Understanding economic and environmental impacts of single-stream collection systems

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This report was authored by Clarissa Morawski, principal of CM Consulting and a leading expert on extended producer responsibility (EPR), with a specific focus on beverage container recovery systems. Ms. Morawski developed and publishes the report *Who Pays What—An Analysis of Beverage Container Recovery and Costs in Canada,* which features the most recent recovery and cost data concerning beverage container recovery programs, and she provides research to public and private sector clients including the beverage industry, beverage packaging sector, end-markets, and provincial governments.

The report was edited by Betty McLaughlin and Marge Davis, and formatted and proofread by Valerie Hoy. Graphics were conceived and created by Ms. Hoy and Ms. Morawski. Cover photography was provided by Todd Johnson.

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Foreword

In 2009, the Container Recycling Institute undertook a study on the impacts of single-stream collection of residential recyclables, with a particular focus on the economic and environmental impacts of this collection method on the final material sent to end-markets for recycling.

The past decade has experienced a significant increase in packaging generation. At the same time, recycling collection systems have shifted from source-separated programs to single-stream collection models in which all recyclable materials are placed in the same receptacle.

While these system changes have resulted in lower collection costs, they have also led to an increased level of contamination at Material Recovery Facilities (MRFs). Processed materials sold to recyclers also contain higher levels of contamination and require further processing. Bales of paper-based secondary material, for instance, contain more glass, metal and other contaminants, which lowers the economic value of the material and can impact recycling operations in terms of extra labor and capital requirements. Polyethylene terephthalate (PET) bottles collected through commingled collection systems usually require additional sorting by recyclers or are simply too contaminated for high-end uses.

To date, the impacts on various collection methods—source-separated curbside, commingled curbside, deposit/return—on the quality of materials destined for recycling have not been formally researched and documented. In fact, rarely is “material quality” or the “end-destination” of the material considered by government decision-makers when choosing an appropriate recycling system.

The following report provides information on the impact of single-stream collection systems on material quality with respect to recycling and its economic value. For municipalities that are being asked to consider a shift to a single-stream system from a curbside sort or a dual-stream (fiber and containers) system, this report attempts to highlight the economic and environmental impacts that this decision may have. Our goal is to provide guidance on what strategies to incorporate when considering a single-stream collection system for maximum efficiency and environmental effectiveness.

Research for this report was attained through a series of interviews with recyclers representing different material end-markets and MRF operators. In addition, CRI reviewed existing reports that address issues relating to material quality and related end-market applications. These resources are listed at the end of the report.

Ask post-consumer material recyclers about single-stream collection, and they will consistently tell you that collecting recyclables mixed together is problematic. This is especially relevant today, where Material Recovery Facilities (MRFs) are facing new challenges in their own market conditions.

Specifically, in the wake of the late-2008 economic collapse, domestic demand for scrap materials also fell, scrap exports to China dropped dramatically, and the cost of energy plummeted to less than $60 per barrel—a 50% decrease from early 2008.

These factors have created a “perfect storm” for municipalities and/or their MRFs currently collecting recyclables, especially if the quality of their bales is low-grade. These new market conditions enable end-markets to discriminate among suppliers and to choose high-quality feedstock over those suppliers whose quality has never been up to the recyclers’ standards.

This new marketplace has in effect tested the single-stream system. Those single-stream haulers and MRFs who have not applied best practices have been riding the wave of rapid economic growth and unprecedented global scrap demand over the past decade. Today, many single-stream MRFs face a situation where their material is worth very little, worthless, or considered garbage.

The new marketplace requires a fundamental reassessment of the economics of single-stream collection. One must weigh the lower collection costs of single-stream against the higher sorting costs at the MRF, from slowing down the sorting belt, to hiring more workers, to spending more on sorting equipment—all in an effort to improve the quality of the material.

Executive Summary

This report describes the evolution of single-stream recycling in the United States, the recent downturn in the scrap market for all recyclable materials, and explains factors affecting collection costs. The real purpose of the study, however, is to examine the impacts of single-stream recycling, as compared to other methods, on every step of the recycling process, including:

- Initial ease of collection and collection costs;
- Contamination rates and overall material yield at Material Recovery Facilities (MRFs);
- Impacts on material yield at paper mills;
- Impacts on yield at plastics processors;
- Impacts on paper mills, on quality, quantity, equipment maintenance and costs;
- Impacts on aluminum processors on contamination levels, resulting equipment shutdowns, and profit losses;
- Impacts on glass, including color mixing, suitability for certain end-uses, and increased operating costs; and,
- Impacts on plastic quality and costs.

Recycling's real purpose is to substitute virgin inputs with secondary feedstock at the manufacturing stage. Most lay people, and perhaps most local officials, assume that all recycled items go to their best use. They are shocked to learn that the materials they dutifully put in a recycling bin may in fact wind up in a landfill. The key to achieving the environmental and economic benefits of recycling is to keep the material circulating for as many product lives as possible. This is the closed loop that reduces the need for virgin materials, thus avoiding the energy consumption and greenhouse gas emissions associated with primary materials extraction, transportation and processing.

Ensuring that secondary recovered recyclables are utilized for the highest possible end-use is a critical part of successful diversion. For plastic, high-end uses can have ten to twenty times the environmental benefit in terms of the replacement of virgin materials and those avoided upstream impacts. Using glass to make containers saves much more energy than using recycled glass for other purposes.

The historical focus of residential recycling (in the 1990's) has been on keeping materials out of landfills. This led to creating systems that could collect the greatest volume of material, with less of a focus on final end-use of the materials. Now, in 2009, we see a developing shift in public solid waste policy to focus more on reducing energy use, creation of greenhouse gases, and production of toxics.

In an effort to increase recycling volumes and reduce high recycling collection costs, the waste management sector created single stream recycling collection, which increases efficiencies by collecting more material with less labor and less distance traveled. Automated single stream collection can reduce the number of employees, improve route efficiency, and reduce workers compensation costs. Single stream can encourage residents to place more material in their recycling bin by giving them a larger bin and by simplifying the system.

Glass is the material most affected by the amount of breakage in each type of collection system. In single-stream programs, it is virtually impossible to prevent glass from breaking as it goes to the curb, is dumped in the truck, gets compacted, gets dumped on the tipping floor of the MRF, is repeatedly driven over by forklifts, and is dumped on conveyor belts to be processed by the MRF. On average, 40% of glass from single-stream collection winds up in landfills, while 20% is small broken glass ("glass fines") used for low-end applications. Only 40% is recycled into containers and fiberglass. About one third of the non-recyclable glass is broken glass, too small to separate for recycling, some of which can be used for sandblasting base, aggregate material, or Alternative Daily Cover (ADC). These "down-cycled" uses do not have the same savings in terms of energy conservation and avoided emissions. In contrast, dual-stream systems have an average yield of 90%, and container-deposit systems yield 98% glass available for use in bottle-making. (Only glass that is sorted by color can be used to make glass containers.)

In general, the final commodities from single stream programs will be more contaminated than those that are collected in a dual-stream system or sorted at the curb. This contamination increase often results in the commodity being worth less than cleaner material, and can create problems at paper mills, leading to equipment failure, lost productivity and expensive repairs. In other words, the cost savings for a municipality from single-stream collection show up as cost increases for the processors and recyclers. The contaminants are thrown away by the paper mills. So, an item such as a plastic bottle that was recyclable when it was placed at the curb becomes trash by the time it is sorted out as a contaminant by the paper mill.

A study conducted in 2002 by Eureka Recycling (of St. Paul, Minnesota) compared five different collection methods, and found that single-stream collected 21% more material than the baseline method. However, the study did not ultimately recommend a single-stream system, because the lower collection costs were outweighed by higher processing costs and lower material revenues.

In another study, Daniel Lantz of Ontario, Canada-based Metro Waste Paper Recovery analyzed recovery rates for three single-stream and four dual-stream programs in that province. The study found that a drop in collection costs sees a commensurate rise in processing costs. In an article for Resource Recycling magazine, Mr. Lantz concludes that the supposed benefits of single-stream systems over dual-stream do not outweigh their costs:

> "In summary, with increased processing costs and lost revenues in total far exceeding collection savings in most instances (and zero under alternating-week collection), overall single-stream recycling does not show the cost advantage that was originally anticipated. As

well, the expected increases in capture rate are also not apparent. Overall, dual-stream recycling still appears to be more advantageous."

Outlook

In spite of these challenging conditions and their impact on the current demand for recyclables, recycling continues to be a vital component of a national strategy to conserve resources, supply the manufacturing base and reduce greenhouse gas emissions, toxics and waste going to landfills and incinerators.

Manufacturers of new glass, metal, plastic and fiber products continue to encourage clean collection so that they can use secondary feedstock instead of virgin material for manufacturing. While manufacturers will continue to invest capital into their systems to increase recycled inputs, these investments will remain contingent upon a regular supply of clean material.

The upstream environmental benefit of closed loop recycling is 10 to 20 times greater than downcycled[2] or disposal options. More simply put, when a product is made from recycled material, the use of virgin materials is not required. Therefore, all the upstream energy and associated environmental impacts from the extraction, transport and processing of those virgin materials are not required, or "avoided." When the benefits of recycling are measured, calculations assume "avoided" environmental impacts such as greenhouse gas emissions and energy consumption. These savings are expressed as metric tons of carbon equivalent (MTCE) and "saved" energy, expressed as millions of British Thermal Units (MBTUs).

Table 1 highlights the energy and avoided emissions derived from closed-loop recycling.

Table 1: Environmental Benefits from Recycling
(data source: US EPA, 2006)

Material	Energy Savings (MBTUs/ton)	Avoided GHG emissions (MTCE/ton of recovered material)
Aluminum cans	207	3.7
HDPE/LDPE[1]	51-56	0.38–0.46
PET plastic	53	0.42
Steel cans	20	0.49
Newsprint	17	0.76
Corrugated	16	0.85
Phone books	12	0.72
Office paper	10	0.78
Glass containers	2.7	0.08
Aggregate	0.6	n/a

[1] HDPE (high-density polyethylene) and LDPE (low-density polyethylene) are two types of plastic.
[2] "Downcycling" is the recycling of a material into a feedstock of lesser quality, often into another product that cannot currently be recycled at the end of its life. Some refer to this open-loop recycling as "delayed disposal."

Recommendations

The following set of recommendations should be carefully considered by municipal and state governments.

1) Municipalities should undertake analyses of how single-stream collection systems will impact their own collection costs, including:

   - Capital investment such as new bins
   - Processing costs
   - Costs to their domestic end-markets (paper mills, glass beneficiation, smelters and plastics recyclers)
   - The impact on the quality of the material that is processed
   - The amount of available options for end-use, and the level of risk associated with marketing that material, i.e., how well the quality of their bales can maintain demand in a variety of economic conditions.

2) Municipalities should consider all other options for more efficient collection, such as dual-stream and modified single-stream.

3) Any municipality currently operating or considering a single-stream collection approach should adopt all of the best practices outlined in the *Single-stream Recycling Best Practices Implementation Guide,* 2007, by Richard Gertman, Environmental Planning & Consulting, and Susan Kinsella, Conservatree. See Appendix A.

4) The thirty-nine states that have not enacted beverage-container-deposit legislation should support municipal recycling programs by implementing such a law. Container deposit legislation (CDL) shifts the financial burden of end-of-life management to distributors and consumers, significantly increases clean collection of empty glass, aluminum, steel, and plastic beverage containers, reduces the contamination of paper-based materials, and reduces municipal waste disposal and litter abatement costs.

5) All municipalities should consider alternative approaches such as take-back and drop-off programs for materials whose collection at curbside is problematic.

The evolution of single-stream collection

Single-stream collection was created by the waste-management sector in an effort to reduce their high recycling costs. Costs for labor, workers' compensation and specialized recycling trucks are significant expenditures for the hauling industry. Single-stream collection increases efficiencies by collecting more material with less labor and less distance traveled. Costs are reduced by automating collection, using larger bins, eliminating manual curbside sorting, and using single-compartment compaction trucks to transport recyclables. These cost-saving measures fundamentally revise the economics of collection and compete with more traditional methods such as curbside sorting and dual-stream (fiber and containers) collection.

For municipalities struggling to divert more waste with less money, the concept of single-stream collection may seem like an attractive alternative. Municipalities may be persuaded that offering residents an easier way to recycle—one that allows homeowners to commingle all their recyclables in one bin—would increase collection rates. Even though processing costs would increase and the quality of the collected material would decrease due to increased contamination, single-stream collection does offer a cost-avoidance advantage for local governments and the waste industry.

Today there are more than 160 single-stream Material Recovery Facilities in the United States, which is up from just 70 a mere four years ago.[3] It is estimated that about 27% of the U.S. population with access to curbside collection is participating in single-stream programs.[4] The majority of single-stream programs are operating in the states of California, Florida, Ohio, Texas, Illinois and Washington.

Single-stream in a strong economy

The evolution of single-stream collection occurred during the past decade—a time of tremendous global growth, especially in developing areas like China and Asia Pacific. China, for example, experienced a 68% increase in demand for pulp and recycled paper grade from 1990 to 2003,

Table 2: Growth in demand for recycled materials leading to increased single-stream collection

Location	Product	Time period	Increase in demand
China	Pulp & recycled paper grade	1990-2003	68%
China	Pulp & recycled paper grade	2003-2010	33% (projected)
USA	Recycled Plastic	1993-1996	27% per year (projected)

[3] *To Single-stream or Not to Single-stream?*, power point presentation, Lori Scozzafava, SWANA, U.S EPA Meeting, July 19, 2007 Philadelphia, PA

[4] AFPA, 2005

and a 95% increase in net imports of these products for the same period.[5] Projected growth in demand from 2003 to 2010 was 33% and the projected growth in net imports for the same period was 40%. In spite of China's efforts towards self-sufficiency, with the rapid growth in demand and supply expected in the pulp and paper sector, China would continue to rely heavily on imports to meet its needs for raw materials.

Other secondary commodities also experienced tremendous global growth over the last ten years. In 1993, U.S. demand for recycled plastics was predicted to increase 27% yearly to 1996—more than five times the rate for total plastics demand[6] —while Chinese plastics industries' output grew by 19% in 2006, compared to 13% growth in 2005.[7] See Table 2. Demand grew also for aluminum and steel containers.

Strong global demand meant that MRF operators processing single-stream material were able to sell to China and other Asian countries. These markets were not concerned with the quality of the materials they purchased because the cheap labor in these developing countries allowed them to further clean the material. Even in North America, paper mills became significantly less discriminating about quality because they needed to secure secondary feedstock and were competing with China.

The market for single-stream material was strong despite the fact that paper mills and container recyclers were receiving a higher degree of contamination ("out-throws"). Out-throws increase costs for processors in three ways: The contaminated materials must be cleaned up, the contaminants must be disposed of, and the equivalent tonnage of the contaminant must be re-purchased for the processor to attain full-load capacity. It is estimated that paper mills spend $5 to $13 more per ton to process material from single-stream systems compared to material collected using cleaner methods.[8]

Single-stream and glass

Secondary glass marketability is primarily dependent on two things: proximity to a beneficiator[9], and the beneficiator's particular quality specifications. In many cases, broken mixed glass from single-stream systems is too contaminated to efficiently beneficiate.[10] This breakage forces MRFs to sell the mixed broken glass for low-end uses, such as road base and landfill cover. Even when a single-stream system applies best practices, container glass recycling is still costly and extremely challenging because of breakage and contamination.

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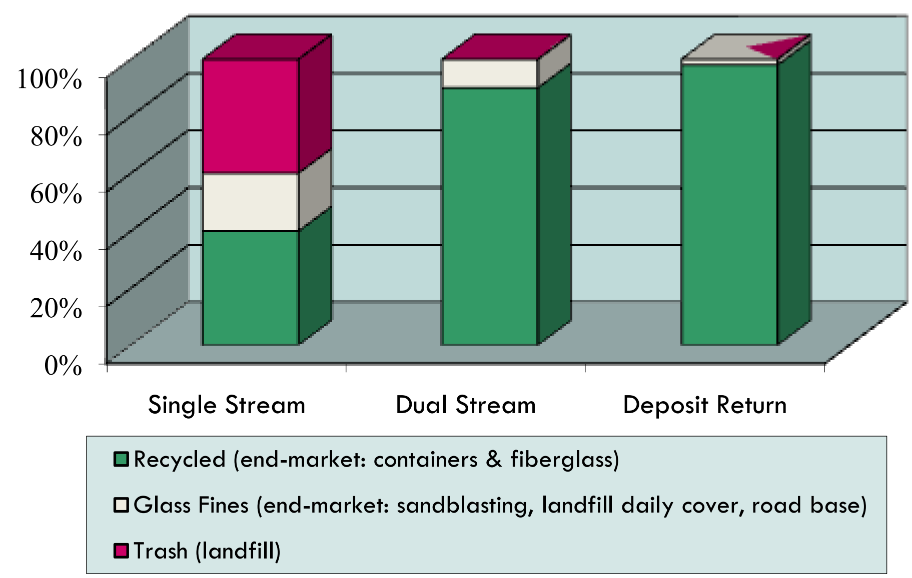
[5] Presentation on China and Asia Pacific, Forest Markets for Sustainable Markets and Livelihoods. *Modeling Demand, Supply and Trade In China's Pulp and Paper Markets*, China Economic Consulting Inc, June, 2005. www.forest-trends.org.
[6] High Performance Plastics, Monday, February 1, 1993.
[7] China Plastics Processing Industry Association (CPPIA).
[8] *Paper Recycling is Key to Long-Term Success*, American Forest and Paper Association, 2004.
[9] Beneficiation of glass is a process of preparing glass cullet feedstock for high-end recycling markets: used bottle manufacturing and/or fiberglass. In order to be able to market glass to high-end recycling markets, a glass beneficiator located within reasonable proximity to a MRF is needed.
[10] Conversation with Tex Corley, Strategic Materials.

Figure 1 shows that, on average, 40% of glass from single-stream collection winds up in landfills, while 20% is small broken glass ("glass fines") used for low-end applications. Only 40% is recycled into containers and fiberglass. About one third of the non-recyclable glass is broken glass, too small to separate for recycling. Much of the breakage occurs during compaction in the single-stream truck or in the MRF separation process.

In contrast, mixed glass from dual-stream systems yields an average of 90% being recycled into containers and fiberglass, with 10% glass fines used for low-end applications, and nearly nothing sent to landfill. In container-deposit systems, color-sorted material results in 98% being recycled and only 2% marketed as glass fines.

A system that reduces contamination and glass breakage to enable color sorting is a more effective way to recycle glass into high-value re-manufactured goods such as new glass bottles and fiberglass.

Figure 1: End-markets for collected glass
(Source: Strategic Materials)



Economic downturn results in material quality discrimination

The fall 2008 economic downturn fundamentally changed the market dynamics that had prevailed over the previous decade. In a conference held in the United Kingdom (UK) on October 23, 2008,[11] delegates learned that the economic upheaval was making it increasingly difficult for recyclers to move low-quality commodities.

[11] WRAP Conference—October 23, 2008—Issue: Focusing on navigating the current economic downturn.

According to Roy Hathaway of the UK Department for Environment, Food and Rural Affairs, the quality of material would play an increasingly pivotal role in trade, with the market set to face short-term financial constraints. “It is going to be the low-quality end of the spectrum,” he said, “which is going to be squeezed out by an economic downturn.” Dr. Liz Goodwin, head of the Waste & Resources Action Program (WRAP), made a similar point, saying that quality was “one of the biggest issues of … all,” and noting that China had just raised the barrier for the type and quality of material it would accept.

A multi-national aluminum company[12] reported that in the last half of 2008, it had canceled supply from many MRFs due to insufficient quality. This action came even after it had attempted to incentivize quality improvements through a price penalty. The company based its decisions on an analysis of the impact of low-quality aluminum on their production. According to the company, the increase in single-stream collection has resulted in overall dirtier feedstock.

The China factor

Demand for secondary feedstock from China has also changed market dynamics for secondary material suppliers. First, cheap freight and inexpensive labor have helped maintain relatively high value in the marketplace for low-quality scrap material that can be further sorted in China. Second, with a significant portion of materials (paper fiber, plastic and metals) marketed to China, domestic purchasers have had to tolerate sub-par material in order to compete with off-shore shipments.

Since the last quarter of 2008, however, demand from China has fallen dramatically for reasons other than the economic downturn. These factors include an increase in China’s domestic capacity, higher labor costs, and a host of new environmental requirements that are regularly being added to China’s regulatory landscape.

The bottom line on single-stream collection

Late-2008 market dynamics have tested existing single-stream systems. As global manufacturing has slipped and overseas markets have eroded, domestic end-markets such as paper mills and metal and plastics recyclers have found they can afford to discriminate against processed material with high rates of contamination. The result is that collection systems that have been unable to adapt to these new quality standards have found themselves saddled with processed material that cannot be diverted to any recycling market either domestically or overseas.

On the surface there are several pros to single-stream collection. It is believed that single-stream systems increase participation by a few percentage points and significantly reduce the costs of

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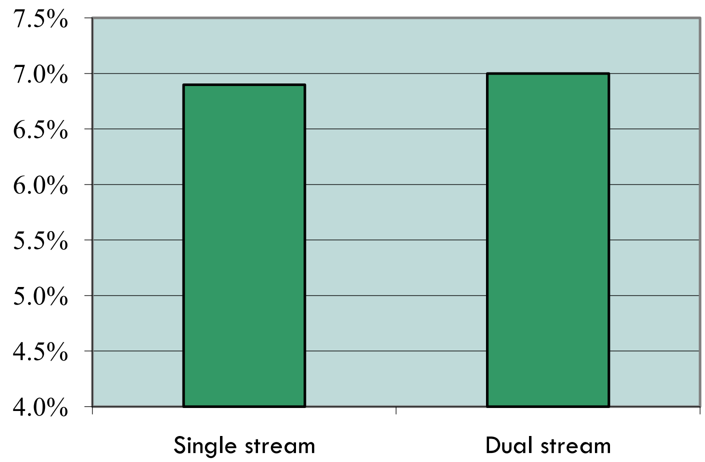
[12] Novelis, 2008.

collection. However, increased participation rates may not be solely the result of the collection method; they may also be impacted by other factors that usually come with the introduction of any new recycling program, such as increased promotional efforts, distribution of larger recycling container to residents, bag limits or user-pay programs for garbage.

In 2008, for instance, Daniel Lantz of Ontario, Canada-based Metro Waste Paper Recovery analyzed recovery rates for three single-stream and four dual-stream programs in that province. According to findings reported in the December 2008 issue of *Resource Recycling*, the weighted averages of recovery increases from 2003 to 2007 were virtually the same for both systems: 6.9% and 7%. See Figure 2.

Figure 2: Increase in recovery rates based on weighted average from 2003-2007
(Source: Lantz, D., Resource Recycling, December 2008 - from study conducted by Metro Waste Paper Recovery, 2008)



Switching to a single-stream system requires substantial financial investment—larger and more expensive carts for the households, new trucks for haulers, new sorting technology at the MRFs, and more public education for participants. Processing costs rise due to issues related to contamination, even as revenues for processed materials are likely to shrink. Processors bear the financial burden of added expenses for equipment failure and shut-downs; they lose their investment in non-recyclables included in purchased loads; and they have to pay to dispose of unusable material.

Municipalities contemplating a shift to single-stream collection must examine their own waste management system in its entirety, including the level of education of their residents and whether their existing infrastructure is compatible with single-stream programs. Perhaps most important, municipalities must understand who the end-markets are for the collected material, both today and in the future, and how secure these markets are and will continue to be.

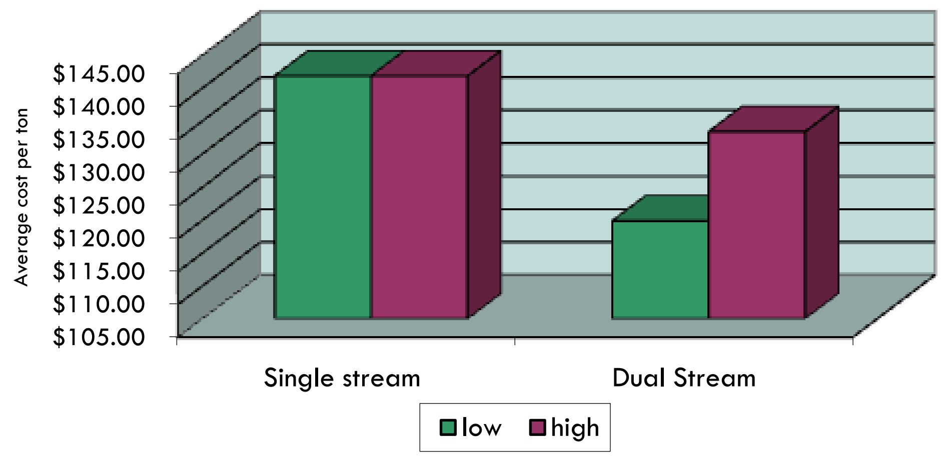
Collection cost reductions and ease for householders tell only part of the story. Municipalities need to appreciate their role in choosing collection options that maintain quality, scrap revenue generation, reliable markets and recycling infrastructure investment, including commitments to using recycled content.

Consider the 2008 analysis conducted in Ontario by Metro Waste Paper Recovery. That analysis looked at the system costs of three single-stream and four dual-stream programs. All seven programs served relatively large population densities and collected a similar assortment of materials.

The 2008 study conducted by Metro Waste Paper Recovery in Ontario also looked at the system costs of the three single-stream and four dual-stream programs.[13] See Figure 3.

Figure 3: Average net cost estimates - single stream vs dual stream 2007

(Source: Lantz D., *Mixed Residuals*, Resource Recycling, December 2008 - Based on Metro Waste Paper Recovery study, 2008)



Without a full understanding of how single-stream collection will be incorporated into an existing system, and what changes are required within the entire waste management system in order for single-stream to be effective, municipalities may actually end up spending a significant amount of money to collect and process waste even as they create new waste from material that should have been recovered.

In the same *Resource Recycling* article referenced above, Daniel Lantz concludes that the supposed benefits of single-stream systems over dual-stream do not outweigh their costs:

"In summary, with increased processing costs and lost revenues in total far exceeding collection savings in most instances (and zero under alternating-week collection), overall single-stream recycling does not show the cost advantage that was originally anticipated. As well, the expected increases in capture rate are also not apparent. Overall, dual-stream recycling still appears to be more advantageous."

[13] Lantz, D., *Mixed Residuals*, Resource Recycling, December 2008. (Source of data findings, Metro Waste Paper Recovery, 2008).

The genesis of single-stream collection

Single-stream collection began in California, as municipalities were attempting to find a way to increase diversion while keeping recycling costs down. The existing dual-stream and dropoff mechanisms for collection were not achieving high diversion rates for two reasons: 1) the citizens did not participate fully enough; and 2) even if costly education programs could convince the public to participate, it was simply too expensive to collect and process the material. The sale of the end products would not justify the costs incurred.

For a recycling program to be viable, municipalities must use a collection method that yields high participation rates in a cost-effective manner. And it is true that in many ways, single-stream collection seems to do both. Because single-stream systems typically use one large cart,[14] residents can place all recyclable materials into one receptacle without the so-called "trouble" of separation. Municipalities assumed that this level of convenience and simplification would increase participation significantly.

On the collection side, the use of the large cart allows the collector to automate pick-up from inside the truck cab. Co-mingled loads allow them to use single-compartment trucks, saving significant labor and transportation costs.[15] Labor costs area also lower, because an automated truck requires only one worker. And since the cart is emptied by a machine, injuries and the attendant worker compensation costs are also lessened.

At the same time, single-stream collection lowers transportation costs, because the one-compartment trucks cost less to purchase and usually have the ability to compact the load. In some cases, the same one-compartment truck that picks up garbage can also be used for recyclables collection, eliminating the need for additional capital expenditure. In addition, the one-compartment single-stream truck saves time and fuel because they can return to the MRF only with full loads, whereas dual-stream and curbside-sort systems must halt collection as soon as one compartment is full.[16]

In 1987 there were just four single-stream recycling systems in the United States.[17] In 1989, California passed AB 939, requiring "each city or county plan to include an implementation schedule which shows: diversion of 25 percent of all solid waste from landfill or transformation facilities by January 1, 1995, through source reduction, recycling, and composting activities; and

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[14] A cart is a large plastic bin on wheels with an integrated lid. A common brand name is Toter.

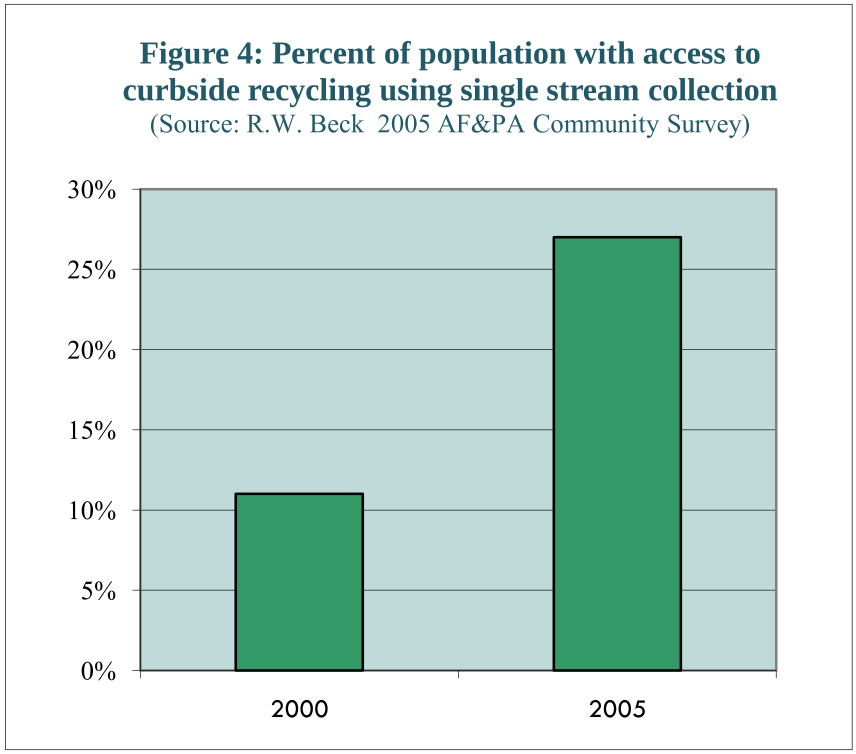
[15] Wisconsin Department of Natural Resources. www.dnr.wi.gov/org/aw/wm/recycle/issues/singlestream.pdf.

[16] Jim Close, Public Works Director, City of Harrisburg, PA www.apwa.net/Publications/Reporter/ReporterOnline/index.asp?DISPLAY=ISSUE&ISSUE_DATE=032003&ARTICLE_NUMBER=569.

[17] Tamsin Ettefagh, Envision Plastics www.conservatree.com/learn/SolidWaste/Roundtable/benefits.shtml.

diversion of 50 percent of all solid waste by January 1, 2000, through source reduction, recycling, and composting activities"[18]

This law spurred many more California municipalities to adopt single-stream collection to achieve that goal. As the potential economic savings appealed to more haulers, single-stream collection began to move east. A survey by R.W. Beck released in July 2005 found that in 2000, roughly 11% of the population with access to curbside recycling had single-stream collection. By 2005 that percentage had grown to 27%.[19] See Figure 4.



A study conducted in 2002 by Eureka Recycling (St. Paul, Minnesota) and comparing five different collection methods found that the single-stream method collected 20.8% more material than a baseline of 402 pounds per household per year (lb/HH/yr) at a cost of $51/ton. However, it should be noted that the study did not ultimately recommend a single-stream system, because the lower collection costs outweighed by higher processing costs and lower material revenues.[20]

Another study by R.W. Beck in December 2005 explored the impact of a switch to single-stream collection on two groups of a different affluence demographic within the same city. Both groups increased their total weight of recyclables (after non-recyclables had been subtracted) during a pilot period following the switch. One group went from an average of 21.33 pounds per household per collection, to 28.16. The other went from 26.87 pounds per household per collection to 34.39.

It is important to understand that diversion from disposal is not recycling. Collection is not recycling. A product is not recycled until it is made into another product. Broken glass used as

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[18] California Integrated Waste Management Board. www.ciwmb.ca.gov/Statutes/Legislation/CalHist/1985to1989.htm.
[19] R.W. Beck, 2005 AFPA Community Survey.
[20] Eureka recycling May 2002, www.eurekarecycling.org/pdfs/ExecSummaryReport.pdf.

landfill cover is "downcycled" into one use only. Closed-loop recycling occurs when a product can be made and remade infinitely, such as recycling containers back into aluminum cans and glass and PET bottles.

Today, single-stream programs are being implemented on a regular basis. In 2008 alone, new single-stream programs have been implemented in 40 U.S. cities, townships and counties. See Figure 5.

Given the growth of single-stream collection, the current economic situation has had a significant impact on both program economics and marketability of recovered materials. All affected municipalities should consider the current design of their program, apply best practices, and consider alternative collection systems for those materials that may impose larger problems within their existing program.

Figure 5: New single-stream collection programs January 2008 through January 2009

In 2008, new single-stream programs were implemented in Baltimore, MD; Gilroy, CA, Macon, GA; Mount Airy, MD; Philadelphia, PA; Saco, ME; Appleton, WI; Marion, FL; Sumter, FL; De Pere, WI; Cheyenne, WY; Denver, CO; Des Moines, IA; Lady Lake, FL; Baton Rouge, LA; Hartford , CT (pilot program); Portland, OR; Howland Township, OH; Longmont, CO; North Andover, MA; St. Mary's County, MD; Weymouth, MA; Plymouth, PA; Corning, CA; Falls Church, VA; Fort Collins, CO; Loveland, CO; Ridley, PA; Oak Ridge, TN; Springfield, MA, Superior, CO, Orange Beach, AL, Plano, TX, Frederick County, MD, Galloway Township, NJ, Mason County, WA, Orange County, NC, Raleigh, NC, and South Whitehall Township, PA (Source: Resource Recycling)

Single-stream lowers collection costs

As noted elsewhere, collecting materials in a single-stream system can indeed be less expensive than in either a curbside sort or a dual-stream collection. The 2002 the Eureka Recycling study comparing single-stream to curbside sort and three different methods of dual-stream collecting showed that single-stream cost $51/ton. This cost compared to $60/ton for curbside sort and a range of $50-$65/ton for the three dual-stream methods that did not include organics collection.

A 2007 presentation by the Solid Waste Association of North America (SWANA) put the collection savings from single-stream at $10-$20/per ton.[21] The actual collection cost differs from municipality to municipality as variables such as population density and types of materials collected are considered, but the main cost savings are realized in labor and transportation.

A fully automated truck can be operated by only one worker, reducing labor costs. Injury insurance and compensation costs are also lowered, since the operator does not need to manually lift the heavy loads onto the truck.

Transportation savings are realized in several ways. The SWANA presentation showed that in a fully automated single-stream system, the average stop time was 26 seconds. With an assumed time of 12 seconds between stops, the collector is able to service 171 households per hour. SWANA compared this time to a dual-stream, two-bin system, with a stop time of 36 seconds, allowing 130 households to be serviced per hour; and a dual-stream, one-bin system, with a stop time of 61 seconds, allowing only 82 households to be serviced per hour.[22]

Another significant savings in transportation comes from fuel savings. Since a curb-sort system requires materials to be put into different compartments of the truck, it is inevitable that one compartment will fill before the others. The truck is forced to leave the route and go to the processing facility to unload. Since the other compartments are not full, the truck is making this trip at less than capacity. Processing facilities are often located far from residential neighborhoods, making fuel usage even less efficient. A one-compartment truck (for single-stream or biweekly dual-stream collection) can stay on the route until the truck is completely full. This advantage is magnified by a compacting truck: a 4X compactor will take one quarter of the trips to the facility that a regular one-compartment truck makes, and an even lower ratio compared to that of a multi-compartment truck.

These numbers seem compelling. However, the Metro Waste Paper Recovery study by Daniel Lantz (2008) concludes that the savings in collection from single-stream compared to dual-stream are not nearly so impressive. Lantz's findings show that the cost savings in collection between single-stream and dual-stream is as little as $0–$3/ton.

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[21] *To Single Stream or Not to Single Stream?* Presentation by SWANA at US EPA Meeting, Philadelphia, PA, 2007: www.epa.gov/reg3wcmd/urban2007/Single%20Stream%20Recycling%20Presentation%20SWANA_Jul07.pdf.
[22] Ibid.

Indeed, before a municipality can realize any savings from a switch to single-stream, it must make significant investments in the system. Costs associated with switching to a single-stream system include costs of the bins, costs of the trucks, and the costs of educating residents on how to use the single-stream system.

Single-stream collection bins are expensive. The town of Mooresville, North Carolina, was to begin implementing a pilot single-stream project in 2009. Over three years the town plans to give a 50-gallon bin to each of 10,000+ households at an estimated cost per bin of $40. Even with a $20,000 grant to assist, the town will be spending roughly $400,000 just to purchase the bins.[23] One advantage to investing in these expensive lidded bins is that recycled paper stays dry, making it easier to process and more likely to sell at a higher value.

Trucks constitute another large set-up cost for a municipality beginning a single-stream system. While much of the cost savings from single-stream are derived from using fully automated compacting trucks, these vehicles are expensive to procure. A new truck can cost up to $250,000, although examples of less expensive purchases can be found.

Brian Jongetjes, president of John's Disposal Service in Whitewater, Wisconsin, reported that when the city decided to pilot a single-stream program in 2002, John’s bought a few 10-year-old automated trucks and rebuilt them for a total cost of less than $20,000 each. When the program moved from the pilot to the citywide stage, John’s bought five new Heil 7000 bodies on existing Crane Carrier chassis for about $100,000 each.[24]

Single-stream and dual-stream collection also makes it possible to collect a wider range of goods. For example, all types of plastic containers can be put into a single-stream or dual-stream collection system to be sorted out at the MRF, while it would be totally impractical to expect collectors to separate all household plastics labeled #1 through #7, or to have trucks with a different compartment for each type.[25]

A final cost is educating the public on how to use the single-stream system. Municipalities can use many avenues for this education. Some of the most popular are pamphlets, newspaper ads, TV and radio ads and billboards. All of these cost money, however. Mooresville, with just over 10,000 households, expects to spend $15,000 over three years on education as it switches to single-stream collection. In a larger city, education costs are considerably more. In 2006, Philadelphia launched a $1.2 million education program to coincide with its introduction of a simplified recycling program that has evolved into a single-stream system.[26] In San Jose, California, and Seattle, Washington, the processor is required to help pay for or provide materials for education.[27]

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[23] Curbside recycling feasibility study. Town of Mooresville environmental protection committee, January 2008.
[24] Brian Jongetjes. In MSW Sept/Oct 2003 written by Darlene Snow.
[25] If the trucks did have compartments for each, the compartments for a low-volume plastic such as #5 PP would fill up far more slowly than the #1 PET compartment and essentially be wasted space in the truck.
[26] Jim Mccaffrey, Staff Reporter. The Evening Bulletin. www.recyclenowphilly.org/media_item.php?media_id=29.
[27] US Environmental Protection Agency. www.epa.gov/osw/conserve/tools/localgov/economics/processing.htm.

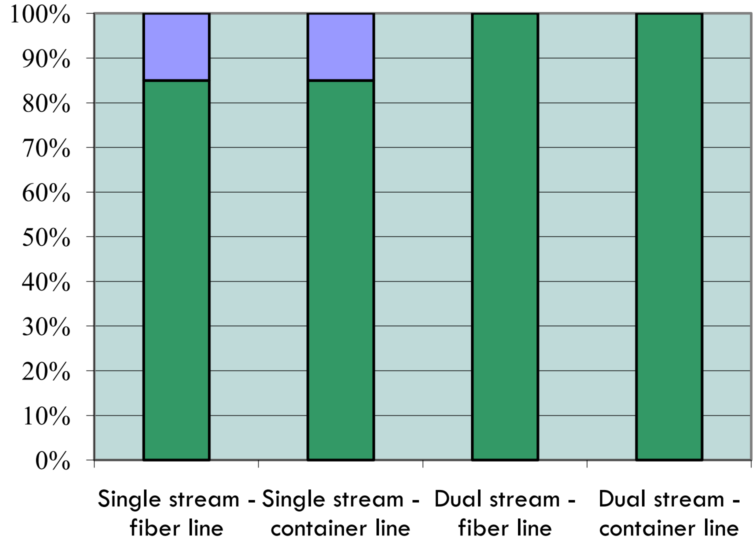
Single-stream collection raises processing costs and inefficiencies

After the initial investments are made, a municipality may enjoy the cost savings from single-stream collection. But a drop in collection costs sees a commensurate rise in processing costs. The materials arrive at the MRF unsorted, and it is left to the recovery facility to sort the materials to be marketed.

In general, the final commodities will be more contaminated than those that are collected in a dual-stream system or sorted at the curb. This contamination increase often results in the commodity being worth less than cleaner material. Contamination can also affect the ability of the recycler to produce quality end products. For example, if paper grades are not properly separated at a MRF, it can mean that old corrugated cardboard (OCC) might be improperly baled with old newspaper (ONP). Once the bale has been purchased by the newspaper processing mill, it can be very difficult to sort the ONP prior to its entry into the processing system. This type of contamination can affect the quality of the final newsprint. In addition, contamination can cause equipment failure, leading to lost productivity and expensive repairs. Both add costs to processors' and recyclers' bottom lines. The processor may have its load rejected by the recycler, or simply be paid less based on poorer quality, while the recycler must dispose of the contaminant OCC and purchase additional secondary ONP to make up for the loss. In other words, the cost savings for a municipality from single-stream collection show up as cost increases for the processors and recyclers.

Historically, one of the greatest challenges in single-stream collection has been glass. It is virtually impossible to prevent glass from breaking as it goes to the curb, is dumped in the truck, gets compacted, gets dumped on the tipping floor of the MRF, is repeatedly driven over by forklifts, and is dumped on conveyor belts to be processed by the MRF. Therefore, it is highly unlikely that glass collected in single-stream systems will be used for its highest closed-loop application—glass bottles or fiberglass. Unless there is beneficiation capacity nearby, which can clean the glass to recyclers' specifications, single-stream glass will be downcycled to a use that is far less desirable in terms of energy conservation, avoided emissions and other high-end benefits. The most likely end uses for mixed cullet from a MRF is sandblasting base, aggregate material, or Alternative Daily Cover (ADC) for landfills.

Figure 6: Efficiency comparisons in material recovery facilities (MRFs)
(Source: Resource Recycling, December 2008)



Another inefficiency related to single-stream versus dual-stream or curbside sorting is related to the lost revenue associated with recyclables ending up in the wrong separated stream (containers in the fiber stream, and fiber in the container stream). Equipment manufacturers suggest that the efficiency of a typical single-stream processing line is about 85%.[28] This means that about 15% of the container stream sent to market has unwanted fibers, and about 15% of the fiber stream has unwanted containers. (See Figure 6.) Most of the time, these "unwanted" recyclables are sent by the recycler (end-market) directly to disposal. This new waste not only represents a significant amount of lost revenue; it also artificially boosts recovery rates.

The MRF switching to feedstock from a single-stream system must either buy or lease a new facility to accommodate increased volume; retrofit an old facility; purchase new sorting equipment; or accept the increased labor costs for a workforce to operate and maintain the equipment. Most important, the MRF must achieve a level of quality of the output material that makes these other investments worthwhile.

It is critical that any municipality considering a shift to single-stream collection consult with its MRF first. A municipality cannot switch to single-stream unless the MRF is able to process materials that arrive commingled. Equally important, the municipality must avoid collecting materials that the MRF is not set up to sort and market. Timing plays an important role in a decision to switch to a single-stream system. Just as it is more advantageous for the collector to make changes when it is time to replace equipment such as trucks, the MRF owner will have to acquire some new equipment, or even a new facility to accept materials collected in a single-stream. If a municipality is going to switch to single-stream collection, it is best to do so when the older equipment at the MRF is obsolete and investments are going to have to be made regardless of collection technique.

[28] Lantz, D., *Mixed Residuals*, Resource Recycling, December 2008.

The cost of a new facility varies widely depending on the size of the facility, the siting of the facility, the amount and type of machinery going in the facility, the materials the facility is going to process, and other factors. In 2008, the capital cost for a new single-stream MRF serving Brown, Outagamie and Winnebago counties in Wisconsin was estimated at $8 million.[29] Other important considerations in siting a new MRF include the proximity to the municipality being served to control transportation costs, and proximity to existing transport infrastructure such as railways, ports and highways to control shipping costs for outgoing processed materials.

Because of these considerations, it is more common to retrofit an existing dual-stream MRF to suit single-stream collection. This allows the MRF owner to save money on machinery that does not need to be replaced and to bypass any objections that may arise with the siting process.

As in the case of new facilities, the cost of retrofitting an existing MRF varies. While a large dual-stream MRF with modern equipment could be prepared to take single-stream materials with the addition of one screen machine costing only $500,000, another facility could need upgrades in every area at a cost in excess of $3 million.

How the MRF will affect the quality and value of the final material depends on a wide range of factors. Some MRFs are showing better results than others regardless of the method of collection. Indeed, some MRFs that receive goods from single-stream sources are able to produce cleaner processed materials than others that collect from dual-stream sources. On average, though, materials that come from a source-separated collection will be easier to process than materials from dual-stream collectors, and dual-stream-collected materials will be easier to process than those from single-stream. Therefore, if all MRFs were equal, the materials from the single-stream collected system will, after passing through the MRF, be more contaminated, and less material, as a percentage of the total input, will be diverted or recycled.

Although limited data is available, studies seem to show that single-stream MRFs do indeed receive more recyclables due to the higher participation rates. However, as noted elsewhere, there is little evidence to prove that it is the single-stream system alone, or even principally, that motivates increased participation.

It is also important to note that because these materials are more contaminated, MRFs have to invest more to clean them up and, in some cases, to dispose of a higher proportion of the rejects. Though the gap is shrinking, single-stream MRFs in general produce materials of a lower quality, and with more residuals and outthrows.

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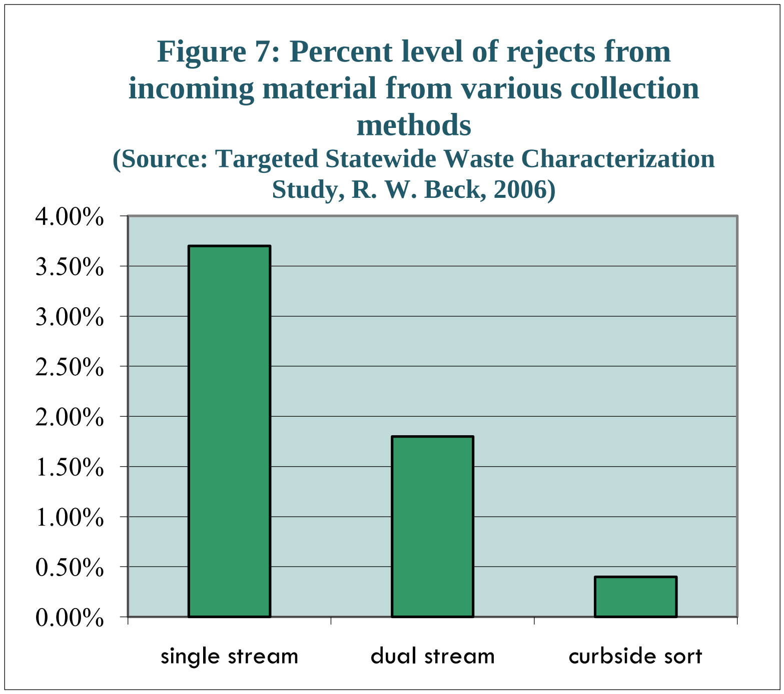
[29] Single-stream Recycling. Brown, Outagamie, and Winnebago Counties. City of Oshkosh Common Council. June 10, 2008.

A 2006 R.W. Beck study in Pennsylvania showed that even as single-stream collection had matured somewhat, a higher percentage of contaminants were found in the incoming streams at single-stream MRFs than at dual-stream MRFs, with 3.7% of materials rejected in the former, versus 1.8% rejected in the latter. Curbside sorts had the smallest proportion of rejects—0.4%.[30] See Figure 7.



The quality of sorting at single-stream MRFs has definitely improved over the last few years, but the fact remains that if containers and newspaper are not mixed going into the MRF, there is less chance that they will be mixed coming out.

Single-stream collection decreases material yield

Another factor to be considered in choosing between recycling systems is yield. While single-stream MRFs appear to take in a greater volume of recyclable material compared to dual- or multi-stream MRFs, they send a smaller volume of it out for recycling. And what does get sent out tends to be of a lower quality.

According to the 2002 Eureka Recycling study in Minnesota, source-separated MRFs lost only 1.6% of materials to residuals or outthrows, compared to 10%-12% for each of the four tested forms of dual-stream collection; and 27.2% for the three single-stream systems. So even though the single-stream systems showed a 20.8% increase in tonnage collected, they also showed a net *decrease* of 12.2% in overall tons recycled.[31]

(Note: A December 2005 study by R.W. Beck that covered the same region as the Eureka study showed that residual rates were not as high as they had been in 2002. The 2005 study reported a residual rate of 17%.[32])

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[30] *Targeted Statewide Waste Characterization Study: Characterization and Quantification of Residuals from Materials Recovery Facilities*, June 2006, R.W. Beck, Inc., Cascadia Consulting Group.
[31] Eureka Recycling May 2002 www.eurekarecycling.org/pdfs/ExecSummaryReport.pdf.
[32] R.W. Beck. Report. City of Roseville recycling pilot program summary. Ramsey County, Minnesota December 2005.

In 2005, William Sacia and Jay Simmons published a compelling report, *The effects of single-stream on a paper mill*, measuring the impacts of residuals on a NORPAC paper mill in Longview, Washington. Prior to 2001, all of the mill's incoming feedstock came from 100% source-separated programs. The mill had an outthrows[33] rate of a half a percent or less, a "prohibitives"[34] rate of zero percent, and a glass rate[35] that was also zero. This product was sold as ONP #8[36]. The yield loss at the pulper was 1%, with the mill purchasing an additional 2,500 tons of fiber to replace the rejects.

Between 2003 and 2005, the study reported, the mill's input changed dramatically. During that period, roughly 42% of incoming secondary newsprint came from commingled (single or dual-stream) programs; the outthrows rate increased to 5.7%; the prohibitives rate increased to 1.3%; and the glass rate increased to 0.1%. This material was sold as ONP #8, and #7.[37] The yield loss at the pulper increased to 9%, and the need for replacement fiber ballooned five-fold to 20,000 tons. At the same time, the mill's annual cost base for replacement fiber and disposal increased to $2 million a year.

From September 2006 to December 2006, the commingled material increased to 68% of total incoming fiber. The outthrows rate had tripled to 15%; the prohibitives rate also tripled to 3.4%; and the glass rate increased to 0.33%. See Table 3.

Table 3: The effects of single-stream on a paper mill, by W. Sacia and J. Simmons, 2005

Time period	Feedstock source (as a % of total incoming material)	Outthrows	Prohibitives	Glass rate	End-Market	Pulper Yield Loss
2001 and prior	Curbside Sort (100%)	0.25%-0.5%	0.0	0.0	ONP#8	1%
2003-2005	Single or Dual-stream (42%)	5.7%	1.3%	0.1%	ONP #8 & #7	9%
Sept–Dec 2006[38]	Single or Dual-stream (68%)	15%	3.4%	0.33%	ONP #8 & #7	n/a

[33] Outhrows is material which must be removed from the paper delivered to a mill before the paper is recycled/repulped. AFPA, 2005.

[34] Prohibitives are any materials which by their presence in a packing of paper stock, in excess of the specification amount allowed, will make the fiber unusable as the grade specified, or any materials that may damage the equipment. Source: AFPA, 2005.

[35] "Glass rate" refers to the percentage of glass residue found in the incoming material.

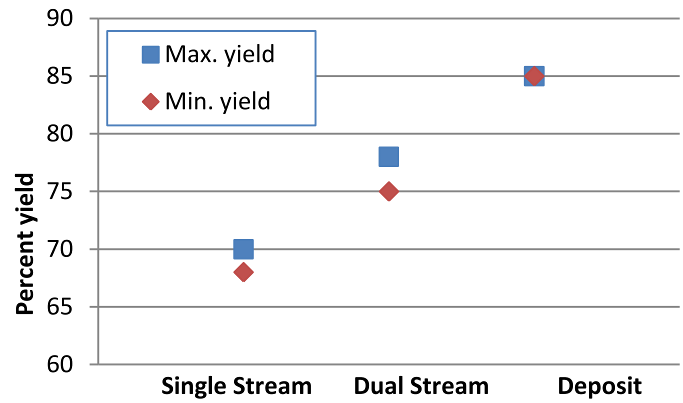
[36] Special News, De-ink Quality (#8 ONP), Consists of sorted, fresh newspapers, not sunburned, free from magazines, white blank, pressroom over issues, and paper other than news, containing not more than the normal percentage of rotogravure and colored sections. This grade must be tare free. (Weyerhaeuser)

[37] ONP #7—News, De-ink Quality, consists of sorted, fresh, not sunburned newspapers. May contain magazine paper (OMG). No prohibitives are allowed, and less than .0025 outthrows. (Conservatree)

[38] The data for the more recent timeframe of Sept-December 2006 was derived from a presentation made by Jay Simmons: Impact of Single-stream Collections on ONP Quality EPA Roundtable, *July 11, 2007,* Jay Simmons - (Weyerhaeuser, NORPAC). The "pulper yield loss" data was not included in his presentation, and therefore is listed as N/A.

Plastics recyclers report that in general, material from single-stream MRFs has a yield rate of about 68%–70%, compared to dual-stream systems which usually yield about 75%-78%. Bales of PET from deposit return systems generally have a yield rate of about 85% (Figure 8).

Figure 8: Estimate of yield rates from collected plastic



Based on qualitative information from interviews with plastic end-markets.

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While a yield differential of five to ten percent may not seem like a lot, consider that if a facility has an annual capacity of 60 million pounds per year (5 million pounds per month), every one percent of lost yield represents about 50,000 pounds of new waste, for a loss in value[39] to the recycler of $7,500. A processor who averages just 5% loss in yield due to poor quality is losing about $37,500 per month, not including the cost of sending these residuals to disposal.

For the most part, it is widely agreed that single-stream collection systems generally result in a lower quality of material output destined for recovery. However, the range of impacts on material quality and levels of contamination is directly related to a variety of factors that need to be considered on a case-by-case basis. These include:

- The level of promotion and education
- Whether the single-stream system is in an urban or rural environment
- Whether there is a pay-as-you-throw program in place for trash collection (i.e., user fees charged for garbage, usually by the bag or by the pound)
- Whether there is an existing container deposit and return system in place
- Whether glass is included in or excluded from the program
- The quantity of different materials that are accepted in the recycling program
- Whether materials are compacted during collection
- The level of technical sophistication at the MRF
- Type of collection bins, e.g.,18-gallon open bins, or rollout bins with lids
- Whether collectors can visually inspect the material going into the truck
- The level of manual labor on the processing line
- The kind of automated sorting equipment at the MRF
- Whether the facility is working within its capacity or exceeding capacity
- The speed of the conveyor belts at the MRFs
- Amount, if any, of pre-sorting after the material has been tipped

[39] Based on a three-year average for lower quality PET of 15-cents per lbs.

Each of these variables will have a direct impact on the level of contamination ending up in the MRF and in the bales being sent from the MRF to end-markets.

Closing the loop: Recycling's real purpose

Most lay people, and perhaps most local officials, assume that all recycled items go to their best use. They are shocked to learn that the materials they dutifully put in a recycling bin may in fact wind up in a landfill. So a key question that needs to be asked by municipalities considering collection options, is: What will become of the materials collected in a given system?

To date there is little quantitative data on how the reduced quality of single-stream material impacts the total life cycle of the material from its extraction as a raw material, to its final end-of-life.

Though too often ignored, this question is absolutely central. The key to successful recycling, from the perspective of total environmental footprint, is to keep the material circulating for as many product lives as possible. This is the closed loop that reduces the need for virgin materials, thus avoiding the energy consumption and greenhouse gas emissions associated with primary materials extraction, transportation and processing. Recycling glass bottles back into bottles over and over again is by far the best use of secondary glass, just as it is for aluminum cans. Recycling reduces the need for extraction of raw material, and therefore manufacturing consumes less energy than it would from raw materials.

Downcycling or "open loop" recycling of a product provides for one incarnation only—a use that will likely not be repeated. Downcycled glass bottles, for instance, can be ground into drainage material or road aggregate, but that's the end of the line; there is no further recycling for that recycled glass. Similarly, PET resin can be recycled into strapping, but nobody is recycling strapping, at least not yet.

Recyclers are the most vocal opponents of single-stream collection systems. These companies purchase secondary materials from MRFs to use as feedstock in the manufacture of new products which include paper, plastic, glass and metal products.

Impacts on Paper

With the growth of single-stream collection, manufacturers have seen their costs escalate. Specifically, these are the additional expenses related to cleaning and screening poorly processed materials, repairing damage to equipment, more frequent equipment cleaning, equipment replacement, buying new raw materials to replace those that were unusable, and disposal of the residual materials that cannot be used.

The 2005 paper*, The Effects of Single-stream on a Paper Mill,* reports that prior to receiving commingled materials (from either single or dual-stream collection), the NORPAC paper mill managed the costs associated with maintenance from contamination in their budget and did not spend money to improve incoming material quality. However, in the post-commingling period from 2004 to the present, the company reported a fourfold increase in maintenance costs related to contamination, while capital investment to improve the quality of incoming material exceeded $100,000.

In a regression analysis called *Single-stream Recycling—Total Cost Analysis*, by Jaakko Poyry and Skumatz Economic Research Associates (SERA) in 2004, the consultants interviewed a number of paper mill representatives and extrapolated data on the production costs of new newsprint. Their findings showed a strong correlation between using recycled content and increased production costs. More specifically, at 100% recycled content there was a cost increase of $6.50 per ton produced. These results indicate that there are significant costs associated with the use of secondary fiber, which creates a disincentive for manufacturers to use recycled materials or to increase recycled content.

Table 4: Average cost differences by value chain segment

	Collection	Processing	Pulping/Papermaking	Net increase
Cost savings with Single-stream	$15 ($10-$20)			
Cost increase with Single-stream		$10 ($5–$15)	$8 ($5-$13)	$3 ($0-$8)

Source: *Single-stream Recycling—Total Cost Analysis*, prepared by Jaakko Poyry and Skumatz Economic Research Associates (SERA) in 2004.

The analysis further calculates an estimated cost to paper mills if all dual-stream recycling systems were converted to single-stream (summarized in Table 4). The estimate assumes recycled content newsprint at 56%; recycled paperboard at 100%; tissue at 51%, and other grades where recycled content varies. The analysis determined that the industry would incur an additional $48M to $51M in costs associated with increased production costs stemming from increased contamination.

In terms of the net costs affecting the entire stakeholder group, the analysis shows while there is an average decrease in collection costs for paper products of $10–$20/ton (a total savings of $90M–$105M), this would be offset by an increase in processing costs of $5–$15/ton (a total increase of $60M–$70M). Combined with additional papermaking costs of $5–$13/ton (a total increase of $48–$51M); this results in an overall net increase of about $3/ton (a total increase of $18M to $21M).

Assessing the impact on paper quality on the paper manufacturing sector is difficult because paper mills receive their secondary feedstock from a variety of suppliers, all of which have different collection methods. It is estimated, however, that for paper pulpers, single-stream material has eight times the yield loss of curbside-sorted material. As Sacia and Simmons conclude, “In the drive to reduce recycling collection costs, the recovered-fiber-consuming mill has been substantially and adversely affected." There is, they conclude, "a strong need for more balance in the system."[40]

Impacts on Aluminum

To determine the impacts of single-stream collection on downstream aluminum manufacturers, we interviewed the largest recycler of used beverage containers (UBCs) in North America, Atlanta-based Novelis. The aluminum recycler reported that it does not inherently segment incoming material by recycling collection method (single or dual-stream, curbside sort, or deposit return systems), because business value is better managed at an individual supplier level rather than for broad segments. They do, however, periodically aggregate segment information to study broader trends and quality issues. The following was based on recent quality information and sampling.

One significant quality concern was with supplier variation—i.e., broad differences in product quality from one supplier to the next. Variation was higher for curbside than for deposit and return collection systems. Within curbside, regardless of whether the material came from single-stream or dual-stream systems, suppliers varied widely in the quality of sorting, based on myriad variables such as quality of employees, quality of supervision, on-site sorting technology (e,g., eddy currents and magnets) and quality of physical assets.

In comparing curbside-collected material versus material collected through container deposit and return systems, the contaminant level (excluding moisture) was, on average, 78% higher for curbside sources. Contaminants cause facility equipment to shut down at contamination levels well below what many sources supply today. As Novelis explained, "Too much moisture absorbs BTUs and the equipment shuts down until it can reach a high enough operating temperature to burn off the paint/lacquer, etc. PET (polyethylene terephthalate, or #1 plastic) and paper cause the equipment to shut down from excessive operating temperature as burning these materials is exothermic. Glass, sand, non-aluminum metallics and other contaminants cause a myriad of problems as well."[41]

Although curbside material was, on average, significantly lower quality than bottle-bill material, Novelis found that some MRFs had better quality than the bottle-bill average. Given that a variety of MRF types have good quality, improved future material value seems achievable, for many suppliers, if they apply improved business and resource management.

Voluntary supplier action was not yielding measurably improved quality. This was true even during the 2007–2008 commodities boom, during which material revenue and supplier profit far exceeded historical standards. As a result, Novelis implemented a financial penalty for poor

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[40] *The Effects of Single-stream on a Paper Mill*, Sacia and Simmons, Tappi Journal January 2006.

41 John M. Woehlke, Novelis North America.

suppliers, discounting prices paid by 10 cents per pound. Though it might seem a rigorous measure, the surcharge did not fully compensate Novelis for profit losses due to low productivity from substandard materials. Recently, a number of suppliers left, and many more have been redirected to a special off-site cleaning facility where markedly lower prices will be applied to offset the site's operating costs and investment return.

Novelis' action highlights how serious the company is about not accepting low-quality material. The company has indicated that other aluminum buyers such as Alcoa and Aleris are "also serious, and the rest of the industry is coming on line as well."[42]

Impacts on Glass

Container glass is also marginalized in the single-stream process. Glass from single-stream MRFs is not only color-mixed, but highly contaminated. Meanwhile, even as glass-beneficiation facilities are faced with a feedstock that is increasingly contaminated, glass container and fiberglass manufacturers are setting more stringent quality standards.

In an effort to control maintenance and production equipment costs, reduce downtime and increase usage, container glass and fiberglass manufacturers are requiring cleaner cullet. As the percentage of cullet use increases, their quality requirements also increase. Contaminated cullet reduces the life expectancy of production equipment; increases operating costs; and limits how much cullet can be used.[43] With the growth of single-stream recycling programs, and the subsequent downgrading of cullet quality, a beneficiation facility will run significantly higher costs for energy and cleaning, which adversely impacts the economics of building additional beneficiation capacity.

Impacts on Plastic

The value of PET from a single-stream MRF is worth on average about one to two cents less per pound (representing from 9% to 13% of the overall price offered per pound) compared with PET collected via dual-stream. While plastics recyclers were unable to quantify the cost impact that dirtier bales are having on their operations in terms of equipment repair, increased maintenance and unplanned system shut downs, they consistently reported that there is a relationship between dirtier material and increased costs.

Ensuring that secondary recovered recyclables are utilized for the highest possible end-use is a critical part of successful diversion. High end-use can have 10 to 20 times the environmental benefit in terms of the replacement of virgin materials and those avoided upstream impacts.[44]

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42 Ibid.
43 Market Status Report: Container and Plate Glass, CIWMB web site. http://www.ciwmb.ca.gov/markets/StatusRpts/glass.htm.
44 Making Co-mingled Work: Agreeing to new standards to get the most out of our curbside mix. Viccy Salazar, US EPA, Region 10. Power Point presentation, RCC Web Academy –March 2008.

An additional benefit beyond the environmental merit of closed-loop recycling is that higher end-use application will always generate the greatest income because of the value of secondary feedstock. Even if a recycler produces the same resin from clean material and dirtier material, he must absorb all the costs associated with additional cleaning, increased maintenance and capital replacements.

Conclusion

Choosing an appropriate recycling program for their communities can be challenging as municipal leaders attempt to find a balance between economic and environmental sustainability. Over the past decade, recycling systems have evolved towards collecting the maximum amount of recyclables in the shortest amount of stop time with the least amount of labor. This strategy has achieved cost savings at the collection end.

However, with a greater number of materials being collected, increased commingling and compaction, the quality of recyclables destined for recyclers has suffered. The decline in quality of secondary feedstock has impacted the cost to the processor, the cost to the manufacturer and ultimately the cost to the consumer. Increased contamination in bales sent to recyclers has ended up costing more money in terms of equipment replacement and maintenance, increased disposal costs, and increased replacement costs as yield rates decline. This cost pressure on recyclers has not only decreased the value of secondary feedstock, but with the global economic downturn, the demand for poorer quality material has also been significantly compromised.

Recent analysis demonstrates that single-stream systems, on average, actually cost more in total system costs (collection, processing and recycling) compared with dual-stream programs (separate fiber and container collection). In addition, the evidence indicating that single-stream systems actually divert more material than other collection methods is anecdotal. To date, little research has been done that considers actual recycling rates that factor in yield rates from the end-user.

In conclusion, municipalities and states need to work to improve recycling rates and reduce their economic risk by maintaining high-quality recyclables to meet the requirements of domestic recyclers, instead of relying solely on overseas markets. Through a variety of policies, which include implementing producer-responsibility initiatives, expanding product take-back programs for packaging recovery where curbside programs have limited scope, and improving existing curbside recycling, the United States can make significant gains from recycling in terms of avoided upstream pollution and greenhouse gases.

Appendix A: Single-stream collection best practices

A chain is only as strong as its weakest link

Applying best practices in any single-stream recycling system is essential for sustainable recycling. Each and every component of recycling, from relationships, communication, education, collection system design, processing system design, contract terms and low-risk sustainable marketing, must be considered equally. If any one component is not properly implemented, the entire system can be compromised.

This concept is perhaps best described in *Single-stream Recycling: Best Practices Implementation Guide*, by Kinsella and Gertman, February 2007.

> "The recycling cycle represents a collaborative system, and no one sector can operate independently of the others. The success of recycled product manufacturers depends on the success of processors to properly sort the materials they receive. Processors, in turn, depend on collectors to pick up loads of recyclables from residents who understand what should go into their recycling carts and what should not.
>
> Problems in any part of the system require resolution or ultimately every sector suffers, even those that originally benefited. Receiving poorly sorted materials from a processor discourages manufacturers from investing in new or expanded recycled product manufacturing capacity and even may cause some to close or return to using raw virgin resources. Low quality recovered materials can lead to defects in finished products, which threaten buyers' acceptance of recycled products. If customers, whether industrial or consumer, do not buy products with recycled content, losses cascade back through the system. Quality problems with some recycled products may taint buyers' acceptance of other recycled products, as well.
>
> Any of these outcomes will ultimately threaten markets for the materials recovered in community recycling programs. So all recyclers have a stake in making sure that single-stream recycling works as well for manufacturers and processors as it does for collectors."

From S*ingle-stream Recycling: Best Practices Implementation Guide,* by Kinsella and Gertman, February 2007. http://www.conservatree.com/learn/SolidWaste/BestPracticesGuide021407.pdf

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