrates that a high throughput facility (45 Tph) can operate efficiently with a high degree of mechanization and significantly reduced manual sorting staff as compared to smaller facilities and older large facilities. While this facility is not as large as the largest facilities modelled in this report (63.5 Tph), the technologies demonstrated here are extensible to larger facilities with parallel sorting at the locations where equipment and manual sorting limits require.



This facility serves the entire state of Rhode Island and is expected to start receiving materials from neighboring states in June 2012, demonstrating the economies of transferring to a large central facility.

It is noted that this is a brand new facility that has not withstood the tests of a long-term operation, but it does have significant innovation in the design. The descriptions in section 6 on MRF economies of scale and in section 7.3 on best practices in new technology both incorporate ideas from this facility. They are also not currently advertising that they accept plastic film and mixed rigid plastics, however they do market what comes to the facility anyway. Initially the third optical sorter was for cartons, but has been converted to sort extra PET due to the high percentage in the stream. The cartons are not currently being sorted as a specific grade.

- Equipment Manufacturer: Bollegraaf (Van Dyk Baler)
- Size: 50+tph (45 Tph) operating at 45 tph (40 Tph) currently
- Annual Capacity: 149,000 Tpy at 2 shifts
- Sorters: 26 (Hope to get down to 23/shift once stream stabilizes and staff is better trained)
- Ratio: 1.5 – 1.9 tonnes per Sorter per Hour
- Other Staff: 3 baler/forklift/QC; 2 Loader on tip floor; 2 mechanic; 2 assistant mechanic
- Management includes: Business Manager, Plant Manager, Director of Recycling
- 8.5 production hours per day
- Residue: 5.75%
- Commissioned: March 26, 2012
- Cost of Processing System: $16.9 million (this price does not include the existing fibre storage bunkers, one of the two balers and two of the fibre separation screens)

Large MRF Marketed Materials

<u>Paper Products</u>

#8 ONP; #3 Mixed paper; #11 OCC

Container Products

#1 PETE; #2 HDPE Pigmented; #2 HDPE Natural; Aluminum UBC; Aluminum foil; Tin; Aseptic/gable top cartons; #1-#7 mixed plastics; Large mixed rigid plastics; LDPE film; Scrap metal; Aggregate glass

4.1.2. Medium MRF: Rumpke Columbus

Rumpke Recycling owns and operates MRFs in 6 cities in Ohio and Kentucky including new single-stream facilities in Cincinnati and Columbus. The City of Columbus is currently rolling out a new single-stream cart based collection program over the next few months. This facility demonstrated a high degree of reduced labour requirements in a facility designed to process 32 Tph and able to operate at up to 40 Tph. This facility exceeds the performance in most respects of the medium size facility modelled in this report. The facility design uses mechanical and optical separation to simplify manual sorting tasks. They have minimal manual quality control on the optical sorters. This facility serves portions of three states with materials hauled to the facility from more than 170 km away; demonstrating that transfer to a central facility can succeed economically.

While the facility does have higher than modelled residue rates, with low landfill costs and with no contractual obligation to reduce residue, this has not been a priority for the operator. They are also processing a more limited stream than in Ontario, not accepting plastic film and all plastic containers (only #1-7 bottles). They are also a private facility and did not provide us with specific grades that they are sorting at their facility.

- Size: 35 tph (32 Tph), but runs up to 45tph (41 Tph)
- Annual capacity: 104,000 Tpy – 133,000 Tpy
- Sorters: 25
- Ratio: 1.3 – 1.6 Tonnes per Sorter per Hour (Capacity)
- Residue is currently around 10% but still processing pre-start up single-stream bales
- System commissioning: 2010

Medium MRF Materials Accepted

Paper Accepted

Newspaper with Ad Slicks, Magazines, Phone Books, Brown Grocery Bags, Frozen Food Boxes, "Junk" Mail, Chip Board, Corrugated Cardboard, Office Paper

Containers Accepted

All Plastics Bottles #1-7; Clear, Brown, Green & Blue Glass Bottles and Jars; Gable-Top Containers and/or Paperboard Cartons; Aluminum and Bi-metal Beverage Cans; Aluminum Foil; Steel Food/Tin Cans, Empty Aerosol Cans

4.1.3. Intermediate MRF: Outagamie County

The MRF is a joint effort of three counties – Brown, Outagamie, and Winnebago – and was built to process material from the new single-stream program developed by the three counties. The new MRF services over 500,000 people in more than 60 Brown-Outagamie-Winnebago communities. This facility is the largest publicly owned and operated MRF in Wisconsin.

This facility is the size of the Intermediate MRF modelled in this report. The facility demonstrates that when all of the participants cooperate in facility best practices and resident education that low residue rates are possible (less than 5%). This facility also demonstrates efficient use of transfer to a central facility where none of the three counties could have built a facility to operate at this performance level individually, but with combined streams, a very efficient design was practical.

Similar to the other two facilities, they are not accepting plastic film.

- Size: 25 tph (23 Tph), but runs up to 27 tph (25 Tph)
- Annual capacity: 75,000 – 80,000 Tpy at 2 shifts
- Sorters: 20
- Ratio: 1.2 – 1.3 Tonnes per Sorter per Hour
- Residue rate is “very low”
- System commissioning: 2009

Intermediate MRF Marketed Materials

Paper Products

#8 ONP; Mixed paper; OCC;

Container Products

#1 PETE; #2 HDPE Pigmented; #2 HDPE Natural; Aluminum UBC, Aluminum foil; Steel cans; Aseptic/gable top cartons; Mixed rigid plastics; 3 mix glass

5. Existing Ontario Facilities

To ensure the validity of the model considering Ontario’s unique situation, the modelled MRFs were compared to four existing facilities that are publically owned but privately operated. The detailed costs reported to the WDO were compared on a line-by-line basis to the modelled costs. Although the full analysis cannot be shown due to confidentiality of the reported data, some of the conclusions can be shared.

For each of the comparisons, we used at a minimum our labour estimates, including the 20% management and profit, to compare to the contract cost the City was paying. In each case, we determined which other costs, including O&M, capital replacement and residue, were included in the contract based on the other costs reported by the program. For example, if the program did not report any O&M costs paid by the municipality or very low costs, then our modelled O&M costs were added to our labour and profit to compare to the contract cost.

Peel

The Peel facility currently processes just over 90,000 tpy. We compared this to our Medium MRF operating with 2-shifts and adjusted to their exact tonnage. According to the AECOM report, the facility currently uses 59 sorters per shift. Our Medium MRF assumes 24 sorters per shift. In this case our modelled labour cost is 44% lower than Peel’s. However, if we increase our sorters per shift to 59, then our cost is only 4% higher than the reported contract cost. In addition, our annual capital cost is 5%

lower than their reported cost. We also did a comparison of total costs. For our model we totaled all of our costs including labour, capital, O&M, residue disposal and taxes. For the reported costs we included all costs except municipal oversight, recyclables shipping, and costs listed as 'other'. When comparing these costs, our total cost was 2% lower than the reported costs.

York

The York MRF currently processes about 78,000 tpy. Similar to Peel, we compared this to our Medium MRF operating with 2-shifts and adjusted to their exact tonnage. According to the AECOM report, the facility currently uses 41 sorters per shift. In our base our modelled labour cost is 38% lower than York's. In addition, there are minimal O&M costs reported. Hence, we assume that the contractor pays for O&M costs as well. If we increase our sorters per shift to 41 and include our modelled O&M costs, then our cost is only 2% higher than the reported contract cost. In addition, our annual capital cost is 9% higher than their reported cost. In addition to the cost categories that we included for the Peel facility, we also added revenue kept by the contractor to the total cost reported by the program, assuming that the revenue is offsetting costs they would otherwise charge for. When comparing these costs, our total cost was 8% higher than the reported costs.

Sudbury

The Sudbury facility currently processes about 14,000 tpy for Blue Box material and an additional 5,000 Tpy of ICI tonnage. We compared this to our Small MRF operating with 1-shift and adjusted to their Blue Box tonnage. According to the AECOM report, the facility currently uses 9 sorters per shift. Our Small MRF assumes 18 sorters per shift. In this case our modelled labour cost is 37% higher than Sudbury's. For Sudbury we assumed that the contract included labour, O&M, capital replacement, taxes and residue disposal. In addition, the contractor keeps a large portion of the revenue. If we decrease our sorters per shift to 9, and add in those costs then our total cost is about 15% higher than the reported total cost without the recyclables shipping and costs reported as 'other'. This could be because of the additional IC&I tonnes that the facility is processing, reducing the cost that the contractor charges the program.

6. Analysis of Economies of Scale

This section explores the potential to achieve economies of scale moving to larger facilities and utilizing the available capacity.

Most people who have explored the economies of scale for MRFs can agree that well-designed MRFs gain operating cost efficiencies up to the point that duplication of process line equipment is needed to achieve the required facility throughput on two shifts. In this report, that point is identified as 104,000 tpy based on the Medium MRF running for 2-shifts described in Section 3.2 of this volume.

In scaling up to the 104,000 tonne throughput, the size of sorting equipment is increased, additional sequential steps of mechanical separation are added and additional high-end equipment such as optical sorters for sorting and optical sorters for quality control (QC) of sorted materials.

In order to double the throughput of the 104,000 tonne facility, one option is to duplicate the entire sorting line and to duplicate all of the sorting positions. While this approach provides the option of running one line while the other line is down, assuming the system is well maintained, this is not the most cost-effective approach.

Following is a discussion of a design approach that has been implemented to varying degrees in some facilities, including the Large Reference MRF described in Section 4 of this volume. This is not the only successful approach, but this discussion covers many of the variables addressed in these larger facilities. The specifics of each design are different because each facility has a slightly different infeed stream and different product requirements. If the infeed and output products are standardized, the design can be optimized for that combination. Accordingly, this is a description of a number of design decisions, each affecting a location where equipment and labour savings are possible.

6.1. Feed & Presort

A large presort station is required where there is a high level of contamination or where significant quantities of materials are present that either cannot be sorted mechanically or that create challenges to the effective operation of downstream equipment. Unless the stream is very clean, accommodating a high throughput stream will require two or more parallel presort stations. While the multiple presort stations will likely require twice the sorter staff for twice the throughput, both capital and operation savings are possible through a combined metering feed system. Only one metering bin is required and only one loader and loader operator are needed to feed the system. The trade-off is the addition of a flow splitter and a part time loader operator to manage the tipping pile.

Because the presort stations are parallel, common bunkers under the presort can be used for all of the materials sorted at the presort, allowing a single baler operator to control the flow of these materials to a single baler. If these presorts were in separate facilities, separate bunkers and controls would be required.

6.2. OCC Screen

All streams can be fed to a single large OCC screen or two smaller screens. Several equipment manufacturers have operational large OCC screens that split the smaller fraction into two or more output streams. These streams can be selectively sized such that the downstream fibre screens receive a different fraction. The way this works is that the size of the openings in the OCC screen get successively larger with each deck. The first deck drops out small containers and small fibre. The second deck drops out mixed fibre and most large containers. The third deck drops out ONP and any remaining large containers. In the best installations, the OCC comes off the end of the screen with little or no manual QC required.

6.3. Glass Breaker

A glass breaker is usually used after the OCC screen to remove nearly all of the glass from the small fractions off the OCC screen. With a three-deck OCC screen, the glass breaker may only be needed for the materials passing through the first and second decks of the screen. The glass is broken by the impact of dropping on the steel disks and by the crushing action of the rotors on the breaker. Some fine paper (mostly shredded) leaves with the glass. Where shredded paper is common, the glass cleanup system can be designed to recover the small fibre to the mixed paper post sort conveyor where plastic film and other contaminants can be removed.

Because the stream is much larger than that of a 104,000 tonne facility, it is more cost effective to add components to the glass cleanup system to recover ferrous metals, aluminum and possibly even small plastic caps and lids. By recovering twice as much of the materials with basically the same equipment setup, the payback is more apparent.

6.4. ONP Screen and ONP Post Sort

Secondary presorting is common if the input stream to the system is heavily contaminated. This would be accomplished at a sorting station utilizing one or two sorters at stations prior to the feed of fibre separation screens.

Most of the ONP went through the third deck of the OCC screen. A single ONP screen will separate the ONP from the remaining large containers and small fibre. That material is then directed to an ONP post sort line.

An ONP screen would also be used on the second deck fraction to help recover additional ONP. That fraction would also be conveyed to the same ONP post sort line.

Depending on the sizing of the first deck of the OCC screen, there may not be sufficient ONP in that stream to justify the use of an ONP screen on that material. If an ONP screen is used at that location, the ONP is fed to the ONP post sort line.

The ONP fed to the ONP post sort can be sorted by two to four sorters if the incoming stream is very clean. Where the ONP fraction is heavy or contaminated, the ONP post sort is split to parallel stations, with two to six sorters on each station. Sorters pull out primarily brown fibre (e.g. OCC) and plastic film. Where a very high quality ONP product is desired, or where reduction in sorters makes sense, a De-Ink screen can be used to provide a mechanical secondary sort for the ONP. This type of screen is very selective for ONP. Post sort for brown fibre and plastic film would still be required but staffing needs would be further reduced.

In a larger facility, the OCC screen can be used to prepare material for downstream screens, allowing those screens to be more specialized than in duplicate side-by-side lines or in two separate facilities. The total investment in screens can be reduced and manual sorting tasks can be simplified allowing a reduction in the total number of sorters required as compared to identical side-by-side lines.

6.5. Mixed Paper and Mixed Paper Post Sort

Mixed paper screens are used on all three lines. Depending on the volume of containers and mixed paper in each sub-stream, two or three mixed paper screens would be used for this step. The paper coming off the top of each screen is directed to the mixed paper post sort. This can again be two parallel sort stations or a single sort station based on the composition of the infeed to the system. The sorting staff requirements are generally less critical than for newspaper and accordingly, depending on the relative volume of this stream, fewer sorters are required.

Sorters pick off containers, sending these to the container sort stream, and pick plastic film and other contaminants. Where sufficient quantities are present, ONP may be sorted to the ONP bunker and other fibre grades such as books may be sorted to appropriate containers.

Because the ONP has been removed first and the mixed paper screens can be optimized for the material being delivered to it, these screens can be expected to do a good job of recovering mixed fibre and rejecting containers. This is further improved by choosing a screen design that favours rejecting some fibre in order to assure nearly 100% container rejection. This is possible because fibre lost at this location is recovered in the next step. By having very few containers in the mixed paper stream, sorters can concentrate on other contaminants and the number of sorters required can be reduced. Compared to the 104,000 tonne facility, a higher quality mechanical sort is possible for the same relative investment because more money can be invested in the next stage of separation.

6.6. Container Cleanup

The unders from the mixed paper screens include nearly all containers and small fibre that fell through the screen. Usually a combination of two or more technologies is used to separate the small fibre from the containers. Options include polishing screens, slant screens, optical separators, rotary drum separators and various types of air floatation systems. The result is that very little fibre is left in the container stream when it reaches the container sort line. The fibre pulled from the containers is conveyed to a mixed paper post sort station(s).

In the 104,000 tonne facility, this would typically be a two-stage process with the container stream combined. In the larger facility, this same two-stage separation is still possible with larger versions of the same components. Because of the cost savings over parallel systems, it is possible to add a third or even fourth stage to this separation. Not only does this allow the mixed paper stream to be almost container free, but it also assures a very clean container stream to the optical sorters, which is key to optical sorting efficiency.

6.7. Container Sorting

When starting with a clean container stream, most sorting can be performed optically, including post sort quality control. (See Section 7.3 for a specific example of optical sorting with optical QC).

In a highly mechanized MRF the container sorting line consists of some variation of the following sequence. Magnetic separation of ferrous containers is almost always the first step. After that, in the largest facilities (processing more than 15 tonnes of containers per hour excluding glass), parallel optical sorters are likely needed for each of the first two materials (PET and HDPE). After the two largest volume materials are removed and undergo quality control (QC), the stream can be recombined for optical sorting of other materials because approximately half of the stream has been removed.

Table 7 describes one sequence employed for container sorting. Many variations are possible and would be chosen based on the mix of infeed, desired end products and source of equipment.

Table 7: Container Sorting Process

Container stream delivered after final fibre removal	Start of container sorting
MAGNET	Removes ferrous metals to storage bin. Typically no QC is required
OPTICAL SORT 1 (stream split to parallel optical sorters)	- Ejects PET to PET QC - Other materials continue to next optical sorter
OPTICAL SORT 2 (stream split to parallel optical sorters)	Split side-to-side: - SECTION A ejects contaminants from PET QC stream to storage bin (no manual QC) - SECTION B ejects HDPE from main stream to HDPE QC stream - Other materials continue to next optical sort
OPTICAL SORT 3 (stream split to parallel optical sorters)	Split side-to-side: - SECTION A ejects contaminants from HDPE QC stream to storage bin (no manual QC) - SECTION B ejects mixed plastic grade from main stream to mixed plastic QC stream - Other materials continue to next optical sort
OPTICAL SORT 4 (streams combined)	Split side-to-side: - SECTION A ejects contaminants from mixed plastic QC stream to storage bin (no manual QC) - SECTION B ejects cartons from main stream to carton QC stream - Other materials continue to next optical sort
OPTICAL SORT 5 (streams combined)	Split side-to-side: - SECTION A ejects contaminants from carton QC stream to storage bin (no manual QC) - SECTION B OPTIONALLY splits HDPE to natural and coloured streams - SECTION C scavenges missed plastic materials from balance of stream and feeds back to beginning of container sort
EDDY CURRENT SEPARATION (ECS)	Aluminum is removed from remaining stream. Manual QC on both aluminum and residue conveyors to capture missed aluminum and remove carry over residue in aluminum. In facilities where UBC must be separated from pet food containers and foil, one or two more manual sorters may be required.

Note that the total number of optical sorters needed in this configuration is eight. To achieve the same level of separation in two smaller lines, five optical sorters would be required for each line. Also, each line would require a separate eddy current separator (ECS).

Table 8: Operational Staff Count per Shift

	Medium line	2 medium lines in same facility	2 medium lines in separate facilities	Integrated large line in one facility
2-SHIFT t/y	104,000 t	208,000 t	208,000 t	208,000 t
STATION				
Load Line	1	2	2	1
Manage Tipping Floor	0	0	0	0.5-1
Presort	8-12	16-24	16-24	16-24
OCC Post Sort	0-2	0-4	0-4	0-3
2nd Presort	0-2	0-4	0-4	0-4
ONP Post Sort	2-8	4-16	4-16	4-12
Mixed Paper Post Sort	2-6	4-12	4-12	4-8
Container Presort	1	2	2	1
Aluminum Post Sort	1-2	2-4	2-4	1-4
Residue Sort	1	2	2	1
Baler operators	1-2	2-4	2-4	2-3
Forklift Operators	2	3-4	4	3-4
Line Supervisors	2	3-4	4	2-3
TOTAL/SHIFT	22-41	40-82	42-82	36.5-69
TOTAL FOR 2 SHIFTS	44-82	80-164	84-164	73-138

Note: Excludes clerical, scale, maintenance and overall management

As shown in Table 8, when parallel lines are built in the same facility, there are only very slight labour savings compared to building those same lines in separate facilities. If however, a larger integrated line is built that utilizes parallel components where needed, but also utilizes a greater degree of mechanical separation where practical and saves capital cost by combining streams where most advantageous, significant labour savings are possible compared to parallel lines.

The large range of labour requirements is the result of the level of stream contaminations, materials accepted in the stream and end products. Also, each equipment vendor would implement the processing line differently, affecting the amount of manual sorting required at each station.

Based solely on the labour savings, the integrated large line can save between 7 and 26 sorters for a 2-shift operation. This would equate to $1.40 - $5.10 per tonne savings or an average of $3.25 per tonne.

6.8. Other Economies of Scale in a Large MRF

In addition to the savings discussed above, savings are also possible in the following areas: building, clerical, scale and management staff, maintenance staff and equipment and marketing and coordinating shipments.

One large MRF does not need to be twice as large as the combined size of two smaller MRFs serving the same throughput. While the tipping floor may be twice as large, the larger facility does not need twice the bale storage capacity. Slightly more than one truckload storage for each minority material is enough. While the product storage space needs to be larger in the large facility, it does not need to be twice as large because shipments need to be made nearly every day.

Doubling the floor space of the building does not double the cost of the building as long as spans are kept reasonable and the infrastructure is comparable. Since only one electrical system, one fire suppression system and one ventilation system is needed, significant capital cost savings are possible.

Support staff does not need to be duplicated. One scale operator can manage two scales at one location, but not at two locations. This is generally true for facility managers and clerical staff as well. At a single facility, maintenance staff can be more specialized, receiving training on screens, balers and other key equipment. Covering second shift, managing major repairs and procuring parts are tasks more easily divided among the larger staff in one location.

While a single person can manage sales of products for more than one facility, someone must schedule shipments at each facility and make sure trucks arrive and are loaded on time. That can be accomplished more efficiently for one facility than for two, with the same total volume of products.

7. Best Practices for MRF Operations and Maintenance

This section outlines critical success factors for achieving best practices and economies of scale in the operation of larger MRFs and highlights some common problems observed which can be associated with lower productivity and performance.

7.1. Operations

To achieve the intended benefits of “Economies of Scale” by operating large capacity MRFs, the facilities must employ the latest in technology and process design to minimize direct labour cost and improve recovery rates and product quality. Operations must also be well managed and maintained to optimize the capabilities of the processing system.

Some of the larger MRFs in operation today are not achieving the benefits of economies of scale because of inefficiencies caused by ineffective management practices, lack of maintenance contributing to excessive downtime and poor product quality. One of the key issues facing MRF operations is a lack of training that should start at the top of the management structure and work its way down through the entire operation.

It has been observed on some occasions when members of the project team have been providing services in some of the larger existing MRFs that management appears not to be directly monitoring production or visible to the workers on a frequent basis. This allows or causes workers to make their own decisions on matters concerning operations and sometimes work at a pace which is below expectation, assuming an expectation has been discussed with staff in the first place. This also leads to decisions being made that negatively affect product quality and recovery rates along with productivity. One example is when sorting staff adjust conveyor speeds or automated separator parameters that they feel will best serve their own needs but have detrimental effects on downstream processes, productivity, and quality and recovery rates.

Experienced and well trained managers should be spending more time on the process floor allowing them to make observations, decisions and adjustments as required to assure that operations are running properly. Their presence will also keep staff on task at a proper rate and allow them to deal with staff issues more effectively and timely. The manager's complete knowledge of the entire operation and process along with their constant interaction is crucial. Lack of this leads to operational inefficiencies, poor staff morale, poor productivity, product quality and recovery rates along with poorly maintained equipment.

Another problem that larger MRFs are facing is excessive downtime caused by a lack of housekeeping and preventative maintenance. Instead, maintenance becomes "reactive", not "proactive" causing unexpected downtime due to equipment failure. When the system is back up and running there is a push to catch up causing quality and recovery rates to suffer again. The implementation of a properly managed preventative maintenance program (PMP) would significantly lower downtime caused by breakdowns because the inspections would reveal potential problems that could be dealt with and repaired off-shift on a scheduled basis.

The operational practices of workers observed in some facilities lead to the belief that there has been a lack of proper training and goal setting by management. This causes workers again to make their own decisions with respect to productivity and job function and do what they think is best.

The development of "Best Practices" in MRF management is a vital component to a successful operation. The best way to achieve this is through the development of the following:

1. Implementation of Standard Operating Procedures (SOP)

The development of "standard operating procedures" will act as a "how to manual" that will help to simplify the operations and training process involved in operating a MRF. Another advantage is that it will improve operational consistencies within Ontario making it easier to benchmark performance measures and standardize cost recording and reporting activities. The fast food franchise industry is the best example of how standard operating procedures successfully deliver consistent and predictable results both operationally and financially.

2. Process designs that facilitate good operating practices

For new MRFs, well planned process designs for the equipment layout are an important element that will contribute to the success of the operation. The process system should incorporate the latest in technology to achieve the performance goals of the facility in the most cost-effective manner. Flexibility in design is important to accommodate possible future upgrades with a mind to lowering the impact of the retrofit. As newer sorting equipment becomes available, existing facilities should consider system upgrades to take advantage of the benefits of the latest technology where feasible. A mass balance flow study should be performed prior to designing the process system to assure that the correct equipment is incorporated and sized to do the job.

3. Staff development and training

Training and setting goals for all levels of management and staff will help to achieve the operational performance requirements of the MRF. This will also include regular performance reviews and the use of benchmarks to help measure individual staff performance.

4. Implementation of a comprehensive Preventative Maintenance Program

The implementation of a detailed Preventative Maintenance Program is an important part of the operation. It will assure the all equipment is thoroughly inspected on a regular basis. This will allow the maintenances staff to make adjustments to equipment and monitor wear and tear. If properly monitored, potential problems can be anticipated and repairs can be proactively made off-shift to minimize downtime and enhance system reliability.

5. Implementation of a Benchmarking System to set goals and measure performance

An established benchmarking system will allow the MRF operator to monitor a number of performance measures and compare them against industry standards. While there are not currently any published industry standards, there are comparative measures available in the industry to benchmark against similar size plants with similar size equipment and automation. Proper use of this tool will allow the manager to make informed decisions regarding their operation in a timely manner. This will lead to improved quality control, recovery rate, productivity and profitability.

Benchmark items include:

- Universal productivity metrics
  - Tonnes per direct worker hour
  - Total labour cost per tonne processed
- Plant specific metrics. These must be tailored to each plant given that actual performance depends on the capital employed, amount of automation, etc.
  - Picking rates
  - Equipment throughput rates
- Staffing levels: Productivity measures, tonnes per direct man-hour and total labour $/tonne processed are better universal measures
- tph throughput: tons per hour based on paid time not run time
- Product quality standards based on actual end market specifications and internal testing programs to measure actual performance
- Recovery rates: This can be tracked in various ways, but the key measurement is quantity of recyclables in residue. A related important measurement is the percentage of the total stream that is not recyclable. These materials negatively affect the throughput and product quality achievable by the facility and also provide an indication of the education efforts in the municipalities delivering materials to the facility.
- Residue rates
- Percentage of recoverable recyclables in the residue
- Percentage of recyclables in the residue, not worth recycling
- System Up-Time percentage: There are two components here with downtime due to maintenance and due to operational issues.
- Maintenance costs per tonne

7.1.1. Management Capacity

In order for the operations of a MRF to be successful in achieving the results of the intended performance measures, it must be directed by a well-trained manager that is knowledgeable in all aspects of the operation as outlined below:

- Clear understanding of the obligations of the operating contract
  - Incoming tonnages
  - Residue rates
  - Recovery rates
  - Product quality standards
  - Auditing protocol
  - Penalty implications
  - Material composition
- Complete understanding of how the process equipment operates within the MRF
  - Understanding the equipment flow
  - Understanding the control system
  - Adjustment of conveyor speeds and other basic system calibrations
- Complete knowledge of material composition of the feed stock
  - Complete understanding of mass balance and process flow
  - Ability to determine practical material burden depths and flow rates based on system and equipment specifications and limitations
  - Knowledge of material density of all recyclables individually and comingled
  - Ability to translate material densities into sort line burden depths based on conveyor speeds and flow rates
- Ability to lead a front line team of supervisor/lead hands and a maintenance crew
  - Sets goals in keeping with production and quality targets for supervisors and lead hands to achieve
  - Create a positive work environment that encourages staff to achieve goals
- Ability to carry out a consistent and detailed training program for all jobs within the MRF
  - Carry out formal training sessions for staff
    - i) Teach product identification
    - ii) Teach picking procedures and pick rates
    - iii) Teach proper loading procedures of the main infer conveyor
    - iv) Teach proper management of the tip floor
    - v) Teach proper procedures for bale storage and truck loading techniques
    - vi) Teach how to safely operate loaders and lift trucks
- Strong leadership skills
- Ability to monitor job performance measures to assure that they meet the standards set out in the SOP
- Good Planning and organizational skills
- Be able to schedule workers
- Organize and maintain a health and safety committee
- Oversee and monitor the preventative maintenance program

7.2. Plant Maintenance

For years assembly plants, packaging plants, printing companies, paper mills, breweries and many other manufacturing companies have put a strong emphasis on preventative maintenance to keep the up-time of the facilities to a maximum and remain competitive and profitable. In all aspects of the operation, MRFs should be managed and maintained to the same standard as most manufacturing companies. A MRF is a “Sorting and Packaging” plant in a supply chain that needs to achieve quality standards similar to other industries. For this reason, it should be managed and operated accordingly. In order to assure that MRF operations are run efficiently and productively with the least amount of downtime, it is essential that a formalized comprehensive preventative maintenance program (PMP) is put in place and strictly followed. An excellent model for this are the Packaging Machinery Manufacturing Institute's (PMMI) standards for preventative maintenance represented by the PMMI certified training programs that are available for preventative maintenance. The following will help to emphasize the importance of this:

- Why is preventative maintenance so important?
  - Preventative maintenance is so important because it helps to reduce the occurrence of equipment or machinery breakdown.
  - Preventative maintenance will improve system reliability.
  - A good PMP will help prolong the life of equipment.
- What are the benefits of preventative maintenance?
  - Less downtime
  - Lower maintenance and repair cost
  - Lower operating costs
  - Improved product quality
- Specifically, a well-designed PMP will save you money by reducing your operating costs in the following areas:
  - Lower repair costs caused by breakdowns
  - Lower labour costs caused by downtime
  - Improved product quality leading to reduced market rejections
  - Improved worker productivity due to operational consistency
- How is preventative maintenance performed?
  - Preventative maintenance is performed by:
    i) Regularly scheduled inspections of your equipment and machinery.
    ii) Making minor adjustment during the inspection.
    iii) Following up on potential problems that are flagged during the inspection.
    iv) By the use of properly trained staff.
- How to train maintenance staff to perform proper inspections:
- Maintenance staff should have some technical aptitude, experience or qualification in the maintenance of equipment.
- Consult with the manufacturer of the equipment in your plant and have them provide instruction to your maintenance staff.
- Hire an experienced Preventative Maintenance Consultant to train your maintenance staff.

7.2.1. Workforce Optimization

The workforce is the key to operating at peak efficiency. The best management, technology and preventative maintenance programs are only as good as the team of sorters, line leads, baler operators and equipment operators that run the real day to day and minute by minute life of the plant.

There are techniques developed to help this workforce deliver this peak efficiency. The techniques are universal and can be developed internally, or contracted out in a workforce management service like Leadpoint (see www.leadpointusa.com). These techniques recruit, develop and support a talented, motivated, trusted and effective workforce. While the net result is improved production efficiency, there are a host of workforce quality of life benefits that include reduced employee injury rates, higher worker satisfaction and thus reduced employee turnover. These results feed on themselves as a more reliable workforce develops and creates an internal culture that trains and builds skills in newly recruited talent as well. These practices take the best of lean management and Six-Sigma quality training to bring MRF workforce optimization to the next level of productivity – driven by the very same key performance metrics that are important to overall MRF success.

7.2.2. Equipment Renewal and Replacement Funding

MRF equipment has a fixed life, driven by total tons processed, the quality of preventative maintenance and the attention of the workforce and management to its short and long term care. As well, MRF processing technology is continuously improving – and will someday match the same level of high quality performance seen in modern packaging systems that fill, contain and protect the many food and beverage products that we use in everyday life.

This wear and tear is accounted for in the depreciation or amortization of these equipment assets in the financial management of the MRF. Theoretically this should provide for the necessary funding to renew and/or replace that equipment when it finally wears out.

Unfortunately not all MRF operations actually fund that depreciation account. As a result many MRFs will delay needed renewal or replacement, compromising the overall efficiency of the technology for sorting and separating recyclables. This is especially critical with the more highly automated equipment that serves as the backbone of the state of the art single-stream MRF.

Best practice in management of this equipment renewal and replacement process is achieved by funding the amortization of the equipment over time. In simple terms when a $1,000,000 piece of equipment with a life of 10 years is used for 1 year, then there should be $100,000 held in a reserve account to cover this liability. This can be referred to as “funded depreciation” or a “capital reserve account” or the “renewal and replacement fund”. In all cases it achieves a primary goal, insuring that sufficient capital is available to renew or replace each piece of equipment at the time that its end of useful life is reached. This is critical to achieving optimum performance in a MRF over time. Failure to do so results in higher operating costs, more labour input per tonne processed, high maintenance costs, unexpected downtime, higher residue, lost commodity value from missed recyclables – the start of a downward spiral in lost efficiency and wasted dollars.

7.3. State of the Art Technologies

Many of the technological improvements have been used in recent years to reduce labour requirements. Where the facility has adequate throughput to justify the capital investment, this labour savings reduces the sorting cost per tonne. When technologies are combined or cascaded, it is possible to sort to very high quality products with no manual sorting of some products. Many recent innovations with optical sorters demonstrate how this is possible.

Example 1

An optical sorter can eject PET from a stream of mixed containers at a success rate of 90-95%. The sorting program can be tuned so that most of the errors result in additional materials in the PET rather than missed PET in the mixed stream. If the PET stream then passes through a second optical sorter programmed to eject non-PET materials and succeeds at a 90% rate, the remaining PET stream is 99% PET, which is comparable to good manual sorting and adequate for nearly all end markets.

Now consider that optical sorters may be divided into sections side-to-side. Most recent optical sorters have adequate computer processing capacity to allow each section to be programmed to eject different materials. This means that this same second optical sorter can be performing quality control on the PET on one side and the other side can be ejecting HDPE from the reject stream of the first sorter, with the reject materials from both sorts progressing to one side of a third optical sorter. This third optical sorter performs quality control ejecting contaminants from HDPE one side and ejects a selected mix of plastics from the mixed stream on the other side.

A fourth optical sorter split three ways could be employed to provide quality control on the mixed plastic grade, split coloured and natural HDPE (if market conditions make this desirable) and eject aseptic and gable-top cartons from the remaining stream. These cartons could be fed back to a third split on the third optical sorter for quality control or manual QC could be used.

Typically, an overhead magnet would be used to extract ferrous metal before the first optical sort. If the magnet is properly sized and placed (over a non-magnetic section of conveyor), manual QC of ferrous metal is not required.

After optical sorting is complete, an eddy current separator is usually used to recover aluminum. Because the density and form of aluminum products varies widely, manual QC is usually required to recover aluminum from residue and eject residue from aluminum. Manual sorting is also often used to sort UBC from other aluminum. In streams with a small aluminum volume and low residue rates, a single manual sorter may be able to accomplish all of these tasks. In facilities with larger aluminum volumes or high residue rates the aluminum stream has a dedicated manual QC and one or more sorters may be dedicated to recovering recyclables from residue. If the volume of residue is sufficient, an optical sorter can be used to eject recyclables from residue and direct them back to the container sort line and to mixed paper. In this case a dual eject optical sorter could be used to eject containers up and fibre down.

In this example, as few as four optical sorters can sort the entire container stream with no manual QC until aluminum is sorted on the back end. In larger facilities where the container throughput exceeds 15 tonnes per hour, the first stages of this process may require parallel optical sorters to provide sufficient throughput capacity.

Example 2

A large part of the recyclables that often end up in residue is broken glass. Glass gets broken on trucks, especially with compaction, and again as tipped on the floor and pushed up at transfer stations and MRFs. Many recent MRF designs have included a glass breaker after the OCC screen. This design when implemented well captures well over 99% of the glass at one location before the glass has an opportunity to damage screens and conveyors. Since the glass in nearly all pulled out at this one location, it can be directed to a glass clean up system. The glass clean up system can clean the glass to meet end-market standards and can recover small paper that passes through the glass breaker. Because more and more shredded paper is showing up at MRFs, recovery of this paper is becoming important to keeping residue rates low. Typically this fibre is cleaned sufficiently to allow it to be added to the mixed fibre stream.

Example 3

Mechanical fibre sorting technologies are greatly improved over that of five years ago. Successful mechanical sorting requires that the manual presort captures materials that will cause problems with the screens and that the screens are well maintained. A well-designed sequence of fibre separation screens can produce the following products with very little manual post sorting required:

ONP: The ONP screen separates ONP and other large paper from smaller paper and containers. Manual post sorting is primarily needed to remove brown fibre grades and plastic film missed by the presort and OCC screen.

Mixed paper: The mixed paper screen captures most small and mid-sized paper. Manual post sorting is primarily need to redirect brown fibre, plastic film and a few containers and lids that are not fully separated.

Mixed containers: Various technologies are employed by the various equipment vendors to capture any paper remaining with the mixed containers after the mixed paper screen. Most vendors use a polishing screen or a slant screen that discriminates between flat materials and 3-D materials. That screen may be followed by drum separators, an optical sorter or some means of air floatation. Removal of this small fibre from the container stream is critical to efficient optical sorting on the container line. Usually all of the fibre recovered in this operation is directed back to the mixed fibre post sort.

In all of the above examples, success at design throughput rates is only possible if the system is well managed, preventive maintenance is performed on schedule, screens and optics are cleaned on schedule and the presort does a good job at removing problem materials. If the input stream has a low non-recyclable content, low residue rates are possible.

8. Transfer Station Costing

8.1. Design Assumptions

In the model we have designed and priced out three different transfer station sizes. Each one is designed to serve a local area. They are:

- Small: Design capacity 2,500 tonnes per year
- Medium: Design capacity 10,000 tonnes per year
- Large: Design capacity 50,000 tonnes per year

Assumptions Common to Each Size of Facility

Compaction ratio	Model assumes 2:1. Ratios as high as 3:1 are possible but may cause problems with sorting at some MRFs. The Project Team has documented curbside collection at a ratio of 2.7:1 without any problem at MRF. 2:1 can be accomplished by loading over side of open-top trailer and packing load. Accordingly, equipment cost could be less than modelled at 2:1.
Staffing	At small and medium facilities, full-time operation is not required. It is anticipated that most small transfer stations would be located in a municipal facility that could share staff, avoiding the need for full time staff to work just a few hours.

Small Transfer Station

This design is for remote areas with a small number of trucks making collections. The facility can handle one to six collection vehicles emptying once or twice per day. At more than three collection vehicles, delayed tipping should be expected at peak tipping times, especially if a loader and operator are not on site at time of tipping. Small transfer station assumptions are outlined in Table 9.

- Small building with 1 tip door
- Tipping area able to hold 8-12 truckloads approximately 150 m2
- Tipping area has push walls up 2.5m on at least two sides
- Stationary compactor located to one side with 3-4 m3 charge box and loading hopper extension with 30 HP motor for fast cycling
- Compact into 40.5 m3 boxes
- Utilize a small wheel loader to load. Total service per day is likely limited to 20 minutes per truckload
- Assume haul two containers per trip, one as a pup
- No land costs are included with the assumption that municipal sites with no cost are utilized
- The transfer cost per hour assumes all capital for trucks and trailers are amortized into hourly rate

Medium Transfer Station

This design serves semi-urban areas and rural cities. It can handle six to twelve collection vehicles tipping once or twice per day. Medium transfer station assumptions are outlined in Table 9.

- Building with 2 tip doors.
- Tipping area able to hold 12-24 truckloads, approximately 300 m^2
- Tipping area has push walls up 3m on at least two sides
- Recessed stationary compactor located to one side with 6-8 m3 charge box and loading hopper extension with 40-60 HP motor for fast cycling
- Compact into 92 m^3 transfer trailer.
- Utilize a wheel loader to load. Total service per day is probably limited to 10 minutes per truckload.
- No Land costs are included with the assumption that municipal sites with no cost are utilized
- The transfer cost per hour assumes all capital for trucks and trailers are amortized into hourly rate

Large Transfer Station

This design serves urban areas and multiple adjacent cities. It can handle twelve to forty collection vehicles tipping once or twice per day. Large transfer station assumptions are outlined in Table 9.

- Building with 3-5 tip doors
- Tipping area able to hold 12-40 truckloads, approximately 400 m^2
- Tipping area has push walls up 3m on at least two sides
- Dual fully recessed stationary compactors located to each side with 8 m3 charge box and loading hopper extension with 50-60 HP motor for fast cycling
- Compact into 92 m^3 transfer trailer
- Utilize a wheel loader to load. Total service per day is probably limited to 10 minutes per truckload.
- No Land costs are included with the assumption that municipal sites with no cost are utilized
- The transfer cost per hour assumes all capital for trucks and trailers are amortized into hourly rate

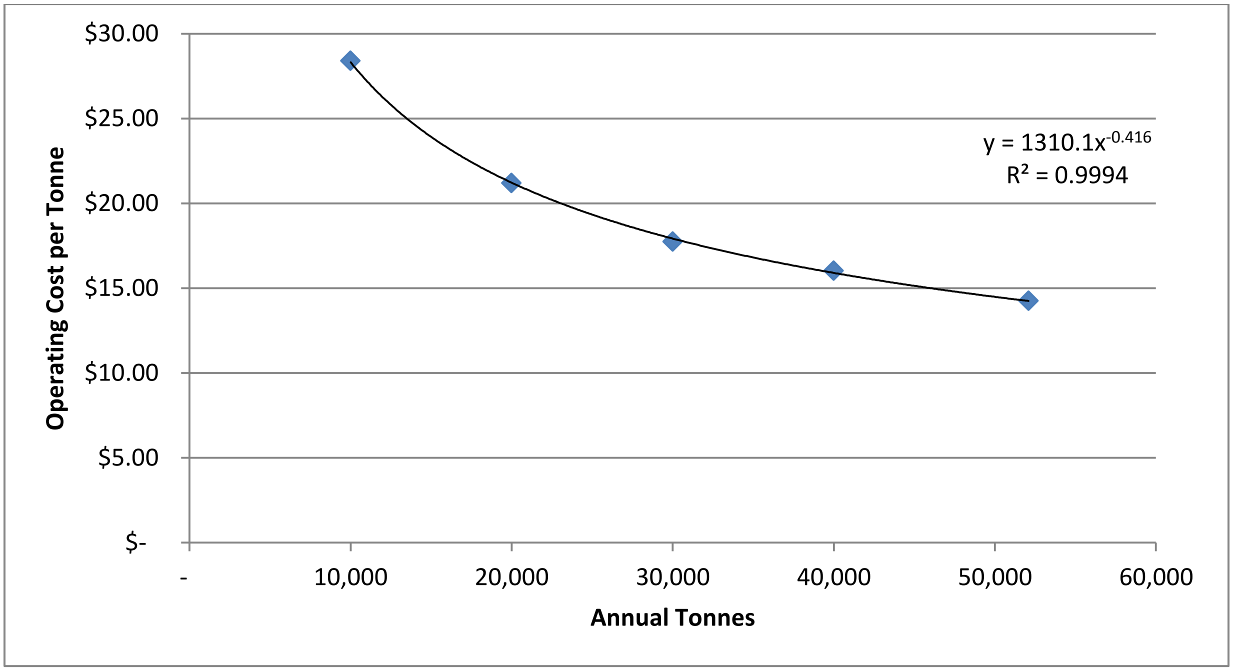
Table 9: Transfer Station Assumptions

	Small Transfer Station Assumptions	Medium Transfer Station Assumptions	Large Transfer Station Assumptions
Facility Size (m^2)	200	500	1,200
Building Capital	$200,000	$500,000	$1,200,000
Rolling Stock	$50,000	$290,000	$470,000
Compactors	$25,000	$210,000	$420,000
Total Capital	$275,000	$1,000,000	$2,090,000
Employees (FTE)	0.40	1.35	4.50
Labour Cost (including benefits)	$24,066	$76,726	$216,996
Annual Building O&M Costs	$3,983	$9,957	$23,896
Building Insurance Costs	$5,000	$5,000	$5,000
Taxes	$5,887	$14,716	$35,319
Annual Processing O&M Costs	$6,125	$24,500	$127,616
Annual Capital Cost	$25,225	$105,755	$209,888
Management and Profit Allowance	$14,057	$47,331	$123,743
Total Facility Costs	$84,342	$283,985	$742,459
Total Facility Cost per Tonne	$34	$28	$14

8.2. Transfer Cost Curve

Because of the large cost difference ($14 - $28 per tonne) and tonnage range between the medium and large (2,500 – 50,000 tpy) facilities, a curve was developed to estimate the operating cost. It was assumed that the building could be sized to properly fit the incoming tonnage. The labour and operating costs also varied with the tonnage, although not linearly, but reflected the increasing economies of scale of the larger operation.

Figure 4: Transfer Station Cost Curve



8.3. Alternative Transfer Station Designs

In smaller operations, several competing transfer technologies should be considered. The report only models a compactor loading roll-off receiver boxes. While this arrangement provides a solution that will work in most applications for receiving and shipping single-stream recyclables, other solutions may work better and/or be more cost effective. While the net cost impact of selected technology for each small transfer station is nearly negligible compared to the overall system cost, making the best choice is important to the performance of the affected local recycling collection systems. Detailed consideration of the appropriate technology is needed before any final technology decision is made.

The various systems trade off capital and operating costs, site requirements and convenience, and long-haul shipping efficiencies. Each of these technologies can be configured and used in multiple ways, so a choice of the appropriate system should not be made from the information presented here.

Transtor is a modular hydraulically dumping transfer storage unit. The collection vehicle dumps over a tip wall into the unit. The storage unit then dumps into an open-top transfer trailer. Each unit holds 31 or 40 m^3 of loose recyclables. Transtor units can discharge into a self-compacting transfer trailer for shipping weights up to 19 tonnes.

Open-top transfer trailer loaded by a loader in a building with a tip floor: This approach allows little compaction and has a haul capacity of 13-15 tonnes in 120-m^3 trailers.

Compacting open-top transfer trailer loaded by a loader in a building with a tip floor: This approach allows 2:1 compaction and has a haul capacity up to 19 tonnes.

Open-top transfer trailer loaded by an excavator: 2:1 compaction is possible and load weights up to 25 tonnes are possible in 120-m^3 trailers.

Compactor loading of roll-off containers: 2:1 or greater compaction is possible. At 2:1 compactions, haul weights of 19 tonnes are possible when hauling two 40-m3 containers with truck and pup trailer.

When collecting materials as single-stream recyclables, it is practical and usually desirable to compact recyclables on the collection vehicle. This allows a single large vehicle to haul as much as 7 tonnes, though loads of 5 tonnes and less are more common. These larger loads allow a vehicle to collect all day on rural routes without unloading, extending the distance that the operator can economically haul to unload. In many areas where operators must empty more than once in a day with current collection methods, the number of transfer stations may diminish because these longer hauls are possible. Transfer stations must not be eliminated without considering the need for drop-off stations where some residents do not receive curbside collection service.

Small transfer stations are required where the volumes collected are too small to make the operation of a local MRF cost effective and the distances to the nearest MRFs are too far for cost effective direct haul.

When shipping small annual volumes less than one to perhaps six collection vehicles are expected to tip at the transfer location on any day. Typically, the total collection at a small transfer station averages ten tonnes or less per day. Accordingly, equipment on site may be actively used less than two hours each day.

Table 10: Transfer Station Technology Comparison

Technology	Capital Cost	Capacity Per Unit	Weight Capacity
Transtor Unit Installed **Compacting Trailer (ea)** **Optional Cover Building**	\$350,000 \$160,000 \$150,000	31 or 40 m^3 100 CY	Up to 4 tonnes Loose Up to 19 tonnes at 2:1
Loader **Open-top Trailer (ea)** **Building w/truck well**	\$200,000 \$120,000 \$400,000	120 m^3 150 m^3	Up to 15 tonnes at 1.2:1 Up to 18 tonnes Loose
Loader **Compacting Trailer (ea)** **Building w/truck well**	\$200,000 \$160,000 \$400,000	100 CY 150 m^3	Up to 19 tonnes at 2:1 Up to 18 tonnes Loose
Excavator **Open-top Trailer** **Building w/truck well**	\$250,000 \$120,000 \$400,000	120 m^3 150 m^3	Up to 25 tonnes at 2:1 Up to 18 tonnes Loose

Technology	Capital Cost	Capacity Per Unit	Weight Capacity
Small Loader	$50,000		
Compactor	$25,000		
Roll-off Container (ea)	$9,000	31 or 40 m^3	Up to 19 tonnes at 2:1 (2 units)
Small Building	$200,000	75 m^3	Up to 8 tonnes Loose

Table 10 does not provide a one to one comparison. Most facilities would be equipped with more than one receiving units and may be equipped with multiple trailers.

The Transtor unit provides the most time and labour efficient load out system, but because the capacity of the receiving unit is small, it must be frequently unloaded into the trailer, requiring a transfer trailer constantly on site, or multiple Transtor units are required to receive loads from multiple collection vehicles. This system has been effectively used in the more urban areas such as Peel where the quick transfer is attractive, and also in rural areas such as Timmins and Dryden.

The roll-off/compactor system requires more labour and time for shipping preparation, but on a long haul for infrequent hauls, that may be acceptable in exchange for the much lower capital cost of the system.

Each of these technologies may be adapted over a range of sizes and conditions. Actual capital and operating costs must be determined for each installation location. Several of these technologies adapt to throughput in the medium transfer model range.

9. Costing of Conversions

Many of the current MRFs will be evaluated on the feasibility of converting them to transfer stations for hauling material to larger central processing facilities. With the available data, a detailed analysis of the ability of each MRF to function as a transfer station was not possible, but instead a general set of assumptions was used for each size of facility. In each case, as long as the building height and size were sufficient to accommodate the tonnage destined for that facility, the following conversion costs presented in Table 11 replaced the greenfield capital cost estimates identified in Section 8 to be included in the cost of implementation.

Compactors were assumed to be needed in all cases, while the loaders were assumed to be available from the MRF operation. When needed, a yard mule was assumed to be purchased as part of the conversion capital. The MRF equipment was assumed to be removed at no cost for the scrap value or for reusing in another operation. While the building and site may need some modifications to handle the larger compactors and to ensure a proper loading height within the building, each site would be unique in the modifications needed to make the changes. Savings are therefore achieved by utilizing the existing building and loader.

When calculating the ongoing capital and operating costs of the facility, the estimated greenfield cost per tonne was still used. It is assumed that the same building replacement amortization schedule would be needed even though an existing building would be used. The end result is that there are no operating cost savings from using an existing facility, but only initial capital investment savings.

Table 11: Conversion Cost

	Small	Medium	Large
Capital Cost for Building and Site Upgrades	$50,000	$125,000	$250,000
Compactors and Yard Mule (if needed)	$75,000	$320,000	$530,000
Total Conversion Cost	$125,000	$445,000	$780,000

Each of the existing public MRFs that were identified as being in optimal locations for central processing facilities were evaluated on the feasibility to be converted to a modern single-stream facility that could handle the tonnage projected to be directed to it. The building size, existing equipment and site constraints were evaluated using the AECOM facility reports and supporting documentation. These facilities are:

- City of Waterloo MRF
- City of Hamilton MRF
- City of Niagara MRF
- Regional Municipality of Peel MRF
- City of Sudbury MRF

In addition, the City of London MRF upgrade was estimated as well. Since it was not included in the AECOM study, the Genivar London Regional MRF Study was used to estimate building size and equipment included in the upgraded MRF. Each of these upgrades is described in the regional assessment (Volumes 4 – 7).

10. Sensitivity Analysis

Some of the variables in the cost analysis have the potential to affect the cost estimates, the economics of transfer versus processing and the decision-making process for each of the players in this process. Four key variables have been identified:

- Compaction on the transfer hauls
- Fuel cost for the transfer hauls
- Sorter productivity at the Medium and Large MRFs
- Redundancy: The feasibility to offer sufficient capacity for processing operations within this or neighbouring regions in the event of emergency that does not potentially exist at other facilities in this or neighbouring regions

A sensitivity analysis for the first three items focuses on the maximum one-way haul distance calculated as a basis for the model. As these factors change they affect the distance that can be hauled either by making the haul more expensive per tonne (compaction and fuel cost) or by increasing the cost per tonne of the destination MRF (sorter productivity).

A sensitivity analysis on redundancy is done on a regional basis by increasing the number of MRFs in the region. The effect on cost is documented by comparing the different options.

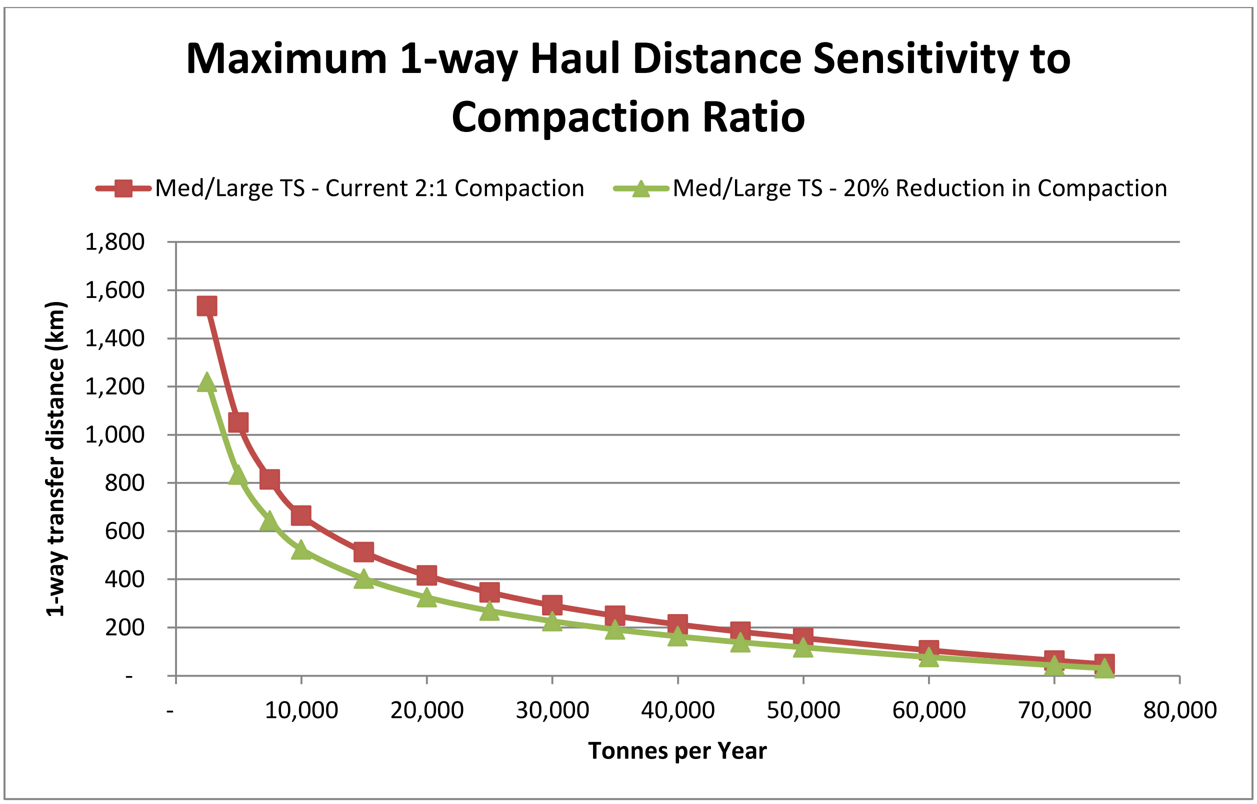
As well, to be conservative, the costs of province-wide optimized options are increased by 5% for the purpose of comparing to the Existing System to reflect the inclusion of additional excess capacity to that already built into the design and modelling. These figures are shown in Volume 1 - the Executive Summary.

10.1. Compaction Sensitivity

Based on the projected stream in 2025, the density of the material collected in the Blue Box program is likely to decrease. This reduction is mostly due to the continued trend toward less newspaper, phone books and glass. Based on the projected material recovery, the loose density would decrease by 30%. For all options in 2025, we have used a 20% reduction in expected tonnes per haul, which reduces the maximum economic haul distance as shown in Figure 5. This is considered conservative.

If the current tonnes per haul can be kept through increased compaction or if material changes do not reduce the density as expected, then the one-way haul distance will increase over the baseline by about 30%.

Figure 5: Compaction Sensitivity



If current compaction rates can be maintained, the overall system cost would be 2.2% lower than projected costs.

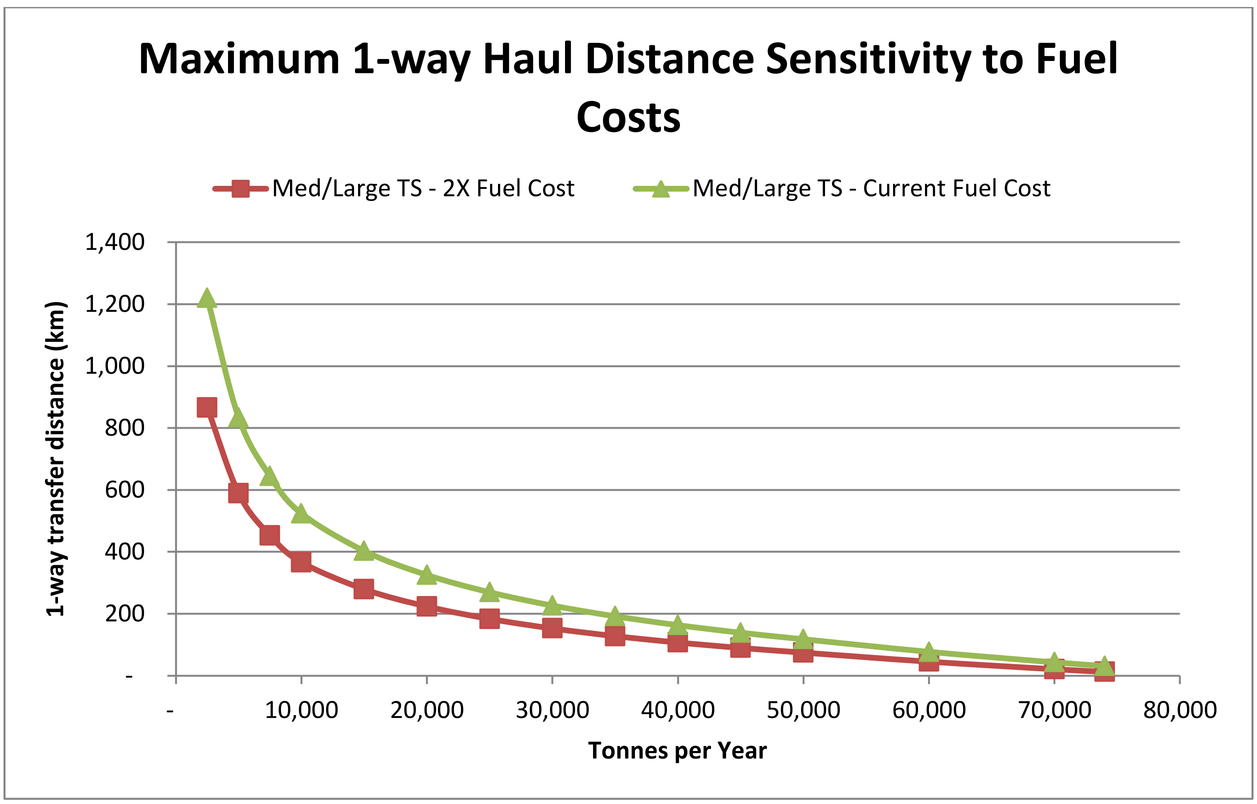
10.2. Fuel Cost Sensitivity

One of the main concerns with moving to a system dominated by transfer of material is fuel cost escalation. Increasing fuel costs will reduce the distance that a program can haul their material economically. Doubling fuel cost will increase the hourly haul rate by 40%. This would imply diesel prices over $2.50 per litre.

- Rolloff haul rate (Small Transfer Station): $125.28 per hour
- Transfer trailer haul rate (Medium/Large Transfer Station): $139.20 per hour

Doubling fuel cost will cause a decrease of approximately 30% in the maximum one-way miles that can be hauled as shown in Figure 6. Even with this steep increase in fuel costs, there are only two potential transfers that will be affected by the reduction in haul distance in the minimum facilities scenario. These are London and Waterloo areas transferring to a large Hamilton MRF. The at-risk transfers are both large transfers (greater than 40,000 tpy) and are hauling approximately 60 min. If compaction, and thus weight on each transfer trailer, is maintained at current tonnes per load then this will offset the fuel cost escalation. These are both in the Southwest region and the risk associated with these transfers and ways to mitigate them are described in detail in Volume 6.

Figure 6: Fuel Cost Sensitivity

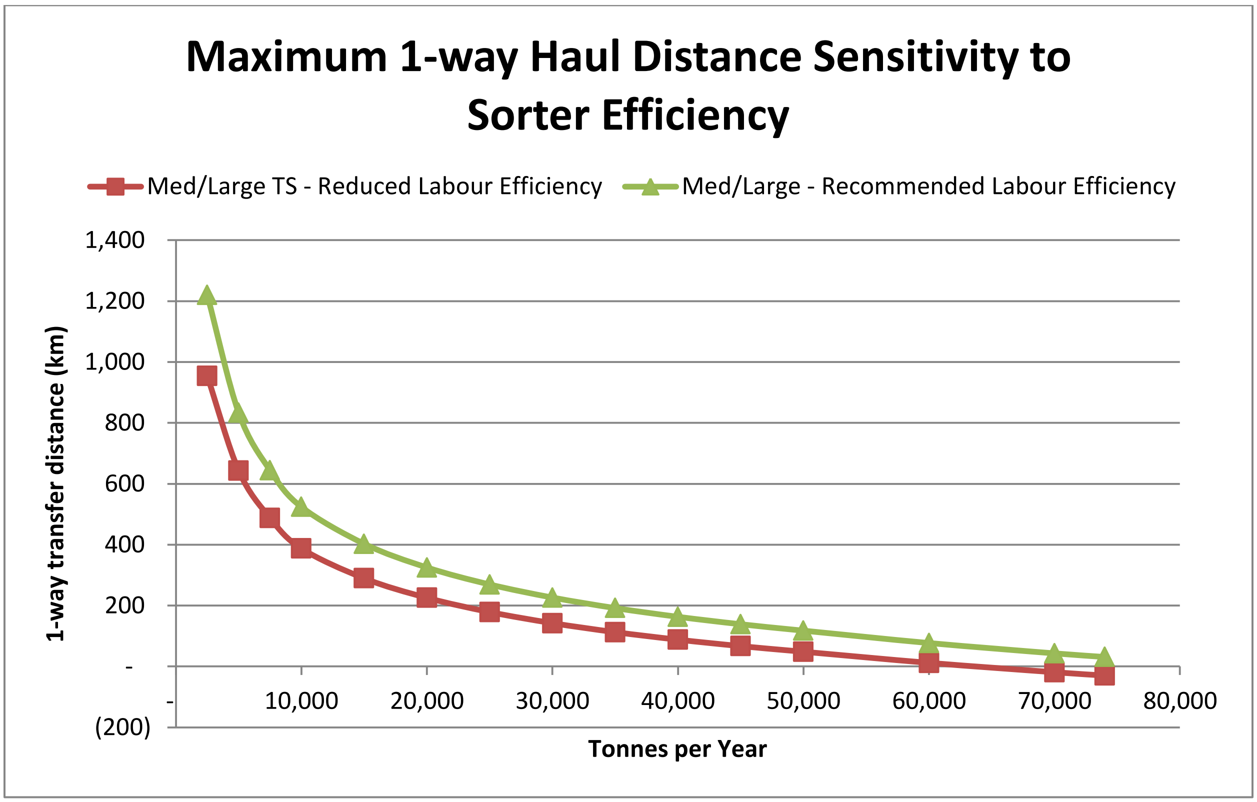


Doubling the fuel costs will increase the overall cost of the system by 4.3% in the minimum facilities (most hauling) scenario. Overall, fuel cost does not appear to be a great risk to the success of the hub and spoke system.

10.3. Labour Productivity Sensitivity

Newer single-stream facilities use increasing automation to reduce the sorting labour required to achieve high quality products and low residue rates. The reference facilities that are sited in this report (see Section 4) have sorter productivity ratios of 1.00 tonnes/sorter/hr to over 2.00 tonnes/sorter/hr. The model uses 1.35 for the Medium and Large facilities. In the hub and spoke system, these will be the dominant facilities, accounting for all of the projected facilities outside of the northern region in most options. Reducing labour productivity from 1.35 tonnes/sorter/hr to 1.00 tonnes/sorter/hr will increase the overall cost of processing at the Medium and Large MRFs by about 10%.

Figure 7: Labour Productivity Sensitivity



Decreasing the sorter productivity will reduce the maximum one-way haul distance by 20% as shown in Figure 7. The only modelled transfer that would be affected by this change is the Waterloo transfer to Hamilton.

Reducing the labour productivity at the largest MRFs will increase the overall cost of the system by 2.5% in the minimum facilities scenario.

Appendix1

1. Benefits of Single-Stream Collection

Single-stream has been selected as the foundation for the optimized processing system for Blue Box recyclables. Single-stream recycling is a collection and processing system where all bottles and cans are combined with all fibre in one collection container. This technology has been a significant part of residential recycling in North America for over 10 years. Looking forward to 2025 and beyond, this rapidly developing technology for moving recyclables from point of generation to market is recommended for its high performance in the critical areas that are key to a successful recycling system.

1.1. Ease of Collection

Collection practices for curbside recyclables benefit from single-stream recycling processing in a number of ways:

- *At Point of Generation:* The generator does not need to separate the items in their home or business, reducing the recycling container footprint in their daily life, both inside (the kitchen, living room, den, etc.) as well as outside or garage (the location of the bin or cart). One container can be used instead of two or more (for dual stream or multi-sort collection programs).

- *The Collection Container:* A major benefit of single-stream recycling is that a single collection container can be used and that this container can be a larger capacity cart with a lid that can be stored outside without cover and whose capacity can match that of the trash container. This allows the convenience of recycling to match or exceed that of throwing “away” in the trash can. This large capacity provides room for recycling all that a household might generate in a week or two week period (depending on frequency of collection), preventing the loss of recyclables because “the bin is full” – something that is common when a program uses the smaller blue-box type recycling bin. This is especially relevant as recycling programs expand the list of acceptable materials to include larger pieces of cardboard, or the larger rigid plastics like pails, laundry baskets and the like, all of which fit easily inside a cart. The cart is also wheeled, greatly increasing the ease of movement of the cart from garage to curb, making it possible for people of all ages and a range of physical abilities to easily and quickly move recyclables from home to curb for collection. Adding new materials is also very easy since it can just be collected with the same large capacity cart. Further, the cart itself becomes a communication tool for recycling, allowing large and visually attractive “molded in” recycling instructions to be included in the cart lid, and making possible the use of RFID-based incentive systems that like RecycleBank and many knock-offs that have been shown to greatly increase the adoption rate of recycling practices across the market. Finally providing this large capacity cart has been proven over and over again to increase the total amount of recyclables recovered from a residential collection program by 20% to 40% and higher. That is the simple result of the higher convenience that motivates a broader range of all types of households to use their recycling system.

- *The Collection Truck:* A single compartment compacting collection vehicle can then be used. This typically is a similar or even identical design to trash collection vehicles, producing many benefits for the collection operation (public or private) since the same type of vehicles can be used for both types of collection, allowing for interchangeability of parts, fewer types of repair procedures for mechanics to be familiar with, fewer number of spare parts to keep in stock, and greater flexibility in management of the fleet of collection vehicles. For a larger fleet this can mean that fewer trucks need to be purchased overall since backup vehicles can cover breakdowns in both the trash as well as recycling collection fleet. Greater opportunities for favorable pricing on truck purchases are also possible given the larger quantities of identical vehicles that can be bought over the long term.

- *Automated and Semi-Automated Collection:* Even more important to cost savings is the fact that single-stream recycling allows use of the rolling cart, which then allows use of semi-automated or fully-automated side loading collection vehicles. This greatly reduces labour allowing use of a single collection worker compared to the two or three that are often part of rear packer and manual collection vehicles. The use of lifting devices can greatly reduce worker injuries related to collection. Automated collection can take it a step further an essentially eliminate those lifting injuries for all practical purposes. As well, use of semi or fully automated side loaders significantly increases the productivity of the collection worker, allowing the time at each stop to drop down to the 20 to 25 second range (semi-automated) and down to the 10 to 15 second range (fully-automated). What this means is that these collection vehicles can handle much larger routes (1000 pass-bys or higher per route) compared to non-automated approaches. This allows for reduced numbers of routes per collection program – meaning fewer trucks, fewer operators and much lower recycling collection capital and operating costs.

- *Direct Haul from Collection Route to Facility:* As a result, the single-stream semi-automated or automated recycling collection truck can cover a larger route before it needs to then leave the route to direct haul to its tipping location. Further, because the single-stream recycling collection truck has only one compartment for recyclables (instead of two or more), the truck doesn't have to stop collecting when just one of its compartments fills up (leaving unused collection capacity in the other compartments). The single compartment also means that compaction technology can be easily incorporated into the truck design and more stops can be made to fill up that one compartment before reaching capacity and having to tip at the MRF or recycling transfer station. And the compacted recyclables can also be direct hauled longer distances economically, given the higher density of the load.

- *Transfer of Single-stream Recyclables:* Single-stream recycling provides for additional savings in the construction and operation of any recycling transfer station that may be used to haul recyclables longer distances to a MRF. Only one tipping floor and one storage bunker is needed, reducing construction costs and allowing for a smaller facility footprint. Less time is needed for wheel loader or skid steer operation to manage one pile of single-stream recyclable material thus lowering operating costs and providing for more efficient operation of that transfer station. The net result is that the transfer station network can push further into more rural areas with more cost effective facilities, allowing the recycling collection network to be more extensive while still operating efficiently.

- *Expansion to Other Generator Types:* The single-stream collection system, with its capacity to collect using the large rolling carts, is much more easily expanded into multi-family complexes, small businesses, schools and institutions, often on the same collection route. This is made possible by the fact that it is much easier to locate and service the cart, able to handle the full list of all the accepted recyclables, especially in very tight situations that are common in most of these higher density non-single family residential locations. The net result is that the collection network can be expanded, significantly increasing the overall reach of the recycling collection system, and greatly increasing the overall tonnage that is collected.

1.2. Ease of Processing

Single-stream recycling collection is made possibly only due to the rapid evolution of sophisticated single-stream sorting technologies at the MRF. These technologies have quickly gone through generations of field development in hundreds of facilities in both Europe and North America. The end result is that the current generation of commercially available single-stream recycling processing systems are now the best practice state of the art in operating efficiency, product quality and overall recovery of recyclables – with new developments in sorting technology continuing to evolve. The two workhorses of state of the art single-stream MRFs are disc screens that separate fibre from containers and optical sorting units that cost effectively separate many of the most common grades of containers. Consider the following:

- State of the art single-stream facilities (processing more than 30,000 tpy) are now able to efficiently sort recyclables and produce quality products with comparable or less labour cost than in a similarly sized dual-stream facility (with the exception of colour sorting of glass).

- Best practices for glass handling in single-stream MRF designs now remove the glass very early in the system, eliminating many of the concerns in earlier single-stream MRFs regarding glass contamination of other recyclables and glass residue impact on equipment life.

- Designs for the fibre screens (the slanted screens at the front of single-stream MRFs) have been improved to the point that OCC, News and Mixed Paper now are effectively separated from bottles and cans with high efficiency, reducing the amount of post sort needed to produce marketable products, at the same time providing a cleaner stream to the container line. The addition of OCC screens at the front end can now eliminate most manual sorting of OCC, making the other screens more effective and reducing staffing requirements at presort and at fibre post sorts.

- Front end metering systems are now used to optimize the flow and mix of materials into these screens – providing for even higher efficiency in the single-stream screen operations while simplifying line loading and allow the loader operator to perform other functions.

- Large presorts ahead of the screens are now used to remove trash, oversize materials and materials that might wrap on screen shafts, and to allow recycling of large rigid plastics and scrap metals – further increasing the efficiency and recovery capabilities of the system.

- Optical sorting of both containers and even some fibre is now common in state of the art single-stream MRFs, significantly reducing labour needs, increase throughput and allowing the sorting of grades of recyclables that humans cannot differentiate visually. Optical sorting can be used for PET, coloured PET, Natural HDPE, coloured HDPE, PLA, #3-7 (or grades within), aseptic cartons, milk and juice cartons, other polycoated papers and various combinations of these. The quality of sort and reliability of this equipment has been refined and dual sort optical units have been developed that perform well in certain mixes of material – helping to reduce capital costs for these units. Optical sorting units achieve pick rates that are unmatched by human sorting, allowing single-stream MRFs to reach much higher levels of throughput capacity without significant increases in total workforce.

- Glass cleanup systems are now used to improve glass quality and in some facilities to reclaim small (shredded) fibre for recycling
- Fibre reclaim from mixed container stream is now common to reduce residue and recovery more recyclable fibre
- Bottle and can reclaim conveyors are now common in state of the art single-stream MRFs to increase recovery from fibre post sort lines

1.3. The Net Result

This combination of benefits in both the collection and processing side of the single-stream recycling collection system have proven their worth in hundreds of installations across North America, where higher levels of overall recycling recovery are being achieved at lower total net costs.

Appendix2

Table 12: Detailed Labour Rates

Wages	Hourly	Annual	Fringes	2012 Total
Sorter	$15.00	$31,200	$9,360	$40,560
Semi Tractor Driver	$23.00	$47,840	$14,352	$62,192
Equipment Operator	$17.50	$36,400	$10,920	$47,320
Maintenance	$17.50	$36,400	$10,920	$47,320
Scale & Clerical	$15.00	$31,200	$9,360	$40,560
Management	$27.00	$56,160	$16,848	$73,008
Benefits/Fringes	30%			
1st Shift capacity	85%			
2nd Shift capacity	85%			
Capacity Utilization	95%			

Table 13: Building and Operating Cost Assumptions

		Unit
Building & Site Maintenance Costs	$13.45	per m^2
Building utilities	$6.46	per m^2
Processing Costs		
Baling Wire Costs	$1.50	per tonne
Processing Fuel Costs	$0.50	per tonne
Maintenance Costs	$4.41	per tonne
Process Utilities Costs	$2.20	per tonne
Transfer Loading Fuel Costs	$0.20	per tonne
Transfer Equipment Maintenance Cost	$2.25	per tonne
Safety/Office/Phone/Supplies	$2.48	per tonne
Residue Disposal Cost	$80	per tonne Residue
Residue Rate	7%	
Management Profit Allowance	20%	
Interest Rate	4%	
Rolling Stock		
Forklift	$35,000	
Skidsteer with Grapple	$50,000	
Small Loader	$85,000	
Large Loader	$180,000	
Yard Mule	$110,000	