

REGIONAL OPTICAL SORTER FOR MIXED GLASS FEASIBILITY STUDY



Prepared For

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EXECUTIVE SUMMARY

Over the last several years there has been a marked decline in the amount of glass containers delivered to Anchor Glass Container, Minnesota's largest market for recycled glass. The primary reason for this decline is the increase in single-stream recycling in the Minneapolis/St. Paul Metro Area, which significantly reduces the supply of clean, color-separated container glass. At the same time, Anchor Glass Container went through a market shift with their customers as well as an overall financial slump for the company. This resulted in pricing changes for cullet and the cessation of accepting green glass. For the first time in Minnesota's recycling history, the supply of color-separated glass shrunk and the demand for this glass contracted down to only one color.

The MPCA contracted with Tim Goodman & Associates to undertake a feasibility study to address the concerns of the regional and statewide recycling industry. The primary objectives of this study are:

- Determine the preliminary technical and economic feasibility of developing a regional glass beneficiation facility that would mechanically remove contaminants from the mixed-glass stream and color-sort the glass utilizing optical scanning technology.
- Identify and research alternative regional markets for clean glass (mixed or color-separated) in order to provide a broader range of market options for MRFs around the state.
- Assist the MPCA staff in establishing a dialog with glass recycling industry players regarding the development of a regional glass beneficiation facility.

Feasibility Study Key Findings

- Over 90% of the mixed glass potentially available for processing at the facility is generated at four MRFs located in the Minneapolis/St. Paul Metro Area. This amounts to approximately 53,000 tons annually of pre-beneficiated, mixed glass.
- Based on estimated contamination levels, processing loss due to particle size, optical sorter operational efficiencies, and an assumed breakout of glass into the three colors of flint, amber and green, this 53,000 tons would yield approximately:
 - o 24,018 tons of flint cullet;
 - o 8,662 tons of amber cullet; and
 - o 8,766 tons of predominantly (80%) green cullet.
- Cullet can be used at levels as high as 80% in the manufacturing of new glass containers. For every 10% of cullet used in the manufacturing process there is:
 - o A 6° C drop in furnace temperature allowing a furnace to be operated at a lower temperature resulting in prolonged furnace life;
 - o Up to a 3% reduction in fossil fuels leading to a 3% reduction in CO₂ emissions;
 - o A 6% reduction in NO_x emissions; and
 - o A 17% reduction in CO₂ emissions associated with raw material conversion.
- Due to the high capital and operating costs associated with a regional glass beneficiation facility, it should be located close to major suppliers of mixed glass, major glass markets, and a well developed transportation network. By these standards the most logical location for a facility would be in the metro area.

- The longer haul distances and smaller quantities of mixed glass generated at MRFs in Greater Minnesota make it unlikely that any significant amounts of glass would be delivered to a glass beneficiation facility in the metro area from these facilities.
- Though Anchor Glass Container is the major market for recycled glass in the state, several other markets are available to MRFs in Greater Minnesota. These include:
 - o Glass Advantage (West Fargo, ND) – Blasting media manufacturer.
 - o Raguse Manufacturing (Wheaton, MN) – Blasting media manufacturer.
 - o Road construction aggregate replacement – Localized throughout Minnesota.
- The processing line for glass beneficiation should include a mechanical processing component that would first remove contaminants from the mixed-glass stream and an optical scanning system that would color-separate the glass into flint, amber and green streams or flint and a mixed amber/green (gramber) stream.
- In total, the estimated capital cost of a dedicated glass beneficiation facility designed for up to 60,000 tons of mixed-glass feedstock is estimated at approximately \$5.5 to \$6.5 million. This cost can be broken out as follows:
 - o The capital cost for the glass processing equipment (mechanical processing and optical sorting) needed to process up to 60,000 tons annually of mixed glass is estimated at \$3.25 million for a three-color sort system (flint, amber and green); and \$2.75 million for a two-color sort system (flint and amber/green).
 - o The capital cost for two wheel loaders and a truck scale is estimated at approximately \$400,000.
 - o Land and building costs are highly variable based on location, acreage, use of an existing building versus Greenfield development, utilities, availability, and real estate market conditions at the time a facility is constructed. Depending on these variables the cost of real estate, including a new or existing building, is estimated to be between \$2.3 and \$2.9 million.
- The estimated annual operating costs (including debt service payments) ranges between \$2.1 and \$2.3 million.
- Based on low, medium, and high revenue scenarios, estimated annual revenue from cullet sales (either to Anchor Glass or as road construction aggregate) ranges between \$1.2 and \$1.7 million.
- Depending on the same variables mentioned above, the estimated tipping fee, after applying revenues from cullet sales, would be between \$12 and \$24/ton.
- Though some refinement of numbers are needed, it appears that if the overall costs come down to a per ton tipping fee in the \$12 - \$16/ton range a glass beneficiation facility could be economically attractive for some of the larger mixed-glass generators in the metro area.

Recommendations

- 1) Due to the geographic, economic and market-infrastructure differences between the Minneapolis/St. Paul Metro Area and Greater Minnesota, the MPCA should work with recyclers in Greater Minnesota to develop region-specific strategies and market development initiatives for recycled container glass.
- 2) The MPCA should expand the dialog regarding a regional glass beneficiation facility to serve the Metro Area and surrounding region. To accomplish this, an open forum should be conducted involving a variety of stakeholders in the region. At a minimum, representatives from the following groups should be invited to participate.

- Regional MRF operators
 - Anchor Glass Container
 - MnDOT
 - Solid Waste Management Coordinating Board (SWMCB)
 - Recycling Association of Minnesota (RAM)
 - Association of Recycling Managers (ARM)
 - Solid Waste Administrators Association (SWAA)
- 3) The MPCA should identify and research public/private partnership options for how the State can more directly assist in the development of a regional glass beneficiation facility. The State already offers no-interest loans to businesses through an application and selection process. Other avenues to explore could be:
- Capital Assistance Grants to private sector project developers; and
 - Public ownership with a contracted private operator.
- 4) The MPCA should engage in a dialog with all the glass markets serving the state to determine how they can assist in growing those businesses, developing new product lines or markets for the products produced, and improving operational efficiencies. A variety of assistance can be offered such as:
- Market development assistance;
 - Working with suppliers of glass to improve the quality of feedstock; and
 - Consulting services (paid for by the State) to assess operational efficiencies.
- 5) The MPCA should engage MnDOT in a dialog regarding the use of more recycled glass in road construction projects throughout all regions of the state and encourage MnDOT's use of this material in state highway projects. With critical shortages of aggregate in some portions of the state, the use of recycled glass could help alleviate some of the aggregate shortages.

I. INTRODUCTION

In 2005 a study was conducted for the Minnesota Pollution Control Agency (MPCA) looking at the impacts single-stream recycling and dual-stream recycling have on the processing of recyclables and the marketing of recovered materials.¹ One of the findings coming out of that study was how single-stream recycling, and to a lesser extent dual-stream recycling, is affecting the quality and quantity of recovered glass for container-to-container recycling. As a result, over the last several years Anchor Glass Container's Shakopee, Minnesota, facility saw a drop of nearly 50% in the delivered quantity of color-separated recycled glass (also known as cullet) to be used in the manufacturing of new glass containers.

Since that report was published, further reductions in the availability of clean, color-separated cullet, along with market shifts for the glass containers manufactured at the Shakopee facility and a general financial slump for Anchor Glass, has resulted in an increased price paid for flint glass, a decreased price paid for amber glass, and the cessation of accepting green glass altogether. Additionally, the supply of cullet has decreased even further to the point where Anchor is now taking in approximately 26,000 tons per year of cullet with approximately half of this being flint. With both furnaces operating at the Shakopee plant, there is a need for up to an additional 77,000 tons of flint cullet.

In the meantime, much of the glass being processed at Minneapolis/St. Paul Metro Area materials recovery facilities (MRFs) is a color mixed product with varying degrees of contaminants ranging as high as an estimated 25% (by weight) contamination level. In Greater Minnesota some MRFs are also having difficulties in finding markets for their recycled glass (especially green and green/amber mix). Not wanting to discontinue glass recycling, because of the recycled tonnages lost, the negative message it sends to the public, and the limitations on how much they can stockpile until markets grow or are developed, many MRFs find themselves in a bind. Markets for this material (including Anchor Glass) are available if the mixed-glass stream could be cleaned up and color-separated.

The primary objectives of this current study are three-fold:

- 1) Determining the preliminary technical and economic feasibility of developing a regional glass beneficiation facility for mechanically removing contaminants from a mixed stream of glass and color separating the glass using optical sorting technology;
- 2) Researching alternative regional markets for clean cullet (mixed or color-separated) in order to provide a broader range of options for recycling the glass processed at MRFs around the state; and
- 3) Assisting MPCA staff in meeting with and establishing a dialog with potential project partners including Anchor Glass Container, other market outlets, MRF representatives, equipment vendors, and other third party entities (public and private) regarding the development and operation of a regional glass beneficiation facility.

¹ Single-Stream and Dual-Stream Recycling: Comparative Impacts of Commingled Recyclables Processing, Tim Goodman & Associates, January 2006.

II. CONTAINER GLASS CHARACTERIZATION IN MINNESOTA

MRF owners and operators from around the state were interviewed to obtain information on the processing of glass containers as well as what they are currently doing with the glass that they recover. To help ensure that a statewide representation of MRFs was contacted, a list of MRFs within each of the state's six regions was compiled. These regions are reflected in Figure 1.

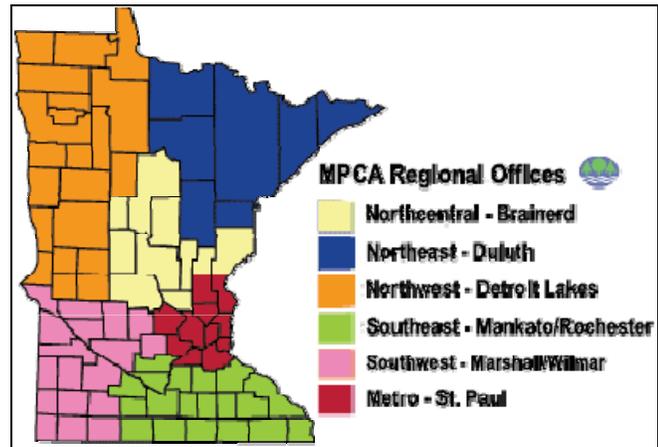


Figure 1: Map of MPCA Regions

For SCORE reporting purposes, a MRF is defined as:

“A recycling facility that prepares at least three different material categories for market. Preparation for market is the processing of materials through crushing, baling, shredding or other densifying.”

For purposes of this discussion a slightly narrower definition of a MRF was used focusing on those facilities that process a significant container stream as well as a fiber stream. Facilities where recyclable containers make up a small portion of the materials collected and processed were excluded since the focus of this study is on glass containers.

Based on this definition, forty-six (46) MRFs were identified statewide. The project budget did not allow for interviewing all of the MRFs statewide but over 40% of the MRFs on the list were contacted. Attempts were made to survey multiple MRFs in each region.

With the most significant quantities of glass containers being consumed and/or recycled in the metro region, much of the focus centered on facilities serving the Twin Cities. However, it was also recognized that many MRFs in Greater Minnesota don't have readily available access to glass markets. This is due largely to their geographic distance to identified markets and the smaller amounts of recovered glass captured at their facilities adding up to costlier options for getting that glass to markets. As a result, just over a third of the MRFs serving Greater Minnesota were contacted.

Based on the 2005 SCORE Report² 119,464 tons of glass was reported recycled in Minnesota for that year. Of that amount, approximately 68% (81,427 tons) was container glass – glass bottles and jars. Other glass, such as plate glass, windshield glass, or specialty glass accounts for the remaining 32% of glass reported recycled in the state. Several manufacturers and/or processors are located in Minnesota that recycle non-container glass, including Marvin Windows (Warroad), Viracon/Curlite, Inc. (Owatonna), and Strategic Materials (Owatonna).

² Report on 2005 SCORE Programs, Minnesota Pollution Control Agency, December 2006.

The SCORE recycling data provided to the state does not break out recycled glass containers by color. In Greater Minnesota, many MRFs still hand sort glass by color although with recent developments in glass markets (discussed in the next section) some facilities are opting to not color sort glass containers or doing a partial color sort with flint going in one bin and amber/green going in another bin.

Some MRFs serving the metro area also still hand sort glass containers by color. This is especially true for facilities set up for dual-stream processing although a couple of single-stream processors have incorporated some level of manual color sorting of glass into their operations. However, this is not typical for glass processing in the Twin Cities and currently the majority of the glass processed is not color sorted.

For example, the quantities of recycled container glass reported by the three largest counties making up the Minneapolis/St. Paul Metro Area – Hennepin, Ramsey, and Dakota – amounts to over 36,000 tons annually. Yet, in talking with the five major MRFs serving these counties, only about one-third of this recycled container glass was delivered to the MRF color separated or was color separated during processing at the MRF.

Based on conversations with MRF owners/operators around the state the reported breakout of glass by color varies considerably with flint (clear) ranging from 50% to 75%, amber (brown) ranging from 17% to 29%, and green ranging from 2% to 25%. Most of these reported numbers are estimates and with such wide ranges it's difficult to obtain a reasonable breakout of recovered glass by color.

For purposes of this study, it's assumed that recovered glass will more or less reflect the pattern of container glass still in the MSW stream. Based on the most recent Minnesota composition study conducted by R.W. Beck³, container glass was found in MSW in the following breakout.

- Metro Area: 61% flint, 22% amber, and 17% green.
- Greater Minnesota: 64% flint, 20% amber, and 16% green.
- Statewide Aggregate: 65% flint, 20% amber, and 15% green.

Reported contamination of the mixed-glass stream generated at MRFs around the state can vary significantly. In Greater Minnesota, the facilities that were contacted reported minimal amounts of contaminants in their recovered glass. Since in most cases, glass is hand-sorted (all three colors, two colors, or a mixed-glass product) this isn't surprising. Glass pieces that end up in the residue stream at the end of the line typically make up a small proportion of that stream and as such can't be considered a mixed-glass stream.

The MRFs operating in the Minneapolis/St. Paul Metropolitan Area reported estimates of how much contamination is found in their mixed-glass product. This ranges from about 2% up to 25% on a weight basis with a weighted average of approximately 8%. Typical contaminants found in the mixed glass include metals (ferrous and non-ferrous), paper, plastics, and other inert materials (ceramics, stones, non-container glass, etc.). Again it should be noted that the percentages reported above are estimates and that from day-to-day and processing batch-to-processing batch there could be a wide variation within any given facility.

³ Statewide MSW Composition Study: A Study of Discards In The State of Minnesota, R.W. Beck, March 2000.

A. CONTAINER GLASS PROCESSING IN THE METRO AREA

Of the 81,427 tons of container glass reported recycled in 2005, approximately 58% (47,214 tons) is recovered from the Minneapolis/St. Paul Metropolitan Area.⁴ Almost all of this material is processed in MRFs located in the metro area. Additionally, some of the recycled container glass generated in non-metro counties is processed at metro area MRFs although exactly how much is unknown.

There are nine MRFs located in the MPCA Metro Region. These MRFs and their locations are listed in Table 2.1.

Table 2.1
Material Recovery Facilities Located in the MPCA Metro Region

Facility	Location	Ownership
Allied Waste Services	Minneapolis	Private
Allied Waste Services	Inver Grove Heights	Private
Buckingham Recycling	Prior Lake	Private
Eureka Recycling	Minneapolis	Private
SRC Recycling	Wyoming	Private
Tennis Sanitation	St. Paul Park	Private
University of Minnesota	Minneapolis	Public
Waste Management	Minneapolis	Private
Wright County	Buffalo	Public

Of the 9 MRFs listed in the table, five of them are considered to handle the vast majority of the commingled recyclables generated in the metro area – Allied Waste Services (both facilities), Eureka Recycling, Tennis Sanitation, and Waste Management.

In conversations with these five facilities, a variety of information was collected on how glass containers are processed, estimated annual amounts of color-separated glass marketed, estimated annual amounts of mixed-glass streams generated, estimated levels of non-glass contamination in the mixed-glass streams, and estimated amounts of mixed, broken glass potentially available for optical sorting.

Eureka Recycling is moving forward with the installation of an optical sorting system at their Minneapolis MRF. They have secured low-interest or interest-free loans from the State of Minnesota (\$100,000) and Ramsey County (\$500,000). Eureka's glass-processing operation is anticipated to be operational by the end of the year.

Their new system will have the capability of processing and optically sorting a nominal 10,000 tons/year of mixed glass. The incoming glass stream must meet a 5/8" size specification. The vast majority of glass would be color-sorted into flint, amber, and green streams.

⁴ Minneapolis/St. Paul Metropolitan Area in this context is defined based on MPCA designated regions. The MPCA Metro Region consists of Anoka, Carver, Chisago, Dakota, Hennepin, Isanti, Ramsey, Scott, Washington, and Wright Counties.

The initial focus will be on glass generated from residences in Ramsey County. Mixed glass will be accepted from Eureka’s four curbside programs in the county, as well as from other local haulers and facilities that can meet the specifications for the delivered cullet. Since there will be excess capacity beyond the quantities of residential glass currently separated for recycling in Ramsey County, there will be the opportunity to process glass from other metro counties. However, Eureka Recycling will not have nearly enough capacity to process the vast majority of mixed glass generated within the metro area.

Since Eureka will be managing their own mixed-glass stream, the mixed glass they generate is excluded from the discussion below.

This leaves the other four MRFs cited above. Table 2.2 shows some of the aggregated information collected from these other facilities.

**Table 2.2
Container Glass Processing at the Waste Management,
Allied Waste Services, and Tennis Sanitation MRFs**

Annual Tons of Color-Separated Glass Recovered (Estimate)	7,600 tons
Annual Tons of Mixed Glass Recovered (Estimate)	53,000 tons
Percentage of Contaminants in Mixed-Glass Stream (Estimate)	2% to 25% by weight depending on which MRF
Weighted Average of Contaminants in Mixed-Glass Stream (Estimate)	8%
Markets and/or Uses for Recycled Glass	<ul style="list-style-type: none"> • Anchor Glass (2) • Sent out of state for further processing or to other regional mixed-glass markets (1) • Used as drainage media in landfill leachate collection and gas collection systems (1) • Disposed in landfill as process residual (1)
Rail Access On-Site or Nearby	<ul style="list-style-type: none"> • Allied Waste Services (Minneapolis) and Waste Management - Yes • Allied Waste Services (Inver Grove Heights) and Tennis Sanitation – No
Would You Consider Sending Your Mixed Glass to a Regional Beneficiation Facility?	All said yes.

Approximately 7,600 tons of glass is recovered as a clean, color-separated cullet that is sold to Anchor Glass in Shakopee. This 7,600 tons comes from two of the four MRFs represented in the above table.

The majority of glass processed at the MRFs highlighted in Table 2.2 comes out in the form of a mixed-glass stream (an estimated 53,000 tons annually). Of this 53,000 tons it’s estimated that contaminants in the mixed-glass stream run from about 2% up to 25% on a weight basis with a weighted average of approximately 8% or approximately 4,230 tons annually of non-container glass materials in the mixed-glass stream.

As noted previously, these contaminants fall into several categories – metals (ferrous and non-ferrous), a light fraction (paper and plastics), and other inert materials (ceramics, stones, non-container glass, etc.).

As of early 2007 the majority of this material (61%) is being used as drainage media in landfill leachate collection and gas collection systems. Though the use of glass as a drainage media in landfill leachate or gas collection systems is not as desirable as “bottle-to-bottle” recycling of glass, it is currently recognized as a legitimate recycling option by the MPCA.

Another 34% of the generated mixed-glass stream is being sent to the Container Recycling Alliance (CRA) glass beneficiation facility in Chicago for further processing and recycling as well as to other regional recycling markets for mixed glass.

Approximately 5% of the mixed-glass stream is being landfilled as processing residual.

Two of the facilities have on-site rail access – Allied’s facility in Minneapolis and the Waste Management facility in Minneapolis. Allied’s Inver Grove Heights facility does not currently have rail access but materials could be trucked up to the Minneapolis facility for rail transport. Tennis Sanitation also does not have on-site rail access.

In discussions with Allied Waste Services, Tennis Sanitation, and Waste Management all indicated an interest in sending their mixed glass to a regional glass beneficiation facility depending on certain conditions. These conditions, not all of which were voiced by all facilities, include:

- The cost for using the facility would need to be no more and preferably less than what they’re paying now for managing their mixed glass;
- Preference for a facility owned or controlled by a third party and not by a local competitor;
- Required specs for the mixed glass would not necessitate further processing or cleanup of the materials;
- The company that owns/operates the facility must demonstrate financial stability; and
- The company that owns/operates the facility must have a proven environmental and safety record.

B. CONTAINER GLASS PROCESSING IN GREATER MINNESOTA

In 2005, Greater Minnesota counties reported recycling approximately 34,214 tons of container glass. Unlike container glass collected for recycling in the metro area, not all of this material was processed in MRFs located in Greater Minnesota. Some portion of this material was collected and transferred to one of the MRFs located in the Twin Cities for processing though how much is unknown.

Thirty-seven (37) MRFs were identified in Greater Minnesota. Though there may be a few smaller facilities unaccounted for these 37 facilities represent the dominant ones in operation in the non-metro counties. The thirteen (13) facilities listed in Table 2.3 were contacted to determine the estimated annual amounts of color-separated glass recovered, the estimated annual

amounts of mixed glass recovered or otherwise managed, what markets or uses the glass is going to, and whether they have access to rail on-site or nearby. Also gauged was their interest in sending glass to a regional beneficiation facility.

Table 2.4 shows the aggregated responses to those questions from the thirteen MRFs interviewed. It should be noted that in many cases the reported tonnages are estimates and are based only on one year’s worth of data.

**Table 2.3
Greater Minnesota Material Recovery Facilities Surveyed**

Facility	Location	Ownership
Buecker’s City Sanitation	Sauk Center	Private
Dodge County	Mantorville	Public
Howard Waste Paper	Duluth	Private
Kandiyohi County	Willmar	Public
McLeod County	Hutchinson	Public
Mower County	Austin	Public
North Mankato	North Mankato	Private
Olmsted County	Rochester	Public
Pope-Douglas Solid Waste Management Authority	Alexandria	Public
Python’s Recycling	St. Cloud	Private
Redwood County	Redwood Falls	Public
Rice County	Dundas	Public
St. Louis County	Virginia	Public

**Table 2.4
Container Glass Processing At
Thirteen MRFs In Greater Minnesota**

Annual Tons of Color-Separated Glass Recovered (Estimate)	2,470 tons
Annual Tons of Mixed Glass Recovered (Estimate)	2,750 tons
Amount of Contaminants In Mixed-glass Stream (Estimate)	Minimal
Markets and/or Uses for Recycled Glass	<ul style="list-style-type: none"> • Anchor Glass – Flint Only (5) • Anchor Glass – Flint & Amber (3) • Glass Advantage (1) • Road construction aggregate (6) • Drainage media for septic systems (1) • Currently being stockpiled (3)
Rail Access On-Site or Nearby	<ul style="list-style-type: none"> • Dodge County, Howard Waste Paper, Kandiyohi County, North Mankato Recycling, Python’s Recycling, and Rice County – Yes • All others - No
Would You Consider Sending Your Mixed Glass to a Regional Beneficiation Facility?	<ul style="list-style-type: none"> • Yes (9) • Maybe (3) • No (1)

Of the estimated 5,220 tons of glass recovered at these thirteen facilities, approximately 2,470 tons (47%) was recovered as color-separated glass containers. The remaining 2,750 tons (53%) was recovered as a mixed-glass product. As far as color-separation, some MRFs sorted the glass containers into the traditional flint, amber and green categories whereas others were just separating out the flint and leaving the green and amber (sometimes referred to as gramber) mixed together. Most of the facilities reported contamination of the mixed glass as minimal since much of this material is still hand sorted (pulled off the conveyor at picking stations). A couple of facilities did indicate that contamination can vary but this is primarily in situations where the mixed container stream is a negative sort flowing off the end of the container line.

Eight of the thirteen facilities contacted were sending some of their recovered glass to Anchor Glass in Shakopee. In most cases they were only shipping flint but three facilities were sending the amber glass to Anchor as well. Delivery distances to Anchor typically ranged from 50 to 125 miles although one facility is shipping their flint almost 200 miles to Anchor's door.

One interviewed facility is currently shipping their mixed glass (~ 330 tons) to Glass Advantage (West Fargo, ND) where it is further processed and sold as a sandblasting product. The distance they're transporting their material is approximately 220 miles. There are several other MRFs in the western part of the state (none of whom were among those facilities that were interviewed) that are also shipping their mixed glass to Glass Advantage. A discussion of this growing, alternative market is provided in the next section.

Another use for mixed glass, which is growing, is as an aggregate replacement in road construction projects. Six of the MRFs interviewed are currently using the mixed glass for this purpose, either sending it to a construction contractor or collaborating with their own county highway departments on road construction projects. In addition, one of the facilities stockpiling their mixed glass is doing so to build up inventories for a road construction project.

Use as drainage media for septic systems was reported by one facility and two others are stockpiling a portion of the glass they recover, as they don't have any markets for that material.

Six of the facilities reported they have access to a rail spur either on site or nearby with the other seven facilities indicating they don't.

When asked if they would consider sending their mixed glass to a regional beneficiation facility only one facility flatly said no. The responses received from the other twelve MRFs indicated a willingness to consider it. As would be expected all the facilities indicating yes or maybe said the decision as to whether or not they send any glass to the facility would be made based on cost. Many said it would have to be competitive with what they're doing now and in a few cases transportation costs would need to be covered.

C. CONTAINER GLASS CHARACTERIZATION SUMMARY

The key points of this section can be summarized in the following bullet points:

- Based on 2005 SCORE data, over 47,000 tons of glass containers generated in the Minneapolis/St. Paul metro area was reported recycled that year. Several MRFs located in

the Twin Cities also process recyclables (glass included) collected from outside the metro area significantly increasing this number.

- According to the most recent Minnesota solid waste composition study, of the container glass in the MSW stream approximately 61% - 65% is flint, 20% - 22% is amber, and 15% - 17% is green. Recovered container glass is assumed to mimic this representation.
- Of the glass containers recovered and/or recycled by the five largest processing facilities located in the metro area, approximately 82% of this glass is in the form of a mixed color glass stream containing a weighted average of 8% non-glass contaminants.
- Though Eureka Recycling is moving forward with the installation of glass beneficiation equipment at their MRF it will reduce the mixed color glass stream generated in the metro area marginally leaving approximately 53,000 tons of pre-beneficiated mixed glass that has the potential for greater beneficiation into a cleaner, color-sorted cullet.
- Based on estimated contamination levels, processing loss due to particle size, optical sorter operational efficiencies, and an assumed breakout of glass into the three colors of flint, amber and green, this 53,000 tons would yield approximately:
 - 24,018 tons of flint cullet;
 - 8,662 tons of amber cullet; and
 - 8,766 tons of predominantly (80%) green cullet.
- Based on 2005 SCORE data, over 34,000 tons of glass containers generated in Greater Minnesota were reported recycled that year. The majority of this glass was either transported to the Twin Cities for processing or was processed in approximately thirty-seven MRFs located in Greater Minnesota.
- Based on interviews with thirteen of the Greater Minnesota MRFs, approximately 5,200 tons of glass containers were recovered and/or recycled with about 47% of that amount being color-separated cullet. Contamination of the remaining mixed stream with non-glass materials was generally considered minimal.
- All four of the metro area MRFs contacted (Eureka Recycling was excluded) indicated an interest in delivering their mixed glass to a regional beneficiation facility depending on certain conditions. Among these conditions were:
 - Cost for delivering and tipping glass at the facility would need to be competitive with how they are currently managing their mixed glass;
 - Required specs for the mixed glass would not require further processing or cleanup on their end; and
 - The company that owns/operates the glass beneficiation facility must demonstrate financial stability and have a proven environmental and safety record.
- Almost all of the Greater Minnesota MRFs contacted indicated some level of interest in sending mixed glass (or color-separated green glass) to a regional beneficiation facility. All of them indicated the most important consideration would be cost and that it would have to cost no more, and preferably less, than their current management practices.

III. REGIONAL MARKETS FOR CONTAINER GLASS

Many MRFs around the state, especially in Greater Minnesota, are struggling to find a cost-effective method for recycling or reusing their green glass, amber glass, and/or mixed glass. Though Anchor Glass has a strong demand for flint cullet the demand is much weaker for amber and green cullet. Based on the color breakout described in Section II, between 35 – 39% of the glass containers found in the waste stream are amber and green.

Because of the low or non-existent value regionally for green and amber cullet in the manufacturing of new glass containers, in many situations it is not cost-effective to ship this material to Anchor Glass. Likewise, transporting mixed glass to a regional beneficiation facility located in the metro area from many locations around the state may not be an economically viable alternative.

As a result, other markets and uses for recovered cullet (color-sorted and mixed) will play an important role in stabilizing and increasing the recycling of glass around the state. Based on a report prepared for the California Department of Conservation⁵ glass end use markets can be divided into three general categories:

- High Value/High Volume end uses that require extensive processing (glass containers and fiberglass);
- Low Value/High Volume end uses that require less processing and less (or no) scrap value (aggregate and drainage media); and
- High Value/Low Volume specialty uses (art glass, tile, and brick).

A discussion of some of the types of markets available regionally is provided below. Contact information for specific markets can be found in Appendix A.

A. GLASS CONTAINER MANUFACTURING

Based on a 2002 report on the glass industry⁶, the container glass sector is the industry's largest producer, manufacturing roughly ten million tons of product per year. Two alternative materials, plastics and aluminum, have made substantial inroads into the container market, especially for food and soft drinks. However, some consumer products (beer, wine, liquor, and cosmetics) are still dominated by glass containers, and there appears to be a slight resurgence in the use of glass containers in some industries. The advantages associated with glass containers include:



- Impermeability in that it provides a strong barrier against outside agents;

⁵ Market Analysis for Recycled Beverage Container Materials, NewPoint Group, February 2005.

⁶ Glass Industry Technology Roadmap, Energetics, Inc., April 2002.

- Versatility as it can be manufactured in differentiated shapes and sizes more easily; and
- Recyclability with glass having properties allowing it to be continuously recycled without chemical or physical breakdown of the raw material.

According to information obtained by the Glass Packaging Institute (GPI), for every 10% of cullet used in the manufacturing process there is:

- A 6° C drop in furnace temperature allowing a furnace to be operated at a lower temperature resulting in prolonged furnace life;
- Up to a 3% reduction in fossil fuels leading to a 3% reduction in CO₂ emissions (a potent greenhouse gas);
- A 6% reduction in NO_x emissions (another greenhouse gas); and
- A 17% reduction in CO₂ emissions associated with raw material conversion.

Cullet can be used at levels as high as 80% in the manufacturing of new glass containers.

As of 2006 there were 49 U.S. glass container manufacturing plants in operation one of which is located in Minnesota. This facility, owned by Anchor Glass Container, has been the primary cullet market for much of Minnesota and western Wisconsin and is discussed below.

1. Anchor Glass Container

The Anchor Glass Container facility located in Shakopee, Minnesota, began operation in 1961 under its original owner, American-Wheaton Glass Company. The Shakopee facility went through a series of name changes and acquisitions with Anchor Glass Container acquiring the facility in 1984.

Over the last few years they've been in bankruptcy but emerged from this late last year when the company was again acquired, this time by Wayzata Investment Partners, an investment group based in Wayzata, Minnesota.

With the new ownership and restructuring, the Shakopee plant is poised to move forward with growth. The facility has two furnaces, one of which is relatively new, and it's the only Anchor Glass facility that can accept non-furnace-ready cullet as they do have some ability to remove contaminants. This additional processing capability for the received cullet includes manual ceramic removal, mechanical ferrous and aluminum removal, and a series of shakers and screens. It should be noted, however, that their pre-processing capabilities are limited and they have no method for separating cullet by color. Table 3.1 summarizes key characteristics of Anchor Glass Container as a cullet market.

In 2006, Anchor took in approximately 26,000 tons of cullet, half of which was flint. They are currently running both furnaces at or near capacity and have the potential to use up to 60% cullet in their mix. This equates to almost 90,000 tons of cullet annually. Both furnaces are producing flint containers so the current need for cullet is flint. Anchor is accepting amber cullet and is considering the resumption of accepting green cullet. However, their real need is for flint and the other colors would be shipped elsewhere for processing. At this time they cannot accept deliveries by rail but may be able to do so in the future.

**Table 3.1
Anchor Glass Container**

Location	Shakopee, MN	Cullet Specifications	<u>Furnace-Ready</u> : Crushed to 5/8"; color-separated; no metals, ceramics, plastics, or paper (bottle labels are acceptable)
Product Manufactured	Glass Containers		<u>Non-Furnace-Ready</u> : Color-separated; minimal tolerance for contaminants (will work with supplier).
2006 Quantities of Cullet Used	26,000 tons (~ 13,000 is flint)		
Capacity for Additional Cullet	Up to 77,000 additional tons of flint	Payment for Cullet	<u>Furnace-Ready</u> : \$90 - \$120/ton (flint only).
Delivery Method	For now truck only. May be able to receive by rail in the future.		<u>Non-Furnace-Ready</u> : \$65/ton (flint) \$10/ton (amber)

With regard to glass specifications and pricing of cullet, there are two types – furnace-ready and non-furnace-ready. Furnace-ready cullet needs to be crushed to 5/8" and contain no metals, ceramics, plastics, and paper (except for labels). It also needs to be color-separated and at this time there is only a need for flint. For furnace-ready cullet Anchor is paying between \$90 - \$120/ton.

For non-furnace-ready cullet the material needs to be color-separated and they do have some tolerance for contaminants. They don't specify exactly what that tolerance level is but instead work with suppliers on an individual basis to reduce contaminants to acceptable levels. Currently they are paying \$65/ton for flint and \$10/ton for amber.

B. BLASTING MEDIA

A wide range of materials can be used in the blasting abrasives industry including silica sand, coal slag, aluminum oxide, steel grit, and crushed glass. Crushed glass grit, made from recycled container glass, has several properties and characteristics that allow it to compete favorably with other mineral/slag abrasives. Some of these properties and characteristics include:

- The angular particles in the crushed glass make for an aggressive surface abrasive and is particularly well suited for the removal of coatings such as epoxy, paint, alkyds, vinyl polyurea, coal tar, and elastomers;
- It is lighter weight than many slag abrasives increasing consumption efficiency and reducing production time;
- Crushed glass delivers low particle embedment resulting in a whiter, clear finish;
- It contains no free silica (commonly found in blasting sand) resulting in lower health risks; and
- It is free of heavy metals (commonly found in coal and mineral slag) also reducing health risks.



With the need for a clean, dry, and dust-free product, further processing of glass coming from a typical MRF is required. Glass grit used as a blasting abrasive can be processed down to a variety of mesh sizes depending on its use. The smaller the mesh number, the coarser the grit. For example, a glass grit meeting a mesh size of 10-40 would be considered a coarse grit and have specific applications. A grit meeting a mesh size of 80-200 would be considered a very fine grit and, likewise, would have specific applications.

Though the processing of cullet for the abrasives industry requires screening of contaminants and fine-sizing glass to appropriate specifications, it typically does not require the color separation that the glass container manufacturing industry does. As a result, in areas where access to the glass container market may be limited and the abrasives manufacturing market has a foothold, this option may be a viable one for recycled, post-consumer glass containers. This is not, however, always the case depending on what other abrasives (and the abundance of those abrasives) are available to the marketplace.

On a regional basis, there are primarily two companies that manufacture blasting abrasives from cullet that are within a reasonable transportation distance from Minnesota MRFs, especially those in Greater Minnesota. These companies – Raguse Manufacturing and Glass Advantage – are discussed below.

1. Raguse Manufacturing

Raguse Manufacturing (Wheaton, MN) owns and operates a commercial glass pulverization facility serving a multi-county region in western Minnesota. At the facility glass is crushed and screened to produce a medium to fine grit. Table 3.2 summarizes key characteristics of Raguse Manufacturing as a cullet market.

**Table 3.2
Raguse Manufacturing**

Location	Wheaton, MN	Cullet Specifications	Free from contaminants (plastic, metal, paper, ceramics); does not have to be color-separated.
Product Manufactured	Blasting Media		
2006 Quantities of Cullet Used	~ 1,040 tons (20 tons/week)		
Capacity for Additional Cullet	Limited but can take some.		
Delivery Method	Truck only.	Payment for Cullet	Free tipping. Supplier responsible for freight.

According to Steve Raguse, President of Raguse Manufacturing, they are producing about 20 tons/week (1,040 tons/year) of sandblast media. The demand for their product is seasonal with their biggest competition being blasting abrasive made from coal slag. They have some capacity for receiving more glass but Mr. Raguse says it’s limited.

Glass delivered to Raguse Manufacturing does not have to be color separated but does need to be free of contaminants (i.e., plastics, metal, paper, etc.). They do have some tolerance for these

other materials but Mr. Raguse said it is very limited (no specific numbers or percentages were given).

Raguse does not pay for glass nor do they have a tipping fee. Their suppliers of mixed cullet pay the freight for delivery. They cannot accept deliveries by rail; only truck.

2. Glass Advantage

Glass Advantage (West Fargo, ND) is another facility, which manufactures blasting media from glass cullet. In the past they’ve had a number of problems including developing markets for the material they produce and receiving very dirty loads of materials from suppliers. They appear to have resolved most of their marketing problems and have stopped taking loads from suppliers with significant contamination problems. They have just recently rid themselves of the backlog of dirty mixed glass they received previously.

Their operation appears to be more extensive than Raguse’s and includes:

- Manual sorting to remove large contaminants such as paper, plastics, and aluminum;
- Trommeling (first stage materials sizing);
- Overhead belt magnet to remove ferrous;
- Incineration to burn off labels and glue;
- Pulverizing; and
- Screening (second stage materials sizing).

Table 3.3 summarizes key characteristics of Glass Advantage as a cullet market.

**Table 3.3
Glass Advantage**

Location	West Fargo, ND	Cullet Specifications	Free as possible from contaminants (plastic, metal, paper, ceramics); does not have to be color-separated.
Product Manufactured	Blasting Media		
2006 Quantities of Cullet Used	~ 7,200 tons (600 tons/month)		
Capacity for Additional Cullet	Up to 6,000 additional tons/yr.		
Delivery Method	Truck only.	Payment for Cullet	Zero up to \$23/ton depending on quantity and quality. Supplier responsible for freight.

According to Newton Davis and Tom Williams, both of Glass Advantage, they’ve developed strong markets for their blasting abrasive. For example, they have recently won a contract where they are one of four companies providing blasting media for cleaning a major gas pipeline. The pipeline is 400 plus miles long and it takes, on average, about 63 tons of blast media to clean one mile of pipeline.

Glass Advantage is currently processing approximately 600 tons/month (7,200 tons/year) of mixed cullet. At these amounts they’re at about 55% capacity and could take in another 500 tons/month (6,000 tons/year) if cullet were available.

Like Raguse Manufacturing, they do not require cullet to be color separated but it should be as free as possible of contaminants such as plastics, paper, metals, and ceramics. Minimal amounts of contamination are acceptable but no detailed specifications were available. Aluminum contamination of loads has been a big problem for them and they are considering the addition of an eddy current separator to help capture the aluminum. Also like Raguse, they do not have access to rail and can only accept deliveries of cullet by truck.

They are actively looking for suppliers of cullet and are currently taking glass from several counties in western Minnesota as well as from sources in North Dakota. Payment for cullet can vary depending on the quantities and quality of the materials delivered. According to Mr. Davis this can range from taking the materials for free to paying up to \$23.00 plus per ton. Cullet suppliers, however, must arrange for their own transport and cover the cost of freight.

C. LANDSCAPING, PAVERS, AND TERRAZZO PRODUCTS

Crushed, color-separated glass is finding new life in a variety of landscaping and architectural applications. Among these are use as an attractive ground cover or plant mulch, terrazzo-style tiling (outdoor and indoor), and decorative outdoor planters, benches and even trash containers.



With the greater awareness of incorporating sustainable design into homes, commercial and government buildings, and public plazas the use of products such as these will likely increase in the future. The Leadership in Energy and Environmental Design (LEED) program and similar initiatives are likely to spur on greater use of construction materials containing recycled content such as glass tiles and decorative glass landscaping materials especially in government and commercial buildings.

As a landscaping material, recycled glass must be especially contaminant-free. Loose paper labels or metal caps will stand out in a landscape environment. Sizing is also important in that glass pieces too large will appear “shardy” and irregular in size. Using a 3/8” or smaller glass that can be tumbled to smooth edges will have a much more aesthetically pleasing look and should eliminate any safety concerns for its use.

How the glass is to be used and the characteristics of the glass may also determine the sizing of the material. For example, glass without fines may drain quickly. However, as water retention

may be a desirable characteristic incorporating glass fines (or some other material) into the mix may be a consideration in selecting the physical properties of the glass to be used.

Recycled glass is also finding its way into terrazzo tiles. A number of companies around the country are now making 100% recycled glass terrazzo flooring both in tile form and pour-in-place applications. Additionally, 100% recycled glass terrazzo can be found in a number of exterior landscaping structures including benches and planters. With the use of new technologies and the availability of recycled glass this application has become a cost-effective alternative to marble.

In an article in Retail Construction Magazine⁷, a number of benefits are cited for the use of recycled glass terrazzo. These include:

- Durability (harder than marble);
- Resistance to corrosion, abrasion, bacteria, and chemicals;
- Does not require sealant;
- Maintains a shine without polishing; and
- Low maintenance costs as compared to other flooring such as carpeting, vinyl tile, porcelain tile, ceramic and quarry tile, and cement terrazzo.

The overall floor color is determined by the color of the epoxy and the color of the glass chips mixed in. Manufacturers typically offer a wide range of colors to choose from enabling a custom look of the finished floor.

Though Glass Advantage is looking at developing a business line for clean, tumbled glass to sell as landscaping material at this time they are not aggressively pursuing that market. As for 100% recycled glass terrazzo there is a Wisconsin-based company that makes and sells a product line of tiles, planters, benches and other outdoor furnishings (see below).

1. Wausau Tile

Wausau Tile (Wausau, Wisconsin) was founded in 1953. The company manufactures and sells precast concrete and thermo-coated metal site furnishings, paving products, terrazzo floor tiles, and architectural specialties. One of their product lines offers a wide variety of tiles (indoor and outdoor) and site furnishing made from 100% recycled glass. Table 3.4 summarizes key characteristics of Wausau Tile as a cullet market.

According to Rodney Dombrowski of Wausau Tile, in making their recycled glass terrazzo tiles, Wausau tiles replaces the aggregate with recycled glass in their molds. They are currently using approximately 300 to 360 tons/year of cullet. There is no specific limit as to how much glass they can take but it does depend on demand for their products. Their recycled glass terrazzo products are gaining in popularity and he expects to see more demand for these products in the future especially with the growing interest in the green building movement and LEED certification.

⁷ Recycled-Glass Terrazzo Flooring Environmentally Friendly Alternative, Tim Whaley, January/February 2006.

Table 3.4
Wausau Tile

Location	Wausau, WI	Cullet Specifications	Color-separated; 3/8" – 1/4" size; free of all contaminants including plastics, paper, metal, ceramics, and other color of glass
Product Manufactured	Glass Tiles, Pavers and Site Furnishings		
2006 Quantities of Cullet Used	300 – 360 tons (25 - 30 tons/month)		
Capacity for Additional Cullet	No specific limit. Depends on demand of product.	Payment for Cullet	Depending on demand and quality of glass supplies anywhere from \$0.25 - \$0.85/lb. (\$500 - \$1,700/ton)
Delivery Method	Truck only.		

The cullet they purchase needs to meet very stringent specifications including being color-separated, sizing of between 3/8" and 1/4", and be virtually free of any non-glass or other color glass contaminants. They have very little tolerance for contamination of any kind.

Meeting that tight of a specification may be difficult but if a supplier can provide a superior product they could be rewarded well for their efforts. Mr. Dumbrowski indicated that depending on demand and assuming the material can meet their specifications they pay between \$0.25 and \$0.85/pound. This translates to \$500 to \$1,700 per ton of delivered cullet.

They do not have access to rail so all deliveries need to be via truck. Mr. Dumbrowski also said that due to their high specifications almost all of the cullet they receive comes from commercial or industrial customers who can provide a homogenous waste glass stream (e.g., manufacturing facility) or a carefully hand-sorted glass stream (e.g., commercial recycled glass route from bars and restaurants or MRFs that use manual labor for sorting and crushing for size-reduction). He is not familiar with optical sorting technology and would need to see any product coming out of an optical sorting facility to be able to judge as to how it would meet their specifications.

D. OTHER LOCAL MARKETS AND USES

Though not specific markets or existing commercial outlets for recycled glass, several other potential avenues for recycling mixed glass are discussed below. A couple of these options are already in use or are being explored by public and private MRF operators.

1. Drainage Media

Recycled glass can be used as a substitute for other types of drainage media (sand, gravel, etc.) in some applications including:

- As an aggregate replacement in septic system drainfields; and
- As an aggregate replacement in landfill gas or leachate collection systems.

According to a newsletter put out by the National Environmental Services Center of the West Virginia University Research Corporation⁸, aggregate used with on-site wastewater treatment systems must be able to be crushed or chipped to meet certain size specifications, yet not contain too many fines. The aggregate should also be reasonably priced and available locally. Effective media should not react chemically with the water or degrade over time.

The newsletter cited a recent study in the state of Washington the primary focus of which was to do a direct comparison between two biological filters (i.e., drainfields) – one using standard sand as the treatment medium and the second using crushed recycled glass. The two filters were installed side-by-side at a private, single-family home that had a history of system failure due to the poorly draining underlying soil and historical high groundwater levels.

One filter was filled with sand and the other filled with glass ground to a similar size. Over a two-year period, the output was analyzed for various biological and chemical values. The minor differences in results were considered insignificant and the researchers concluded that the glass did not perform any better or worse than the sand media. There were, however, several reasons why the researchers preferred the glass including a much higher infiltration capacity and pore space, and the cleanliness of the glass product.

At least one MRF surveyed in Greater Minnesota indicated they were using some of their crushed, mixed glass as drainage media in septic system drainfields.

Another use for crushed glass as drainage or filter media is around leachate collection or gas collection pipes in landfills. The porous nature of the material allows the flow of leachate and/or gas to migrate more easily to the perforated pipes allowing for the collection of these byproducts. At least one solid waste management company in Minnesota has been using crushed, mixed glass coming from their MRF operation in this manner at several landfills they own.

2. Glassphalt

Glassphalt is a type of asphalt where some portion of the aggregate has been replaced with crushed glass. Glassphalt is not a new concept and has been in use for over 30 years as an alternative to conventional hot-mix bituminous asphalt pavement.

Over that time period, a number of glassphalt demonstration projects have been performed around the country including here in Minnesota (Hennepin County). Typically most installations of glassphalt have been designed to meet medium traffic standards, which specify a maximum speed limit of 40 mph. These standards include requirements for stability, flow, voids in mineral aggregate, percentage of air voids in the mix, and unit weight.



⁸ Alternatives to Gravel Drainfields, National Environmental Services Center, West Virginia University Research Corporation, Spring 2005.

The most common applications for glassphalt are as surface pavement for residential streets, secondary roads, parking lots, and trails .

In a report prepared for the Rural Conservation Alliance by Joanne McEntire⁹, at least six states have specifications in place for glassphalt. These include Connecticut, Florida, New Jersey, New York, Pennsylvania, and Virginia.

Glassphalt has its benefits and limitations. Some of the benefits include:

- In some locations, recycled cullet may be a less expensive aggregate than other types of materials including virgin aggregate;
- In a number of locations glassphalt demonstrated to be more durable outlasting the normal 20-year life of standard asphalt mixes;
- Due to the glass content, glassphalt can hold heat longer than conventional asphalt, which could be useful in situations where roadwork is conducted in cold weather;
- Glassphalt surfaces dry faster than traditional paving after rain because the glass particles do not absorb water; and
- Glassphalt surfaces can be more reflective than conventional asphalt improving nighttime road visibility in some areas.

Some of glassphalt's limitations include:

- In some instances when glassphalt is placed and compacted, larger glass particles can align themselves parallel to the road surface, which could result in lower skid resistance than that of conventional asphalt; and
- The smoother surface of the glass can result in a higher stripping level (separation of the asphalt from the aggregate) increasing the potential for premature failure.

3. Glass As Road Aggregate

The use of glass as an aggregate substitute in road construction has been around for at least 15 years with some of the early adapters to this idea being California, Connecticut, New Hampshire, New York, Oregon, and Washington. Here in Minnesota over 15 counties and the Minnesota Department of Transportation (MnDOT) have used crushed glass in road base and many of these entities continue to use this material. Some of the counties that have done such projects include Chippewa, Meeker, Otter Tail, Ramsey, Redwood, Rice, St. Louis, and Stearns.



⁹ Recycled Materials: Substitutes for Mining Products Used in Road Construction, Joanne McEntire, June 2004.

MnDOT has created a specification for recycled aggregates for use in road base (Specification 3138: Aggregate for Surface and Base Course), which includes a new class (Class 7). Some of the specifications outlined for the use of recycled glass as a road construction aggregate are described in Table 3.5.

Table 3.5
Specification for the Use of Reclaimed Glass in Road Construction

Category	Specification
Composition	<p><u>Acceptable Glass Products:</u> Container glass used for consumer food and beverages, beverage drinking glasses, plain ceramic or china dinnerware, building window glass free of any framing material, and other types of glass that can be certified and approved by MnDOT's Office of Environmental Services on an individual source basis.</p> <p><u>Unacceptable Glass Products:</u> Glass from automobiles including windshields, light bulbs, porcelain products, laboratory glass, cathode ray tubes from televisions and computer monitors, hazardous waste as defined in MPCA Rules 7045, and hazardous substances in regulated quantities listed in 40CFR, Table 302.4.</p>
Debris Content & Type	No more than 5% debris by visual inspection. Debris includes any non-glass material such as paper, foil, plastics, metal, corks, wood, food, or other deleterious materials.
Ratio of Reclaimed Glass	Up to 10% by weight reclaimed glass may be mixed with virgin and/or other salvaged/recycled aggregate materials during the crushing operation in the production of the aggregate mixture.
Application	Aggregate in base course mixtures. Cannot be used in aggregate surfacing applications including shoulder surfacing.

The specification also outlines interim storage requirements for reclaimed glass stockpiles as well as certification procedures for reclaimed glass.

Though the road aggregate market is one that could be targeted by a large regional glass beneficiation facility, the Class 7 specifications are relatively easy to meet and may be ideal for smaller public and private MRFs located in Greater Minnesota. Some MRFs are not doing much more than hand-sorting glass to get as contaminant-free a product as possible, and then delivering the material to local aggregate processors for crushing and further screening. Others do an initial crushing of the glass on-site in order to get a more condensed product for transportation to aggregate processors or other markets. For facilities that are interested in size reduction of glass for producing a more uniform product or for reducing transportation costs, Appendix B is a list of equipment vendors that design, manufacture, and/or sell glass crushing equipment for the recycling industry.

As a general rule of thumb, 200 tons of recycled glass will yield roughly a half a mile of road after blending the glass at a 10% mix in road aggregate. Therefore, to use reclaimed glass as road base aggregate could require storing glass for a long time until sufficient quantities are generated, especially in much of Greater Minnesota where some public and private recycling facilities may only generate 200 to 300 tons of glass per year. This could prove a barrier to some

facilities where space for on-site storage may be limited, and the length of time the material needs to be stored may be considered excessive.

On the other hand, crushed glass (maximum 1" particle size) with minimal quantities of non-glass contaminants can compete, both performance and price wise, with other natural and salvaged aggregates. The properties of recycled aggregates, including reclaimed glass, are similar to those of natural aggregates. Reclaimed glass has demonstrated no appreciable environmental impact and have also tested safe for potential harmful contaminants. Additionally, supplementing road base with recycled glass can improve permeability and gradation.

Recycled glass could also play a larger part as an aggregate supplement in future construction projects. In 1998, the Ad Hoc Aggregate Committee for the Aggregate Resources Task Force prepared a report on Minnesota's aggregate resources.¹⁰ According to that report, Minnesota's aggregate resources are declining yet there is increasing demand for aggregate materials. Some of the key findings of the report include:

- Expanding population is driving an increase in consumption of aggregate materials with roughly a 2 to 3% annual growth in the aggregate industry;
- Aggregate is vital to the state's infrastructure (i.e., roads, bridges, dams, airports, public buildings, etc.) and is tied to a high standard of living and quality of life;
- Aggregate inventories are lacking or declining in critical areas of the state (Minneapolis/St. Paul Metropolitan Area, St. Cloud, Rochester, Duluth);
- There is a need to rebuild and repair aging infrastructure, which will require large volumes of aggregate;
- There is a need for new infrastructure in growth corridors such as those surrounding the Minneapolis/St. Paul Metro Area, Rochester, St. Cloud, Duluth, Moorhead, and Mankato; and
- Hauling aggregate longer distances to where it is needed can be costly (A city of 100,000 can expect to pay an additional \$1.3 million for the aggregate it uses in a year for each increase of 10 miles in haul distance).

In February of 2000, the Aggregate Resources Task Force submitted its final report to the Minnesota Legislature.¹¹ There were no significant deviations from the information presented in the Ad Hoc Aggregate Committee's report though it did elaborate on some of the key findings reported above, and discussed some of the environmental and social costs associated with mining aggregates and delivering them to marketplace.

The Aggregate Resources Task Force listed fourteen actions and grouped them into six categories. One of these categories is expanding the use of recycled materials with recommendations related to providing incentives to recycle construction materials and promoting additional sources of recycled aggregate materials. Though the report does not mention recycled glass per se, in talking with several staff members at MnDOT, they did say that reclaimed glass fits well within the category of recycled aggregate and should be promoted.

¹⁰ Minnesota's Aggregate Resources: Road to the 21st Century, Ad Hoc Aggregate Committee for the Aggregate Resources Task Force, November 1998.

¹¹ Final Report to the Minnesota Legislature, Aggregate Resources Task Force, February 1, 2000.

As for a source of revenue, recycled glass meeting the MnDOT specifications are cost-competitive with other aggregates. Pricing on aggregate in road construction will vary from location-to-location within the state. In the metro area crushed aggregate for base course is selling for \$5 to \$7/ton. The price will likely increase as sources for natural aggregate, especially in the metro area, continues to decline.

IV. OPTICAL SORTING TECHNOLOGY REVIEW AND REGIONAL BENEFICIATION FACILITY ASSESSMENT

A. TECHNOLOGY DESCRIPTION AND SYSTEM VENDORS

Optical sorting technologies, in their broadest sense, encompass a variety of scanning technologies including camera, high-resolution laser, x-ray, and near infrared (NIR) sensor technologies. These technologies were first developed for the food processing industry and the seed industry to separate out foreign bodies from bulk food or seed stocks.

Over the last 20 years this technology was adapted to the waste industry. It's been popular throughout Europe in particular where it's used for sorting plastics and glass from other waste stream materials. Over the last 10 to 15 years this technology has moved into the North American market where it has been used primarily for plastics but in more recent years has been applied to the color-separation of glass.

The most common optical scanning technologies utilized in the recycling industry are cameras and NIR sensor technologies. X-ray technologies are sometimes used in combination with one or the other and appear to be best suited for sorting PVC from other plastic resins.

Camera systems use the reflective quality of visible light (0.38 – 0.75 μm) to sort materials by color. If only one single color is to be separated high resolution black and white cameras can be used. Systems that provide multiple color separation require color cameras. Some commercially available systems can now sort a wide variety of colors including very faint translucent color bottles.

NIR sensor technologies can detect a portion of the light spectrum that is invisible to the human eye (0.9 – 2.5 μm). When materials passing under an NIR sensor are exposed to the NIR signals, each resin or type of material absorbs specific wavelengths and transmits others that constitute unique characteristic responses. The advantage of using NIR sensors is that surface contamination such as labels does not affect the efficiency of the sorting process.

The operating principle behind these two types of systems is the same. The materials to be sorted pass through a detection system comprised of cameras and/or NIR sensors. Based on resin type, color, or physical characteristics an ejector is triggered (usually a high-pressure air jet) which precisely targets a specific item and blows it off the conveyor belt into a storage bin or on to another conveyor.

A number of optical sorting vendors can and do combine both technologies into their systems to provide a wider range of sorting capabilities.

In addition to the different types of scanning technologies there are also two general methods for feeding materials to the sorting system – singulated feed systems and mass feed systems. Singulated feed systems require objects to be fed to the sensor one-by-one while mass feed systems allow materials to be spread out in a single-layer fashion over the width of the belt. Mass systems have higher throughputs than singulated systems and generally require less maintenance.

There are approximately seven optical sorting equipment vendors that have made inroads into the North American recycling industry. These companies include:

- Binder+Co (Gleisdorf, Austria)
- Magnetic Separation Systems, Inc. (Nashville, TN)
- National Recovery Technologies, Inc. (Nashville, TN)
- Pellenc Selective Technologies (Pertuis, France)
- S + S Separating & Sorting Technology GmbH (Schönberg, Germany)
- SEA International (Imola, Italy)
- TiTech VisionSort (Oslo, Norway)

All of these vendors have installations of one kind or another operating in the North American market for the separation of plastics or other materials by resin type, material density, or color. At this time, only three of the above vendors have moved into the North American glass processing industry – Binder+Co, Magnetic Separation Systems, Inc., and SEA International.

SEA International, based in Imola, Italy, launched their first prototype of an optical electronic color-sorting machine for rice in 1968. Since that time they developed a variety of other optical sorters for numerous industries including the recycling industry. These latter sorting machines were specifically designed for plastics and glass.

According to a report prepared by Enviro RIS for the City of Ottawa, Québec¹², SEA International signed an exclusive agreement with Count Recycling Systems of Des Moines, IA, to market glass color sorters. SEA glass color sorters have been installed in a number of processing facilities around the country including ones in Maryland, New Jersey, Pennsylvania, and Rhode Island.

Though the machines were quite effective in removing contaminants from the glass stream and color sorting the glass, the abrasiveness of the glass damaged the air jets in the automated sorting process leading to above average levels of maintenance and expertise compared to other glass sorting technologies. These problems, along with issues related to the language barrier and time differences, posed difficulty during times of maintenance and startup. As a result, Count Recycling Systems (who later became associated with CP Manufacturing in California) severed their relationship with SEA. The Enviro RIS report did say, however, that Count Recycling Systems verified that the SEA International glass sorting equipment does work well once it is properly installed with the proper presorts and maintenance personnel.

At this time, SEA International has not developed another exclusive marketing agreement with a U.S. company and no recent installations of their glass color sorting equipment have been made in the U.S.

Binder+Co is internationally active as a mechanical engineering company in processing, environmental, and packaging technology. They are based in Gleisdorf, Austria, and have been involved in glass processing for over 20 years with a number of optical sorting units in operation throughout the world many of which are located in the European Union countries.

¹² Material Recycling Facility Technology Review, Enviro RIS, July 2001.

According to their website the company is the world leader in screening technology for hard-to-screen bulk material and for glass recycling. Their Clarity-PLUS optical sorting units use a camera system that can recognize a wide color spectrum with high resolution. The glass shards are separated according to color in one work step while ceramic, stone, and porcelain (CSP) impurities are removed.

Their company's 2006 annual report, as well as press releases on their website, indicates they have a number of Clarity-PLUS units in operation throughout the U.S. Two of their installations can be found in a Container Recycling Alliance (CRA) facility located in California and the MRF in Westchester County, NY. Another CRA facility in Chicago has recently upgraded their glass processing facility and is installing Binder optical sorting equipment. It also appears they're poised to make further inroads into the U.S. market over the next several years. At this time, one of their biggest disadvantages is that they do not appear to have a U.S. company or sales staff to drive their marketing efforts in this country or, for that matter, to contact to get further information. Based on their lack of a U.S.-based representative and little public information on their U.S. installations no further information was gathered on them.

Magnetic Separation Systems, Inc. (MSS) is by far the most prominent of the mixed-glass optical-sorter vendors in the U.S. marketplace. Based out of Nashville, TN, they were recently acquired by CP Manufacturing and have been manufacturing optical sorting equipment for nearly 30 years. MSS has over 50 of their Glass ColorSort™ units in operation in the U.S., Canada, Japan, Australia, and Europe.

Using high-speed optical detectors and digital signal processing, the sensing array identifies the degree of opacity and true color of each glass particle. The computer also activates and controls the precisely metered compressed air pulse to minimize the amount of glass product loss and carry-over during the ejection process.

MSS's Glass ColorSort™ systems have recently been upgraded from halogen to LED technology to boost accuracy and better highlight color differences. According to company literature the Glass ColorSort™ modules remove ceramic at a rate of 20 tons/hour and color-sorts glass at a rate of 5 tons/hour. Reported removal efficiency is greater than 95%.

B. SIZING AND PROCESS FLOW FOR A REGIONAL BENEFICIATION FACILITY

1. Facility Sizing

As reported in Section II, based on the information collected from four of the larger MRFs operating in the Twin Cities there is approximately 53,000 tons of pre-beneficiated mixed glass generated annually. All of these facilities indicated an interest in bringing their mixed glass to a regional beneficiation facility if the cost was competitive with their current management methods and if certain other conditions are met.

The 53,000 tons of mixed glass does not include the mixed-glass stream coming out of the Eureka Recycling facility since Eureka is moving forward with plans for installing their own glass beneficiation equipment at their facility. This number also doesn't include mixed glass

coming from several smaller recycling facilities located in what is considered the MPCA's Metro Region. However, these facilities are all fairly small operations and their contribution above and beyond the 53,000 tons of mixed glass would be insignificant.

As for Greater Minnesota, approximately one-third (13) of the identified MRFs were contacted to determine estimated quantities of mixed glass and unmarketable colored glass (green) recovered, as well as to find out their interest in bringing these materials to a regional glass beneficiation facility. Many of these Greater Minnesota MRFs were not only the larger ones located in the out-state regions but many were also the facilities that were geographically within a reasonable transportation range of the metro area. These 13 MRFs between them generate approximately 2,800 tons per year of mixed glass.

All but one of the MRFs contacted in Greater Minnesota indicated some interest in bringing mixed glass to a regional beneficiation facility located in the metro area if it was cost-effective to do so. With the smaller amounts of mixed glass generated at these MRFs and the transportation distances involved, this may not be a viable option for many of these facilities.

Assuming a base flow of pre-beneficiated mixed glass coming from metro area MRFs of between 50,000 and 56,000 tons of mixed glass per year, and another 2,000 to 3,000 tons of mixed glass delivered by MRFs in Greater Minnesota, a regional glass beneficiation facility sized for between 52,000 and 59,000 tons per year should be of sufficient capacity to handle the expected quantities of mixed glass.

Based on an operating schedule of 260 days/year, the facility would need the capabilities to process approximately 200 – 230 tons/day or 13 – 15 tons/hour based on a two-shift operation.

2. Facility Configuration and Process Flow Description

To determine the necessary processing equipment, facility configuration and process flow for a stand-alone, regional glass beneficiation facility a series of enquiries and discussions were held with MSS, Inc. MSS, Inc. was chosen for primarily two reasons:

- Their presence and extensive experience with glass processing equipment (especially optical sorters) in the U.S. marketplace; and
- Being a U.S. based company, working with them to determine equipment needs and pricing did not require dealing with major time zone differences or language barriers.

In talking with Felix Hottenstein, U.S. Sales Director for MSS, Inc., several assumptions were put forth regarding the quantity and characteristics of the mixed-glass stream to be processed in a regional facility. These included:

- The annual amount of mixed glass to be processed would likely be in the range of 50,000 to 60,000 tons;
- The glass portion of this mixed-glass stream could range from 75% up to 95% by weight with the non-glass (contaminant) portion of the stream ranging from 5% to 25% by weight;
- Contaminants in the mixed-glass stream would include paper, plastics, metal (ferrous and non-ferrous), ceramics; and other inert materials such as stones and dirt;

- The breakout of glass by color in the delivered mixed-glass stream is assumed to be:
Flint: 61% – 65% Amber: 20% – 22% Green: 15% - 17%
A “worst-case” scenario was put forth by Mr. Hottenstein with regard to the breakout of glass by color. The assumption here is that the flint and amber are at 30% each and green makes up the remaining 40%.
- The primary glass market for the flint recovered is Anchor Glass Container;
- Anchor’s specifications for glass are:
Furnace Ready: Crushed to 5/8"; color-separated; no metals, ceramics, plastics, or paper (bottle labels are acceptable)
Non-Furnace-Ready: Color-separated; minimal tolerance for contaminants
Anchor’s current demand for cullet is primarily flint.
- Other potential markets may not need color-separation of cullet; and
- Two facility scenarios should be considered – one for three-color separation of glass (flint, amber, and green) and one for two-color separation of glass (flint and amber/green mix).

Several additional assumptions were made by Mr. Hottenstein:

- Approximately 15% of the incoming cullet is smaller than 10 mm (~ 3/8");
- Processed flint glass and processed green/amber (gramber) glass will contain no more than 15 grams/ton of CSP (ceramics, stones, porcelain), 3 grams/ton magnetic metals, and 15 grams/ton of non-ferrous metals;
- Processed flint glass will be of 99.7% color purity with < 0.3% dark green or blue; and
- The minimum plant capacity is to be no lower than 15 tons/hour and will be operated on a double-shift basis.

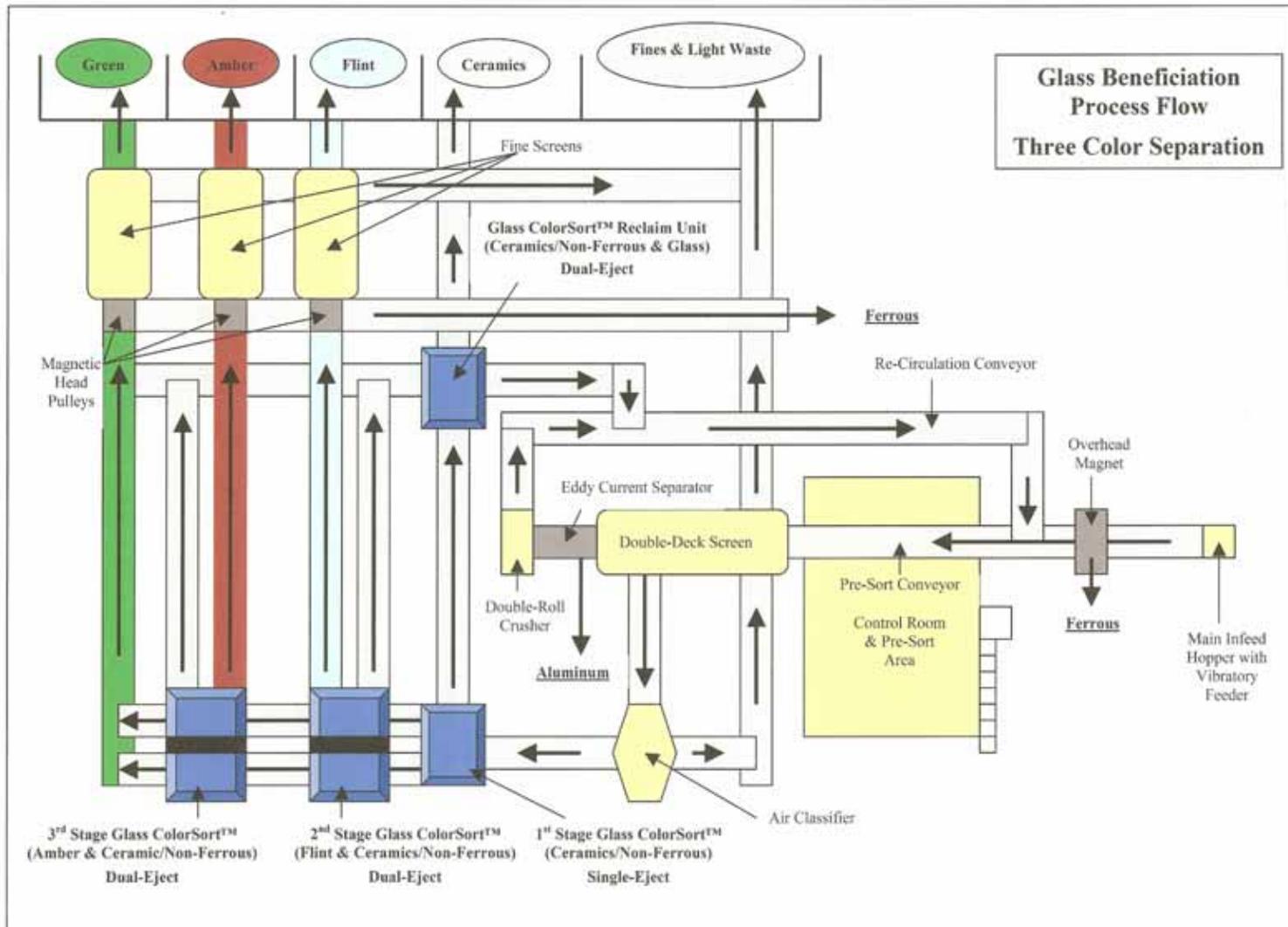
Figure 4.1 shows a conceptual flow diagram for a proposed glass beneficiation facility based on the assumptions above and designed to provide three-color separation. This flow diagram is based on the primary process description and draft drawings submitted by MSS, Inc. The facility layout shown in Figure 4.1 can be broken down into two general processing components – mechanical pre-processing and the optical sorting process line.

Mechanical Pre-Processing System

Mechanical pre-processing starts with the mixed glass being loaded in the main infeed hopper. The infeed hopper can either be fed by a front-end wheel loader or a transfer conveyor. The infeed hopper incorporates a vibratory feeder and inclined conveyor setup to spread the material out as it hits the pre-sort conveyor. This pre-sort conveyor is integrated with a continuous material weighing system to allow for precise metering of the input stream.

Prior to any manual sorting (optional) the material passes under an overhead belt magnet, which removes the majority of the ferrous contamination such as tin cans, lids, caps, wires, etc. Several magnetic head pulleys are also integrated into the incline conveyors throughout the system to pull out ferrous missed by the overhead belt magnet.

Figure 4.1
Glass Beneficiation Facility
Three-Color Separation



The optional pre-sort area is required to allow for manual inspection of the input material to remove large ceramics and other contaminants such as film, trash, and residue. This pre-sort area is a fully enclosed sorting cabin, which can also serve as the main control room for the system. This enclosed sorting cabin/control room will have the necessary environmental controls (HVAC system) to provide a safe and comfortable work environment for staff.

As material flows out of the pre-sort area it empties onto a double-deck screen that generates three output fractions – < 10 mm, 10 – 50 mm, and > 50 mm. The < 10 mm fraction will be transported to a fines bunker via transfer conveyor and not be processed any further. The 10 – 50 mm fraction will be screened out and go on to the air classification unit.

The > 50 mm fraction will fall onto a conventional eddy current separator to remove aluminum cans and other large aluminum pieces. From there, the large glass items fall into a double-roll crusher, which insures that all > 50 mm pieces are crushed completely while generating a minimum amount of fines. Once exiting the crusher, all materials will be re-circulated back via a transfer conveyor (the re-circulation conveyor) and dump out on the pre-sort conveyor for another run through the manual pre-sort area. This is to insure that, for example, any enclosed contamination in the whole bottles can be picked out by the manual pre-sorters.

The air classifier has an integrated vacuum system, which removes light contaminants from the 10 – 50 mm fraction. This light material (i.e., film, foil, paper, dust, etc.) is blown onto the transfer conveyor that empties into the fines bunker. The remaining materials, primarily glass, pass through the air classifier and enter the optical sorting process line.

Optical Sorting Process Line

The MSS Glass ColorSort™ (GCS) sorting module (Model GCS-384) is the unit recommended by MSS for the proposed facility. When operating in the ceramic/metal removal mode, each unit is capable of processing between 15 and 20 tons/hour of glass. When used to sort colors, the units generally work best running at 5 to 6 tons/hour.

In order to achieve the required levels of contaminant removal for ceramics, porcelain, stones and metals, there will be a need for at least three stages of removal for these items. In order to accomplish this, MSS has incorporated upgrades into the equipment proposed for this facility. These include:

- Additional metal detection (ferrous and non-ferrous) capabilities in the standard glass sorting units to allow for greater capture of this material from the glass and improve the quality of the recovered cullet; and
- Dual-eject capabilities in the standard glass sorting units to allow for the separation of more than one type of material in a single pass.

In total, MSS is recommending six (6) GCS sorting modules for this configuration.

The first stage of removal after leaving the air classifier (**1st Stage Glass ColorSort™**) will be used to remove most of the ceramics, stones, porcelain as well as ferrous and non-ferrous metals from the glass. This rejected material will be transported via a transfer conveyor into a Glass Reclaim Unit (described later) where any carried-over glass is recovered and transferred to the re-circulation conveyor described previously. The pass fraction of this 1st ceramic/metal sorter

will be transported via incline conveyor to the first stage of color-separation and 2nd stage of ceramic sorting, referred to in Figure 4.1 as the 2nd Stage Glass ColorSort™.

This 2nd Stage Glass ColorSort™ involves two dual-eject GCS modules working in parallel with one of the ejectors in each unit setup to positively eject flint. The additional ejection is reserved for ceramics/non-ferrous metal, which will be conveyed to the Glass Reclaim Unit. Each unit operates at 5 tons/hour. Gramber glass will come out of the unit as the pass fraction.

The 3rd Stage Glass ColorSort™ consists of another set of two dual-eject GCS modules working in parallel with one of the ejectors in each unit setup to positively eject amber. Again, the additional ejection is reserved for ceramics/non-ferrous metal to be diverted to the Glass Reclaim Unit. Green glass will come out of the unit as the pass fraction.

The ceramics/metal fraction diverted from all three stages of automated sorting will be transferred to the Glass Reclaim Unit. This is a GCS module, which is designed to extract carried-over glass from all the ceramic rejects. The unit is set up to positively eject good glass (all colors). The ceramics, metals and other contaminants are transported via conveyor to the ceramics bunker. The recovered glass is transported back to the main infeed conveyor.

All three colors of glass separated by the GCS units will go through a final screening process prior to being deposited in their respective bunkers. This final screening process involves each of the three cullet streams going through their own fines screen to separate out glass particles less than 10 mm in size. This material is conveyed back to the fines conveyor for disposal purposes. Prior to the fines screen, each glass stream passes under a magnetic head pulley for a final ferrous removal stage.

Figure 4.2 shows a conceptual flow diagram for a proposed glass beneficiation facility based on a two-color separation system – flint and gramber.

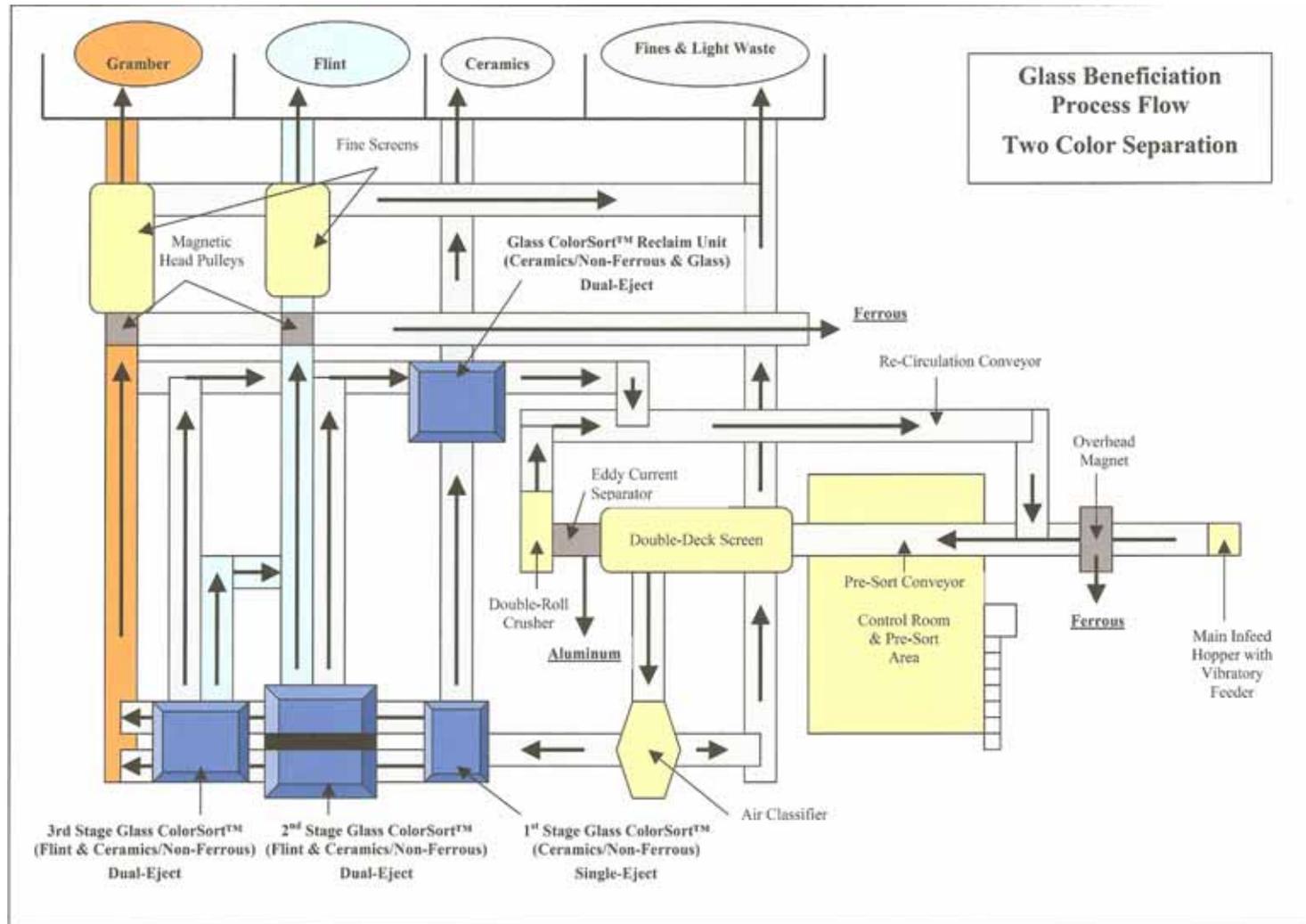
The configuration and process flow for the two-sort configuration is identical to the three-sort scenario until the 3rd Stage Glass ColorSort™ module. Under this configuration the two, dual-eject GCS modules are set to eject ceramics/non-ferrous metals and any carry-over flint that may have been missed previously. The flint is transferred to the flint conveyor from the 2nd stage sorting process while the ceramics/non-ferrous metal is ejected to the conveyor system feeding the Glass Reclaim Unit. Meanwhile, the gramber goes as a pass through material to a conveyor that transports it under a magnetic head pulley and fines screen prior to it emptying out into a bunker dedicated for gramber.

This configuration of equipment allows for the use of five (5) GCS sorting modules and eliminates the need for a third fines screen and a few conveyors.

C. OTHER CAPITAL EQUIPMENT NEEDS

In addition to the processing equipment discussed above, there will be a need for other capital equipment, primarily rolling stock and a truck scale.

Figure 4.2
Glass Beneficiation Facility
Two-Color Separation



For rolling stock it's recommended that the facility have two front-end wheel loaders. These machines would be used for loading mixed glass into the infeed hopper of the processing system, loading roll-off boxes and other vehicles with processed cullet for delivery to market, switching out waste and recyclable dumpsters from various locations within the sorting lines, and other routine site operations activities. The wheel loaders should have solid rubber tires due to the type of materials that they will be handling (e.g., broken glass). Attachments for these machines should include at a minimum a couple different interchangeable buckets (2 yd. to 5 yd. in size) and a set of pallet forks.

A truck scale will also be needed for weighing in deliveries of mixed glass and weighing out loads of different recyclable commodities (i.e., glass product, recyclable metals, etc.). The recommended truck scale would be a pitless model with a concrete deck. Both of these features make for easier maintenance. In addition, a concrete deck, though a bit more expensive, will typically last longer than a steel plated deck. The truck scale should be large enough to accommodate a variety of vehicles (70' x 11') and have a 100-ton rating. It should also be computerized for easier and more efficient weighing of vehicles. Depending on how the overall facility is laid out on the site there may not be a need for a separate scale house. Instead the scaling function could be incorporated into the overall building layout.

D. BUILDING AND SITE NEEDS

The building structure to house the processing system described above needs to be approximately 12,000 ft². Another roughly 10,000 – 12,000 ft² is needed for tipping floor space allowing for up to three days worth of incoming materials storage. Finally, 6,000 – 8,000 ft² will be needed for office space and related operating personnel space (i.e., break room, locker rooms, etc.). All tallied it is estimated that a building of approximately 30,000 ft² will be needed. To accommodate equipment and vehicle dumping requirements, a ceiling clearance height of 34 feet will be needed, at least for that portion of the building housing the tipping floor and processing equipment. The facility should also have at least three loading docks for delivery of supplies and other related uses. Adjacent, outside storage bunkers can be utilized for product storage but should at a minimum have a concrete pad and roofing over the bunkers for protection of marketable product from the elements.

As far as the site itself, it should be relatively flat and approximately five acres in size. This should provide enough space to accommodate an on-site road system, outside storage area, employee/visitor parking, truck/equipment maneuvering room for delivery of incoming loads and supplies as well as the loading out of product, and a perimeter buffer area.

E. FACILITY LOCATION

There are a number of factors that should be considered when determining the location for a regional glass beneficiation facility. Among these are:

- The geographic proximity to glass suppliers;
- The geographic proximity to preferred markets;
- Availability and cost of land/buildings;
- Access to utilities (i.e., water, sewer, etc.);

- Access and proximity to major transportation arterials; and
- Rail access for shipping and receiving.

Some of these variables may compensate for lack of others in a given situation. As an example, if a particular piece of property is farther away from major glass suppliers but the site has the necessary infrastructure (i.e., buildings, on-site road system, utilities, etc.) and costs less than a comparable site closer in to the glass suppliers, it may be a good choice especially if it has an on-site rail spur and the major mixed-glass suppliers have the capabilities for shipping their material by rail. One site that fits this description is located in Olivia, Minnesota, (approximately 100 miles west of Minneapolis) where a gravel company (Gravel Express) is considering developing a regional glass beneficiation facility (with optical sorters) that could serve the needs of that region of the state, and potentially the Twin Cities area.

Another example would be a situation where glass beneficiation equipment (including an optical sorting system) is added on to an existing MRF which then serves as a regional facility for other mixed-glass suppliers in the area. Even if the location itself is not ideal, the potential savings realized from not having to purchase real estate, construct a building from the ground up, and extend utilities, as well as being able to utilize existing processing equipment, may offset any shortcomings the site may have such as an out-of-the-way location or a somewhat longer drive distance.

With these things being said, it's assumed that a regional glass beneficiation facility would likely be located in the Minneapolis/St. Paul Metropolitan Area. Reasons for this include:

- Over 90% of the mixed glass generated by MRFs in Minnesota comes from facilities located in the Minneapolis/St. Paul Metro Area;
- Fuel and trucking expenses being what they are, the costs for delivering the large quantities of mixed glass generated in the metro area outside of the region could be very high;
- Though there are some markets in Greater Minnesota, the major markets and demand for glass are located in the Twin Cities; and
- The small amounts of mixed glass and scattered locations of the MRFs generating this material in Greater Minnesota would likely make it cost-prohibitive to haul the glass any great distance. As an example, it's not likely that mixed glass generated in the northwestern portion of the state would be hauled to a glass beneficiation facility located in the Twin Cities or to a facility located in the southwestern or southeastern portions of the state.

As for locating a glass beneficiation facility in the metro area, transportation distances are such that it should not have a large impact one way or another where in the metro area such a facility would be sited. For purposes of this analysis, the southwest metro was identified as the general geographical location for siting a processing facility. Several reasons for this include:

- The primary market for color-sorted flint cullet, Anchor Glass Container, is located in the southwest metro (Shakopee);
- Anchor glass is already receiving a significant portion of their flint cullet from Minnesota MRFs suggesting that a mixed-glass beneficiation facility located in the southwest metro area would not significantly alter transportation routes for getting glass to market whether it's coming from the metro area or from Greater Minnesota; and

- If alternative markets are developed for glass not going to Anchor, being in or near a major urban hub such as the Twin Cities may make it easier to attract new supplies of mixed glass and ship out finished product to those markets.

Another reason for targeting a location in the southwest metro is the potential availability of industrial sites (with and without buildings). A cursory review was conducted of the industrial real estate market in the southwest metro and as the industrial real estate market goes that portion of the metro area may offer the best potential for finding a site that meets most of the key criteria for an ideal location.

According to Grub & Ellis/Northco Real Estate Services¹³, the Twin Cities industrial real estate market can be broken out into six geographic submarkets.

- Minneapolis
- St. Paul
- Northwest
- Northeast
- Southwest
- Southeast

Within each of these submarkets, industrial properties can be further identified by type of building or structure. Though there are some differences in nomenclature these property types generally fall into three categories – office showroom, bulk warehouse, and office warehouse.

For purposes of this assessment only the latter two of these categories were examined.

An overall assessment of availability for these types of properties within each of the six geographic submarkets can be made based on a couple of related indicators. Comparing total square feet of space within a given submarket/property type with the square feet of space that is currently vacant is known as the *vacancy rate*. The vacancy rate reflects the balance between supply and demand.

The second indicator, *absorption*, measured in square feet, refers to the amount of additional space that becomes occupied during a year. Absorption is a demand side indicator, which signals a strong real estate market. Vacancy rates and absorption are inverse indicators. When one is down the other is up.

According to Welsh Companies¹⁴, in the second quarter of 2006 vacancy rates were declining and absorption rates were rising in all but the southwest submarket. The southwest industrial submarket showed vacancy rates of 19.7% for bulk warehouse space, 9.9% for office warehouse space, and 9.7% for office showroom space. Overall average vacancy rates for industrial properties in the southwest submarket were reported at 11.7% as compared to vacancy rates in the other submarkets ranging from 5.0% to 9.4%.

¹³ Industrial Market Trends Twin Cities: First Quarter 2007, Grubb & Ellis/Northco Real Estate Services.

¹⁴ Industrial Update for Minneapolis/St. Paul, Second Quarter 2006, Welsh Companies.

Another way to look at this is that of approximately 9,585,600 ft² of bulk warehouse, office warehouse, and office showroom vacant space in the Minneapolis/St. Paul Metropolitan Area in mid-2006, approximately one-third of these properties are located in the southwest submarket.

The southwest industrial submarket covers a large area of the southwestern Minneapolis suburban region. A supply analysis of commercial/industrial land performed by Maxfield Research, Inc.¹⁵ in 2006 focused on commercial and industrial properties within Scott County.

According to the supply analysis draft report, as of mid-2006 Scott County had approximately 7,026 acres of industrial-zoned land with 2,143 acres of this being vacant (31%). The amount of industrial-zoned land available in the three largest municipalities in the County (Shakopee, Savage, and Prior Lake), along with their vacancy rates, are shown in Table 4.1

Table 4.1
Industrial-Zoned Acreage in Shakopee, Savage & Prior Lake

Municipality	Industrial-Zoned Acreage	Vacant Industrial Acreage	Vacancy Rate
Shakopee	1,851	233	12.6%
Savage	1,143	18	1.6%
Prior Lake	781	368	47.1%
Total	3,775	619	

Shakopee has the most industrial-zoned land at approximately 1,850 acres with a vacancy rate of approximately 13%. On the other hand, Prior Lake with only about 780 acres of industrial-zoned land has a 47% vacancy rate. For these three cities most of this industrial-zone land is found in the following general geographic locations.

- Shakopee: Between Highway 169 and Highway 101 bounded to the north by Valley Fair amusement park and to the west by Canterbury Downs racetrack.
- Savage: North and south of Highway 13, and east of the intersection with Highway 101. Also, a planned industrial district is sited immediately west of the business park at Eagle Creek Parkway and Highway 13.
- Prior Lake: Around the commercial land use at County Road 21 and the city limits.

All of these locations are within 10 miles of the Anchor Glass Container facility and it's likely that some of these properties have the ability to be rail accessible as the Union Pacific rail line runs through much of this area paralleling Highway 101 in Savage and Shakopee.

Developed industrial properties (properties with buildings and utilities) show some of the same characteristics as industrial-zoned land. In mid-2006 the vacancy rate for industrial space in Scott County was at 58% for bulk warehouse space and 11% for office warehouse space. These are the primary industrial spaces available in Scott County with little to no office showroom space available. Much of this space, whether for lease or for sale, is concentrated in Shakopee. Table 4.2 shows the square footage of developed industrial properties that were being marketed (for lease and sale) as of June 2006 in Shakopee, Savage and Prior Lake.

¹⁵ Commercial/Industrial Land Supply Analysis for Scott County, Minnesota, Maxfield Research, Inc., July 2006.

Table 4.2
Developed Industrial Properties Available In
Shakopee, Savage & Prior Lake (June 2006)

Municipality	Number of Units			Total Square Footage Available
	Bulk Warehouse	Office Warehouse	Office Showroom	
Space For Lease				
Shakopee	12	7	1	2,960,410
Savage	2	2	0	499,863
Prior Lake	0	1	0	3,024
Total	14	10	1	3,463,297
Buildings For Sale				
Shakopee	4	2	0	1,965,698
Savage	0	0	0	0
Prior Lake	8	0	0	32,000
Total	12	2	0	1,997,698

The Maxfield Research, Inc. report also provides an analysis of infrastructure development within Scott County including transportation, sewer and water.

Interstate 35, U.S. Highway 169, State Highways 13, 21, 282, and County Roads 42 and 18 are all primary routes for Scott County businesses and residents and offer commercial and industrial users excellent access. The Bloomington Ferry Bridge makes Highway 169 a viable alternative to Interstate 35W for direct access to the southwestern suburbs and Minneapolis.

As for sewer and water, most if not all of the already developed industrial properties in and around Shakopee, Savage and Prior Lake are on municipal sewer and water lines. It is assumed that much of the undeveloped industrial land within these three communities are within reasonable distances to sewer and water if not currently available at property boundaries.

As for the future extension of sewer and water, short-term development efforts (2007 – 2010) are focused primarily south of Savage and just west of Shakopee and Prior Lake. Sewer and water extension in areas surrounding Belle Plaine, Elko, New Market, and New Prague are not scheduled to occur until 2040 or later.

In summary, as of June 2006:

- Shakopee, Prior Lake, and Savage have the most industrial-zoned land with availability (vacancy rates at 12.6%, 47.1%, and 1.6%, respectively);
- Almost all of the pockets of undeveloped industrial-zoned land in Shakopee, Savage, and Prior Lake are within 10 miles of the Anchor Glass Container plant;
- The greatest availability for leased industrial space can be found in Shakopee (approximately 2,960,000 ft², and Savage, approximately 500,000 ft²);
- Developed industrial properties (land and buildings) for sale are most available in Shakopee with six buildings accounting for nearly 1,966,000 ft²;
- Transportation infrastructure within Scott County is excellent with major transportation routes serving much of the County but in particular Shakopee, Savage, and Prior Lake; and

- Most, if not all, of the industrial-zoned properties (developed and undeveloped) surrounding the communities of Shakopee, Savage, and Prior Lake are on sewer and water currently or will have easy access to these services within the next several years.

V. CAPITAL & OPERATIONAL COST ANALYSIS

The estimated capital and operating costs, as well as potential revenues from marketing recovered glass, are discussed below. Though the cost information presented below is preliminary, some of the estimated costs are harder than others. For example, the vendors providing the processing system and other equipment costs felt confident that the numbers presented are realistic, and in some cases conservative numbers.

On the other hand, real estate costs could vary considerably depending on location, building type and condition, real estate supply and demand, and overall economic conditions. Therefore, costs associated with acquiring property and buildings are a best guess estimate at this time.

Estimated operating costs, as well, are best guess at this point. Again, lots of variables can dictate what these costs are including the complement of staff needed for facility operation, labor costs at the time a facility goes into operation, utility and fuel costs, insurance, transportation costs for getting materials to market, and contracted service costs.

Having said this, the costs below do give some reasonable expectation of what it will take to construct and operate a regional glass beneficiation facility. Should a “bricks and mortar” project begin moving forward it is strongly recommended to firm up these prices as early as possible so that all involved parties have the same expectations.

A. PROCESSING SYSTEM AND OTHER EQUIPMENT COSTS

As discussed in Section IV.B. the processing system is sized for processing up to approximately 60,000 tons per year of a mixed-glass stream coming from MRFs in Minnesota. The mixed-glass stream is primarily pre-beneficiated meaning it still contains a significant amount of contaminants and is not crushed to a uniform size. The overall processing system has two components – a mechanical pre-processing component which removes many of the contaminants (trash, metals, paper and plastic) and crushes the glass to a uniform size, and an optical sorting component, which finishes the process for removal of contaminants and sorts the cullet by color. Additionally, the optical sorting component can be configured two different ways sorting the mixed glass into three-color streams (flint, amber, and green) or two color streams (flint and a amber/green mixture also known as gramber).

The major difference between the two configurations is that in the latter case, there are 5 GCS sorting modules (instead of 6), one less fines screen, and a couple less conveyors. MSS provided an estimated cost for the processing system of between \$3.0 and \$3.5 million for a three-color sort system and between \$2.5 and \$3.0 million for a two-color sort system. This cost is based on a turnkey system installation and covers the design, construction, delivery, installation, and commissioning of the system. The variation in costs for each of the systems is due to the unknowns of building design or renovations, which may require some reconfiguration of the processing system to fit into the footprint of the building. MSS feels comfortable that these cost ranges are realistic. For purposes of this analysis, it is assumed that the estimated cost for a three-sort system and a two-sort system will be \$3.25 million and \$2.75 million, respectively.

Other capital equipment that will be needed for operation of the facility include two wheel loaders and a truck scale. The two wheel loaders priced out for the operation are a CAT 950H and a CAT 914G both with solid rubber tires. Included accessories are a 4.5 yd. bucket, a 2.0 yd. bucket, and a set of pallet forks, which are interchangeable to either machine. The estimated cost provided by Ziegler CAT (Bloomington, MN) for this equipment is approximately \$350,000.

A quote from Kennedy Scales, Inc. (Coon Rapids, MN) was obtained for a pitless, concrete deck (Mettler Toledo) truck scale. This scale has a rating of 100 tons and is 70' L x 11' W. The estimated cost for a turnkey system (including foundation work, installation, and commissioning) is \$60,000.

Both companies (Ziegler CAT and Kennedy Scales, Inc.) were very comfortable with these cost estimates.

Total capital costs for the processing system (three-stream separation and two-stream separation options), two wheel loaders, and a truck scale are estimated at \$3,60,000 and \$3,160,000, respectively. These costs are summarized in Table 5.1.

Table 5.1
Estimated Capital Cost for
Processing System and Other Equipment

Item	Estimated Cost	
	Three-Stream Separation System	Two-Stream Separation System
Processing System	\$3,250,000	\$2,750,000
Wheel Loaders (2)	\$ 350,000	\$ 350,000
Truck Scale	\$ 60,000	\$ 60,000
Total	\$3,660,000	\$3,160,000

B. ESTIMATED LAND AND BUILDING COSTS

In developing preliminary land and building costs, two different options were identified. These include:

- Purchase undeveloped land, construct a building, and extend utilities; and
- Purchase developed property with a building and utilities already in place.

Though another option would be to lease space at an existing industrial complex, this option is not a likely scenario. Finding suitable lease space for a facility of this kind along with the necessary site features (i.e., queuing area, truck scale, building height and configuration, etc.) would be very difficult. Additionally, without control of the property, any site, building or operational modifications would need to have approval from the property owner and this could hinder the overall operations of the facility.

Table 5.2 shows the estimated land and building costs of a facility if an undeveloped industrial site is purchased requiring construction of a building (Greenfield development). The site is assumed to be located in northern Scott County in the Shakopee/Savage/Prior Lake area. The

cost for extending utilities is too site specific and is therefore not included in the capital cost estimate below.

Table 5.2
Estimated Capital Cost for a Regional
Glass Beneficiation Facility (Greenfield Development)

Item	Estimated Cost
Land	\$1,250,000
Building	\$1,650,000
Land and Building Total	\$2,900,000

The numbers above are based on the following assumptions:

- Facility to be located in the Shakopee/Savage/Prior Lake area.
- Total acreage is estimated at 5 acres at a cost per acre of \$250,000. Property is undeveloped and zoned for industrial.
- Building to be constructed is a 30,000 ft², pre-engineered steel structure with a 34' clear height. Construction cost is estimated at \$55/ft². Any significant extension of utilities (electric, water, sewer) is not included in the construction cost.

As can be seen in Table 5.2, the estimated cost for a Greenfield development (land and building) is approximately \$2,900,000.

Table 5.3 shows the estimated land and building costs if a developed industrial property is purchased (existing building and on-site utilities already in place). The property is assumed to be located in northern Scott County in the Shakopee/Savage/Prior Lake area and meets most, if not all, the acreage and building requirements of the operation. Other on-site infrastructure (roads, parking area, delivery and load-out areas, site lighting, etc.) is assumed to be in place with only minor site work required.

Table 5.3
Estimated Capital Cost for a Regional
Glass Beneficiation Facility (Existing Site and Building)

Item	Estimated Cost
Building & Land	\$2,100,000
Minor Building & Site Modifications (estimate)	\$ 250,000
Land/Building Total	\$2,350,000

The numbers above are based on the following assumptions:

- Facility to be located in the Shakopee/Savage/Prior Lake area.
- Total acreage is estimated at 5 acres. Estimated cost of a building on up to 3 acres of land is \$2.1 million. Additional 2 acres cost approximately \$250,000/acre. On-site utilities already in place as well as on-site roads and parking area.
- Existing building is approximately 30,000 ft² with a clear height of 34'.
- Only minor modifications need to be made to site and building to accommodate the processing system and shipping/receiving functions.

As can be seen in Table 5.3, the estimated land and building cost, assuming a suitable developed industrial property (building, utilities, other on-site infrastructure) can be located and purchased, is approximately \$2,350,000.

Putting the costs from Tables 5.1, 5.2, and 5.3 together, there are essentially four variations for total capital and real estate costs for a regional glass beneficiation facility. These are summarized in Table 5.4 and range from approximately \$5.5 to \$6.6 million, depending on the scenario pursued.

Table 5.4
Total Estimated Capital and Real Estate Costs
for a Regional Glass Beneficiation Facility

Facility Development Scenario	Estimated Cost			
	Processing System	Other Equipment	Land & Building	Total
Greenfield Development With Three-Stream Separation	\$3,250,000	\$410,000	\$2,900,000	\$6,560,000
Greenfield Development With Two-Stream Separation	\$2,750,000	\$410,000	\$2,900,000	\$6,060,000
Existing Site and Building With Three-Stream Separation	\$3,250,000	\$410,000	\$2,350,000	\$6,010,000
Existing Site and Building With Two-Stream Separation	\$2,750,000	\$410,000	\$2,350,000	\$5,510,000

It should be stressed again that the cost numbers presented in Tables 5.2 and 5.3 are preliminary numbers and will need some refinement. These real estate costs (land and buildings) are prone to variability one way or another. This cost variation could be significant as the land/building costs, as presented in Table 5.4 represent between 39% and 48% of the estimated total capital cost. As the numbers above indicate the purchase of an already existing property/building of the appropriate size and configuration will likely be the less costly option.

Furthermore, should an existing MRF or glass market incorporate beneficiation/optical sorting equipment into their existing operation, much like Eureka Recycling is doing, the overall capital costs would come down significantly since the land and at least some of the building/equipment would already be in place.

C. ESTIMATED FACILITY OPERATING COSTS

Though many MRFs, public and private, have added optical sorting systems to their existing operations, there are a relatively few examples of dedicated glass beneficiation facilities to look to for obtaining hard annual operating costs. Most, if not all, of these facilities are privately owned facilities and they are reluctant to share what those costs are.

Adding to the difficulty in obtaining hard numbers are the variations in processing capacity, the complement of equipment for processing the glass, staff complement and regional differences in wages, the amount and cost of fuel and energy used for facility operations, equipment maintenance, and regional differences in the cost of energy. Therefore, the annual operating

costs presented below is a preliminary estimate and it is recommended that should a project be pursued a refinement of these costs should be prepared.

It is assumed that the facility will operate 16 hours/day, 5 days/week, 52 weeks/year. Table 5.3 shows a proposed staff complement for operating the facility. There are obviously other ways to structure the personnel for facility operation (addition/deletion of positions and more/less staff within a position category) but for purposes of determining and estimating annual operating costs the staff complement shown in Table 5.5 is a reasonable assumption.

Table 5.5
Facility Staff Complement

Position	Shift 1	Shift 2	Total
Facility Manager	1	0	1
Clerical Support	1	0	1
Shift Supervisor	1	1	2
Scale Operator	1	0	1
Laborers	2	2	4
Mechanics	1	1	2
Loader Operators	2	2	4
Total	9	5	14

Based on the complement provided above a total of 14 individuals would be needed for overall facility management. The staff-count for actually running the glass beneficiation facility (processing line and loading materials into the line) is estimated at four (4) per shift. This would include one loader operator for feeding the line, the shift supervisor who would monitor the system and adjust the processing equipment as needed for maintaining a trouble-free flow/processing of materials, and two laborers. Both laborers could work the pre-sort line or, as an alternative, one laborer would work the pre-sort line and the other would perform general maintenance and custodial services around the facility.

Table 5.6 shows the estimated annual operating costs for the facility. Again, this is a preliminary estimate and the numbers will need to be refined if a decision to move forward with a project is made.

Based on estimated wages for the positions above, including a 33% benefit multiplier, the total personnel cost (labor/administrative/management) is estimated at approximately \$950,000/year.

Beyond the cost of labor there are a number of other costs associated with operation of the glass beneficiation facility. These costs include:

- Equipment maintenance/spare parts;
- Wheel loader maintenance/repair/fuel;
- Utilities (electricity, water, sewer, heat);
- Office equipment/supplies;
- Insurance;
- Building/site/scale maintenance; and
- Contract services (residue/waste disposal, trucking, specialized maintenance, etc.).

Table 5.6
Estimated Annual Operating Costs

Item/Description	Estimated Annual Cost
Labor/Staffing (includes benefits)	\$ 950,000
Equipment Maintenance/Spare Parts	\$ 100,000
Wheel Loader Maintenance/Repair/Fuel	\$ 90,000
Utilities	\$ 100,000
Office Equipment/Supplies	\$ 25,000
Insurance	\$ 35,000
Building/Site/Scale Maintenance	\$ 25,000
Contract Services (i.e., waste disposal, transportation, specialized services, etc.)	\$ 125,000
Subtotal	\$1,450,000
Contingency (10% of non-labor costs)	\$ 50,000
Total	\$1,500,000

In talking with MSS, Inc., they typically estimate equipment maintenance/spare parts at 3% of total capital investment (processing equipment). Based on a processing system capital cost of \$3,250,000 this equates to approximately \$100,000 annually.

Based on discussions with a local heavy equipment dealership, as well as looking at the current price of fuel, it is estimated that annual costs for maintenance and operation of the wheel loaders will be approximately \$90,000 annually.

Other annual operating costs were estimated at approximately \$310,000 for an estimated annual operating cost of \$1,450,000. A 10% contingency was calculated on non-labor operating costs bringing the estimated total annual operating cost to approximately \$1,500,000.

D. ESTIMATED ANNUAL REVENUES

In Section III, a variety of glass markets were discussed. Generally speaking, glass is a low value recyclable material. However, in some markets it can demand a high price and there is no doubt that the overall energy and environmental savings associated with recycling glass, especially in a bottle-to-bottle application, has high value (see discussion under Glass Container Manufacturing in Section III). Perhaps the largest roadblock in getting a strong commodity price for recovered cullet is in the fact that once mixed together with other materials and other colors of glass, separating the container glass back out into a pure stream is very difficult. If this can be successfully accomplished there are markets available that offer strong pricing for this commodity.

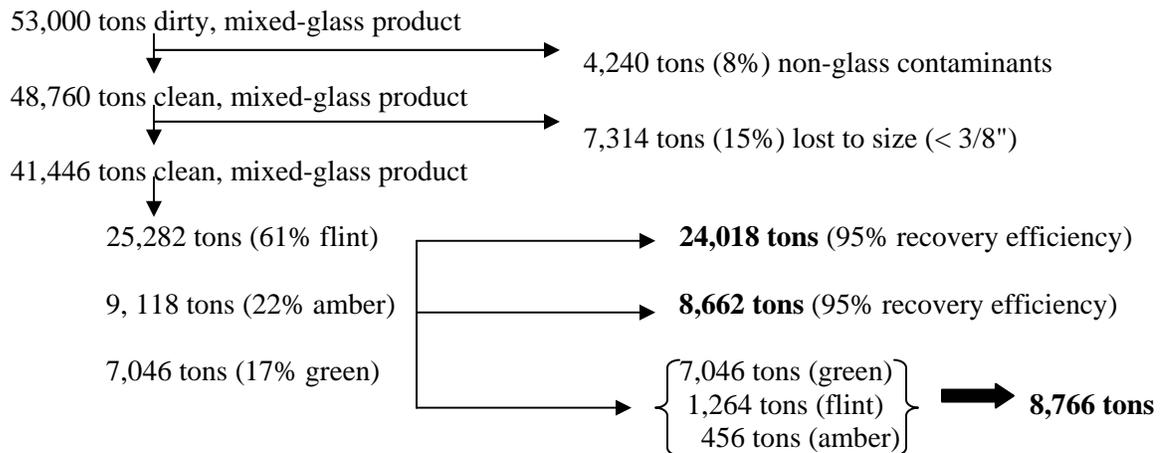
Currently, there are two local markets for recovered container glass that appear locally viable for the near future – Anchor Glass Container for flint and amber cullet, and the road aggregate market for green cullet and mixed glass. The terrazzo tile market (Wausau Tile) may be another market to research further but it is unclear at this time if the recovered glass product coming from a regional beneficiation facility would meet the strict purity specifications for this market.

For purposes of this analysis, the market scenarios being considered are recovered flint and amber cullet going to Anchor and a green or mixed-glass product being sold as construction aggregate. Additionally, three revenue scenarios are laid out – a low revenue scenario, a medium revenue scenario, and a high revenue scenario. General assumptions and pricing assumptions for these scenarios are presented below.

General Assumptions

- The base quantity of pre-beneficiated mixed glass delivered to the beneficiation facility is approximately 53,000 tons annually.
- The amount of non-container glass contaminants in the quantities delivered is approximately 8% on a weighted average basis.
- Approximately 15% of the incoming cullet is smaller than 10 mm (3/8") and is non-recoverable.
- The color mix of the recovered glass mimics the metro area breakout as reported in the most recent waste characterization study – 61% flint, 22% amber, and 17% green.
- The recovery efficiency for flint and amber cullet is approximately 95% for each color. Approximately 5% of the sorted flint and amber cullet ends up in the green cullet stream in a three-sort system and 5% of the flint ends up in the gramber stream in a two-sort system.

These general assumptions can be summarized in the following mass balance diagram.



Pricing Assumptions

- Low Revenue Scenario
 - o Three Sort Facility: Flint cullet sold to Anchor at \$45/ton; amber cullet and green cullet sold as construction aggregate at \$6/ton.
 - o Two Sort Facility: Flint cullet sold to Anchor at \$45/ton; mixed cullet (gramber) sold as construction aggregate at \$6/ton.
- Medium Revenue Scenario
 - o Three Sort Facility: Flint cullet sold to Anchor at \$55/ton; amber cullet sold to Anchor at \$5/ton, and green cullet sold as construction aggregate at \$6/ton.
 - o Two Sort Facility: Flint cullet sold to Anchor at \$55/ton; mixed cullet (gramber) sold as construction aggregate at \$6/ton.

- High Revenue Scenario
 - o Three Sort Facility: Flint cullet sold to Anchor at \$65/ton; amber cullet sold to Anchor at \$10/ton, and green cullet sold as construction aggregate at \$6/ton.
 - o Two Sort Facility: Flint cullet sold to Anchor at \$65/ton; mixed cullet (gramber) sold as construction aggregate at \$6/ton.

Based on these assumptions, the estimated annual revenue from the sale of recovered cullet is shown in Table 5.7.

**Table 5.7
Estimated Revenue From the Sale of Recovered Cullet¹**

System Configuration	Commodity Type	Annual Tons Marketed	Market	Estimated Annual Sales Revenues		
				Low Revenue	Medium Revenue	High Revenue
Three Sort Facility	Flint Cullet	24,018	Anchor Glass	\$1,080,800	\$1,321,000	\$1,561,200
	Amber Cullet	8,662	Anchor Glass	Included Below ²	\$ 43,300	\$ 86,600
	Green & Mixed Cullet	8,766	Construction Aggregate	\$ 104,600	\$ 52,600	\$ 52,600
	Total	41,446		\$1,185,400	\$1,416,900	\$1,700,400
Two Sort Facility	Flint Cullet	24,018	Anchor Glass	\$1,080,800	\$1,321,000	\$1,561,200
	Mixed Cullet (incl. amber)	17,428	Construction Aggregate	\$ 104,600	\$ 104,600	\$ 104,600
	Total	41,446		\$1,185,400	\$1,425,600	\$1,665,800

¹ Numbers rounded to the nearest hundred.

² Under the low revenue scenario amber cullet is sold as construction aggregate for \$6/ton.

There may be opportunities for greater annual revenue under certain conditions. These include:

- Anchor Glass Container begins paying higher prices for separated amber and green cullet;
- Wausau Tile specifications for color-sorted cullet can be met, and their demand for this material increases, resulting in a price of \$500 plus for pure amber and/or green cullet; or
- Anchor Glass Container specifications for furnace-ready cullet can be met fetching a price of \$90 - \$120/ton for flint.

This latter opportunity is unlikely at this time for several reasons.

The specifications for furnace-ready cullet require the material to be free of contaminants, or at least contain only minimal amounts of contaminants, and meet a size requirement of no less than 5/8" in particle size. This sizing is necessary since wet cullet less than 5/8" has a tendency to bind and harden creating issues with material flow in the handling and firing of the glass.

A glass beneficiation facility with optical sorting capabilities should be able to produce a cullet product that is by and large contaminant free. Going to a larger particle size, however, will result in a lower overall capture rate of cullet for recycling since more material will end up in the fines. According to MSS, this could result in the amount of fines increasing from 15% to 30% or more. Adding more sorting modules and screens for additional capture of material is possible but would add significantly to the capital cost. Additionally, based on the interviews with the metro area MRFs, of the 53,000 tons of potentially available pre-beneficiated mixed glass, over 60% of

this material is estimated to be less than 5/8" in size representing a significant loss of recoverable glass that wouldn't meet the furnace-ready cullet size specifications.

In short, though the facility could be designed and configured to recover cullet meeting the furnace-ready specifications, the additional capital cost for processing equipment, as well as the lower recovery rates anticipated for meeting this spec, are unlikely to be offset by the higher revenue stream received for this material.

E. PRELIMINARY FINANCIAL FEASIBILITY AND ESTIMATED TIPPING FEES

To determine the preliminary financial feasibility of constructing and operating a regional glass beneficiation facility a number of components need to be considered, most of which have been discussed previously. These include the capital cost of the facility (equipment, land and building), annual operating costs, and annual revenue from the sale of recovered cullet. To simplify the analysis it is assumed that an existing property/building of the appropriate size and configuration is acquired versus developing a Greenfield facility.

Tables 5.8 thru 5.10 show the overall annualized cost of operation for two facility scenarios – a facility designed to optically sort glass into three color streams (flint, amber and green) and a facility designed to optically sort glass into just two streams – flint and gramber.

For purposes of the examples presented in these tables the assumptions are:

- The facility is publicly owned and financed; and
- The facility is financed through revenue bonds with a 5% interest rate.

Each of the tables depicts a different revenue scenario showing low, medium, and high revenue from the sale of cullet and how that impacts estimated tipping fees.

**Table 5.8
Glass Beneficiation Facility Cost Analysis
Public Ownership (Low Revenue Scenario)¹**

Annual Cost Breakdown		Three Sort Facility²	Two Sort Facility²
	Debt Service	\$ 662,600	\$ 597,800
	Operating Costs	\$1,500,000	\$1,500,000
Total Cost of Operation		\$2,162,600	\$2,097,800
Annual Revenue From Sale of Cullet			
	Anchor Glass Container	\$1,080,800	\$1,080,800
	Construction Aggregate	\$ 104,600	\$ 104,600
Total Revenue from Sale of Cullet		\$1,185,400	\$1,185,400
Cost of Operation Less Cullet Revenues		\$ 977,200	\$ 912,400
Per Ton Tipping Fee Needed		\$18.44/ton	\$17.22/ton

¹ Flint sold to Anchor Glass Container for \$45/ton; other glass sold as construction aggregate for \$6/ton.

² Numbers rounded to the nearest hundred.

Table 5.9
Glass Beneficiation Facility Cost Analysis
Public Ownership (Medium Revenue Scenario)¹

Annual Cost Breakdown		Three Sort Facility²	Two Sort Facility²
	Debt Service	\$ 662,600	\$ 597,800
	Operating Costs	\$1,500,000	\$1,500,000
Total Cost of Operation		\$2,162,600	\$2,097,800
Annual Revenue From Sale of Cullet			
	Anchor Glass Container	\$1,364,300	\$1,321,000
	Construction Aggregate	\$ 52,600	\$ 104,600
Total Revenue from Sale of Cullet		\$1,416,900	\$1,425,600
Cost of Operation Less Cullet Revenues		\$ 745,700	\$ 672,200
Per Ton Tipping Fee Needed		\$14.07/ton	\$12.68/ton

¹ Flint sold to Anchor Glass Container for \$55/ton; Amber sold to Anchor Glass Container for \$5/ton; other glass sold as construction aggregate for \$6/ton.

² Numbers rounded to the nearest hundred.

Table 5.10
Glass Beneficiation Facility Cost Analysis
Public Ownership (High Revenue Scenario)¹

Annual Cost Breakdown		Three Sort Facility²	Two Sort Facility²
	Debt Service	\$ 662,600	\$ 597,800
	Operating Costs	\$1,500,000	\$1,500,000
Total Cost of Operation		\$2,162,600	\$2,097,800
Annual Revenue From Sale of Cullet			
	Anchor Glass Container	\$1,647,800	\$1,561,200
	Construction Aggregate	\$ 52,600	\$ 104,600
Total Revenue from Sale of Cullet		\$1,700,400	\$1,665,800
Cost of Operation Less Cullet Revenues		\$ 462,200	\$ 432,000
Per Ton Tipping Fee Needed		\$8.72/ton	\$8.15/ton

¹ Flint sold to Anchor Glass Container for \$65/ton; amber sold to Anchor Glass Container for \$10/ton; other glass sold as construction aggregate for \$6/ton.

² Numbers rounded to the nearest hundred.

Under the scenarios presented in Tables 5.8 thru 5.10 the estimated tipping fee ranges from approximately \$8.00/ton to \$18.50/ton.

Tables 5.11 thru 5.13 are similar to the previous tables in that they compare the cost of a three sort facility with a two sort facility under the three scenarios of low, medium and high revenue streams. The difference in these tables is that the facility would be a privately owned/operated facility. The assumptions in this table are:

- Private financing is used for construction of the facility with an interest rate of 7.5%; and
- A 20% profit margin is built into the annualized operating costs minus the revenue from the sale of materials.

Table 5.11
Glass Beneficiation Facility Cost Analysis
Private Ownership (Low Revenue Scenario)¹

Annual Cost Breakdown		Three Sort Facility²	Two Sort Facility²
	Debt Service	\$ 763,700	\$ 690,900
	Operating Costs	\$1,500,000	\$1,500,000
Total Cost of Operation		\$2,263,700	\$2,190,900
Annual Revenue From Sale of Cullet			
	Anchor Glass Container	\$1,080,800	\$1,080,000
	Construction Aggregate	\$ 104,600	\$ 104,600
Total Revenue from Sale of Cullet		\$1,185,400	\$1,185,400
Cost of Operation Less Cullet Revenues		\$1,078,300	\$1,005,500
Profit Margin Markup (20%)		\$ 215,700	\$ 201,100
(Cost of Operation – Cullet Revenues) + Markup		\$1,294,000	\$1,206,600
Per Ton Tipping Fee Needed		\$24.42/ton	\$22.77/ton

¹ Flint sold to Anchor Glass Container for \$45/ton; other glass sold as construction aggregate for \$6/ton.

² Numbers rounded to the nearest hundred.

Table 5.12
Glass Beneficiation Facility Cost Analysis
Private Ownership (Medium Revenue Scenario)¹

Annual Cost Breakdown		Three Sort Facility²	Two Sort Facility²
	Debt Service	\$ 763,700	\$ 690,900
	Operating Costs	\$1,500,000	\$1,500,000
Total Cost of Operation		\$2,263,700	\$2,190,900
Annual Revenue From Sale of Cullet			
	Anchor Glass Container	\$1,364,300	\$1,321,000
	Construction Aggregate	\$ 52,600	\$ 104,600
Total Revenue from Sale of Cullet		\$1,416,900	\$1,425,600
Cost of Operation Less Cullet Revenues		\$ 846,800	\$ 765,300
Profit Margin Markup (20%)		\$ 169,400	\$ 153,100
(Cost of Operation – Cullet Revenues) + Markup		\$1,016,200	\$ 918,400
Per Ton Tipping Fee Needed		\$19.17/ton	\$17.33/ton

¹ Flint sold to Anchor Glass Container for \$55/ton; amber sold to Anchor Glass Container for \$5/ton; other glass sold as construction aggregate for \$6/ton.

² Numbers rounded to the nearest hundred.

Table 5.13
Glass Beneficiation Facility Cost Analysis
Private Ownership (High Revenue Scenario)¹

Annual Cost Breakdown		Three Sort Facility²	Two Sort Facility²
	Debt Service	\$ 763,700	\$ 690,900
	Operating Costs	\$1,500,000	\$1,500,000
Total Cost of Operation		\$2,263,700	\$2,190,900
Annual Revenue From Sale of Cullet			
	Anchor Glass Container	\$1,647,800	\$1,561,200
	Construction Aggregate	\$ 52,600	\$ 104,600
Total Revenue from Sale of Cullet		\$1,700,400	\$1,665,800
Cost of Operation Less Cullet Revenues		\$ 563,300	\$ 525,100
Profit Margin Markup (20%)		\$ 112,700	\$ 105,000
(Cost of Operation – Cullet Revenues) + Markup		\$ 676,000	\$ 630,100
Per Ton Tipping Fee Needed		\$12.75/ton	\$11.89/ton

¹ Flint sold to Anchor Glass Container for \$65/ton; amber sold to Anchor Glass Container for \$10/ton; other glass sold as construction aggregate for \$6/ton.

² Numbers rounded to the nearest hundred.

Under the scenarios presented in Tables 5.11 thru 5.13 the estimated tipping fee ranges from approximately \$12.00/ton to \$24.50/ton.

In summary, there are a number of ways to distinguish between and assess the assumptions and various cost scenarios presented in this section. Three of the major factors, however, are the sources of mixed glass delivered to the facility (metro area versus Greater Minnesota), ownership/operations of the facility (public versus private), and three-color separation versus two-color separation.

As noted in the assumptions, the base quantity of pre-beneficiated mixed glass delivered to the facility is approximately 53,000 tons. This assumption is based on most, if not all, of this mixed glass being generated in the Minneapolis/St. Paul Metropolitan Area. It is estimated that over 90% of the mixed glass generated statewide comes from the metro area.

Though a few of the Greater Minnesota MRFs contacted for this study are stockpiling green or mixed glass, most have found outlets for this material. In some cases these MRFs are paying for transportation to their respective markets and giving the material away for free, while in other cases they are receiving enough revenue to cover the cost of transportation. None of the MRFs are paying transportation costs and tipping fees. As a result, it's not likely that they would be willing to transport their mixed glass to a beneficiation facility in the metro area and pay a tipping fee to have their material processed.

In addition, in those areas where MRFs are stockpiling their glass there may be more cost-effective methods for managing and recycling the mixed glass than to send it to a regional glass beneficiation facility. This is especially true in portions of Greater Minnesota that are farther away from the Twin Cities marketplace.

Table 5.14 shows a comparative range of estimated tipping fees for ownership options (publicly versus private) and color separation options (three color sort versus two color sort). Public ownership would likely result in an overall lower tipping fee. This is based primarily on the lower interest rate financing options available to public entities as well as the assumption that a public facility would need to cover its overall cost but would not need to generate a profit.

Table 5.14
Tipping Fee Range Comparison For Ownership
Options and Color Separation Options¹

Type of Facility	Public Ownership	Private Ownership
Three-Color Separation	\$9 to \$18/ton	\$13 to \$24/ton
Two-Color Separation	\$8 to \$17/ton	\$12 to \$23/ton

¹ Tipping fees are rounded to the nearest dollar.

A privately financed facility, on the other hand, would likely have a higher interest rate on the borrowed money that would be needed to develop the facility. Through state or federal programs, there may be an opportunity to obtain a low-interest loan, which could lower the debt burden. Even so, unlike a governmental body, a private company or group of investors would need to see a profit on their investment.

As for the cost difference between a facility designed for two-color separation versus three-color separation, the overall estimated tipping fee for the latter type of facility is approximately \$1/ton higher cost. Depending on whether the facility is publicly owned versus privately owned, and across the three different levels of revenue scenarios, the average additional cost runs about \$1.22 per ton for the three-color separation system. The additional benefit in choosing the three-color separation is the flexibility available if and when market conditions change.

Based on the cost analysis, it appears that developing a regional glass beneficiation facility could be a cost-effective means for processing and marketing the mixed glass generated at Twin City MRFs and, perhaps, at some of the Greater Minnesota MRFs that may be in a closer proximity to the Minneapolis/St. Paul Metropolitan Area. A publicly owned facility would likely result in a lower overall tipping fee though at this time there appears to be no interest from the public sector in developing such a facility. Though a simpler two-color separation facility would result in an overall lower capital cost the difference in the estimated tipping fee between a two-color processing system and a three-color processing system would likely be less than \$1.50/ton. The flexibility and adaptability a three-color separation facility has when short-term or long-term markets change may be worth the added investment.

VI. CONCLUSIONS AND RECOMMENDATIONS

In the Introduction it was stated that the primary objectives of this current study were to:

- 1) Determine the preliminary technical and economic feasibility of developing a regional glass beneficiation facility for mechanically removing contaminants from a mixed stream of glass and color separating the glass using optical sorting technology.
- 2) Research alternative regional markets for clean cullet (mixed or color-separated) in order to provide a broader range of options for recycling the glass processed at MRFs around the state; and
- 3) Assist MPCA staff in meeting with and establishing a dialog with potential project partners including Anchor Glass Container, other market outlets, MRF representatives, equipment vendors, and other third party entities (public and private) regarding the development and operation of a regional glass beneficiation facility.

A variety of data was collected, technology and markets researched, and cost analyses performed in conducting this study. For the first two objectives a number of conclusions have come out of the overall feasibility analysis many of which drive the recommendations. As for the third objective, a number of parties have been engaged in dialog over the course of the study and that dialog should be continued and broadened. This dialog will play an important role in resolving the marketability of recycled glass on a regional and statewide level.

A. CONCLUSIONS

The significant conclusions drawn from this study include the following:

- Over 90% of the mixed glass suitable for further beneficiation and optical sorting is generated in the Minneapolis/St. Paul Metro Area. This includes container glass that was originally generated in portions of Greater Minnesota but was delivered to metro area MRFs for processing. This pre-beneficiated, mixed-glass stream amounts to approximately 53,000 tons per year.
- Based on estimated contamination levels, processing loss due to particle size, optical sorter operational efficiencies, and an assumed breakout of glass into the three colors of flint, amber and green, this 53,000 tons would yield approximately:
 - o 24,018 tons of flint cullet;
 - o 8,662 tons of amber cullet; and
 - o 8,766 tons of predominantly (80%) green cullet.
- Cullet can be used at levels as high as 80% in the manufacturing of new glass containers. For every 10% of cullet used in the manufacturing process there is:
 - o A 6^o C drop in furnace temperature allowing a furnace to be operated at a lower temperature resulting in prolonged furnace life;
 - o Up to a 3% reduction in fossil fuels leading to a 3% reduction in CO₂ emissions;
 - o A 6% reduction in NO_x emissions; and
 - o A 17% reduction in CO₂ emissions associated with raw material conversion.
- Due to the high capital and operating costs associated with a regional glass beneficiation facility it should be located close to major suppliers of mixed glass, major glass markets, and

a well-developed transportation network. By these standards the most logical location for a facility would be in the metro area.

- Due to the longer haul distances and smaller quantities of mixed glass generated in Greater Minnesota, in most cases sending glass to a regional glass beneficiation facility located in the metro area will not be a cost-effective alternative for Greater Minnesota MRFs. Utilizing other localized markets and developing beneficial uses for mixed glass coming from these facilities will likely be more cost-effective and could be environmentally beneficial as well depending on the use of the glass.
- Anchor Glass Container (Shakopee, MN) is the major glass market in the state. Other more regionalized glass markets and uses that could be utilized by Greater Minnesota MRFs include:
 - Glass Advantage (West Fargo, ND)
 - Raguse Manufacturing (Wheaton, MN)
 - Construction aggregate (localized)
- The most likely near term glass markets for a regional glass beneficiation facility located in the metro area would be Anchor Glass Container (flint and possibly amber) and for use as a road aggregate supplement (green and/or gramber).
- A regional glass beneficiation facility sized to process between 50,000 and 60,000 tons per year would require an hourly processing design capacity of 15 tons/hour over a double shift (16 hours/day).
- The glass beneficiation facility would include the following operations:
 - Ferrous recovery units;
 - Pre-sort conveyor;
 - Eddy current separator;
 - Double-roll glass crusher;
 - Air classifier;
 - Five to six optical sorting units; and
 - Various screens and conveyor systems.
- The estimated capital cost for the processing system including the optical sorting units is:
 - \$3.0 to \$3.5 million for a three-color sort system (flint, amber and green); and
 - \$2.5 to \$3.0 million for a two-color sort system (flint and gramber).
- The building needed to house a stand alone glass beneficiation facility including processing equipment, tipping floor, indoor storage space, and offices is estimated to be approximately 30,000 ft² in size.
- The estimated total capital cost for the glass beneficiation facility (building, land, processing system, truck scale, wheel loaders, etc.) is estimated to be \$5.5 to \$6.5 million depending on several variables including real estate costs, building costs for housing the equipment and tipping floor, and whether the facility will have three-color sorting capabilities or two-color sorting capabilities.
- Annual operating costs (including debt service payments) are estimated to be between \$2.1 and \$2.3 million.

- Based on low, medium and high revenue scenarios, annual revenue from the sale of cullet (either to Anchor or as road construction aggregate) is estimated to be between \$1.2 and \$1.7 million.
- Assuming private ownership of the facility and based on processing 53,000 tons per year of mixed glass (making allowances for the removal of non-glass contaminants and some loss in product) the estimated first year per ton tipping fee could range from \$12 - \$23/ton for a facility with two-color sort capabilities and \$13 - \$24/ton for a facility with three-color sort capabilities. These scenarios assume a 7.5% financing rate and a built in 20% profit margin.
- The significant cost swings in the previous four bullets are due to several variables that are not known at this time. Among them are facility location, real estate costs, Greenfield versus existing industrial site development costs, and revenue streams from the sale of cullet.
- Though some refinement of numbers are needed it appears that if the overall costs come down to a per ton tipping fee in the \$12 - \$16/ton range a regional glass beneficiation facility could be economically attractive for some of the larger generators of mixed glass in the Minneapolis/St. Paul Metro Area.

B. RECOMMENDATIONS

Based on the findings and conclusions, recommendations include the following:

- 1) Due to the geographic, economic and market infrastructure differences between the Minneapolis/St. Paul Metro Area and Greater Minnesota, the MPCA should work with recyclers in Greater Minnesota to develop region-specific strategies and market development initiatives for recycled container glass. Examples of region-specific strategies could include:
 - Researching and piloting cost-effective methods for processing and transporting glass to regional markets;
 - Through regional meetings, forums and workshops identify barriers, challenges, and opportunities for using crushed glass as supplemental road base aggregate or as filter media for on-site wastewater treatment systems;
 - Through the MPCA's Environmental Assistance Open Grant program, over a two-year period, dedicate a certain portion of the funds for innovative glass recycling initiatives and demonstration projects in Greater Minnesota; and
 - Through the MPCA's CAP Grant program, dedicate some of the available funds for capital improvements that would help publicly owned MRFs cleanup and/or size glass for specific targeted markets.
- 2) The MPCA should expand the dialog regarding a regional glass beneficiation facility to serve the Metro Area and surrounding region. To accomplish this an open forum should be conducted involving a variety of stakeholders in the region. At a minimum representatives from the following groups should be invited to participate:
 - Regional MRF operators
 - Anchor Glass Container
 - MnDOT
 - Solid Waste Management Coordinating Board (SWMCB)
 - Recycling Association of Minnesota (RAM)

- Association of Recycling Managers (ARM)
 - Solid Waste Administrators Association (SWAA)
- 3) The MPCA should identify and research public/private partnership options for how the State can more directly assist in the development of a regional glass beneficiation facility. The State already offers no-interest loans to businesses through an application and selection process. Other avenues to explore could be:
- Capital Assistance Grants to private sector project developers; and
 - Public ownership with a contracted private operator.

If the State does take a more direct role in the development of a facility (i.e., acting as a financial partner or investor in a private venture), it will be necessary for the selection process to be fair, open and transparent. In this case, it is recommended that some type of Request for Proposals (RFP) or Solicitation of Interest (SOI) process be undertaken to select a full-service vendor for constructing, owning and operating a facility.

- 4) The MPCA should engage in a dialog with all the glass markets serving the state to determine how the Agency can assist in growing those businesses, developing new product lines or markets for the products produced, and improving operational efficiencies. A variety of assistance can be offered such as:
- Market development and penetration assistance;
 - Working with suppliers of glass to improve the quality of the feedstock; and
 - Consulting services (paid for by the State) to assess operational efficiencies.
- 5) The MPCA should engage MnDOT in a dialog regarding the use of more recycled glass in road construction projects throughout all regions of the state and encourage MnDOT's use of this material in state highway projects. With critical shortages of aggregate in some portions of the state, the use of recycled glass could help alleviate some of the aggregate shortages. Other initiatives that the MPCA and MnDOT should team up on include:
- Identifying policies and incentives that would reward contractors and local highway departments for using up to 10% recycled glass in road construction projects;
 - Aggressively promote the use of recycled glass with county highway departments and construction contractors; and
 - Provide extra points to contractors who propose using 10% recycled glass in their road base construction bids.

APPENDIX A

GLASS MARKET CONTACT INFORMATION

1. Anchor Glass Container
4108 Valley Industrial Boulevard North
Shakopee, MN 55379

Russ Barto, General Manager
(952) 445-5000 Ext. 300

Kyle Fiebelkorn, Mix & Melt Supervisor
(952) 445-50000 Ext. 311

2. Glass Advantage, Inc.
230 15th Street NW
West Fargo, ND 58087

Newton Davis or Tom Williams
(701) 277-9200

3. Raguse Manufacturing
RR 2 Box 24,
Wheaton, MN 56296

Steve Raguse
(320) 563-8389

4. Wausau Tile, Inc.
9001 Bus. Hwy. 51
P.O. Box 1520
Wausau, WI 54402

Rodney Dombrowski
(800) 388-8728

APPENDIX B

GLASS CRUSHING EQUIPMENT VENDORS

1. Andela Products Ltd.
493 State Route 28
Richfield Springs, NY 13439
Tel: (315) 858-0055
Web: andelaproducts.com
2. C.S. Bell Company
170 W. Davis St., P.O. Box 291
Tiffin, OH 44883
Tel: (888) 958-6381
Web: csbellco.com
3. Compactors, Inc.
P.O. Box 5918
Hilton Head Island, SC 29938
Tel: (843) 686-5503
Web: compactorsinc.com
4. Glass Aggregate Systems
P.O. Box 464
Faribault, MN 55021
Tel: (507) 334-6437
Web: glassagg.com
5. McLanahan Corporation
200 Wall St., P.O. Box 229
Hollidaysburg, PA 16648
Tel: (814) 695-9807
Web: mclanahan.com
6. Recycling Equipment Manufacturing, Inc. (REM)
6512 N. Napa
Spokane, WA 99217
Tel: (509) 487-6966
Web: remfg.com
7. Williams Patent Crusher & Pulverizer Co.
2701 N. Broadway
St. Louis, MO 63102
Tel: (314) 621-3348
Web: williamscrusher.com