J. ENVIRONMENTAL SYSTEMS, Vol. 21(1) 21-37, 1991-92

PACKAGING AND PROCESS IMPROVEMENTS: THREE SOURCE REDUCTION CASE STUDIES

GREGORY A. KEOLEIAN

DAN MENEREY

University of Michigan, Ann Arbor

ABSTRACT

This is the second of a two-part article (part one appears in *J. Environmental Systems*, Vol. 20(4), pp. 343-357, 1990-91) documenting five case studies of successful solid waste source reduction programs. The substitution of washable dishware and cloth diapers for single-use equivalents was investigated in the first article. This article includes the following three case studies: 1) bulk merchandising at a cooperative grocery, 2) process improvements and packaging reduction at a furniture manufacturer, and 3) a department store chain's use of shredded waste paper as a packing material. Two bulk items studied at the grocery generate less packaging waste than their packaged equivalents if customer-provided containers for bulk purchases are used at least twice. Total labor, space and disposal costs to the store are the same or lower for the two bulk products. Process improvements and packaging reduction achieved through reuse and redesign lower both costs and solid waste production in furniture manufacture and distribution. At the department stores, shredding paper for use as a packing material cuts costs 57 percent and lowers solid waste generation by 99 percent compared to the previous system.

INTRODUCTION

This is the second in a series of two articles documenting successful solid waste source reduction programs at five businesses. The first article analyzed changes in processes and costs resulting from the replacement of disposable diapers and dishware with reusable equivalents. Other source reduction strategies are now

doi: 10.2190/RX6R-PRM7-PVTF-0CKC
http://baywood.com

Table 1. Selected U.S. Material Discards, 1988[a]

Case Study Material	Gross Discards (millions tons)	Recovery Rate (percent)	Net Discards (million tons)	Percent of U.S. Net Discards
OCC	23.09	45.4	12.61	8.0
Ledger paper	20.35	14.5	17.41	11.1
Glass containers[b]	12.11	9.7	10.94	7.0
Plastic containers[b]	2.95	2.8	2.87	1.8

[a] Based on EPA estimates from [8-10].
[b] Based on averaging 1986 data and 1990 projections from [9].

examined in case studies of bulk liquid merchandising at a cooperative grocery store [1], process improvements and packaging reduction at a furniture manufacturer [2], and packaging material substitution at a department store chain [3]. The case studies were conducted to facilitate the transfer of similar solid waste reduction programs to other businesses.

The EPA recognizes that source reduction, including reuse, is generally a more desirable waste management strategy than recycling, incineration or disposal in landfills [4]. Innovations in product design that increase durability and repairability or reduce material inputs have been suggested as strategies to achieve source reduction of municipal solid waste (MSW) [5, 6]. Whether an item is reused, recycled or discarded often depends on design factors specified by manufacturers which are not directly controlled by end users [7]. Incorporation of environmental requirements into product or process design can facilitate source reduction. The source reduction methods discussed in this article are based on both process and product design changes and waste management improvements.

Source reduction at the case study firms involved materials that constitute a significant portion of MSW discards, as shown in Table 1. The cooperative grocery store reduced discards of old corrugated containers (OCC), and glass and plastic containers. Packaging improvements at the office furniture manufacturer reduced OCC discards. The department store chain's shredded packing program decreased ledger paper discards.

Table 2 shows that gross discards will increase significantly by 1995 for all materials included in the case studies except glass. Estimates of future gross discards are based on consumption patterns. Projections of future net discards are based on a range of increased recovery activities including bottle deposit laws, regulations, recycling, combustion and source reduction. The source reduction techniques documented in this article offer opportunities for reducing both gross and net discards of municipal solid waste.

Process and economic analyses were used to evaluate the effectiveness of source reduction programs in each case study. The analyses quantify changes in

Table 2. *Projected Increase in Gross and Net Discards by 1995*[a]

Material	Gross Discards Compared to 1988 (percent)	Net Discards Compared to 1988 (percent)
OCC	+18.8	-13.6
Ledger paper	+31.3	+24.7
Glass containers	+1.7	+0.7
Plastic containers	+21.0	+20.0

[a] Based on EPA estimates from [8, 9].

solid waste generation, and capital and operating costs. The advantages and limitations of each source reduction strategy are also discussed.

METHODOLOGY

The methodology for conducting process and cost analyses at the case study firms is described in the first article of this set [11].

BULK PRODUCTS CASE STUDY: COOPERATIVE GROCERY

Previous studies of bulk food merchandising have concentrated on customer attitudes and comparative prices of such dry items as baking supplies, grains, beans, nuts, pasta, dried fruit and herbs. A survey of nineteen northern California supermarkets found that prices for one-pound quantities of unpackaged goods were 53 percent lower than comparable packaged products [12]. Savings on bulk foods varied considerably over the range of items chosen for study. Bulk grains and beans were least likely to offer savings. When purchased in five-pound quantities, bulk items cost 8 percent more than comparable packaged items.

In a study of the three highest volume supermarkets in the Washington, D.C. area, 93 percent of packaged foods were more expensive than bulk equivalents [13]. Prices averaged 66 percent less for bulk items, but larger (two- to ten-pound) quantities of flour, beans and grains were more expensive in bulk. Packaged generic products were more likely to cost the same or less than bulk equivalents.

No studies have apparently been done on the comparative solid waste generation of bulk and packaged food merchandising. Overall solid waste generation attributable to bulk food sales depends on both in-store practices and consumer behavior during and after purchase.

The merchandising of two bulk items was analyzed at a cooperative grocery store with annual sales of $1.2 million. Waste stream constituents generated by a grocery store include old corrugated containers, plastic wrap and packaging, spoiled produce, outdated food products, register receipts and office paper. Typical postconsumer wastes are discarded food and packaging made from plastic, glass, aluminum, steel and paper. Packaging accounted for 31.6 percent of all municipal solid waste generated in the United States in 1988 [10].

Two liquid items available in both packaged and bulk form at the grocery were chosen for study. Selecting the same brand and composition of packaged and bulk products simplified the analysis. Dry items comprise the overwhelming majority of products sold in bulk at the case study grocery store, but liquid products provide an interesting model because they present more of a challenge for the bulk grocer. Storage and delivery systems may require some in-store adaptation, and spillage from dispensing can be a nuisance.

An inventory of packaged items is taken once a day and restocking is done as needed. Merchandise taken from storage is priced and shelved. Empty shipping containers, primarily corrugated cardboard boxes, are either reused, recycled or disposed in a landfill. After packaged items are purchased, product packaging can be reused, recycled or discarded by customers. Because in-store and postconsumer waste generation are inextricably linked in the systems under study, both are quantified.

Liquids are purchased in rigid containers, while most dry bulk items are typically purchased in lightweight bags. The tare weight of containers must be measured by customers before purchasing a product. At checkout, the container is weighed again by store employees to calculate net product weight. After products are consumed, containers may be washed and reused, recycled or discarded in landfills.

Process Analysis

Olive Oil

Process analysis data for olive oil sales are summarized in Table 3. Bulk olive oil is received in a five-gallon, twelve-inch corrugated cardboard cube with a plastic liner called a "cubi-tainer." The cubi-tainer, which is neither reusable nor locally recyclable (the materials are bonded together), also serves as a dispenser for the oil after a reusable spigot is attached. The container weighs 2.8 pounds, and five gallons of olive oil weigh about 37.6 pounds, yielding a packaging to product weight ratio of 0.073. Packaged olive oil is delivered in a corrugated cardboard case of twelve one-pint glass gars with paperboard slats between individual bottles. Each case contains 7.5 pounds of packaging for 11.3 pounds of olive oil, resulting in a packaging to product weight ratio of 0.661.

The amount of waste generated in the bulk distribution system depends on the reuse rate of consumer containers. For this analysis, it is assumed that customers provide their own glass bottles for olive oil purchases, and that bottles for each system are identical (i.e., one-pint capacity, holding about one pound of oil). If a new container is used for each bulk purchase, the total packaging to product

Table 3. Process Analysis of Bulk and Packaged Olive Oil

Item	Bulk Olive Oil	Packaged Olive Oil
Unit	"cubi-tainer"	case of 12
Packaging Specifications		
Product weight	37.6 lb	11.3 lb
Packaging weight[a]	2.8 lb	7.5 lb
Packaging/product weight ratio	0.073	0.661
Product volume	640 oz.	192 oz.
Shipping container volume	1730 cu. in.	840 cu. in.
Shipping container/pint product	43 cu. in.	70 cu. in.
Waste Generation		
Case 1 package/product weight ratio[b]	0.657	0.661
Case 2 package/product weight ratio[c]	0.190	0.661
Waste Discards with Recycling		
Shipping container recycle rate	0%	67%
Preconsumer package/product weight ratio	0.073	0.609
Postconsumer recycling rate	50%	50%
Net packaging/product weight ratio, case 2	0.131	0.317

[a] Includes shipping container and product packaging.
[b] New container for bulk purchases used each time.
[c] Containers for bulk purchases used five times.

weight ratio is 0.657 (Case 1, Table 3), compared to 0.661 for the packaged system, a reduction of less than 1 percent. Solid waste generation is reduced 71 percent when customers reuse containers for bulk purchases five times (Case 2, Table 3).

Net waste figures are included in Table 3 to demonstrate the effect of preconsumer and postconsumer packaging recycling. The shipping container recycling rate for packaged olive oil reflects current practice at the grocery store. In 1988, an estimated 47.9 percent of all old corrugated containers used in the United States were recovered for recycling. The recovery rate for OCC is projected to be 63 percent by 1995 [8]. Franklin states that a 65 percent national recycling rate for corrugated board approaches the limit of practical recovery, given current techniques for material separation [8].

Essentially all uncoated corrugated containers are recycled at the cooperative grocery. The packaged olive oil shipping container is uncoated, but one-third of the container by weight consists of paperboard slats that are not locally recyclable. Thus, the actual recycling rate at the store for this item is 67 percent.

Because the shipping container for the packaged system is partially recyclable while the bulk container is not, under certain conditions bulk olive oil sales will not reduce MSW discards. If customer-provided containers for bulk purchases are not reused and no postconsumer recycling occurs, bulk olive oil sales yield a packaging to product weight ratio of 0.657 compared to 0.609 for the packaged system. A refillable shipping container would reduce solid waste generation in the bulk system regardless of customer behavior.

Postconsumer recycling is also addressed in Table 3. An estimated 9.7 percent of all glass containers were recycled in 1988 [9]. Glass containers for the following products were used to calculate the overall recycling rate: beverages, food, medicine, cosmetics and industrial and household cleaners. Recycling is confined to beverage containers in the preceding estimate. The recycling of glass containers similar to those used for olive oil was assumed to be negligible. Allen, et al. (1988) found that communities with comprehensive recycling programs (e.g., mandatory curbside pickup, collected weekly) can achieve a 50 percent recycling rate, although some find the procedures used in deriving these figures controversial [14].

Assuming customer-provided bottles are used five times and glass olive oil bottles for both systems are recycled at a 50 percent rate, the net packaging to product weight ratio for bulk sales is 0.131 compared to 0.317 for packaged sales. Under these conditions, bulk merchandising reduces waste discards by 59 percent.

Shampoo

Both bulk and packaged shampoo are shipped to the grocery store in high-density polyethylene (HDPE) bottles, multi-packed in corrugated cases without slats. Bulk shampoo is packed in a case of four one-gallon containers, while packaged shampoo is shipped in a case of twelve eighteen-fluid-ounce containers. For this analysis, customers are also assumed to use eighteen-fluid-ounce HDPE containers for their purchase of bulk shampoo.

Table 4 contains the results of the process analysis of shampoo sales. Bulk shampoo is delivered with 2.4 pounds of packaging for 34.9 pounds of product; the packaging to product weight ratio is 0.07. This ratio is 0.114 in the packaged case, as 1.7 pounds of packaging is used to deliver 14.8 pounds of shampoo.

In Case 1, which assumes a new customer-provided container is used for each bulk purchase, the packaging to product weight ratio in the bulk system is 0.142 or 25 percent more than the packaged system's ratio of 0.114. If customer-provided containers for bulk purchases are used twice, the bulk system generates less waste. When customer-provided containers are used five times (Case 2, Table 4), the bulk system waste generation ratio is 26 percent less than the packaged system ratio.

Both types of shampoo are shipped in fully recyclable corrugated boxes. The clear HDPE bottles used for shipping bulk shampoo are also currently recycled at the store. Preconsumer packaging for both systems is thus recycled by the grocery at a 100 percent rate.

Table 4. Process Analysis of Bulk and Packaged Shampoo

Item	Bulk Shampoo	Packaged Shampoo
Unit	4-gallon pack	case of 12
Packaging Specifications		
Product weight	34.9 lb	14.8 lb
Packaging weight[a]	2.4 lb	1.7 lb
Packaging/product weight ratio	0.070	0.114
Product volume	512 oz.	216 oz.
Shipping container volume	1950 cu. in.	1040 cu. in.
Shipping container/pint product	61 cu. in.	77 cu. in.
Waste Generation		
Case 1 package/product weight ratio[b]	0.142	0.114
Case 2 package/product weight ratio[c]	0.084	0.114
Waste Discards with Recycling		
Shipping container recycle rate	100%	100%
Postconsumer recycling rate	50%	50%
Net packaging/product weight ratio, case 2	0.007	0.036

[a] Includes shipping container and product packaging.
[b] New container for bulk purchases used each time.
[c] Containers for bulk purchases used five times.

Plastic recycling is frequently less established at the residential level. Factors such as resin incompatibility and the large volume to weight ratio of plastic are likely to provide a continuing challenge for recyclers. Only 2.4 percent of all plastic containers were recycled in 1986. The plastic container recycling rate is expected to be 3.1 percent in 1990 and rise to 3.8 percent by 2000 [9]. A 50 percent consumer recycling rate for HDPE containers appears unlikely in the near future, but it is presented as an optimistic projection of trends in plastic recycling. With recycling added to the reuse assumptions of Case 2, the bulk system reduces waste discards by 80.6 percent compared to the packaged system.

Cost Analysis

Olive Oil

Costs of selling olive oil are summarized in Table 5. Wholesale price and total added costs (space, labor, waste disposal) of bulk olive oil are $3.10 per pound. The retail price of bulk olive oil is $4.99 per pound or $1.89 per pound more than

Table 5. Cost Analysis of Bulk and Packaged Olive Oil

Item	Bulk Olive Oil	Packaged Olive Oil
Product Information		
Unit	"cubi-tainer"	case of 12
Weight of product	37.6 lb	11.3 lb
Wholesale cost/unit	$110.650	$35.810
Wholesale cost/lb	$2.940	$3.172
Space		
Storage area cost/lb	$0.012	$0.023
Shelf space cost/lb	$0.015	$0.022
Labor and Waste		
Wage	$13.600	$13.600
Ordering labor cost/lb	$0.006	$0.020
Storage labor cost/lb	$0.003	$0.010
Stocking labor cost/lb	$0.020	$0.130
Check-out labor cost/lb[a]	$0.095	$0.019
Total recycling cost/lb		$0.003
Total disposal cost/lb	$0.009	$0.005
Added Costs/lb[b]	$0.160	$0.231
Total Store Costs/lb[c]	$3.10	$3.40
Retail Price/lb	$4.99	$5.15

[a] Assuming customers purchase a quantity of 1 lb.
[b] Sum of space, labor and waste costs.
[c] Wholesale costs plus added costs.

analyzed store costs itemized in Table 5. Packaged olive oil costs the store $3.40 per pound and is sold for $5.15 per pound, a difference of $1.75 per pound. Only those added costs necessary for a comparative evaluation were identified. Therefore, differences between retail price and store costs do not represent actual margins. Assuming that such costs are assigned equally to bulk and packaged goods, a more comprehensive analysis would preserve the bulk system's $0.14 per pound merchandising cost advantage.

The total analyzed store cost of selling a pound of bulk olive oil is about $0.30 less than selling a pound of packaged olive oil. The lower wholesale price of bulk olive oil accounts for virtually all of this cost differential.

Containers sold at the cooperative grocery for bulk purchases are deliberately high-priced to encourage reuse. Customers who purchase new containers pay

Table 6. Cost Analysis of Bulk and Packaged Shampoo

Item	Bulk Shampoo	Packaged Shampoo
Product Information		
Unit	gallon 4-pack	case of 12
Weight of product	34.9 lb	14.8 lb
Wholesale cost/unit	$50.480	$31.680
Wholesale cost/lb	$1.446	$2.147
Space		
Storage area cost/lb	$0.010	$0.043
Shelf space cost/lb	$0.003	$0.016
Labor and Waste		
Wage	$13.600	$13.600
Ordering labor cost/lb	$0.006	$0.015
Storage labor cost/lb	$0.005	$0.006
Stocking labor cost/lb	$0.068	$0.096
Check-out labor cost/lb[a]	$0.095	$0.019
Total recycling cost/lb	$0.007	$0.003
Total disposal cost/lb		
Added Costs/lb[b]	$0.195	$0.198
Total Store Costs/lb[c]	$1.64	$2.35
Retail Price/Lb:	$2.65	$2.92

[a] Assuming customers purchase a quantity of 1 lb.
[b] Sum of space, labor and waste costs.
[c] Wholesale costs plus added costs.

more for one pound of bulk olive oil than customers who choose the packaged alternative.

Shampoo

Results of the cost analysis for the shampoo systems are displayed in Table 6. Bulk shampoo costs $1.64 per pound, and is sold for $2.65 per pound, a difference of $1.01 per pound. Packaged shampoo costs $2.35 per pound, and is sold for $2.92, a difference of only $0.57 per pound. Inclusion of costs not addressed in this analysis will lower actual margins by an undetermined amount.

The total calculated cost of selling a pound of bulk shampoo is about $0.71 less than packaged shampoo, but the retail price differential is only

$0.27. The cooperative grocery store can thus sell bulk shampoo at a lower price than its packaged equivalent while realizing a greater return. As in the bulk olive oil system, customers purchasing a new container pay more for bulk shampoo.

PROCESS IMPROVEMENTS AND PACKAGING REDUCTION CASE STUDY: OFFICE FURNITURE MANUFACTURER

Waste reduction practices were studied at several facilities operated by a multinational office furniture manufacturer. Consolidated North American net sales of the manufacturer were $1.9 billion in 1989, which represents a 21.5 percent share of the North American office furniture market.

In 1990, the office furniture manufacturer generated 13,000 tons of solid waste at the case study facilities. This figure is expected to increase to 15,000 tons per year by 1992. A partial waste stream assessment performed by the company identified corrugated board as a significant waste product resulting from its operations. Other solid waste components include scrap wood and steel, sawdust, foam, fabric and office paper.

Process improvements are one method of achieving significant source reduction of solid waste in furniture manufacturing. During the past five years, the furniture manufacturer has instituted over 100 employee-suggested process improvements to reduce material waste, machine down time, energy consumption and operating costs. Reduction of packaging and packing material is also an important strategy for lessening waste production in furniture distribution.

Process Improvements and Cost Analysis

Table 7 shows results from four selected process improvements.

IMA Edge Bander improvements will be discussed as an example of the process changes initiated through a formal employee involvement program. When a table

Table 7. Process Improvements Results

Process Improvement	Project Cost	Net Annual Savings	Payback Period (months)	Annual Waste Reduction (tons)
IMA Edge Bander	$543	$8,587	0.71	16.9
Assembly Table	$174	$20,697	0.1	4.3
3 Conveyors	$1,750	$8,415	2.07	–
Box Roll Former	$404	$7,721	0.6	–

or desk top enters the IMA Edge Bander, it is first cut to width then rotated and squared with a one-eighth-inch cut before being banded along the edge with a laminated plastic strip. Prior to improvement, mechanical switches occasionally failed to sense tops as they were delivered, resulting in misaligned cuts. Such failures occurred three or four times per day, and each misaligned top was discarded.

To improve the reliability of the machine, switches were upgraded and photoeye sensors were installed to sense tops as they entered the cutting unit. A blow-off fan was also installed to keep the photoeye sensor clear of dust.

Sensor improvements and other adjustments reduced waste production by three forty-five pound pieces of composite board per day. Over a 250 day annual production schedule, IMA Edge Bander improvements reduced waste generation by 16.9 tons per year.

The cost of these improvements was $543 and the net annual saving was $8,587. The IMA Edge Bander adjustments also significantly improved production scheduling. The payback period for this improvement was 0.71 months.

Although no economic data were available for several other employee-suggested process improvements, waste reduction resulting from such changes can be significant. As an example, new computer hardware and software installed on a high speed roll form line allowed faster processing of motor commands and quicker response to those commands. Accuracy of the flying cutoff on the new system tripled after the improvements. On the old system, the feeder could only be tuned with difficulty, and adjustments were soon lost, forcing reduced production rates.

Dramatically improved accuracy on the new system can be maintained by software tuning which does not deteriorate. Line speed could thus be increased and is no longer a significant factor in accuracy. Improvements on the flying cutoff and feeder reduced scrap from two-to-five parts at start up to zero-to-two parts each start up. The only major cause of cutting errors now is variation in the steel feedstock. Improvements to the high speed roll form line saved 70,000 parts per year and reduced solid waste generation by 45 tons annually.

The identification of major waste sources is a primary step in the development and implementation of waste reduction programs at the furniture manufacturer. Scrap generation is now recorded for each process step within many individual facilities. Operations generating the most waste can thus be effectively targeted for improvement.

Packaging Reduction

Waste generated by packaging was decreased by board grade reduction, reusable containers and uncartoned shipments. The office furniture manufacturer currently ships 40 percent of its orders to distributors uncartoned. Several substitutes for protective cartons have been used to reduce waste: expanded polystyrene buns, desk caps, blankets and stretch wrapping.

Reusable polystyrene buns protect chair seat cushions, allowing uncartoned chairs to be stacked without damage. The buns are backhauled to the factory by delivery trucks after chairs are unloaded. Shipping chairs in buns rather than cartons reduces solid waste generation by 1200 tons per year, and saves the company $890,000 annually.

Sixty-inch binder bins are also shipped uncartoned. This practice reduces waste generated outside the company's facilities by an additional seventy tons per year.

Reusable corrugated cardboard desk caps that fit both ends of a desk are also used for some shipments. A pair can be used on a desk of any length, so only the depth of the desk matters. As a result, three standardized sizes fit all models.

Blankets are also used alone or in conjunction with desk caps to protect uncartoned furniture. Replacing single-use containers with reusable packaging helps reduce waste generation resulting from furniture shipments while also producing cost savings for the manufacturer.

PACKING MATERIAL CASE STUDY: DEPARTMENT STORE CHAIN

The department store chain selected for study operates seventeen stores in Michigan containing 4.2 million square feet of retail floor space. The chain accounts for 12 percent of total sales in the state's department store sector. Department stores and general retailers generate solid waste from on-site activities, and they also act as conduits for products and packaging that will eventually be added to the municipal solid waste stream.

The substitution of shredded office paper for purchased packing material was documented at the department store chain. Until early in 1990, many of the chain's stores used expanded polystyrene (EPS) "peanuts" as a packing material when shipping items to customers or returning merchandise to vendors. The department store replaced EPS packing with a purchased paper material before deciding to shred a portion of their own collected office paper waste for use as packing. The following analysis is based on a comparison with the purchased paper packing in use immediately before the inception of an internal paper shredding program. Paper is shredded for packing material at one central location in suburban Detroit then distributed to all other Michigan stores.

Process Analysis

Table 8 shows that the department store chain's shredding program reduces MSW discards by 3464 pounds each month. Before converting to the new system, the department stores purchased approximately 2750 pounds of paper packing per month. An estimated 20 percent of the stores' 17,500-pound monthly ledger paper

Table 8. Monthly Shredded Packing Process

Unit	Before Case Purchased	After Case Shredded	Difference
Packing	2750 lb	3500 lb	
Solid waste	3500 lb	36 lb	3464 lb
Utilities	0	333 kwh	-333 kwh
Labor			
Gathering	0	59.5 hrs	-59.5 hrs
Shredding and bagging	0	145.8 hrs	-145.8 hrs
Total	0	205.3 hrs	-205.3 hrs

purchase is recovered for shredding. Some stores project an eventual recovery rate as high as 50 percent, but at a conservative 20 percent rate, the paper shredding operation yields 3,500 pounds of packing per month. The excess shred is available for sale to other retailers. When paper collections outstrip shredder capacity the surplus is recycled.

Ledger paper waste generated at most locations was disposed in landfills prior to the inception of a shredding program. In the new system, paper suitable for shredding is collected in each office and placed in original delivery boxes which are later recycled. Staff at each store gather paper selected for shredding on the same carts used for general waste collection. Approximately 3.5 extra hours per month are required at each store to collect office paper and deposit it in large corrugated boxes placed on a pallet. Boxes and pallets are obtained from vendor shipments to the stores. Boxes are used several times before they are recycled, and pallets can be reused many times without being significantly damaged.

Used paper gathered from all stores is transported to a central distribution center located near the store where shredding is performed. Waste paper is delivered on return trips after shipments have been received, so no additional transportation is required for this phase of collection. Paper is forwarded to the shredding location when there is room on a truck making normal deliveries. Shredded packing is then backhauled to the distribution center for subsequent shipment to individual stores, again avoiding additional transportation inputs.

The department store chain purchased a large shredder capable of handling the volume of gathered paper. One full-time employee shreds incoming paper and bags it for distribution to other stores. The shredder operator devotes five hours per week to tasks not directly related to packing production.

Material discarded in landfills is reduced by 3464 pounds per month in the new system. The only wastes generated by the new system are the plastic bags used for

Table 9. Monthly Packing Costs

Item	Before Case	After Case	Difference
	Purchased Packing	Shredded Packing	
Purchased packing material	$3,339.92	$0.00	$3,339.92
Equipment and Supplies			
Shredder depreciation	$0.00	$60.00	-$60.00
Shredder maintenance	$0.00	$83.33	-$83.33
Plastic bags for shipping	$0.00	$36.17	-$36.17
Total	$0.00	$179.50	-$179.50
Labor			
Cost of gathering	$0.00	$490.88	-$490.88
Cost of shredding	$0.00	$1,203.13	-$1,203.13
Total	$0.00	$1,694.00	-$1,694.00
Utilities			
Cost of electricity	$0.00	$27.13	-$27.13
Waste disposal cost	$22.62	$0.23	$22.39
Total	$22.62	$27.36	-$4.75
Total Costs	$3,362.53	$1,900.86	$1,461.67

shipment and some shredding litter. Weight of the bags used to package purchased packing was not included in the analysis because it was less than 1 percent of the total solid waste generated in the purchased system.

Even in those cases where paper is currently recycled, shredding it for use as a packing material is a superior resource management practice. Packing material made from shredded ledger paper can be reused many times by customers, and it can also be recycled when it is no longer deemed useful.

Cost Analysis

Table 9 demonstrates how a paper shredding program saved the department stores $1,462 each month compared with the purchased packing system.

Costs in the purchased packing case consist of packing material and disposal costs for the used ledger paper now diverted to shredding.

In the shredded packing system, shredder depreciation includes the cost of purchasing a new machine and installing appropriate wiring. Maintenance was estimated by the manufacturer to be 12.5 percent of original equipment purchase price per year. The payback period for this investment was 0.12 month.

Total costs for labor, equipment and supplies in the shredded packing system are significantly less than purchasing packing material from a vendor. The cost of discarding paper now recovered for shredding did not significantly contribute to the overall cost of the purchased system. The department stores reduced costs incurred in the previous system by 57 percent after implementing a shredded packing program.

As described in the process analysis, the department stores plan to shred approximately 27 percent more collected ledger paper than internal demand requires. If this product can be sold to other retailers, the shredding system could be even more economically advantageous. Before conversion to a shredding program, the stores purchased paper packing material for $1.21 per pound. An excess shred of 750 pounds could therefore produce as much as $900 per month in additional revenue. When monthly savings are combined with possible revenues from sale of excess packing, the shredding program could yield as much as $2,300 per month.

CONCLUSIONS

Each of the source reduction methods studied lowered waste generation and was cost effective. These source reduction strategies can be classified as either having their major impact on preconsumer or postconsumer waste. The furniture manufacturer implemented process changes that reduced preconsumer waste by limiting internal scrap production. Reducing or eliminating packaging through board grade reduction and the replacement of some single-use containers with reusable alternatives are strategies that lower postconsumer waste generation.

The conversion of previously discarded ledger paper into packing material at the department stores is an innovative preconsumer source reduction technique. Other businesses requiring packing material for customer shipments could also adopt this strategy. Reusing waste ledger paper for packing material extends its useful life without precluding eventual recycling.

Bulk merchandising at the cooperative grocery store does not necessarily reduce total solid waste generation associated with preconsumer shipping containers and postconsumer product packaging. Customer participation is the key to overall waste reduction in the bulk sales system. If customers use a new container for every purchase, bulk products generate an equal or greater amount of waste per unit sold compared to the packaged items studied. When customer-provided containers are used at least twice, both bulk systems generate less waste than comparable packaged systems. The cooperative grocery case study demonstrates how public behavior can either contribute to or impede source reduction efforts. Customers of grocery and department stores could also be encouraged to bring reusable containers for their purchases through rebates, sale of multi-use totes for their purchases and advertising. Although most source reduction attention has focused on businesses to date, changing patterns of public consumption can also achieve substantial waste reduction.

Preconsumer waste generation in the bulk systems is affected by sizes and types of shipping containers. The packaging to product weight ratio for a given material is generally inversely related to shipping container size. Bulk products studied here were shipped to the grocery in single-use containers. A further reduction in waste generation could be achieved if bulk shipping containers were reusable.

Other opportunities for source reduction exist in food retail. Grocery stores can donate unsalable but still wholesome food to community groups. Where appropriate, product packaging for non-bulk items could also be reusable, such as refillable bottles. Both department and grocery stores can encourage vendors to reduce product packaging to a minimum and avoid single-use shipping containers.

By intervening during the waste producing stage, source reduction offers a waste management strategy that lessens the possibility of transferring environmental costs or impact to other stages of the product life cycle. Waste management programs that rely on recovering waste materials after they are produced require additional energy inputs and may produce pollution or other cross-media impacts. In many cases, waste avoidance and simple material reduction techniques such as those followed by the furniture manufacturer or the department store chain can be accomplished with no ancillary impacts. Recycling, composting and other recovery methods will remain an important adjunct to waste management planning, but expected increases in waste generation, both on a national and per capita basis, give added urgency to source reduction practices.

A life cycle framework that traces a product or process from initial extraction to manufacture, distribution, use, possible reuse or recycling, and final disposal provides the most complete means of evaluating any system's environmental impacts. A life cycle analysis of the source reduction programs documented here may uncover further advantages when compared to the systems they replaced.

ACKNOWLEDGMENTS

The source reduction case studies were funded through the State of Michigan Departments of Commerce and Natural Resources, Solid Waste Alternatives Grant Program. Dr. Jonathan W. Bulkley and the following Research Assistants also participated in the case studies: Andrew Duncan, Elise McLaughlin, Martha Monroe and Thomas Swenson.

REFERENCES

1. Solid Waste Research Group, *Waste Reduction in Food Retail, Case Study Report: People's Food Cooperative Packard Store,* Office of Waste Reduction Services, Lansing, Michigan, 1991.

2. Solid Waste Research Group, *Waste Reduction in the Furniture Manufacturing Sector, Case Study Report: Steelcase, Inc.*, Office of Waste Reduction Services, Lansing, Michigan, 1991.
3. Solid Waste Research Group, *Waste Reduction in the Department Store Sector, Case Study Report: Hudson's Department Stores*, Office of Waste Reduction Services, Lansing, Michigan, 1991.
4. EPA, OSWA, *The Solid Waste Dilemma: An Agenda for Action*, Washington, D.C., p. 17, 1989.
5. W. D. Conn, Consumer Products in the Context of Material and Energy Flows, in *Resource Conservation*, D. W Pearce and I. Walters (eds.), NYU Press, New York, pp. 127-130, 1988.
6. W. D. Conn, Product Design and Municipal Solid Waste, *Journal of Resource Management and Technology, 17*:2, pp. 100-103, 1989.
7. M. E. Henstock, *Design for Recyclability*, North American Publication Center, Brookfield, Vermont, pp. 2-5, 1988.
8. W. E. Franklin, *Paper Recycling: The View to 1995*, Franklin Associates, Ltd., Prarie Village, Kansas, pp. 1-20, 21, 1990.
9. Franklin Associates, *Characterization of Municipal Solid Waste in the United States 1960-2000*, U. S. EPA Office of Solid Waste and Emergency Response (WH-565E), Update, pp. H-6, I-14, April 1988.
10. EPA, *Characteriziation of Solid Waste in the United States: 1990 Update*, Washington, D.C., EPA 530-SW-90-042A, pp. ES 5, 6, 1990.
11. G. A. Keoleian and D. Menerey, Disposable vs. Reusable Systems: Two Source Reduction Case Studies, *Journal of Environmental Systems, 20*:4, pp. 17-31, 1992.
12. S. L. Johnson and R. Sommer, Prices of Unpackaged and Packaged Foods, *The Journal of Consumer Affairs, 19*:2, pp. 309-311, 1985.
13. D. P. Odland, Bulk Foods–Cost and Other Considerations, *Family Economics Review, 1*, pp. 34-36, 1986.
14. T. Allen, B. Platt, and D. Morris, *Beyond 25%–Material Recovery Comes of Age*, Institute for Local Self Reliance, Washington, D.C., pp. 10, 11, 1989.

Direct reprint requests to:

Gregory A. Keoleian
National Pollution Prevention Center
University of Michigan
Dana Bldg. 430 E. University
Ann Arbor, MI 48109-1115